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For the families of North Dakota we research and report on agricultural methods that . . .

- are SENSIBLE
- appear SUSTAINABLE
- advance STEWARDSHIP

AGRONOMY RESEARCH

VARIETY TRIAL INFORMATION

GRASSLAND RESEARCH

HORTICULTURE RESEARCH

LIVESTOCK RESEARCH

2009 BEEFTALK ARTICLES

Written by Dr. Kris Ringwall,
Animal Scientist and Director of the Dickinson Research Extension Center

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SUSTAINABLE AGRICULTURE

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Evaluation of foliar fungicide treatments Gem, Stratego, and Prosaro for control of leaf spot diseases & FHB in spring wheat at Mott, ND, 2009.

The experiment was conducted in a producer's field near Mott, ND (NW ¼ Section 15, T136N, R93W, Hettinger County, ND) with a previous cropping history of wheat in 2008. A randomized complete block design with four replications was used. Plots were 10 ft wide by 50 ft long with a 3 ft buffer strip of winter wheat seeded between each plot. A preplant application of glyphosate was made on 5 May. Plots were seeded with a drill equipped with Cross-slot openers on 7 May at the rate of 200 pls m^{-2}. Urea at the rate of 110 lbs/a (50.6 lbs/a N) was applied through the drill in a separate band during the seeding operation. A post emergent herbicide application of Harmony GT XP (Thifensulfuron-methyl) at 0.6 oz/a + MCP Ester at 0.75 pt/a + Puma (Fenoxaprop-P) at 0.66 pt/a was applied with a pickup mounted field sprayer on 13 Jun. Fungicide applications at Feekes growth stage (FGS) 2 were made on 10 Jun, applications at FGS 9, flag leaf fully emerged, were made on 3 Jul and applications at FGS 10.51 (beginning flowering) were done on 17 Jul. All fungicide treatments were applied in 19.1 gal/a water at 30 psi using a CO_2 pressurized hand-held spray boom equipped with 8002VS flat fan nozzles. Tan spot disease evaluations were conducted on 17 Jun, leaf spot disease evaluations were done on 17 Jul, and tan spot, septoria and leaf rust evaluations were conducted on 24 Jul. Evaluations consisted of observations made on ten consecutive plants in the center row of each plot. Incidence was recorded as the percent of plants with at least one lesion observed, and severity was recorded as the average leaf area covered by lesions for all leaves for the early season evaluation, only the top three leaves for the mid-season evaluation, and the flag leaf for the late season evaluation. Crop injury observations were made at the same time as the disease evaluations. No crop injury from the fungicide applications was observed. No visual symptoms of Fusarium head blight (FHB) were detected in an evaluation of 10 consecutive heads in the center of each plot at soft dough. Grain samples from the control plots were sent to NDSU for DON analysis and no DON was detected in these samples. No further testing for DON in grain samples produced from fungicide treatments was done. Precipitation at the site was measure and recorded with the use of a RainWise™ self tipping bucket and a Hobo™ pendant temp/event logger in May, Jun, Jul and Aug was 2.07, 2.92, 3.96, 0.63 inches respectively. Moist conditions in May, Jun, and most of Jul promoted tan spot, and septoria and dry, cool weather conditions in late Jul and through Aug were not conducive for FHB development. Leaf rust was not prevalent in the area this year and therefore 24 Jul evaluation consisted of septoria and tan spot infections. Disease ratings reflect moisture conditions at the time the crop was susceptible to infection. Wheat stem sawfly damage was noted though no visual differences in injury among treatments were noted. Harvest was with a Massy Ferguson 8XP combine on 9 Sep. Grain yield and test weight were adjusted to a 12% moisture basis. All data was statistically analyzed using SAS Statistical software v 9.1 Proc ANOVA.

Significant differences in disease incidence and severity were noted during all three disease evaluations. Treatments where fungicides were applied shortly before the evaluation had lower incidence and severity ratings compared to treatments that did not have a fungicide applied within 2 weeks of the evaluation. No significant differences were observed for yield and test weight in this trial.

Treatment[1]	--- 17-Jun-09[2]---			--- 17-Jul-09[2] ---			--- 24-Jul-09[2]---		
	I	S	CI	I	S	CI	I	S	CI
	------------------------------------- % -------------------------------------								
Untreated Check	100.0	35.0	0	100.0	18.8	0	100.0	36.3	0
Stratego 4 oz @ FGS2	60.0	10.0	0	95.0	12.5	0	100.0	27.5	0
Gem 2 oz @ FGS2	62.5	7.5	0	95.0	21.3	0	100.0	40.0	0
Stratego 8 oz @ FGS9	97.5	33.8	0	17.5	3.0	0	40.0	8.8	0
Prosaro+ NIS 6.5 oz @ FGS9	100.0	31.2	0	20.0	2.5	0	56.3	6.3	0
Prosaro+ NIS 6.5 oz @ FGS10.51	100.0	33.8	0	100.0	17.5	0	100.0	18.8	0
Stra 4 oz @ FGS2 - Pro+NIS 6.5@FGS10.51	57.5	8.8	0	87.5	18.8	0	87.5	20.0	0
Pro+NIS6.5 oz + test cmp 1pt @FGS10.51	100.0	31.3	0	100.0	16.3	0	100.0	17.5	0
Mean	84.7	23.9	0	76.9	13.8	0	85.5	21.9	0
CV%	5.1	16.1	-	7.2	35.4	-	7.8	23.8	-
LSD.05	6.3	5.7	-	8.1	7.2	-	9.7	7.7	-

[1] Treatment is fungicide at rate specified per acre applied during the specified growth stage of wheat. FGS2 = Feekes Growth Stage 2 or 4- to 5-leaf, FGS9 = Feekes Growth Stage 9 or flag-leaf, FGS10.51 = Feekes Growth Stage 10.51 or flowering.

[2] Evaluation date. I = incidence of disease, S = severity of disease, and CI = crop injury from fungicide application.

Treatment[1]	--- Grain[2]---	
	Yield	Test Wt
	bu/a	lb/bu
Untreated Check	57.4	64.6
Stratego 4 oz @ FGS2	73.0	64.3
Gem 2 oz @ FGS2	61.9	64.2
Stratego 8 oz @ FGS9	68.0	66.0
Prosaro+ NIS 6.5 oz @ FGS9	64.3	65.1
Prosaro+ NIS 6.5 oz @ FGS10.51	71.0	65.1
Stratego 4 oz @ FGS2 - Pro+NIS 6.5@FGS10.51	65.1	65.3
Pro+NIS6.5 oz + test cmp 1pt @FGS10.51	59.4	65.1
Mean	65.0	65.0
CV%	11.9	1.35
LSD.05	NS	NS

[1] Treatment is fungicide at rate specified per acre applied during the specified growth stage of wheat. FGS2 = Feekes Growth Stage 2 or 4- to 5-leaf, FGS9 = Feekes Growth Stage 9 or flag-leaf, FGS10.51 = Feekes Growth Stage 10.51 or flowering.

[2] Grain yield and test weight reported on a 12% moisture basis.

Wheat (*Triticum aestivum* ‘Parshall’)
Target diseases: *Fusarium* spp.
Pythium spp.
Bipolaris sorokiniana

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Rancona HRSW seed treatment performance trial near Mott, ND, 2009.

This experiment was conducted in a field located near Mott, ND (NW ¼ Section 15, T136N, R93W, Hettinger County, ND). The previous crop was wheat in 2008. A soil sample was collected on April 21and analyzed by the North Dakota State University Soil Testing Laboratory. Nutrient levels reported were N=61 lb/a, P (Olsen) = 16 ppm, K= 110 ppm, pH=6.5, and OM = 2.2%. Roundup Original Max (Glyphosate) at the rate of 16 fl oz/a + Actimaster (AMS) at the rate of 32 fl oz/a was applied 5 May to control emerged volunteer wheat and weeds. Prior to seeding, seed was treated with Vitaflo 280, Rancona Pinnacle, Rancona Crest, UBI 9291-00 or UBI 9292-00. Untreated seed was used as a check. Plots were seeded with a drill equipped with Cross-slot openers on 7 May at the rate of 150 pls m^{-2}. Urea at the rate of 110 lbs/a (50.6 lbs/a N) was applied through the drill in a separate band during the seeding operation. A post emergent herbicide and foliar fungicide application of Harmony GT XP (Thifensulfuron-methyl) at 0.6 oz/acre, MCP Ester at 0.75 pt/acre, Puma (Fenoxaprop-P) at 0.66 pt/acre + Tilt (Propiconizole) at 2 oz/acre. Plant emergence estimates were made on 14 and 21 May with plant stand counts and vigor ratings made on 28 May. Soft dough root and crown evaluations were made on 20 Jul. Harvest was with a massy Ferguson 8 XP combine on 28 Aug. Grain yield and test weight were adjusted to a 12% moisture basis. All data was statistically analyzed using SAS Statistical Software.

No significant differences in emergence, plant stands, or vigor ratings were noted though treated seed tended to emerge faster, stand densities and vigor tended to be greater than the untreated check. Treated seed subcrown internodes exhibited significantly fewer lesions than the untreated check. Head density tended to be greater for treated seed compared to the untreated check but not significantly. No significant differences were detected in yield or test weight. Wheat stem sawfly injury was noted in this trial but did not appear to favor any particular treatment.

		Emergence[1]		Plant[2]	
		7 DAP	14 DAP	Stand density	Vigor
Treatment Name	Rate (ml/Kg)	---------- % ----------		m^{-2}	%
Untreated Check	-	0	55.0	184.0	100.0
Vitaflo 280	260	0	61.3	206.8	116.3
Rancona Pinnacle	325	0	58.8	203.5	118.8
Rancona Crest	325	0	60.0	210.7	116.3
UBI 9291-00	325	0	61.3	218.3	130.0
UBI 9292-00	325	0	61.3	192.0	112.5
Mean		0	59.6	202.5	115.6
CV%		-	12.7	18.2	21.9
LSD .05		-	NS	NS	NS

[1] Crop emergence and crop injury 7 days after plant = 14 May, 14 days after planting = 21 May.
[2] Plant stand and vigor ratings = 28 May

		Root Evaluation[1]				Grain[2]	
		Root color	Root mass	SCI	Head density	Yield	Test wt
Treatment Name	Rate (ml/Kg)				m^{-2}	bu/a	lb/bu
Untreated Check	-	1.98	2.58	1.17	537.5	69.5	65.8
Vitaflo 280	260	1.87	2.67	1.03	583.3	68.7	65.7
Rancona Pinnacle	325	2.02	2.50	1.04	545.8	67.2	66.0
Rancona Crest	325	1.93	2.39	1.04	585.4	66.3	64.7
UBI 9291-00	325	2.05	2.62	1.00	647.9	74.6	65.5
UBI 9292-00	325	2.10	2.70	1.04	612.5	73.7	65.6
Mean		2.0	2.6	1.1	585.4	70.0	65.5
CV%		19.3	10.1	6.1	13.8	7.3	1.7
LSD .05		NS	NS	0.0963	NS	NS	NS

[1] Root Evaluation: Color 1-4: 1= white, 4= dark; Mass 1-4: 1 = few roots, 4 = many roots; SCI Subcrown Internode Rating: 1 = 0 to 25% of root covered by lesions, 2 = 25 to 50% covered by lesions; 3 = 50 to 75% covered by lesions; 4 = 75 to 100% covered by lesions and or lesions coalesce

[2] Grain yield and test weight are adjusted and reported on a 12% moisture basis.

WHEAT (*Triticum aestivum* L. 'Freyr')
Tan spot; *Pyrenophora tritici-repentis*
Septoria; *Septoria* spp.
Leaf rust; *Puccinia recondita*
Fusarium head blight; *Fusarium graminearum*
Wheat stem sawfly; *Cephus cinctus*

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Evaluation of foliar fungicides Quilt, Quilt Xcel, Tilt, and Prosaro, and Warrior II insecticide treatments for control of leaf spot diseases, FHB, and wheat stem sawfly in spring wheat near Regent, ND, 2009.

The experiment was conducted in a producer's field near Regent, ND (SW ¼, Section 18, T134N, R95W, Hettinger County, ND) with a previous cropping history of wheat in 2008. A randomized complete block design with four replications was used. Plots were 6.3 ft wide by 50 ft long with a 4 ft buffer strip of spring wheat seeded between each plot. A preplant application of glyphosate was made on 19May to eliminate volunteer wheat and emerged weeds. Plots were seeded with a JD 1895 drill equipped with single disc openers and mid-row fertilizer disc openers on 26 May at the rate of 200 pls m^{-2}. Urea at the rate of 225 lbs/a (103.5 lbs/a N) was applied through the mid-row band disc openers of the drill and 75lbs/a of 12-36-6-5 (9 lb/a N, 27 lbs/a P2O5, 4.5 lbs/a K2O, and 3.8 lbs/a S) as a starter was placed with the seed during the seeding operation. A post emergent herbicide application of Bromac Advamced (Bromoxynil + MCPA Ester) at 1pt/a + Harmony GT XP (Thifensulfuron-methyl) at 0.6 oz/a + Puma (Fenoxaprop-P) at 0.66 pt/a was made with a pickup mounted sprayer on 3 Jul. Fungicide and insecticide applications at Feekes Growth Stage (FGS) 2, 4- to 5-leaf stage, were made on 30 Jun, and applications at FGS 8, flag leaf emerging, were made on 13 Jul. All fungicide and insecticide treatments were applied in 19.1 gal/a water at 30 psi using a CO_2 pressurized hand-held spray boom equipped with 8002VS flat fan nozzles. Tan spot disease evaluations were conducted on 9 Jul, and leaf spot disease evaluations and wheat stem sawfly evaluations were done on 4 and 5 Aug. Fungicide evaluations consisted of observations made on ten consecutive plants in the center row of each plot. Incidence was recorded as the percent of plants with at least one lesion observed, and severity was recorded as the average leaf area covered by lesions for all leaves for the early season evaluation, and the flag leaf for the late season evaluation. Wheat stem sawfly evaluation was done by selecting 25 consecutive plants in a treated row near the end of each plot and dissecting main stem and tillers to observe larva. Crop injury observations were made at the same time as the disease evaluations. No crop injury from the fungicide or insecticide applications were observed. No visual symptoms of Fusarium head blight (FHB) were detected in an evaluation of 10 consecutive heads in the center of each plot at soft dough. Grain samples from the control plots were sent to NDSU for DON analysis and no DON was detected in these samples. No further testing for DON in grain samples produced from fungicide treatments was done. Precipitation in the area recorded at the North Dakota Agricultural Weather Network (NDAWN) site at Mott in May, Jun, Jul and Aug was 1.79, 5.4, 2.5, and 1.39 inches respectively. Moist conditions in Jun, Jul, and Aug promoted tan spot, and septoria and cool weather conditions in Jul and through Aug were not conducive for FHB development. Leaf rust was not prevalent in the area this year and therefore 24 Jul evaluation consisted of septoria and tan spot infections. Disease ratings reflect moisture conditions at the time the crop was susceptible to infection. Harvest was with a Massy Ferguson 8XP combine on 17 Sep. Grain yield and test weight were adjusted to a 12% moisture basis. All data was statistically analyzed using SAS Statistical software v 9.1 Proc ANOVA.

No significant difference in wheat stem sawfly infestation was observed. However, significant differences were noted for infection incidence and severity among fungicide treatments. Both early and late season applied fungicide treatments produced significantly higher yields while insecticide treatments whether applied singularly or in combination with a fungicide produced yields no better than the untreated check. All fungicide treatments except in combination with the insecticide had significantly greater yields than the untreated check. No significant differences were detected in test weight.

Treatment	Sawfly[1]	--- Early --- I[2]	S[3]	--- Late --- I[4]	S[5]	--- Grain[6]--- Yield	Twt
	----------------------	%	------------------------			bu/acre	lb/bu
Untreated check	26.0	90.0	32.5	97.5	25.0	66.2	62.9
Quilt 7 oz @ FGS2	24.0	42.5	4.5	97.5	16.8	80.9	62.4
Tilt at 2 oz @ FGS2	32.0	45.0	6.5	100.0	25.0	83.2	62.3
Tilt at 2 oz + Warrior II @ 1.28 oz @ FGS2	16.0	60.0	6.0	92.6	14.3	75.9	62.7
Warrior II at 1.28 @FGS2	24.0	87.5	29.3	100.0	25.0	69.9	63.1
Tilt at 2 oz @FGS2 FB Quilt 14 oz @ FGS8	19.0	52.5	6.5	37.5	1.3	79.6	62.5
Quilt 14 oz @ FGS8	30.0	85.0	31.3	45.0	2.5	71.6	62.9
Prosaro at 6.5 oz+ NIS @ FGS2	20.0	42.5	6.0	97.5	17.5	79.8	62.4
Quilt Xcel at 14 oz @ FGS8	23.0	87.5	30.5	42.5	3.8	70.5	63
Quilt at 14 oz + Warrior II at 1.28 oz @ FGS8	31.0	9.0	33.8	50.0	1.5	66.5	62.8
Mean	24.5	6.8	18.7	76.0	13.0	74.4	62.7
CV%	36.3	14.2	17.3	21	35.7	4.3	0.92
LSD .05	NS	1.4	4.7	23.1	6.7	4.7	NS

[1] Percent of stems infested with sawfly.

[2] Percent incidence of plants exhibiting tan spot/septoria.

[3] Percent severity of infection on last three leaves.

[4] Percent of plants with flag leaf exhibiting tan spot/septoria

[5] Percent of severity of infection on flag leaf.

[6] Grain yield and test weight adjusted to 12% moisture basis.

No injury was detected from treatments.

Wheat (*Triticum aestivum* 'Howard')
Target diseases: *Fusarium* spp.
Pythium spp.
Bipolaris sorokiniana

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Vincit HRSW seed treatment performance trial near Mott, ND, 2009.

This experiment was conducted in a field located near Mott, ND (NW ¼ Section 15, T136N, R93W, Hettinger County, ND). The previous crop was wheat in 2008. A soil sample was collected on April 21and analyzed by the North Dakota State University Soil Testing Laboratory. Nutrient levels reported were N=61 lb/a, P (Olsen) = 16 ppm, K= 110 ppm, pH=6.5, and OM = 2.2%. Roundup Original Max (Glyphosate) at the rate of 16 fl oz/a + Actimaster (AMS) at the rate of 32 fl oz/a was applied 5 May to control emerged volunteer wheat and weeds. Prior to seeding, seed was treated with Vincit Minima, Vincit 5, Vincit Minima + Metalaxyl, Vincit 5 + Metalaxyl, or Raxil MD. Untreated seed was used as a check. Plots were seeded with a drill equipped with Cross-slot openers on 7 May at the rate of 150 pls m^{-2}. Urea at the rate of 110 lbs/a (50.6 lbs/a N) was applied through the drill in a separate band during the seeding operation. A post emergent herbicide and foliar fungicide application of Harmony GT XP (Thifensulfuron-methyl) at 0.6 oz/acre, MCP Ester at 0.75 pt/acre, Puma (Fenoxaprop-P) at 0.66 pt/acre + Tilt (Propiconizole) at 2 oz/acre. Plant emergence estimates were made on 14 and 21 May with plant stand counts and vigor ratings made on 28 May. Soft dough root and crown evaluations were made on 20 Jul. Harvest was with a massy Ferguson 8 XP combine on 28 Aug. Grain yield and test weight were adjusted to a 12% moisture basis. All data was statistically analyzed using SAS Statistical Software.

Plant counts and vigor observed tended to be greater than the untreated check for seed treatments. No significant difference were observed for root color, mass or subcrown internode ratings though root mass tended to be greater for seed treatments than the untreated check. No significant differences for test weight were detected. Significant differences were detected in head density counts for all seed treatments compared to the untreated check except for the high rate of Vincit Minima and the high rate of Vincit 5 + Metalaxyl and Raxil MD. Grain yield for both seed treatment rates of Vincit 5 and for Vincit Minima + Metalaxyl were significantly higher than the untreated check. Wheat stem sawfly injury was noted in this trial but did not appear to favor any particular treatment.

Trt Name	Rate	Crop Emergence[1]		Plant[2]		Crop Injury[1]	
		7 DAP	14 DAP	Stand	Vigor	7 DAP	14 DAP
	fl oz/cwt	---------- % ----------		m^{-2}	%	---------- % ----------	
Untreated Check		0	51.2	142.7	100.0	0	0
Vincit Minima	3.07	0	57.5	162.3	121.3	0	0
Vincit Minima	6.14	0	57.5	168.7	128.8	0	0
Vincit 5	1.54	0	51.3	149.5	110.0	0	0
Vincit 5	3.07	0	56.3	149.9	107.5	0	0
Vincit Minima + Metalaxyl	3.07 + 0.3	0	58.8	156.9	116.3	0	0
Vincit 5 + Metalaxyl	1.54 + 0.3	0	52.5	159.7	116.3	0	0
Raxil MD	5	0	55.0	164.1	130.0	0	0
Mean		0	55	156.7	116	0	0
CV%		-	11.8	14.7	17.7	-	-
LSD 0.05		-	NS	NS	NS	-	-

[1] Crop emergence and crop injury 7 days after plant = 14 May, 14 days after planting = 21 May.
[2] Plant stand and vigor ratings = 28 May.

Trt Name	Rate	Root Evaluation[1]				Grain[2]	
		Color	Mass	SCI	Head density	Yield	Test wt
	fl oz/cwt				m^{-2}	bu/acre	lb/bu
Untreated Check		1.52	2.80	1.2	493	59.9	65.6
Vincit Minima	3.07	1.78	3.07	1.05	594	62.6	66.1
Vincit Minima	6.14	1.68	2.92	1.2	533	61.4	64.8
Vincit 5	1.54	1.58	3.23	1.1	624	65.6	65.4
Vincit 5	3.07	1.92	3.03	1.23	611	66.1	66.1
Vincit Minima + Metalaxyl	3.07 + 0.3	1.54	3.02	1.15	626	66.3	65.1
Vincit 5 + Metalaxyl	1.54 + 0.3	1.53	3.10	1.18	534	60.6	64.9
Raxil MD	5	1.32	3.18	1.15	556	62.3	65.2
Mean		1.61	3.04	1.16	571	63.1	65.4
CV%		21.6	12.2	14.2	8.7	4.8	1.5
LSD 0.05		NS	NS	NS	73	4.5	NS

[1] Root Evaluation: Color 1-4: 1= white, 4= dark; Mass 1-4: 1 = few roots, 4 = many roots; SCI Subcrown Internode Rating: 1 = 0 to 25% of root covered by lesions, 2 = 25 to 50% covered by lesions; 3 = 50 to 75% covered by lesions; 4 = 75 to 100% covered by lesions and or lesions coalesce

[2] Grain yield and test weight are adjusted and reported on a 12% moisture basis.

Wheat (*Triticum aestivum* 'Wahoo')
Target diseases: *Fusarium* spp.
Pythium spp.
Bipolaris sorokiniana
Tilletia tritici

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Vincit HRWW seed treatment performance trial near New Hradec, ND, 2009.

This experiment was conducted in a field located near New Hradec, ND (NE 1/4 Section 4, T141N, R96W-Dunn County, ND). The previous crop was spring wheat in 2008. Roundup Original Max (Glyphosate) at the rate of 32 fl oz/a + Actimaster (AMS) at the rate of 32 fl oz/a was applied 20 Sep to control emerged volunteer wheat and weeds. Prior to seeding, seed was treated with Vincit Minima, Vincit 5, Vincit Minima + Metalaxyl, Vincit 5 + Metalaxyl, or Raxil MD. Untreated seed was used as a check. Plots were seeded with a drill equipped with Cross-slot openers on 2 Oct 2008 at the rate of 150 pls m^{-2}. As plots were seeded 100 g of ground wheat seed known to be contaminated with *Tilletia tritici* was added at the rotary distribution unit of the planter for each plot seeded. Urea at the rate of 100 lbs/a (46 lbs/a N) + 60 lbs/a of 11-52-0 (6.6 lbs/a N, 31.2 lbs/a P_2O_5) + 20 lbs/a 0-0-60 (12 K_2O) was applied through the drill in a separate band during the seeding operation. An additional 30.7 lbs/a N and 3.6 lbs/a S was top dressed on 17 Apr in the form of liquid fertilizer (11 gal/a 26-0-0-3). A post emergent herbicide and foliar fungicide application of Buctril (bromoxynil) at 1 pt/a, Puma (Fenoxaprop-P) at 0.66 pt/a + Tilt (Propiconizole) at 2 oz/a was made on 21 May 2009. Plant emergence estimates were made on 9 and 16 Oct 2008 with vigor scores on 16 Oct 2008 and crop injury scores on 16 and 30 Oct 2008. Soft dough root and crown evaluations were made on 13-15 Jul 2009. Harvest was with a Massy Ferguson 8 XP combine on 13 Aug 2009. Grain yield and test weight were adjusted to a 12% moisture basis. Bunted kernels in a 50 g grain sample from each plot were counted after harvest. All data was statistically analyzed using SAS Statistical Software.

No significant differences were detected in any of the characteristics measured except for the number of bunted kernels. The number of bunted kernels found in treated seed was less than found in the untreated check. Seed treatments tended to improve root color, root mass and reduce root lesions compared to the untreated check. Head density and grain yields also tended to be greater for treated seed compared to the untreated check.

		Emergence[1]		Vigor[2]	Crop Injury[3]	
Treatment		7 DAP	14 DAP	14 DAP	14 DAP	28 DAP
Name	Rate	%				
Untreated Check	fl oz/cwt	0	48.8	100.0	0	0
Vincit Minima	3.07	0	55.0	98.8	0	0
Vincit Minima	6.14	0	48.8	103.8	0	0
Vincit 5	1.54	0	51.3	102.5	0	0
Vincit 5	3.07	0	55.0	101.3	0	0
Vincit Minima + Metalaxyl	3.07 + 0.3	0	52.5	107.5	0	0
Vincit Minima + Metalaxyl	1.54	0	56.3	110.0	0	0
Raxil MD	5.00	0	53.8	105.0	0	0
Mean		0	52.7	103.6	0	0
CV%		-	9	5.6	-	-
LSD .05		NS	NS	NS	NS	NS

[1] Emergence, 7 days after planting = 9 Oct 2008, 14 days after planting = 16 Oct 2008.
[2] Vigor, 14 days after planting = 16 Oct 2008.
[3] Crop injury, 14 days after planting = 16 Oct 2008, 28 days after planting = 30 Oct 2008.

Treatment		Root evaluation[1] Color	Mass	SCI	Plant height	Head density	Bunted kernels	Grain[2] Test wt	Yield
Name	Rate				inches	#/yd^2	#/50g	lb/bu	bu/a
Untreated Check	fl oz/cwt	2.07	2.10	1.27	28	633	23.5	60.2	93.4
Vincit Minima	3.07	2.00	2.17	1.18	29.3	708	0.75	60.9	95.3
Vincit Minima	6.14	1.87	2.32	1.15	28.2	733	1.75	61.3	96.9
Vincit 5	1.54	2.05	2.43	1.04	29.6	782	1.00	60.9	98.6
Vincit 5	3.07	1.72	2.32	1.12	29.9	691	1.50	60.8	96.6
Vincit Minima + Metalaxyl	3.07 + 0.3	1.70	2.39	1.09	29.8	808	4.50	61.1	99.3
Vincit Minima + Metalaxyl	1.54	1.85	2.47	1.10	29.7	765	3.75	60.9	96.3
Raxil MD	5.00	1.97	2.55	1.17	29.1	784	4.50	60.6	94.9
Mean		1.9	2.33	1.14	29.2	738	5.2	60.8	96.4
CV%		14.9	15.7	10.2	6.01	14.3	71	1.3	4.1
LSD .05		NS	NS	NS	NS	NS	5.4	NS	NS

[1] Root Evaluation: Color 1-4: 1= white, 4= dark; Mass 1-4: 1 = few roots, 4 = many roots; SCI Subcrown Internode Rating: 1 = 0 to 25% of root covered by lesions, 2 = 25 to 50% covered by lesions; 3 = 50 to 75% covered by lesions; 4 = 75 to 100% covered by lesions and or lesions coalesce

[2] Grain yield and test weight are adjusted and reported on a 12% moisture basis.

Barley Cultivar Performance Following Corn in Clean- and No-Till Systems

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SUMMARY

Tillage is being reduced in dryland cropping regions. Our objective is to determine if tillage systems impacts barley cultivar ranking for yield and grain quality traits. Six barley cultivars were compared for grain yield, test weight, and kernel plumpness under clean- and no-till management in southwestern North Dakota during 2009. Grain yield ranged from 86 bu/acre for the 6-rowed cultivar Stellar-ND to 121 bu/acre for the 2-rowed cultivars Conrad and Pinnacle ($P < 0.05$). Grain test weight ranged from 46 lb/bu for Stellar-ND to 50 lb/bu for Conrad and another 2-rowed cultivar, Conlon. Fewer plump kernels were produced by Conlon than all other cultivars. Tillage had no or minimal effect on grain yield and quality. Similarly, tillage did not affect barley cultivar rank for any grain trait. These results suggest that barley cultivar rank is unchanged as tillage is reduced, but additional data are needed to verify this preliminary observation.
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INTRODUCTION

Tillage is declining in western North Dakota and other dryland cropping regions (Carr et al., 2003a). Previous research at the NDSU Dickinson Research Extension Center indicated that cultivar rank was unchanged for grain yield and quality when tillage was reduced in a wheat-fallow system (Carr et al., 2003a, 2003b). Grain yield also was unaffected by tillage in that study (Carr et al., 2003a). Grain yield and quality were enhanced under no-till compared with clean-till when cropping intensity was increased from crop-fallow to crop-crop in a subsequent study (Carr et al., 2006). This suggests that cultivar rank may be affected by tillage system when crops are grown annually. The objective of this research is to determine if barley cultivar rank changes across contrasting tillage systems in a barley-corn rotation.

MATERIALS AND METHODS

Three 2-rowed (Conlon, Conrad, and Pinnacle) and three 6-rowed (Lacey, Stellar-ND, and Tradition) barley cultivars were established in no-till and clean-till plots in a field where corn previously was grown. A barley-corn rotation was selected because of interest in determining if fusarium head blight would become a problem when these two crops are grown in a 'tight' 2-yr rotation in western North Dakota. Tillage plots were maintained as described previously (Carr et al., 2006). Soil surface coverage by previous crop cover and barley stand counts were determined as described elsewhere (Carr et al, 2006). Days to heading were recorded for plants in each plot, as was plant height at physiological maturity. Grain yield was determined by harvesting each plot. A subsample was used for determination of grain test weight, kernel weight.

Plots were arranged in a randomized complete block in a split plot arrangement. Tillage system comprised whole plots and barley cultivar comprised subplots. Tillage by barley cultivar combinations were replicated three times. Data were analyzed using PROC GLM from SAS for balanced data.

RESULTS AND DISCUSSION

Over 70% of the soil surface was covered by previous crop residue in no-till plots, compared with less than 10% in clean-till plots (Table 1). However, no impact was detected on barley stand establishment by surface residue coverage. Barley heading date, plant height, and spike density were unaffected by tillage system. Grain yield averaged over 100 bu/acre and test weight over 48 lb/bu, regardless of tillage system. There was a statistically significant advantage in kernel weight when barley was grown in clean-till plots (9726 kernels/lb) compared with no-till plots (9999 kernels/lb), as well as in kernel plumpness (clean-till = 98.5% and no-till = 97.9%), although the practical impacts of these small differences are limited.

Barley cultivar selection did not affect plant stand (Table 1). In contrast, Conlon headed 3 to 6 days earlier than other cultivars included in the study. Plant height was similar among all cultivars except for Conrad, which was 4 to 5 inches shorter. Over 50 reproductive spikes/ft^2 were counted in plots of each 2-rowed cultivar included in the study, compared with fewer than 35 for the three 6-rowed cultivar. This may explain why 2-rowed cultivars generally produced more grain than 6-rowed cultivars in this study. Average grain yield of Conlon, Conrad, and Pinnacle were 105, 121, and 121 bu/acre, respectively, compared with an average grain yield of 87, 86, and 97 bu/acre, respectively, for the 6-rowed cultivars Lacey, Stellar-ND, and Tradition (LSD = 12). With the exception of Tradition, 2-rowed cultivars also produced grain with a heavier test weight than 6-rowed cultivars. Heavier kernel weight was produced by Conlon and Pinnacle than any 6-rowed cultivar, but no advantage in kernel weight occurred between Conrad and 6-rowed cultivars. Conrad also produced a relatively low number of plump kernels (96%) compared with other cultivars (98-99%).

Cultivar ranking was unaffected by tillage system for any trait considered in this field experiment (data not presented). Cultivar selection may not be impacted by the tillage reductions that are occurring across cropping systems in western North Dakota. However, additional research is needed to validate the preliminary results generated from this study in 2009.

ACKNOWLEDGEMENT
The authors wish to thank Glenn Martin, agronomy research specialist along with student workers Ben Russ and Chalsy Steier for their assistance in conducting this study, along with all the suppliers who provided the herbicides that were evaluated in this study.

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Table 1. 2009 Tillage System and Barley Tillage Study, NDSU Dickinson Research Extension Center[1]

	Surface Cover	Plant count	Days to heading	Plant height	Spike density	Grain Yield	TW	Kernels	
Tillage system	-%-	-no./ft^2-	-d-	-in-	-no./ft^2-	-bu/ac-	-lb/bu-	-no./lb-	-% plump-
Conventional	8	19	55	30	42	107	48.7	9726	98.5
No-till	73	16	56	29	40	99	48.4	9999	97.9
LSD 0.05	57	NS	NS	NS	NS	NS	NS	84	0.1
Barley cultivars									
Conlon	41	17	52	30	51	105	50	8841	99
Conrad	45	18	58	26	56	121	50	10,297	96
Lacey	-	19	55	30	24	87	49	10,621	98
Pinnacle	-	17	56	31	51	121	48	8439	98
Stellar-ND	-	18	56	30	30	86	46	10,272	99
Tradition	-	19	55	30	32	97	49	10,702	99
LSD 0.05	NS	NS	1	2	11	12	1	360	0.9

Crop Cultivar Performance Testing Under Organic Management in Southwestern North Dakota

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SUMMARY

Small-grain and field pea cultivar performance testing was done in fields transitioning to certified organic management in 2009. Thirteen hard red spring wheat and six field pea cultivars were compared for grain yield and other selected traits in separate studies. The cultivar Howard produced 61 bu/acre and more grain than other cultivars in the spring wheat study, except for Coteau and Stoa. CDC Mozart averaged 43 bu/acre and more grain than Cruiser and Majoret in the field pea study. Seven emmer treatments representing different seed lots and cultivars were compared in a third field study. Grain yield averaged almost 3600 lb/acre with no difference detected across emmer treatment ($P > 0.05$). These results indicate that grain yield of hard red spring wheat, emmer, and field pea can exceed 40 bu/acre under dryland management when grown in fields transitioning to certified organic management in southwestern North Dakota.
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INTRODUCTION

Cultivar adaptation studies are valued highly and encouraged by organic farmers and their proponents (Sooby et al., 2007). Previous research suggests that crop cultivars developed and selected in environments managed conventionally are adapted to environments managed organically (Carr et al., 2006), but recent studies indicate that cultivars suited to organic farming methods should be developed and selected under organic management (Mason et al., 2007; Murphy et al., 2007). Research is needed that identifies crop species and cultivars that are adapted to organic farming methods in North Dakota, as well as traits (e.g., rapid emergence; Sooby et al., 2007) that those species and cultivars possess which explain their adaptation to organic environments. Crop cultivar comparison efforts were established under organic management in a field transitioning to certified organic production in 2009 so that superior performing cultivars could be identified.

MATERIALS AND METHODS

The 2009 growing season began much later than is typical. As a result, small-grain and field pea cultivar comparison studies were not established until late May and not harvested until late August (field pea) or early September (emmer and spring wheat).

RESULTS AND DISCUSSION

The late seeding is reflected in the later-than-average first-flower (field pea) and heading (spring wheat) dates that were observed (Tables 1 and 2). Date of first flower was similar among the six field pea cultivars that were compared. In contrast, differences occurred between spring wheat cultivars for heading date. 'Thatcher', 'Waldon', 'Glenn', and Howard were among the first cultivars to reach the heading growth stage, while 'Red Fife' and 'Vesta' were among the last. Lodging generally did not occur among spring wheat cultivars at physiological maturity, with the exception of Kota (lodging score = 4.5 on a scale of 0 to 9 where 0 = no lodging and 9 = completely flattened). In contrast, all emmer treatments had lodging scores greater than 5.0 (Table 3). Field pea lodging scores are not reported.

Field pea plant height ranged from 21 inches for Majoret to 27 inches for DS Admiral (Table 1). Differences between cultivars were not detected in the spring wheat study, with plant height averaging 35 inches (Table 2). Similarly, emmer plant height averaged 36 inches with no differences detected across treatments (Table 3).

CDC Mozart field pea produced a grain yield average of 43 bu/acre, compared with 37 bu/acre for Cruiser and 35 bu/acre for Majoret (Table 1). Both Cruiser and Majoret are green cotelydon-type field pea cultivars, whereas CDC Mozart is a yellow cotyledon-type field pea cultivar. However, CDC Striker is a green cotyledon-type pea cultivar that produced comparable amounts of grain (40 bu/acre) to that produced by CDC Mozart

Grain yield ranged from 61 bu/acre for Howard to 44 bu/acre for Thatcher in the spring wheat study (Table 2). Howard is a modern spring wheat cultivar developed and released by the Agricultural Experiment Station at North Dakota State University in 2006. Thatcher is an old spring wheat cultivar released in 1935. Coteau (released in 1978) and Stoa (released in 1984) still are grown on some organic farms, and both cultivars produced yield levels comparable to the grain yield produced by Howard. Glenn, released in 2005, was the most widely grown cultivar in North Dakota in 2009. Glenn produced an average grain yield of 55 bu/acre in the study. Other cultivars producing grain yield levels comparable to those produced by Glenn included Red Fife (widely grown in the late 19th century), Mida (released in 1944), Chris (relased in 1965), Waldron (released in 1969), along with Coteau and Stoa. In contrast, the old cultivars Marquis (released iin 1910), Kota (released in 1921), Thatcher (released in 1935), and Vesta (released in 1942) produced less grain than either Glenn or Howard.

Emmer grain yield averaged 3574 lb/acre, with little variation across the seven treatments that were compared (Table 3). Similarly, differences were not detected between emmer treatments for any growth trait that was evaluated, as well as grain test weight.

Plans are underway to expand cultivar performance testing under organic management at the Dickinson Research Extension Center in 2010 and beyond. This research will aid farmers in selecting cultivars that are adapted to organic farming conditions in western parts of the state.

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The authors wish to thank Glenn Martin, agronomy research specialist along with student workers Ben Russ and Chalsy Steier for their assistance in conducting this study, along with all the suppliers who provided the herbicides that were evaluated in this study.

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Table 1. 2009 Organic field pea trial, NDSU Dickinson Research Extension Center[1]

Cultivar	Cotelydon type	Plant population -1000/acre-	First flower -July-	Plant Height -in-	Grain yield -bu/acre-	Grain test weight -lb/bu-	Seed weight -g/100 seed-
CDC Golden	YELLOW	617	7	25	41	64.7	2067
CDC Mozart	YELLOW	585	6	20	43	64.5	1899
CDC Striker	GREEN	694	7	25	40	65.4	1832
Cruiser	GREEN	602	7	24	37	64.0	2272
DS Admiral	YELLOW	479	7	27	40	65.2	1866
Majoret	GREEN	536	7	21	35	63.8	2132
Mean		586	7	24	39	64.6	2,011
C.V. (%)		10	7	4	7	1	4
LSD (0.05)		84	NS	1.6	4	1	126

[1]Planting date: 20 May; Harvest date: 25 August; Previous crop = Gazelle spring rye

Table 2. 2009 Organic hard red spring wheat trial, NDSU Dickinson Research Extension Center[1]

Cultivar	Approximate Year of Release	Heading date -July-	Lodging Score 0-9	Plant height -in-	Grain yield -bu/acre-
Red Fife	1885	16	0.3	33	51
Marquis	1910	15	0.8	37	49
Kota	1921	15	4.5	37	45
Thatcher	1935	10	0.3	35	44
Vesta	1942	16	3.8	33	47
Mida	1944	12	2.3	37	51
Acadia	1951	11	1.0	36	52
Chris	1965	13	1.3	34	51
Waldron	1969	10	0.0	35	51
Coteau	1978	15	0.0	35	57
Stoa	1984	11	0.3	35	56
Glenn	2005	10	0.0	35	55
Howard	2006	10	0.0	33	61
Mean		13	1.12	35	52
C.V. (%)		8	72	6	7
LSD (0.05)		1	1	NS	5

[1]Planting date: 20 May; Harvest date: 02 September; Lodging: 0 = no lodging, 9 = completely flat; Previous crop = Gazelle spring rye

Table 3. 2009 Organic emmer trial, NDSU Dickinson Research Extension Center[1,2]

	Days to	Plant	Lodging	Test	Grain
	heading	height	score	weight	yield
Cultivar	-d-	-in-	0-9	-lb/bu-	-lb/acre-
Bowman	60	36	5.8	34.4	3617.5
Common H	60	36	5.5	36.0	3639.1
Common M	60	36	5.3	33.8	3236.7
Common R	60	35	6.3	35.3	3599.5
Lucille	61	37	5.5	33.6	3607.4
Common ND	60	36	6.0	35.3	3691.1
Red Vernal	61	36	6.0	33.1	3629.6
Mean	60	36	5.8	34.5	3574.4
CV %	0.5	1.9	25.0	4.7	9.9
LSD (0.05)	0.4	NS	NS	NS	NS

[1]Planting date: 20 May; Harvest date: 02 September; Lodging: 0 = no lodging, 9 = completely flat; Previous crop = Gazelle spring rye

[2]H, M, R, and ND refer to different seed lots of common emmer

Dickinson Natural Products Weed Control Efficacy Study

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SUMMARY

Herbicides generally are prohibited from use in organic management systems. However, a small number of products incorporating naturally-occurring active ingredients are permitted under the USDA National Organic Program. These herbicides could be an important tool for organic farmers and, for that reason, a study was conducted to determine the efficacy of five different herbicide treatments on controlling grass and broadleaf weeds in southwestern North Dakota in 2009: Green Match (active ingredient [a.i.] = lemongrass oil), Matratac AG (a.i. = clove oil), Racer (a.i. = ammonium nonanoate), and vinegar (20% acetic acid). All products were applied in plots arranged in a randomized complete block design prior to seeding hard red spring wheat (cv. FBC Dylan). Treatment blocks were replicated four times. Weed control was rated at 1, 7, 14, 21, and 42 days after application. Grain yield was determined when wheat reached physiological maturity. Visual ratings indicated that all herbicides controlled weeds compared with weedy plots where no herbicide was applied ($P < 0.05$). Wheat yield was enhanced from 44 to 61%, depending on the herbicide treatment. Results of this preliminary study suggest herbicides or products having herbicidal activity do have potential in organic management systems, but caution is urged since many are not cleared for use as herbicides in field crops in North Dakota. The one exception in this study was Green Match, which could be used for weed control in wheat during 2009.

INTRODUCTION

The National Organic Program along with organic certification groups emphasize preventative and cultural measures for weed control. However, oftentimes tillage is relied upon heavily for weed control on many organic farms. Unfortunately, the deleterious impacts of excessive tillage on soil structure, organic matter content and humus formation are well known. Recent interest in reduced- or conservation-till, organic farming systems has kindled interest in natural products that might provide organic farmers with a burn-down herbicide option. There are few products that are registered under the USDA National Organic Standards for use as herbicides. These herbicides typically use naturally-occurring substances for weed control, such as clove and garlic oils, soap salts or acids. Little research has been conducted to determine their efficacy in controlling weeds in North Dakota or neighboring states.

MATERIALS AND METHODS

The 2009 growing season began much later than is typical. Cool temperatures prevented early emergence of summer annual weeds and delayed the onset of regrowth by winter annual weeds. Seeding was delayed much later than is recommended so that annual weeds would emerge or resume growth before treatments were applied. A decision was made to seed on 15 June, much later than is recommended, even though the weed population was lower than anticipated. Hard red spring wheat (cv. FBC Dylan) was seeded at 90 lb PLS/acre using a John Deere 750 grain drill in rows 15 cm apart.

All treatments were applied using a hooded bicycle-type sprayer with a 7.5-ft boom and 8004 nozzle tips at a rate of 150 gallons per hectare (60 gpa) on 18 June, beginning at 8:30 AM and ending at 10 AM, under partly cloudy skies and at a relative humidity of 55%. Wind speed during the application period achieved a maximum velocity of 2.7 mph. Treatments were applied in 10 by 20 ft plots that were arranged in a randomized complete block and replicated four times. An unsprayed 5-ft border separated adjacent plots within each block.

Above-ground weed biomass was collected from a 0.25-m^2 area in each plot on 17 June and separated into grass and broadleaf weed samples. The weed population was low and consisted predominately of common lambsquarters, kochia, Russian thistle, and dandelion for broadleaf species, and green foxtail and barnyardgrass for grass species. Weed samples were dried at 130^{o}F until a constant weight was reached, and then weighed. Weights were reported as g/m^2. A second biomass sample was collected on 19 June, approximately 24 hr after the treatments were applied, following the same procedure.

A visual efficacy rating (% control) was given by comparing the density and necrosis of weeds in the center of each plot to the 5-ft untreated area separating adjacent plots by three individuals independently at 1, 7, 14, 21, and 42 days after treatments were applied. A mean was computed from the three ratings each date by plot combination and recorded. Plot centers were marked by flags but otherwise not identified to minimize bias during the rating process. The lack of identifying plot treatments explains how the mean visual efficacy rating did not = 0 for most dates in weedy check plots (refer to Table 1).

Above-ground crop and weed biomass samples were collected from a 0.25-m^2 area on 13 August. Biomass collection occurred as described earlier. Cool weather delayed grain harvest until 18 September, when grain yield was determined by harvesting the cener 8.7-m^2 (93-ft^2) area in each plot using a research harvester.

Data were analyzed using the PROC ANOVA procedure available from SAS. Results of the analyses are summarized in Tables 1 and 2.

RESULTS

It was observed, beginning approximately 7 days after the application of the treatments, that purslane was present at varying populations in plots; very few if any plants occurred in some plots while there appeared populations >4 plants/0.1-m^2 in the untreated border area separating plots, outside the study elsewhere in the field, and in at least one plot in each of the four blocks of treatments included in the study. This observation suggested varying levels of soil activity on this weed species since no purslane was observed before or within a few days after the treatments were applied.

Differences in grass and broadleaf weed biomass were not detected between plots receiving herbicide treatments and the weedy check plots where no herbicide treatment was applied just prior and shortly after the treatments were applied (Table 1). However, visual weed ratings indicated weeds were controlled in plots receiving all herbicide treatments compared with weedy check plots. Differences in visual weed ratings between plots receiving different herbicide treatments generally were not detected, except at 14 days after seeding FBC Dylan wheat (i.e., 15 days after herbicide application) when weed control appeared superior in plots receiving the Green Match treatment compared with Racer.

Differences in grass and broadleaf weed biomass were not detected in plots receiving herbicide treatments and weedy check plots when the wheat crop reached physiological maturity (Table 2). However, more biomass was produced by wheat in plots where herbicides were applied compared with weedy check plots, except when Racer was used. Less wheat biomass was produced in plots receiving the Racer treatments than in plots where Green Match and Vinegar were applied.

Wheat yield was greater in plots were herbicides were applied compared with the weedy check plots (Table 2). These results demonstrate that all herbicides evaluated at Dickinson in 2009 did control weeds compared with weedy check plots. This work will be expanded and continue in 2010.

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Table 1. Pre-treatment application (PRE) and Post-treatment application (POST) weed biomass and visual weed ratings (percent visual weed control) at 1, 7, 14, 21, and 42 days after seeding (DAS) for six natural products at the North Dakota State University, Dickinson Research Extension Center in 2009.

	PRE		POST		Visual Weed Control				
	g/m2				-%-				
Treatment	Grass	Broadleaf	Grass	Broadleaf	1 DAS	7 DAS	14 DAS	21 DAS	42 DAS
Green Match	70	5	65	0	39	26	40	27	39
Matratec AG	43	3	16	3	23	29	33	27	26
Matratec AG + Act90	38	19	13	3	28	33	37	35	38
Racer	65	8	40	0	36	23	18	20	23
Vinegar (20%)	30	11	8	0	49	44	59	68	52
Weedy check	51	8	105	0	0	2	6	2	2
Mean	42	8	35	1	25	22	28	26	26
CV %	77	238	162	358	47	47	39	37	36
P-value	0.68	0.48	0.32	0.6	0.003	0.006	0.0006	<0.0001	0.0002
LSD (0.05)	NS	NS	NS	NS	21	19	19	17	16

Table 2. Crop, grass weed, and broadleaf weed biomass, and hard red spring wheat grain yield following the application of six natural products at the North Dakota State University, Dickinson Research Extension Center in 2009.

	Rate[1]	Biomass (g/m2)			Wheat grain yield	
Treatment	-%-	Crop	Grass	Broadleaf	kg/ha	Bu/acre
Green Match	14	487	32	65	1982	29
Matratec AG	8	404	83	41	1720	26
Matratec AG + Act90	8	397	85	43	1799	27
Racer	6	338	122	76	1717	26
Vinegar (20%)	100	464	150	29	1953	29
Weedy check	-	236	238	73	1238	18
Mean		332	101	47	1487	22
CV %		18	80	73	15.7	15.7
P-value		0.002	0.10	0.48	0.019	0.19
LSD (0.05)		108	NS	NS	411	6

[1]Number indicates percent of total product (active ingredient plus inerts) in solution applied at a rate of 60 gallons per acre.

Status Report of Cover Crop Studies at the NDSU Dickinson Research Extension Center.

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SUMMARY

Considerable interest in cover crops exists because of the benefits to soil quality, pest suppression, and subsequent crop performance that can result when cover crops are incorporated into rotations with grain, seed, forage, and/or industrial crops. Several cover crops studies are underway at the Dickinson Research Extension Center. Hairy vetch, winter rye, and winter wheat planted alone and in cereal/legume combinations are being compared for their impact on weeds and subsequent performance of buckwheat, corn, and pinto bean after cover crops are disked, undercut, and rolled/crimped. The impact of winter rye and hairy vetch cover crops on soil biological, chemical, and physical properties, soil water content, weed growth, and subsequent crop performance is being compared in a separate study when cover crops are disked and rolled/crimped. Five spring-seeded (fababean, spring rye, spring triticale, sudangrass, and a 4-crop mixture) and five fall-seeded (Austrian winter pea, hairy vetch, winter rye, winter triticale, and a 4-crop mixture) cover crop treatments are being compared for impacts on soil water content, soil quality, and subsequent crop performance when cover crops are disked, undercut, rolled/crimped, and mowed in a third study. Buckwheat, corn, flax, dry bean, and spring wheat performance is being compared after seeding into rolled and crimped spring rye, hairy vetch, and winter rye cover crops. These four studies are ongoing and results will be reported as studies are completed, beginning in 2010.

2009 Winter Wheat - Recrop | **Dickinson, ND**

Variety	Heading Date	Seeds per Pound	Plant Height	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
	June		in	lbs/bu	%	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
Alice	22	14,289	24	59.8	10.2	79.0	15.4	61.5	38.5	52.0
Art	22	13,209	24	61.4	11.8	--	--	55.8	--	--
Striker	22	15,616	24	60.0	11.3	--	--	61.1	--	--
Boomer	26	13,421	26	60.1	10.5	--	--	70.9	--	--
CDC Accipiter	27	14,482	27	61.4	8.9	--	18.6	68.5	43.6	--
CDC Buteo	25	13,346	29	62.5	9.9	82.7	17.6	63.2	40.4	54.5
CDC Falcon	25	13,922	24	60.9	10.2	79.8	17.9	70.4	44.2	56.0
CDC Peregrine	25	12,467	34	62.2	10.0	--	17.5	68.2	42.9	--
Darrell	24	11,134	29	61.5	9.8	79.9	19.4	71.8	45.6	57.0
Expedition	22	12,558	27	61.6	10.3	71.0	15.0	67.1	41.1	51.0
Hawken	21	13,292	23	61.5	9.5	--	13.9	61.7	37.8	--
Jagalene	24	12,517	24	60.6	10.5	64.5	16.4	56.0	36.2	45.7
Jerry	26	11,389	30	60.4	9.1	82.9	18.3	58.9	38.6	53.4
Lyman	21	11,782	26	60.9	9.6	--	18.2	61.4	39.8	--
Mace	24	14,859	26	59.8	9.1	--	--	72.2	--	--
Millennium	24	12,462	28	61.8	10.1	86.7	17.6	60.4	39.0	54.9
Overland	24	12,877	27	61.0	9.4	--	21.4	72.1	46.7	--
Radiant	26	12,742	29	60.8	8.6	70.7	19.5	57.3	38.4	49.1
Wesley	20	12,186	23	59.0	9.8	78.9	14.1	57.3	35.7	50.1
Yellowstone	26	12,725	29	61.4	10.0	75.4	18.8	73.7	46.3	56.0
Trial Mean	24	13,092	27	60.9	9.9	77.7	16.9	65.0	--	--
CV %	4.3	5.4	8.6	1.6	8.2	10.4	12.8	23.9	--	--
LSD 0.05	1	1,474	3	1.6	NS	11.4	3.1	NS	--	--

Planting Date: September 26, 2008
Harvest Date: August 24, 2009
Previous Crop: Field Pea
Seeding Rate: 1 million live seeds/ac
Note: Trial received hail damage

2009 Oat - Recrop **Dickinson, ND**

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
			in	lbs/bu	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
AC Pinnacle	62	13,135	39	36.7	108.5	55.2	213.3	134.2	125.6
Beach	61	12,973	42	39.5	102.4	51.2	167.8	109.5	107.1
Buff*	57	16,205	38	41.6	71.5	48.9	151.2	100.1	90.5
CDC Dancer	61	12,216	41	38.3	112.2	57.8	172.9	115.4	114.3
CDC Minstrel	61	11,301	39	36.8	--	52.1	188.9	120.5	--
Furlong	63	9,195	38	35.7	--	57.4	182.1	119.7	--
HiFi	60	13,615	40	38.0	93.9	50.7	174.8	112.8	106.5
Hytest	59	12,636	41	39.6	96.3	57.0	151.0	104.0	101.5
Jerry	59	13,825	39	37.6	110.0	53.5	157.5	105.5	107.0
Killdeer	59	12,544	37	37.9	115.6	56.3	199.5	127.9	123.8
Leggett	61	11,547	38	38.2	--	--	194.2	--	--
Maida	61	11,922	40	37.5	100.6	50.4	164.6	107.5	105.2
Monida	63	14,224	39	35.2	96.5	60.1	179.2	119.6	111.9
Morton	62	13,409	42	37.9	104.6	49.2	162.8	106.0	105.5
Otana	62	14,243	42	39.1	109.7	66.0	167.9	116.9	114.5
Paul*	63	14,381	40	40.8	81.7	33.7	139.5	86.6	85.0
Rockford	61	13,778	41	40.1	127.4	51.5	187.1	119.3	122.0
Souris	60	13,447	36	36.9	112.9	55.9	175.1	115.5	114.6
Stallion	60	14,833	40	40.0	109.5	61.8	170.9	116.4	114.1
Stark*	63	13,981	40	42.7	73.3	39.9	149.1	94.5	87.4
Youngs	62	9,673	42	36.7	116.8	52.1	178.9	115.5	116.0
Trial Mean	61	12,709	40	38.3	104.3	52.8	173.0	--	--
CV %	1.0	5.4	2.9	1.8	10.1	9.3	6.0	--	--
LSD 0.05	1	1,397	2	1.0	14.8	6.9	14.6	--	--

Planting Date: May 7, 2009
Harvest Date: August 31, 2009
* Hulless
Previous Crop: Field Pea
Seeding Rate: 1 million live seeds/ac

2009 Durum - Recrop Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
			in	lbs/bu	%	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
AC Commander	64	8,945	30	60.0	13.4	61.4	12.3	93.3	52.8	55.7
AC Napoleon	64	9,240	35	59.6	13.6	46.9	13.8	82.6	48.2	47.8
AC Navigator	64	9,788	31	62.1	13.0	48.3	12.7	83.9	48.3	48.3
Alkabo	64	10,084	33	61.6	13.4	46.9	13.5	75.0	44.2	45.1
Alzada	59	9,296	28	59.8	13.4	--	17.5	69.4	43.5	--
Ben	64	9,829	34	61.4	14.1	45.1	13.2	75.6	44.4	44.6
CDC Verona	66	10,063	34	62.2	13.3	--	--	87.0	--	--
DG Max	64	11,187	35	62.7	13.5	--	12.5	87.2	49.8	--
DG Star	60	9,884	34	60.2	13.8	--	11.2	80.4	45.8	--
Dilse	65	9,808	33	62.4	14.1	46.8	13.6	84.4	49.0	48.3
Divide	65	10,172	35	61.5	13.6	44.7	16.6	87.1	51.8	49.4
Grenora	64	9,560	32	61.2	12.9	47.8	13.7	89.6	51.7	50.4
Lebsock	64	9,629	34	61.9	13.4	45.9	15.0	77.9	46.5	46.3
Maier	64	10,064	32	62.0	14.3	45.2	14.7	85.3	50.0	48.4
Mountrail	65	9,450	33	62.1	12.7	46.6	12.4	92.2	52.3	50.4
Pierce	64	11,370	34	62.5	13.3	46.5	17.5	87.7	52.6	50.6
Strongfield	64	10,243	33	61.6	13.9	46.7	13.2	78.0	45.6	45.9
Wales	64	10,988	33	61.7	13.1	--	14.2	92.7	53.5	--
Trial Mean	64	9,923	33	62.0	13.5	48.4	13.6	85.2	--	--
CV %	0.9	5.7	4.0	1.2	4.3	6.7	19.5	7.5	--	--
LSD 0.05	1	1,139	2	1.0	1.2	4.6	NS	8.9	--	--

Planting Date: May 4, 2009
Harvest Date: September 10, 2009
Previous Crop: Field Pea
Seeding Rate: 1.2 million live seeds/ac

2009 Commercial White Wheat - Recrop — Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	-------Grain Yield------- 2007	2008	2009	Average Yield 2 Year	3 Year
			in	lbs/bu	%	---------bu/ac---------			----bu/ac----	
AC Karma	69	10,591	32	61.7	11.7	40.5	29.6	78.3	53.9	49.5
AC Snowbird	70	12,082	38	63.7	13.1	41.4	26.2	59.0	42.6	42.2
AC Snowstar	67	13,111	34	64.3	12.7	--	--	50.1	--	--
AC Vista	70	9,889	33	61.6	10.9	47.0	28.0	66.1	47.0	47.0
Agawam	67	9,861	29	64.6	12.4	49.9	24.8	75.2	50.0	50.0
Alpine	70	11,635	33	62.6	11.9	--	34.0	79.8	56.9	--
Diamond	70	10,558	38	64.1	11.4	44.3	28.1	61.7	44.9	44.7
Explorer	68	13,701	30	61.8	12.8	45.8	29.7	71.6	50.6	49.0
Glenn (hrsw)	67	12,377	36	66.1	13.3	49.4	27.5	52.1	39.8	43.0
Golden 86	69	10,003	29	61.7	12.4	45.8	24.4	72.8	48.6	47.7
IDO377S	70	11,881	30	63.8	10.9	--	27.3	69.3	48.3	--
Kantana	70	13,643	37	62.1	14.5	36.4	24.7	48.7	36.7	36.6
Lochsa	70	10,514	30	59.3	11.3	46.6	27.5	64.5	46.0	46.2
Lolo	70	10,485	32	64.4	11.3	47.8	29.8	76.0	52.9	51.2
Otis	70	9,941	34	65.0	11.8	46.4	27.8	79.5	53.6	51.2
Penewawa	71	11,329	30	61.4	10.0	42.3	29.1	80.5	54.8	50.6
Reeder (hrsw)	69	11,244	31	62.8	13.0	45.5	26.8	67.0	46.9	46.4
Snow Crest	64	12,777	25	60.2	12.6	40.8	25.1	68.8	47.0	44.9
Steele-ND (hrsw)	70	12,152	33	64.2	12.8	47.2	26.7	57.7	42.2	43.8
Waikea	68	9,927	32	59.6	11.8	52.6	27.7	71.1	49.4	50.5
Trial Mean	69	11,385	32	62.7	12.1	44.9	27.6	67.5	--	--
CV %	1.2	4.9	3.0	1.3	4.0	5.6	6.8	11.2	--	--
LSD 0.05	1	1,161	2	1.4	1.0	3.6	2.7	12.5	--	--

Planting Date: April 22, 2009
Harvest Date: August 26, 2009
Previous Crop: Field Pea
Seeding Rate: 1.2 million live seeds/ac
Note: Trial received hail damage

2009 Hannover Durum - Recrop — Dickinson, ND

Variety	Seeds per Pound	Test Weight	Protein	------Grain Yield------ 2007	2008	2009	Average Yield 2 Year	3 Year
		lbs/bu	%	-------bu/ac-------			----bu/ac----	
Alkabo	10,321	58.5	14.3	38.6	34.3	62.1	48.2	45.0
DG Max	10,171	57.7	14.2	--	--	60.5	--	--
Divide	10,583	58.9	14.1	37.5	34.2	60.9	47.5	44.2
Grenora	9,972	57.0	14.2	37.5	35.6	61.4	48.5	44.8
Mountrail	10,398	58.4	13.9	40.3	32.4	67.0	49.7	46.6
Trial Mean	10,279	58.3	14.2	38.5	33.1	63.0	--	--
CV %	4.2	1.6	1.7	4.5	10.0	3.2	--	--
LSD 0.05	NS	1.4	NS	NS	NS	3.0	--	--

Planting Date: May 15, 2009

Harvest Date: September 3, 2009

Previous Crop: Wheat

Seeding Rate: 1.2 million live seeds/ac

2009 Glen Ullin Durum - Fallow **Dickinson, ND**

Variety	Seeds per Pound	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
		lbs/bu	%	bu/ac			bu/ac	
Alkabo	9,889	62.5	14.1	35.7	36.4	68.8	52.60	47.0
DG Max	10,546	62.0	14.0	--	--	71.2	--	--
Divide	9,890	62.1	14.0	36.2	42.9	64.8	53.86	48.0
Grenora	10,218	60.7	13.3	38.4	37.6	69.5	53.57	48.5
Mountrail	10,531	62.4	13.2	44.6	37.0	75.7	56.33	52.4
Trial Mean	10,034	62.3	13.7	39.5	37.0	71.7	--	--
CV %	9.3	2.0	4.2	8.6	23.1	10.0	--	--
LSD 0.05	NS	1.9	NS	5.2	NS	NS	--	--

Planting Date: May 15, 2009

Harvest Date: September 10, 2009

Seeding Rate: 1.2 million live seeds/ac

2009 Barley - Recrop — Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	% Plump	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
			in	lbs/bu	%	>6/64	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
Six Row											
Celebration	68	13,874	28	45.3	11.4	96.4	--	57.8	74.6	66.2	--
Drummond	66	12,433	31	45.8	11.5	95.6	71.2	53.8	71.5	62.7	65.5
Lacey	69	11,491	29	46.1	10.9	96.2	79.3	53.6	74.9	64.3	69.3
Legacy	70	12,005	29	43.9	9.4	97.5	68.1	51.7	72.2	62.0	64.0
Rasmusson	66	11,915	27	47.6	11.9	96.1	75.1	53.5	86.4	69.9	71.7
Robust	69	11,810	31	46.6	11.5	96.8	70.8	49.2	66.2	57.7	62.0
Stellar-ND	68	11,357	28	45.8	12.1	97.7	69.3	50.4	72.0	61.2	63.9
Tradition	68	12,394	28	45.7	11.2	97.7	75.4	53.3	72.5	62.9	67.1
Two Row											
AC Metcalfe	71	10,501	28	51.7	11.4	96.0	70.9	52.3	107.2	79.8	76.8
BG 705	70	11,432	23	60.1	9.7	93.9	--	--	73.1	--	--
BZ493-46E	72	13,381	28	48.6	11.4	12.9	--	--	75.2	--	--
CDC Copeland	76	9,841	28	50.6	11.0	96.8	68.7	45.8	110.0	77.9	74.8
Champion	71	9,987	28	50.9	9.6	98.2	--	--	102.4	--	--
Conlon	67	9,711	25	48.6	11.3	98.4	63.9	49.1	74.5	61.8	62.5
Conrad	71	10,576	26	50.4	10.2	99.0	76.3	52.7	105.6	79.2	78.2
Enduro	71	11,229	24	58.7	8.0	95.5	--	--	83.7	--	--
Harrington	71	10,065	28	49.5	9.8	98.5	63.3	47.5	92.1	69.8	67.6
Haxby	68	9,652	28	53.1	11.0	98.5	76.7	55.1	105.0	80.0	78.9
Pinnacle	69	9,127	30	49.4	9.7	98.3	69.3	54.1	89.3	71.7	70.9
Pronghorn	70	12,628	26	56.1	8.9	80.0	--	--	71.8	--	--
Prowashonupana	69	14,636	24	42.4	13.5	19.9	--	--	73.2	--	--
Rawson	70	8,630	25	48.7	10.8	98.6	66.4	54.9	81.4	68.1	67.6
Salute	70	10,405	26	49.4	11.0	98.1	--	--	113.2	--	--
Scarlett	76	10,380	23	49.0	10.1	98.8	76.7	50.4	104.6	77.5	77.2
Trial Mean	69	11,285	27	48.6	10.7	92	71.8	52.3	83.5	--	--
CV %	1.1	3.2	6.2	2.5	8.11	1.1	9.7	7.1	13.2	--	--
LSD 0.05	1	729	3	2.0	1.8	2	NS	5.2	18.0	--	--

Planting Date: April 22, 2009
Harvest Date: August 24, 2009
Previous Crop: Field Pea
Seeding Rate: 1.2 million live seeds/ac
Note: Trial received hail damage

2009 Glen Ullin Barley - Fallow — Dickinson, ND

Variety	Seeds per Pound	Test Weight	% Plump	Protein	Grain Yield
		lbs/bu	>6/64	%	----bu/ac----
Six Row					
Celebration	11,085	45.4	98.2	12.9	126.2
Stellar-ND	10,239	45.3	98.7	11.8	132.1
Tradition	10,717	48.1	98.7	12.4	121.1
Two Row					
Pinnacle	8,519	48.3	98.0	11.6	125.3
Rawson	8,136	48.1	97.4	11.8	122.0
Trial Mean	9,739	47.0	98.2	12.1	125.3
CV %	3.7	2.1	0.6	1.4	4.7
LSD 0.05	994	1.5	NS	0.5	NS

Planting Date: May 15, 2009
Harvest Date: September 3, 2009
Seeding Rate: 1.2 million live seeds/ac

2009 Hannover Barley - Recrop — Dickinson, ND

Variety	Seeds per Pound	Test Weight	% Plump	Protein	Grain Yield
		lbs/bu	>6/64	%	----bu/ac----
Six Row					
Celebration	10,588	41.0	99.2	12.8	112.1
Stellar-ND	10,159	41.2	99.3	12.3	111.3
Tradition	10,370	43.3	99.2	12.3	113.2
Two Row					
Pinnacle	8,226	46.0	99.0	11.3	107.9
Rawson	8,037	45.3	98.0	11.8	98.8
Trial Mean	9,476	43.4	99.0	12.1	108.6
CV %	2.5	2.0	0.3	1.8	3.0
LSD 0.05	667	1.3	0.7	0.6	5.0

Planting Date: May 15, 2009
Harvest Date: September 3, 2009
Previous Crop: Wheat
Seeding Rate: 1.2 million live seeds/ac

2009 Hard Red Spring Wheat - Recrop — Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
			in	lbs/bu	%	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
Alsen	61	12,260	32	64.6	14.0	51.5	29.5	70.6	50.0	50.5
Barlow	58	11,843	33	65.3	13.6	53.9	28.6	69.4	49.0	50.7
Blade	63	11,968	32	66.7	14.4	--	34.7	77.8	56.2	--
Breaker	63	12,024	32	65.8	14.5	--	36.4	78.7	57.6	--
Brenan	58	12,724	28	63.6	14.0	--	35.1	74.8	54.9	--
Brick	56	12,332	34	65.2	13.8	--	32.8	63.1	48.0	--
Briggs	61	12,195	36	65.4	15.1	50.5	29.6	70.5	50.1	50.2
Brogan	61	11,664	31	64.5	14.3	--	--	74.6	--	--
Choteau	61	12,113	29	63.2	13.8	48.5	34.2	78.5	56.4	53.7
Conan	59	11,499	30	62.6	13.8	--	--	71.8	--	--
Corbin	58	11,024	30	61.7	12.9	--	--	73.3	--	--
Faller	63	10,574	33	64.5	13.5	52.8	29.8	85.3	57.6	56.0
Freyr	61	12,114	32	63.5	14.6	50.4	33.7	72.5	53.1	52.2
Glenn	57	12,413	35	66.4	14.8	52.7	31.0	61.2	46.1	48.3
Granger	59	10,303	34	62.9	14.6	51.2	31.1	63.7	47.4	48.6
Granite	64	12,760	31	65.3	15.6	46.9	34.8	72.1	53.4	51.3
Howard	61	12,318	34	65.5	14.0	53.6	30.9	77.3	54.1	53.9
Jenna	63	11,368	31	64.3	14.1	--	35.2	81.1	58.1	--
Kelby	58	12,194	27	64.3	15.1	53.6	34.2	73.7	54.0	53.8
Knudson	60	11,474	32	64.6	13.5	53.7	32.2	87.8	60.0	57.9
Kuntz	62	13,018	29	64.0	13.2	50.8	31.3	78.2	54.7	53.4
Mott	63	13,563	36	65.8	13.6	50.0	34.0	78.7	56.4	54.2
Parshall	60	12,388	36	65.6	15.3	51.4	31.4	66.8	49.1	49.9
RB07	57	13,617	30	63.9	14.0	57.5	37.2	78.2	57.7	57.6
Reeder	63	13,437	34	65.6	14.6	43.8	28.4	72.0	50.2	48.1
Sabin	61	12,601	32	63.6	13.9	--	--	80.0	--	--
Samson	59	12,016	29	64.0	14.1	--	34.6	82.7	--	--
Steele-ND	61	11,813	33	66.5	13.7	50.8	30.4	75.3	52.8	52.2
Tom	61	10,865	32	64.3	13.6	--	32.3	76.8	54.5	--
Traverse	58	11,557	34	63.3	13.9	53.9	34.4	74.6	54.5	54.3
Vantage	64	13,091	31	65.8	14.0	--	33.0	72.5	52.7	--
AC Lillian	64	11,720	35	59.6	15.3	--	--	65.9	--	--
Agawam	57	10,295	30	64.3	12.6	--	--	74.2	--	--
Trial Mean	60	11,943	32	64.3	14.0	50.5	32.1	74.9	--	--
CV %	1.3	2.9	2.7	2.4	4.7	6.7	10.5	7.5	--	--
LSD 0.05	1	702	1	2.1	1.3	4.7	4.7	7.8	--	--

Planting Date May 6, 2009

Harvest Date: September 4, 2009

Previous Crop: Field Pea

Seeding Rate: 1.2 million live seeds/ac

2009 Glen Ullin Spring Wheat - Fallow — Dickinson, ND

Variety	Seeds per Pound	Lodging Score	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
		0-9	lbs/bu	%	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
Barlow	12,987	2	63.6	14.8	--	51.0	73.2	62.1	--
Brick	12,215	0	64.7	14.5	--	--	77.7	--	--
Blade	13,747	6	64.0	14.7	--	--	64.8	--	--
Choteau	12,891	0	61.1	14.4	39.3	46.1	66.9	56.5	50.8
Faller	12,670	1	60.9	13.6	37.3	46.1	80.0	63.1	54.5
Glenn	12,926	6	64.7	15.2	35.5	40.5	65.9	53.2	47.3
Howard	14,219	4	60.6	14.0	38.2	42.1	68.2	55.2	49.5
Mott	13,381	0	63.4	14.6	--	48.6	82.4	65.5	--
Steele-ND	13,543	3	61.1	14.5	37.1	42.9	68.3	55.6	49.4
Trial Mean	13,175	2	62.7	14.5	35.1	45.2	71.9	--	--
CV %	6.4	73.6	1.7	1.4	8.8	6.8	8.2	--	--
LSD 0.05	NS	3	1.6	0.5	4.4	5.2	8.6	--	--

Planting Date: May 15, 2009
Harvest Date: September 10, 2009
Lodging: 0=No lodging, 9=Completely flat
Seeding Rate: 1.2 million live seeds/ac

2009 Hannover Spring Wheat - Recrop — Dickinson, ND

Variety	Seeds per Pound	Lodging Score	Test Weight	Protein	Grain Yield 2007	Grain Yield 2008	Grain Yield 2009	Average Yield 2 Year	Average Yield 3 Year
		0-9	lbs/bu	%	----------bu/ac----------			----bu/ac----	
Barlow	12,981	4	58.4	15.1	--	33.8	54.7	44.2	--
Brick	12,394	3	58.7	14.5	--	--	52.3	--	--
Blade	14,740	5	57.4	14.9	--	--	46.7	--	--
Choteau	12,752	3	55.9	14.4	32.5	33.7	51.1	42.4	39.1
Faller	13,186	6	53.8	14.3	30.8	30.9	54.1	42.5	38.6
Glenn	13,458	6	59.8	15.4	30.6	29.2	47.6	38.4	35.8
Howard	13,830	6	56.4	14.5	30.4	30.3	46.6	38.4	35.8
Mott	13,072	0	58.8	14.9	--	35.7	63.9	49.8	--
Steele-ND	13,872	6	57.7	14.1	29.8	29.4	43.7	36.6	34.3
Trial Mean	13,365	4	57.4	14.7	29.6	31.7	51.2	--	--
CV %	2.9	33.6	2.8	2.7	8.6	9.9	6.5	--	--
LSD 0.05	894	2	2.3	NS	3.7	NS	4.8	--	--

Planting Date: May 15, 2009

Harvest Date: September 3, 2009

Lodging: 0=No lodging, 9=Completely flat

Previous Crop: Wheat

Seeding Rate: 1.2 million live seeds/ac

2009 Field Pea - Recrop | Dickinson, ND

Variety	Days to Bloom	Bloom Duration	Seeds per Pound	Plant Height	Test Weight	Lodging Score	Protein	Grain Yield
				in	lbs/bu	0-9	%	----bu/ac----
CDC Golden	63	16	1,776	23.2	61.1	6.0		41.0
CDC Mozart	62	16	1,680	21.8	61.1	6.8		41.8
CDC Striker	62	14	1,690	23.4	62.4	6.0		34.4
Cruiser	62	16	2,099	23.0	61.2	7.0		30.0
DS Admiral	62	16	1,830	24.1	62.0	6.3		34.6
Majoret	64	14	1,868	21.1	60.3	6.3		38.1
Trial Mean	62	15.3	1,824	22.8	61.3	6.4		36.7
CV %	0.5	3.7	5.0	7.6	1.0	7.9		7.1
LSD 0.05	0.4	0.9	136	NS	0.9	NS		3.9

Planting Date: April 22, 2009
Harvest Date: August 11, 2009
Lodging: 0=No lodging, 9=Completely flat
Previous Crop: Field Pea
Seeding Rate: 325,000 live seeds/ac
Note: Trial received hail damage

2009 Camelina - Recrop	Dickinson, ND

Variety	Plant Height	Test Weight	Oil Content	Grain Yield
	in	lbs/bu	%	lbsa
Blaine Creek	23.7	51.8		642.9
Calina	26.0	52.8		1102.3
Celine	28.8	52.3		1044.2
Galina	26.0	52.6		1422.9
Ligena	27.3	50.9		1424.8
Suneson	26.1	53.0		1162.0
Trial Mean	26.3	52.2		1133.2
CV %	10.8	1.7		25.8
LSD 0.05	NS	1.4		NS

Planting Date: 4/22/2009
Harvest Date: 8/18/2009
Previous Crop: Field Pea
Seeding Rate: 6 lbs/acre
Note: Trial received hail damage

Circumstances that Impelled Fertilization Treatment Research on Native Rangeland

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Nitrogen fertilization research projects were conducted in the Northern Plains in an attempt to find and develop cultural management practices that could be used to recover the degraded ecological condition, to return the natural botanical composition, and to restore the herbage biomass production of deteriorated native grassland ecosystems. The deterioration of the grassland resources was caused by an accumulation of antagonistic byproducts from naive land management practices that were implemented during the progressive stages of European settlement of the region.

European settlement of western North Dakota followed the railroad. In 1864, Congress passed the Federal Railroad Land Grant Act. Under that act, the Northern Pacific Railroad was given a grant of 39 million acres of land in a checkerboard pattern from Duluth, Minnesota to Puget Sound, Washington. Construction of the railroad started in 1870 at Superior, Wisconsin and reached Moorhead, Minnesota in December 1871. The tracks reached Bismarck, North Dakota in June 1873 and halted there until 1879. The Northern Pacific Railroad sold 4,352,000 acres in North Dakota between 1875 and 1895 for an average price of $3.90/acre. Construction of the tracks started again and reached Dickinson in 1880 and reached the Montana border in 1881. During the early stages of the settlement process, the railroad was used to move people west and to ship regional resources east.

The railroad moved about 5,000 buffalo skinners to Bismarck by 1882 and shipped 1.5 million bison hides to eastern markets between 1880 and 1884. This activity eliminated the northern bison herds west of the Missouri River in western North Dakota and eastern Montana. The last carload of hides containing the skins from the last herd of 300 free roaming bison was shipped from Dickinson, North Dakota in 1884.

While the bison herds were being removed, cattle outfits were trailing livestock from Texas into western North Dakota and eastern Montana to be fattened on the open range grass and then shipped to eastern markets by rail. Several large herds of mostly light weight 2-4 year old steers and dry cows were trailed north in 1882 and 1883. The first regional roundup in western North Dakota was conducted in the spring of 1884. The estimated population of cattle was 30 to 40,000 head in a district that was 100 by 50 miles, with Medora, North Dakota near the center. The stocking level at that time was 80 to 100 acres per head for a year of grazing. In western North Dakota, a 1200 pound cow needs 55.4 acres for a year of forage dry matter. During the fall of 1886, the stockman in western North Dakota and eastern Montana declared the district to be fully stocked and that no new outfits would be permitted to bring in cattle or horses.

The winter of 1886-1887 was very severe with numerous blizzards, very strong winds, and long spells of bitter sub-zero temperatures. By spring, 50% to 75% of the cattle were lost. Most of the absentee owner outfits pulled out. A few locally owned and operated outfits remained. The herd sizes stayed small and the numbers of grazing animals were not intensified because the financial backers considered the business of fattening cattle on western open range grass to be too risky. The cattle numbers were greatly reduced again during the drought of 1891 to 1893. The period of open range grazing of Texas cattle was not long and the grasslands were not heavily stocked. Had the grazing practices that were being developed during the open range period been permitted to progress, land management strategies in the semiarid regions of North America would have been based on low intensity pastoral philosophies similiar to the other grazing regions of the world that did not have homestead activity.

The human population of western North Dakota greatly increased between 1898 to 1915 with the peak period of activity between 1900 and 1910. Title to land was transferred from the US Government to private citizens through the Homestead Act and its many revisions. The Homestead Act provided that a person could claim 160 acres of public domain lands after filing and “prove up” on it for five years. During the period that much of North Dakota was settled, there was a provision in the Homestead Act that allowed a person to commute the homestead by a preemption right and pay the regular price of $1.25 or $2.50 per acre anytime after six months from the date of filing. About half of the acreage changing from public domain to private ownership in North Dakota after 1900 and before 1929 were commuted acres. The proceeds from a single crop of wheat or flax produced on 5 or 10 acre fields could pay for the purchase price. The Taylor Grazing Act of 1934 removed all unappropriated public domain lands from homestead, which included 68,442 acres in North Dakota.

The Homestead Act had many revisions in attempts to adjust the law to meet the needs of the people and the natural resources. None of the many revisions to the Homestead Act met the needs of the country west of the 100th Meridian. Failure of the lawmakers to address the requirements of natural resource management in semiarid regions created numerous long-lasting problems. This predicament was aggravated by the degradation of the grassland resources caused by the exceptionally high stocking rates suggested for use during the homestead period.

The heavy stocking rates used for cattle grazing in western North Dakota until 1934 (Whitman et al. 1943) were the suggested stocking rates ascertained from initial grassland research investigations in North Dakota. A grazing intensity study conducted from 1916 to 1929 by J.T. Sarvis at the Northern Great Plains Research Center, Mandan, North Dakota, examined 5.0-month seasonlong grazing at stocking rates that removed 75% to 80% of the total annual production and left 20% to 25% of the vegetation standing at the end of each season (Lorenz 1970). Sarvis (1941) determined these stocking rates to be neither over nor undergrazed. Whitman et al. (1943) considered the rangelands of western North Dakota to be heavily overstocked and that the livestock grazing pressure was around 67.5% heavier than the grasslands' carrying capacity that had been determined from the then recent range surveys conducted in western North Dakota by the Agricultural Adjustment Administration Office.

This widespread heavy overgrazing of Northern Plains grasslands greatly intensified the damaging effects caused by the drought conditions of 1934 and 1936. The drought damage to the grassland vegetation was severe, resulting in a 57% decrease in total cover density and a 56% reduction in plant height (Whitman et al. 1943). With cessation of the drought conditions, the favorable precipitation and a reduction of more than 60% in the stocking rates were responsible for the recovery of the vegetation in four years, with a return to the predrought densities and no change in composition of the major dominant species (Whitman et al. 1943). After 1936, the Northern Plains prairie and its soil were no longer considered to be inexhaustible.

The severe droughts of the 1930's combined with the economic depressions of the 1920's and 1930's and the low agricultural commodity prices received after 1929 created extreme hardships for the homesteaders in semiarid regions. These struggling people did not have sufficient productivity or financial income from the degraded natural resources on 160 acres to support their families. The homesteaders living on lands declared to be submarginal were given the option to sell their land back to the federal government. The Land Utilization Project was established in 1935 and a resettlement plan was completed that same year. The Bankhead-Jones Farm Tenant Act was passed by Congress on 22 July 1937. Under these legislative acts, 1,104,789 acres were purchased by the US Government in North Dakota. Most of these repurchased lands were managed with a follow up program of land conservation and a utilization plan. The homesteaders living on marginal or better lands did not have the option to sell to the federal government and were faced with abandonment of their land or finding a private buyer with sufficient credit.

Agricultural operations that survived the calamities of the 1930's had painfully discovered that eastern farming and grazing practices did not work west of the 20 inch rainfall line; regardless of these hard lessons, the problems of low productivity from the resulting poor condition of the cropland and grazingland continued. Major efforts to develop agricultural management practices suitable for semiarid lands were started in the 1930's but had to be postponed until after World War II. Tree shelterbelts, crop rotation, and contour strip farming methods were introduced to improve the croplands. Reduced stocking rates and deferred rotation grazing management were introduced to improve the grazinglands. The stocking rate problems were solved when Crider (1955) determined that proper stocking rates removed less than 50% of the herbage and that grass tillers with 50% or more of the aboveground leaf material removed reduced root growth, root respiration, and root nutrient absorption. However, the grazing management problems had not been solved because the deferred method of grazing was found to negatively affect grassland ecosystems. After 12 years of grazing deferment research, Sarvis (1941) was unable to determine any improved benefit to grass plant density from reseeding of the grasses with deferred grazing. Manske et al. (1988), in a three year study, found that total grass basal cover decreased significantly after one year of deferred grazing treatment. Grazing management practices that were beneficial for grassland ecosytems would not be developed until the early 1980's after scientists were able to describe and understand the complex physiological mechanisms and biogeochemical processes of the herbivore-grass-soil organism symbiotic system.

Consequently, those were the circumstances leading up to the 1950's that impelled grassland ecologists and rangeland scientists to investigate fertilization treatments for possible improvement in the deteriorated grassland ecosystems of the Northern Plains.

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Evaluation of Nitrogen Fertilization Treatments on Native Rangeland

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Fertilization treatments on native rangeland were evaluated as potential cultural practices to reverse the declining and deteriorating ecological condition of Northern Plains mixed grass prairie communities resulting from the unmanaged negative aspects of livestock defoliation caused by inappropriate season of use and/or too heavy use over a prolonged period of time (Goetz 1984). The objectives of the research treatments were to improve the nutrient cycles of the ecosystem, to return the natural balance of the botanical species composition, and to restore the productivity of the total herbage biomass of deteriorated native rangelands.

Procedure

Four fertilization treatment plot studies were conducted between 1957 and 1978 at the Dickinson Research Extension Center.

Nitrogen fertilization of native rangeland plot study I (1957)

Nitrogen fertilization of native rangeland plot study I (1957) was conducted by Dr. Warren C. Whitman on a heavily grazed pasture located at the original site of the livestock farm of the Dickinson Research Extension Center. The fertilized strip plots were arranged in a randomized block design with three replications. The ammonium nitrate fertilizer (33-0-0) was broadcast applied 24 April 1957 at three rates: 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac. Plots with no fertilizer applied were used as control checks. Dry matter weight of aboveground herbage was sampled by the clipping method at the end of the active growing season (around early to mid August). Herbage protected from grazing by two 4 X 4 foot movable steel cages was clipped at a height of one-quarter inch and separated into three categories: mid grasses, short grasses, and forbs. The plant material was oven dried and weighed (Whitman 1957).

Nitrogen fertilization of native rangeland plot study II (1962-1963)

Nitrogen fertilization of native rangeland plot study II (1962-1963) was conducted by Dr. Warren C. Whitman on two sites, a creek terrace and a west facing upland slope, located in a west pasture at the original site of the livestock farm of the Dickinson Research Extension Center. The 10 X 40 foot plots were arranged in a randomized block design with four replications. The treatments included a check 0 lbs N/ac, 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac. The ammonium nitrate fertilizer (33-0-0) was broadcast applied in the spring of each year. Dry matter weight of aboveground herbage was sampled by the clipping method at the end of the active growing season (around early to mid August). Herbage was clipped at a height of one-quarter inch and separated into three categories: mid grasses, short grasses, and forbs. The plant material was oven dried and weighed (Whitman 1962, 1963). Differences between yearly means were analyzed for this report by a standard paired-plot t-test (Mosteller and Rourke 1973).

Nitrogen fertilization of native rangeland plot study III (1964-1969)

Nitrogen fertilization of native rangeland plot study III (1964-1969) was conducted by Dr. Warren C. Whitman and Dr. Harold Goetz on four different range sites located within a 35 mile radius of Dickinson, ND. These four sites were representative of the important soils on a major portion of the grazinglands in the region. The soils were: Havre, Manning, Vebar, and Rhoades (Goetz 1969a).

The Havre silt loam soil, Frigid Ustic Torrifluvent, comprised a deep, light colored alluvium that occupied creek bottom floodplains in the Badlands. This overflow range site was located in the Pyramid Park pasture portion of the Dickinson Research Extension Center south of Fryburg, ND. During the study, this site was grazed during the summer and was in near excellent condition. The most important plants were western wheatgrass, plains reedgrass, green needlegrass, and silver sagebrush (Goetz 1969a).

The Manning silt loam soil, Typic Haploboroll, developed on a high river terrace underlain by a gravel layer at about 18-24 inches below the surface. This silty range site was located on private land along the Heart River near Taylor, ND. During the study this site was grazed heavily during early summer and was in low good condition. The most important plants were western wheatgrass, needle and thread, blue grama, threadleaf sedge, and fringed sagebrush (Goetz 1969a).

The Vebar fine sandy loam soil, Typic Haploboroll, developed from weathered weakly-cemented tertiary sandstone and was associated with gently undulating to moderately steep topography. This sandy range site was located in a north pasture at the original site of the livestock farm of the Dickinson Research Extension Center. During the study, this site was grazed heavily during late fall and was in low good condition. The most important plants were western wheatgrass, needle and thread, plains reedgrass, blue grama, threadleaf sedge, and white sagebrush (Goetz 1969a).

The Rhoades silty loam, high sodium, solonetz soil, Leptic Natriboroll, comprised a near impervious layer of dispersed clay particles in the profile varying in depth from the soil surface to approximately 20 inches. This thin claypan range site was studied at two places with both located south of Fryburg, ND; site A was used from 1964 to 1966 and site B was used from 1968 to 1969. During the study, these two sites were grazed during summer and were in low good condition. Because of the numerous claypans and barren panspots and low herbage production, these sites had reduced grazing capacity. The most important plants were western wheatgrass, blue grama, Sandberg bluegrass, and brittle prickly pear (Goetz 1969a).

The 30 X 100 foot plots were arranged in a randomized block design with four replications separated by 6 foot wide alleyways. The treatments included a check 0 lbs N/ac, 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac. Application of phosphorus alone and with nitrogen were treatments also included with this study but not included in this report. The ammonium nitrate fertilizer (33-0-0) was broadcast applied in granular form early in the spring of each year between 10 and 15 April, except in 1967 when a late snowstorm delayed application until 10 May (Whitman 1964, 1967).

The vegetation on each plot was protected from grazing by three steel wire quonset type cages measuring 3 X 7 foot. Dry matter weight of aboveground herbage was sampled by the clipping method at the end of the active growing period (around early to mid August). Herbage was clipped to ground level from three 2.5 X 5 foot steel frames per plot and separated into five categories: tall grasses, mid grasses, short grasses, perennial forbs, and annual forbs. The plant material was oven dried and weighed (Whitman 1964, Goetz 1969a). Differences between yearly means were analyzed for this report by a standard paired-plot t-test (Mosteller and Rourke 1973).

Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method. The point frame was placed at 10 foot intervals in 5 lines of 10 sets. The 5 lines were placed 5 feet apart. A total of 2000 points was taken in each treatment, on each site, during three years (1964-1966) (Goetz 1969a).

Root development and distribution in the soil profile were determined from dry matter weight of root material per soil sample depth. Soil samples were collected with a tractor-mounted hydraulic soil probe using a 1.4059 inch diameter soil tube. Eight samples per plot (32 per treatment) were taken from 0-6, 6-12, 12-18, 18-24, 24-36, and 36-48 inch depths at the end of the growing season, 1966. The root cores were washed over a 60-mesh screen, oven dried at 147.2° F, and weighed. Data were statistically analyzed with the Duncan's multiple range test (Goetz 1969b).

Plant growth in height was determined for major species by measuring to the nearest 1 cm the leaves and stems of 20 plants at approximately 7 to10 day intervals during the growing season from mid April to late August. Only plants protected from grazing by steel cages were measured. Leaf heights were measured from ground level to the tips of extended leaves for species in which leaves and stalks were distinctly separate. For single stalked species where the leaves are attached to a calm, height measurements were made of the extended uppermost leaf. The fruiting stalk measurements were begun immediately following evidence of thickening of culms, and stalk heights were measured from ground level to the tip of the stalk or to the tip of the inflorescence after it had developed. Data were statistically analyzed with the Duncan's multiple range test (Goetz 1970). Phenological data of grass developmental stages were determined by recording observation dates of fruiting stalk initiation, anthesis, seed development, seed maturity, and earliest observed date of seed shedding. Leaf senescence by date was determined as an estimation of percentage of dry leaf in relation to total leaf area (Goetz 1970).

Available mineral nitrogen was determined from soil samples collected with a 1 inch diameter soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at 1 month intervals during early spring and late summer and at 15 day intervals from mid May to late July, 1964 to 1969. Individual samples from each depth were immediately frozen and kept frozen until analysis could be made. The analysis for available mineral nitrogen were made by the Department of

Soils, North Dakota State University, using standard analysis techniques (Goetz 1975a).

Available soil water was determined by the gravimetric procedure from soil samples collected with a 1 inch diameter soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at weekly intervals from mid April to early October, 1964-1969. Data were composited into monthly values (Goetz 1975a).

Crude protein content of major grasses and sedges was determined from a composite of 10 samples of each species collected systematically every 3 paces or from inside areas protected from grazing by wire cages at biweekly intervals from mid May to early September, 1964-1969. Plant material was oven dried at 105° F. Analysis of samples were made by the Cereal Technology Department, North Dakota State University, using standard crude protein determinations (Goetz 1975a).

Nitrogen fertilization of native rangeland plot study IV (1970-1978)

Nitrogen fertilization of native rangeland plot study IV (1970-1978) was conducted by Dr. Harold Goetz and Dr. Warren C. Whitman, with collaboration from Paul Nyren during 1976 to 1978, on a well drained Vebar sandy loam soil on an upland range site located approximately three miles northwest of Dickinson, ND, in a pasture of the Dickinson Research Extension Center. The 30 X 100 foot plots were arranged in a randomized block design with three replications. The treatments included a check 0 lbs N/ac; annual 67 lbs N/ac and 100 lbs N/ac applied every year (EY); biennial 67 lbs N/ac and 100 lbs N/ac applied every other year (EOY); and high rates of 200 lbs, 300 lbs, and 400 lbs N/ac applied one time (OT). Application of phosphorus and potassium alone and with nitrogen were treatments also included with this study but not included in this report. The ammonium nitrate fertilizer (33-0-0) was broadcast applied in the spring. Dry matter weight of aboveground herbage was sampled by the clipping method at the end of the active growing season (around early to mid August) and separated into four categories: mid grasses, short grasses, perennial forbs, and annual forbs. The plant material was oven dried and weighed (Whitman 1970, 1972).

Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method at the end of the growing season (Whitman 1976). Each year 500 points were taken for each treatment in each replication for a total of 1500 points per treatment (Goetz et al. 1978).

Available soil water was determined weekly and available mineral nitrogen was determined biweekly from soil samples collected from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths throughout the growing season (Whitman 1971, 1972). Crude protein content of selected major species was determined from samples collected biweekly (Whitman 1971). The same techniques used during the nitrogen fertilization plot study III were presumably used during the nitrogen fertilization plot study IV.

Results

Nitrogen fertilization plot study I

The 1957 growing season precipitation (table 1) was greater than normal (20.17 inches, 148.86% of LTM). April, June, July, September, and October were wet months and each received 181.12%, 186.20%, 155.86%, 148.87%, and 204.21% of LTM precipitation, respectively. May received normal precipitation at 89.74% of LTM. August was a dry month and received 86.13% of LTM precipitation. Perennial plants were under water stress conditions during August, 1957 (Manske 2008).

Herbage production on the heavily grazed pasture site was considered to be greatly reduced and at quantities considerably below potential as a result of the long-term grazing management practices used. The average dry weight of herbage biomass production had been only 995 lbs/ac during the previous 11 years (Whitman 1957). The total yield of herbage biomass on the 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac fertilization treatments was 37.9%, 111.4%, and 80.8% greater than the total yield produced on the unfertilized treatments (Whitman 1957) (table 2).

The mid grass category consisted mostly of cool season grasses. The herbage weight of mid grasses on the 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac fertilization treatments was 71.1%, 134.8%, and 30.7% greater than the mid grass weight produced on the unfertilized treatment, respectively (Whitman 1957) (table 2). Herbage production and percent composition of mid grasses greatly increased on the 50 lbs N/ac and 100 lbs N/ac rates. The heavy rate of 150 lbs N/ac apparently caused some damage to the cool season mid grasses (Whitman 1957) (tables 2 and 3).

The short grass category consisted mostly of warm season grasses. The herbage weight of short grasses on the 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac fertilization treatments was 29.3%, 105.8%, and 106.1% greater than the short grass weight produced on the unfertilized treatment, respectively (Whitman 1957) (table 2). The high herbage production of short grasses on the 100 lbs N/ac and 150 lb N/ac treatments could be attributed to the above normal precipitation (Whitman 1957) (table 1). The percent composition of short grasses decreased 6.2% and 2.6% on the 50 lbs N/ac and 100 lbs N/ac treatments, respectively (table 3).

This early fertilization treatment study showed that herbage production on previously heavily grazed native grass pastures could be increased by application of nitrogen fertilizer (Whitman 1957). This study also showed the beginnings of the species composition shift in plant communities caused by nitrogen fertilization treatments resulting in an increase in cool season mid grasses and a decrease in warm season short grasses. This study eliminated the 150 lbs N/ac rate from future trials.

Whitman (1957) acknowledged that this study did not have sufficient data to determine if nitrogen fertilization of native rangeland could be economically justified, however, he did submit a predication; that based on the then current price of nitrogen fertilizer, additional benefits would be necessary to make the practice of nitrogen fertilization profitable.

Nitrogen fertilization plot study II

The precipitation during the growing seasons of 1962 and 1963 was greater than normal (table 4). During 1962 and 1963, 16.41 inches (121.11% of LTM) and 16.17 inches (119.34% of LTM) of precipitation were received, respectively. May, July, and August of 1962 were wet months and each received 264.10%, 145.05%, and 145.66% of LTM precipitation, respectively. April received normal precipitation at 78.32% of LTM. June, September, and October were dry months and each received 58.31%, 56.39%, and 57.89% of LTM precipitation, respectively. Perennial plants were under water stress conditions during September and October, 1962 (Manske 2008). April and May of 1963 were wet months and each received 265.03% and 157.69% of LTM precipitation, respectively. June, July and September received normal precipitation at 119.44%, 83.78%, and 101.50% of LTM. August and October were dry and very dry months and each received 60.12% and 21.05% of LTM precipitation, respectively. Perennial plants were under water stress conditions during August and October, 1963 (Manske 2008).

The two year mean (1962-1963) herbage biomass total yield on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 27.1%, 60.4%, and 59.9% greater than the mean total yield produced on the unfertilized treatment on the creek terrace site and was 34.4%, 64.4%, and 66.4% greater than the mean total yield produced on the unfertilized treatment on the upland slope site, respectively (Whitman 1963) (tables 5 and 7). The herbage biomass produced on the 100 lbs N/ac rate was not much different than that produced on the 67 lbs N/ac rate (tables 5 and 7).

The mean herbage weight of mid grasses on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 40.6%, 66.0%, and 34.1% greater than the mean mid grass weight produced on the unfertilized treatment on the creek terrace site and was 61.0%, 21.6%, and 201.9% greater than the mean mid grass weight produced on the unfertilized treatment on the upland slope site, respectively (tables 5 and 7).

The greatest increase in herbage production during 1963 was the mid grass component. The increase in mid grass production was greater on the creek terrace site than on the upland slope site (Whitman 1963). Herbage weight of mid grasses produced in 1963 on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 412.4%, 214.2%, and 36.1% greater than that produced on the creek terrace site in 1962 and was 169.6%, 130.9%, and 50.6% greater than that produced on the upland slope site in 1962 for the respective treatments (tables 5 and 7).

Percent composition of herbage weight of mid grasses in 1963 on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 229.9%, 156.0%, and 36.1% greater than the percent composition on the creek terrace site in 1962 and was 127.5%, 91.7%, and 36.5% greater than the percent composition on the upland slope site in 1962 for the respective treatments (tables 6 and 8).

The mean herbage weight of short grasses on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 20.7%, 58.3%, and 66.1% greater than the mean short grass weight produced on the unfertilized treatment on the creek terrace site and was 28.0%, 55.0%, and 43.7% greater than the mean short grass weight produced on the unfertilized treatment on the upland slope site, respectively (tables 5 and 7).

The short grass production in 1963 was greater for all treatments on both study sites than that produced in 1962. The increase in short grass production was greater on the upland slope site than on the creek terrace site (Whitman 1963). Herbage weight of short grasses produced in 1963 on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 50.8%, 6.9%, and 17.7% greater than that produced on the creek terrace site in 1962 and was 60.8%, 57.6%, and 59.1% greater than that produced on the upland slope site in 1962 for the respective treatments (tables 5 and 7).

Percent composition of herbage weight of short grasses did not change much on the creek terrace site and the upland slope site during the two years of this study (Whitman 1963). The percent composition of short grasses decreased 5.0% and 1.3% on the 33 lbs N/ac and 67 lbs N/ac treatments on the creek terrace site and decreased 4.5%, 5.7%, and 13.6% on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments on the upland slope site, respectively (tables 6 and 8).

The mean herbage weight of perennial forbs on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 51.3%, 84.9%, and 24.8% greater than the mean perennial forb weight produced on the unfertilized treatment on the upland slope site, respectively (table 7). Dry matter weight of forbs on the unfertilized, 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 149.6%, 160.7%, 198.7%, and 127.0% greater on the upland slope site than on the creek terrace site for the respective treatments (tables 5 and 7). Much of this increased forb production on the upland slope site was due to the abundance of fringed sage and white sage (Whitman 1963). The upland slope site had shallower soil structure and less water holding capacity than the creek terrace site and the upland slope site had the problem with a great increase in undesirable perennial forbs on all three fertilization treatments.

This two year study showed that nitrogen fertilization of native rangeland resulted in greater total herbage yield than that produced on unfertilized rangeland. The response to nitrogen fertilization was not the same for different range sites. The plant species composition shift started during the first year of nitrogen fertilization treatments. The increase in herbage weight and percent composition for mid cool season grasses was much greater during the second year than the increase during the first year of fertilization treatments. The herbage weight of short warm season grasses increased during the first and second year of fertilization treatments, however, the percent composition decreased slightly during the two years. The increases in mid cool season grasses was greater than the decrease in short warm season grasses during the first two years of nitrogen fertilization treatments. A great increase in undesirable perennial forbs is a serious problem caused by nitrogen treatments on rangeland sites in poor condition.

Whitman (1962, 1963) considered that the most economical fertilization treatment on the creek terrace site was the 67 lbs N/ac rate based on the percent increase in total grass production, however, he also considered that all fertilization treatments on the upland slope site were uneconomical.

Nitrogen fertilization plot study III

The precipitation during the growing seasons of 1964 to 1969 was normal or greater than normal (table 4). During 1964, 1965, 1966, 1967, 1968, and 1969, 17.28 inches (127.53% of LTM), 20.08 inches (148.19% of LTM), 14.93 inches (101.92% of LTM), 12.51 inches (92.32% of LTM), 13.81 inches (101.92% of LTM), and 14.26 inches (105.24% of LTM) of precipitation were received, respectively. June, July, and August of 1964 were wet months and each received 172.39%, 199.10%, and 165.90% of LTM precipitation, respectively. April and May received normal precipitation at 96.50% and 79.79% of LTM. September and October were dry and very dry months and received 46.62%, and 1.05% of LTM precipitation, respectively. Perennial plants were under water stress conditions during September and October, 1964 (Manske 2008). April, May, and July of 1965 were wet months and each received 238.46%, 259.40%, and 138.74% of LTM precipitation, respectively. June, August, and September received normal precipitation at 119.72%, 94.80%, and 122.56% of LTM. October was extremely dry and received no precipitation. Perennial plants were under water stress conditions during October, 1965 (Manske 2008). June and August of 1966 were wet months and each received 139.15% and 197.11% of LTM precipitation, respectively. May and July received normal precipitation at 92.31% and 98.65% of LTM. April, September, and October were dry months and received 57.34%, 69.92%, and 50.53% of LTM precipitation, respectively. Perennial plants were under water stress conditions during September and October, 1966 (Manske 2008). April and September of 1967 were wet months and each received 270.63% and 186.47% of LTM precipitation, respectively. May received normal precipitation at 119.23% of LTM. October was a dry month and received 64.21% of LTM precipitation. June, July, and August were very dry months and received 45.92%, 32.43%, and 23.70% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July and August, 1967 (Manske 2008). July and August of 1968 were wet months and each received 127.48% and 230.64% of LTM precipitation, respectively. June and October received normal precipitation at 95.21% and 95.79% of LTM. April and May were dry months and received 71.33% and 53.42% of LTM precipitation, respectively. September was a very dry month and received 32.33% of LTM precipitation. Perennial plants were under water stress conditions during September, 1968 (Manske 2008). June and July of 1969 were wet months and each received 172.68% and 198.20% of LTM precipitation, respectively. October received normal precipitation at 90.53% of LTM. April and May were dry months and received

50.35% and 56.41% of LTM precipitation. August and September were very dry months and received 30.06% and 23.31% of LTM precipitation, respectively. Perennial plants were under water stress conditions during August and September, 1969 (Manske 2008).

The mean herbage biomass total yield on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 5.6%, 34.0%, and 22.5% greater than the mean total yield produced on the unfertilized treatment on the Havre overflow range site; 13.7%, 61.6%, and 89.7% greater than the mean total yield produced on the unfertilized treatment on the Manning silty range site; 25.1%, 71.7%, and 75.0% greater than the mean total yield produced on the unfertilized treatment on the Vebar sandy range site; and 23.6%, 45.8%, and 50.7% greater than the mean total yield produced on the unfertilized treatment on the Rhoades thin claypan range site, respectively (tables 9, 11, 13, and 15). The herbage biomass produced on the 100 lbs N/ac rate was not much different than that produced on the 67 lbs N/ac rate (tables 9, 11, 13, and 15). The Havre overflow range site was the highest producing site followed in sequence by the Manning silty range site, the Vebar sandy range site, and the Rhoades thin claypan range site was the least productive site (Whitman 1969).

The plant species composition shift with an increase of mid grasses and a decrease of short grasses occurred during this 6 year study. The mid grass component increased as a result of the fertilization treatments. The mean herbage weight of mid grasses on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 10.4%, 42.8%, and 36.2% greater than the mean mid grass weight produced on the unfertilized treatment on the Havre overflow range site; 10.0%, 57.4%, and 96.5% greater than the mean mid grass weight produced on the unfertilized treatment on the Manning silty range site; 13.5% lower, and 55.3% and 63.6% greater than the mean mid grass weight produced on the unfertilized treatment on the Vebar sandy range site; and 40.9%, 63.6%, and 71.1% greater than the mean mid grass weight produced on the unfertilized treatment on the Rhoades thin claypan range site for the respective treatments (tables 9, 11, 13, and 15).

These increases in the mean herbage weight of the mid grasses were not as great as would be expected because of the reductions in herbage weight produced by mid cool season grasses on all four range sites caused by cool, dry early spring weather conditions of 1966 and 1967 (Whitman 1966, 1967) and caused by a shortage of moisture early in the growing season of 1968 (Whitman 1968). The application of the fertilization treatments was delayed about a month in 1967 because of adverse weather conditions (Whitman 1967). The reductions in production of mid grass weight were greatest on the Vebar sandy range site. The reduced mid grass herbage weight on the 33 lbs N/ac treatment for 1966, 1967, and 1968 caused a reduction in the six year mean mid grass yield that was lower than the mean mid grass yield on the unfertilized treatment. The herbage weight of the mid grasses, however, did increase an average of 26.4 lbs/ac each year for the 33 lbs N/ac rate on the Vebar sandy range site.

The short grass component decreased as a result of the fertilization treatments. The weight of short grass composes less than 2% of the total herbage weight produced on the Havre overflow range site (table 10). The herbage weight of short grass increased slightly on the unfertilized and 33 lbs N/ac treatments and decreased slightly on the 67 lbs N/ac and 100 lbs N/ac treatments on the Havre overflow range site. The mean herbage weight of short grasses on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was greater than the mean short grass weight produced on the unfertilized treatment of the Manning silty range site, the Vebar sandy range site, and the Rhoades thin claypan range site (tables 11, 13, and 15). The percent composition of short grasses decreased 1.5%, 4.2%, and 10.9% on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments on the Manning silty range site; decreased 0.2% on the 100 lbs N/ac treatment on the Vebar sandy range site; and decreased 5.6%, 7.6%, and 12.6% on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments on the Rhoades thin claypan range site, respectively (tables 12, 14, and 16). The percent composition for short grasses on the Vebar sandy range site was substantially increased in 1966 as a result of the great reduction in mid grass herbage production caused by the cool, dry conditions that occurred during the early spring of that year. This increased percent composition of short grasses resulted in a 6 year mean percent composition for short grasses on the three fertilization treatments to be about equal to or greater than that on the unfertilized treatment (table 14) indicating a small increase in the means. The annual percent composition of the short grasses, however, did decrease an average of 5.2%, 5.5%, and 4.8% each year on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments on the Vebar sandy range site, respectively.

The mean herbage weight of perennial forbs on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 27.3%, 100.2%, and 176.6% greater than the mean perennial forb weight produced on the unfertilized treatment on the Manning silty range site; and was 49.0%, 130.3%, and 131.6% greater than the mean perennial forb weight produced on the unfertilized treatment on the Vebar sandy range site, respectively (tables 11 and

13). The percent composition of herbage weight of perennial forbs on the Manning silty range site and the Vebar sandy range site was high (tables 12 and 14). The percent composition of perennial forbs ranged between 20% and 50% of the total herbage yield produced on the Manning silty range site during the first three years. Sometime between the third and fourth year, most of the fringed sage plants died and the percent composition ranged between 4% and 12% of the total yield during the fourth through the sixth years (Whitman 1965, 1967, 1969). The percent composition of perennial forbs ranged between 20% to 42% of the total herbage yield produced on the Vebar sandy range site during the six years of the study (Whitman 1967, 1969). The Manning silty range site and the Vebar sandy range site were both in relatively poor condition as a result of long-term antagonistic grazing management practices (Goetz 1969a) and both had the problem with a great increase in undesirable perennial forbs on all three fertilization treatments.

Total basal cover of grasses and forbs on the Havre overflow range site increased slightly, but not significantly (P<0.05), on all three nitrogen fertilization treatments compared to the unfertilized treatment during 1964 to 1966 (table 17). Western wheatgrass and green needlegrass increased in basal cover. Needle and thread and plains reedgrass decreased in basal cover. The basal cover of the two dominant shrubs, silver sagebrush and western snowberry, decreased resulting in a decreased total basal cover of shrubs, forbs, and grasses (Goetz 1969a).

Total basal cover on the Manning silty range site increased significantly (P<0.05) each year with the increased rates of all three nitrogen fertilization treatments compared to the unfertilized treatment during 1964 to 1966 (table 17). Western wheatgrass showed moderate, but significant (P<0.05), increases in basal cover with all three fertilization rates. Threadleaf sedge showed appreciable increases in basal cover on all three fertilization rates. Needle and thread decreased in basal cover. Blue grama did not change in basal cover. Fringed sage density increased significantly (P<0.05) each year with the increased rates of all three nitrogen fertilization treatments (Goetz 1969a) (table 17).

Total basal cover on the Vebar sandy range site decreased on all three nitrogen fertilization treatments compared to the unfertilized treatment during 1964 to 1966 (table 17). The decreased basal cover was significant (P<0.05) on the 67 lbs N/ac and 100 lbs N/ac fertilization treatments. Most of the reduction in total basal cover was the result of the decrease in basal cover of blue grama (table 17). Needle and thread had a slight decrease in basal cover. Plains reedgrass and threadleaf sedge had slight increases in basal cover with increased rates of nitrogen treatments. Prairie sandreed had increased basal cover on the 33 lbs N/ac and 67 lbs N/ac rates but had decreased basal cover on the 100 lbs N/ac treatment. Western wheatgrass, prairie Junegrass, needleleaf sedge, and sun sedge did not have significant (P<0.05) changes in basal cover. The dominant perennial forb, white sage, did not have significantly (P<0.05) increased basal cover (table 17) or plant density, however, the individual plants increased appreciably in size and weight (Goetz 1969a).

Total basal cover of grasses and forbs on the Rhoades thin claypan range site slightly decreased, but not significantly (P<0.05), on all three nitrogen fertilization treatments compared to the unfertilized treatment during 1964 to 1966 (table 17). Western wheatgrass had increased basal cover with increased rates of nitrogen fertilization (table 17). This increased basal cover was significant (P<0.05) on the 67 lbs N/ac treatment. Sandberg bluegrass had significantly (P<0.05) increased basal cover on the 33 lbs N/ac and 67 lbs N/ac treatments. Brittle prickly pear had increased basal cover and plant density with increased rates of nitrogen fertilization (Goetz 1969a).

Total root weight on the Havre overflow range site on the 67 lbs N/ac and 100 lbs N/ac fertilization treatments was 36.9% and 39.2% greater than the total root weight on the unfertilized treatment, respectively (table 18). The total root weight on the 100 lbs N/ac treatment was significantly (P<0.05) greater than that on the unfertilized treatment (Goetz 1969b) (table 18). The total root weight on the 33 lbs N/ac treatment was 12.0% less than that on the unfertilized treatment. All three nitrogen fertilization treatments had total root weight distribution in the soil profile with a greater percent at the 0-12 inch depth and a lower percent at the 12-48 inch depth than that of the unfertilized treatment. The root weights at the 0-6 inch depth were significantly (P<0.05) greater on the 67 lbs N/ac and 100 lbs N/ac treatments than that on the unfertilized treatment (Goetz 1969b) (table 18).

Total root weight on the Manning silty range site on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 9.1%, 6.4%, and 6.9% greater than the total root weight on the unfertilized treatment, respectively (table 18). The greatest increase in total root weight on the Manning site was on the 33 lbs N/ac treatment (Goetz 1969b) (table 18). The 33 lbs N/ac and 67 lbs N/ac treatments had total root weight distribution in the soil profile with a greater percent at the 0-12 inch depth and a lower percent at the deeper depths than that of the unfertilized treatment. The root weight at the 6-12 inch depth was significantly (P<0.05) greater on the 100 lbs N/ac treatments than that on the unfertilized treatment (Goetz 1969b) (table 18).

Total root weight on the Vebar sandy range site on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 68.8%, 0.9%, and 7.9% greater than the total root weight on the unfertilized treatment, respectively (table 18). The total root weight on the 33 lbs N/ac treatment was significantly (P<0.05) greater than that on the unfertilized treatment (Goetz 1969b) (table 18). The 67 lbs N/ac and 100 lbs N/ac treatments had total root weight distribution in the soil profile with a greater percent at the 0-12 inch depth and a lower percent at the 12-48 inch depth than that of the unfertilized treatment. The 33 lbs N/ac treatment had a greater percent of the total root weight at the 12-36 inch depth than that on the unfertilized treatment. The root weight at the 0-6 inch depth was significantly (P<0.05) greater on the 33 lbs N/ac treatment than that on the unfertilized treatment (Goetz 1969b) (table 18).

Total root weight on the Rhoades thin claypan range site on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments was 30.8%, 87.8%, and 112.3% greater than the total root weight on the unfertilized treatment, respectively (table 18). The greatest increase in total root weight during this study was on the 100 lbs N/ac treatment (Goetz 1969b) (table 18). All three nitrogen fertilization treatments had total root weight distribution in the soil profile with a greater percent at the 0-12 inch depth and a lower percent at the 12-48 inch depth than that of the unfertilized treatment. The root weights at the 0-6 inch depth increased with each increase in rate of nitrogen fertilizer (Goetz 1969b). The root weights at the 0-6 inch depth were significantly (P<0.05) greater on the 67 lbs N/ac and 100 lbs N/ac treatments than that on the unfertilized treatment (Goetz 1969b) (table 18).

Western wheatgrass on the unfertilized treatment of the Havre overflow range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 15.47 inches. Western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 62.5%, and 75.0% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 31 July, and 31 July that was 12.0%, 6.7%, and 14.3% greater than the leaf growth in height on the unfertilized treatment, respectively (table 19).

Needle and thread on the unfertilized treatment of the Havre overflow range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 11.30 inches. Needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 57.1%, and 75.0% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 31 July that was 4.9% less than, and 3.5% and 20.2% greater than the leaf growth in height on the unfertilized treatment, respectively (table 19).

Green needlegrass on the unfertilized treatment of the Havre overflow range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 19.88 inches. Green needlegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 85.7%, and 75.0% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 31 July that was 11.3%, 18.6%, and 17.1% greater than the leaf growth in height on the unfertilized treatment, respectively (table 19).

Western wheatgrass on the unfertilized treatment of the Manning silty range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 11.89 inches. Western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 42.9%, 50.0%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 31 July, and 31 July that was 1.7% less than, and 15.2% and 16.9% greater than the leaf growth in height on the unfertilized treatment, respectively (table 20).

Needle and thread on the unfertilized treatment of the Manning silty range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 11.30 inches. Needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 14.3%, 37.5%, and 37.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 31 July, and 31 July that was 26.1%, 4.2%, and 7.7% less than the leaf growth in height on the unfertilized treatment, respectively (table 20).

Blue grama on the unfertilized treatment of the Manning silty range site had active leaf growth in height during 80% of the growing season and reached maximum leaf height on 31 July at 4.76 inches. Blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 75.0%, 50.0%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 31 July, 31 July, and 31 July that was 21.6%, 20.0%, and 52.1% greater than the leaf growth in height on the unfertilized treatment, respectively (table 20).

Threadleaf sedge on the unfertilized treatment of the Manning silty range site had active leaf growth in height during 60% of the growing season and reached maximum leaf height on 30 June at 4.61 inches. Threadleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 33.3%, and 42.9% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 30 June, and 30 June that was 11.9%, 11.9%, and 17.8% greater than the leaf growth in height on the unfertilized treatment, respectively (table 20).

Needleleaf sedge on the unfertilized treatment of the Manning silty range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 4.80 inches. Needleleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 42.9%, and 71.4% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 15 July that was 13.1%, 13.2%, and 23.8% greater than the leaf growth in height on the unfertilized treatment, respectively (table 20).

Western wheatgrass on the unfertilized treatment of the Vebar sandy range site had active leaf growth in height during 80% of the growing season and reached maximum leaf height on 31 July at 8.98 inches. Western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 50.0%, 77.8%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 August, and 31 July that was 0.9% less than, and 22.3% and 43.3% greater than the leaf growth in height on the unfertilized treatment, respectively (table 21).

Needle and thread on the unfertilized treatment of the Vebar sandy range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 10.43 inches. Needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 28.6%, 28.6%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 31 July that was 1.5%, 8.0%, and 6.4% greater than the leaf growth in height on the unfertilized treatment, respectively (table 21).

Blue grama on the unfertilized treatment of the Vebar sandy range site had active leaf growth in height during 80% of the growing season and reached maximum leaf height on 31 July at 4.57 inches. Blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 50.0%, 62.5%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 31 July, 15 July, and 15 July that was 7.7%, 33.5%, and 36.1% greater than the leaf growth in height on the unfertilized treatment, respectively (table 21).

Threadleaf sedge on the unfertilized treatment of the Vebar sandy range site had active leaf growth in height during 50% of the growing season and reached maximum leaf height on 15 June at 5.67 inches. Threadleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 42.9%, 57.1%, and 42.9% of the unfertilized plant active leaf growth period and reached maximum leaf height on 30 June, 15 July, and 15 July that was 17.3%, 14.6%, and 10.4% greater than the leaf growth in height on the unfertilized treatment, respectively (table 21).

Needleleaf sedge on the unfertilized treatment of the Vebar sandy range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 5.08 inches. Needleleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 42.9%, 57.1%, and 42.9% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 15 June that was 0.8% and 13.2% greater than, and 8.5% less than the leaf growth in height on the unfertilized treatment, respectively (table 21).

Western wheatgrass on the unfertilized treatment of the Rhoades thin claypan range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 8.78 inches. Western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 57.1%, 71.4%, and 57.1% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 15 July that was 1.8% less than, and 12.1% and 15.7% greater than the leaf growth in height on the unfertilized treatment, respectively (table 22).

Blue grama on the unfertilized treatment of the Rhoades thin claypan range site had active leaf growth in height during 80% of the growing season and reached maximum leaf height on 31 July at 3.58 inches. Blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 25.0%, 75.0%, and 62.5% of the unfertilized plant active leaf growth period and reached maximum leaf height on 31 July, 31 July, and 30 June that was 2.2%, 31.8%, and 33.0% greater than the leaf growth in height on the unfertilized treatment, respectively (table 22).

Sandberg bluegrass on the unfertilized treatment of the Rhoades thin claypan range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 3.19 inches. Sandberg bluegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 42.9%, 57.1%, and 57.1% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 30 June, and 15 July that was 8.5%, 5.0%, and 13.5% greater than the leaf growth in height on the unfertilized treatment, respectively (table 22).

Needleleaf sedge on the unfertilized treatment of the Rhoades thin claypan range site had active leaf growth in height during 70% of the growing season and reached maximum leaf height on 15 July at 3.39 inches. Needleleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments had greater rates of growth during 71.4%, 42.9%, and 57.1% of the unfertilized plant active leaf growth period and reached maximum leaf height on 15 July, 15 July, and 15 July that was 16.2%, 21.8%, and 44.0% greater than the leaf growth in height on the unfertilized treatment, respectively (table 22).

Western wheatgrass, a mid cool season grass, was a major species on the Havre overflow, Manning silty, Vebar sandy, and Rhoades thin claypan range sites and unfertilized plants had an active leaf growth period during 72.5% of the growing season. Maximum leaf height was increased an average of 14.1% and 22.6%, respectively, on the 67 lbs N/ac and 100 lbs N/ac fertilization treatments of all four range sites; and was reduced an average of 1.5% on the 33 lbs N/ac treatment of the Manning silty, Vebar sandy, and Rhoades thin claypan range sites. Leaf growth rates of western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments were greater than the leaf growth rates on the unfertilized treatment during 51.8%, 65.4%, and 64.3% of the unfertilized plant active leaf growth period, respectively. Maximum leaf height was greatest on the Havre overflow range site and least on the Rhoades thin claypan range site (Goetz 1970).

Needle and thread, a mid cool season grass, was a major species on the Havre overflow, Manning silty, and Vebar sandy range sites and unfertilized plants had an active leaf growth period during 70.0% of the growing season. Maximum leaf height was increased an average of 1.5% on the 33 lbs N/ac treatment of the Vebar sandy range site; increased an average of 5.7% and 13.3%, respectively, on the 67 lbs N/ac and 100 lbs N/ac fertilization treatments of the Havre overflow and Vebar sandy range sites; reduced an average of 15.5% on the 33 lbs N/ac treatment of the Havre overflow and Manning silty range sites; and reduced an average of 4.2% and 7.7%, respectively, on the 67 lbs N/ac and 100 lbs N/ac treatments of the Manning silty range site. Leaf growth rates of needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 33.3%, 41.1%, and 58.3% of the unfertilized plant active leaf growth period , respectively. Maximum leaf height was greatest on the Havre overflow range site.

Green needlegrass, a mid cool season grass, was a major species on the Havre overflow range site and unfertilized plants had an unfertilized plant active leaf growth period during 70.0% of the growing season. Maximum leaf height was increased 11.3%, 18.6%, and 17.1%, on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments, respectively. Leaf growth rates of green needlegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 57.1%, 85.7%, and 75.0% of the unfertilized plant active leaf growth period, respectively. Maximum leaf height was greatest on the 67 lbs N/ac treatment (Goetz 1970).

Blue grama, a short warm season grass, was a major species on the Manning silty, Vebar sandy, and Rhoades thin claypan range sites and unfertilized plants had an active leaf growth period during 80.0% of the growing season. Maximum leaf height was increased an average of 10.5%, 28.4%, and 40.4% on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments, respectively. Leaf growth rates of blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 50.0%, 62.5%, and 62.5% of the unfertilized plant active leaf growth period, respectively. Maximum leaf height was greatest on the Manning silty range site and least on the Rhoades thin claypan range site (Goetz 1970).

Sandberg bluegrass, an early short cool season grass, was a major species on the Rhoades thin claypan range site and unfertilized plants had an active leaf growth period during 70.0% of the growing season. Maximum leaf height was increased 8.5%, 5.0%, and 13.5%, on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments, respectively. Leaf growth rates of sandberg bluegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 42.9%, 57.1%, and 57.1% of the unfertilized plant active leaf growth period, respectively. Maximum leaf height was greatest on the 100 lbs N/ac treatment (Goetz 1970).

Threadleaf sedge, an early short cool season upland sedge, was a major species on the Manning silty and Vebar sandy range sites and unfertilized plants had an active leaf growth period during 55.0% of the growing season. Maximum leaf height was increased an average of 14.6%, 13.3%, and 14.1% on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac fertilization treatments, respectively. Leaf growth rates of threadleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 45.2%, 45.2%, and 42.9% of the unfertilized plant active leaf growth period, respectively. Maximum leaf height was greatest on the 33 lbs N/ac treatment (Goetz 1970).

Needleleaf sedge, an early short cool season upland sedge, was a major species on the Manning silty, Vebar sandy, and Rhoades thin claypan range sites and unfertilized plants had an active leaf growth period during 70.0% of the growing season. Maximum leaf height was increased an average of 10.1% and 16.1%, respectively, on the 33 lbs N/ac and 67 lbs N/ac treatments of the three range sites; increased an average of 33.9% on the 100 lbs N/ac treatment of the Manning silty and Rhoades thin claypan range sites; and reduced 8.5% on the 100 lbs N/ac treatment of the Vebar sandy range site. Leaf growth rates of needleleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were greater than the leaf growth rates on the unfertilized treatment during 57.1%, 47.6%, and 57.1% of the unfertilized plant active leaf growth period, respectively.

Most of the phenological development of the various species was not appreciably affected by the different rates of nitrogen fertilization (Goetz 1970) (tables 23-26). The dates of flowering (anthesis) were not changed by the nitrogen fertilization treatments. Most of the dates of anthesis occurred within the normal range of variation which was determined by Stevens (1956) to be plus or minus 3 days from an average calculated date based on 10 years of data.

The rates of leaf drying on the fertilization treatments were a little different than those on the unfertilized treatments. Initiation of leaf tip drying began at an earlier date and the beginning stages of leaf drying progressed more rapidly early in the growing season on the unfertilized treatments. As the growing season progressed, this situation was reversed with the rate of leaf drying becoming more rapid on the fertilization treatments and the advanced stages of leaf drying were reached earlier than those on the unfertilized treatments (Goetz 1970).

The lengths of the early and late stages of leaf drying for western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 1 day longer, and 6 and 7 days shorter during the beginning stages and were 1, 1, and 15 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 7, 2, and 4 days longer during the beginning stages and were 4, 15, and 2 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for green needlegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 18, 12, and 17 days longer during the beginning stages and were 21, 12, and 24 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for plains reedgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 11, 1, and 7 days longer during the beginning stages and were 7 days longer, and 7 and 7 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 1, 10, and 7 days longer during the beginning stages and were 1 day longer, and 4 and 4 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early stages of leaf drying for prairie Junegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 7, 6, and 7 days longer during the beginning stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for Sandberg bluegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 30, 22, and 17 days longer during the beginning stages and were 20 days longer, and 5 and 11 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

The lengths of the early and late stages of leaf drying for the upland sedges on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments were 5 days shorter, and 2 and 1 days longer during the beginning stages and were 4, 2, and 2 days shorter during the latter stages than the number of days of the leaf drying stages on the unfertilized treatments, respectively.

Application of nitrogen fertilizer at 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatment rates increased the amount of available mineral nitrogen in the soil during the early portion of the growing season (Goetz 1975a). The peak quantity of available nitrogen in the 0-6 inch depth was reached 30 to 35 days following fertilizer application. The increase was greater with the higher treatment rates. The applied nitrogen was carried down in the soil profile reaching the deeper depths successively later, with some of the added nitrogen reaching the full sampling depth of 48 inches in the latter part of the growing season. During the third year of the study, 1966, there appeared to be a slight accumulation of nitrogen at the deeper depths (Goetz 1975a).

Differences in the amounts of available mineral nitrogen at the various sample depths on the three fertilization treatments diminished rapidly early in the growing season because of nitrogen immobilization by the soil-plant system. Beginning in early June, the amounts of mineral nitrogen on the fertilization treatments were essentially similar to the amounts on the unfertilized treatments (Goetz 1975a).

The quantity of available mineral nitrogen at the various samples depths changed seasonally and occurred as peaks and low points. The available nitrogen during the peaks increased 25% to 50% greater than that available during the low points. Three peaks occurred during the growing season on the unfertilized treatments. The peaks on the four range sites did not coincide exactly with each other. Three peaks occurred on the fertilization treatments of the Manning silty and Rhoades thin claypan sites and two peaks occurred on the Havre overflow and Vebar sandy sites. The observed peaks in available mineral nitrogen appeared to coincide with the phenological events of the major species of the sites rather than with the amount of available soil water. The first peak was reached around 15 May at approximately the same time on the unfertilized and fertilized treatments of all four range sites and occurred while the soils were warming in the spring but prior to rapid plant growth. The second peak occurred at the end of the active growing season in mid to late July. The third peak occurred in late autumn following plant development for the subsequent year’s growth (Goetz 1975a). The low points coincided with periods of active plant growth. The heaviest nitrogen use on all treatments on all sites consistently occurred at the 6 to 12 inch soil depth, corresponding to the most active root zone (Goetz 1975a).

Available soil water increased from early spring through July with the maximum amounts available in June on all sites. The lowest total amounts of available soil water were on the Rhoades thin claypan range site. Soil water use was greater on the fertilized treatments than on the unfertilized treatments. Considerably greater amounts of soil water were extracted from the treatments with the heavier applications of nitrogen fertilizer (Goetz 1975a).

Application of nitrogen fertilizer to rangelands generally increased crude protein content on all species during early growth stages (tables 27-30). The magnitude and duration of the increase varied greatly with sites and species. Most species attained maximum crude protein content by mid May. The crude protein content decreased during the growing season and the decline was progressive with the advancement in maturity. Cool season species showed a more rapid loss of crude protein than warm season species. The rate of crude protein decline was accelerated by the nitrogen fertilization treatments and by the seasonal decline in soil moisture (Goetz 1975b).

Western wheatgrass was a major species on the Havre overflow, Manning silty, and Rhoades thin claypan range sites (tables 27, 28, and 30). Nitrogen fertilization increased the crude protein content during the early portion (early June to mid July) of the growing season. Crude protein content of the early growth stages of western wheatgrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 2.2% lower, and 4.9% and 15.2% greater on the Havre overflow site; 7.7%, 16.3%, and 25.2% greater on the Manning silty site; and 5.3%, 11.3%, and 14.5% greater on the Rhoades thin claypan site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased progressively throughout the growing season as the plants matured. The rate of decline was greater on the fertilization treatments than on the unfertilized treatments. A statistically significant decrease in crude protein was evident by mid June on the Manning silty and Rhoades thin claypan range sites and by early July on the Havre overflow range site (Goetz 1975b). Fertilization treatments generally maintained a slightly higher crude protein level than the unfertilized treatment until early August when the differences became quite small. No significant differences were found between treatment means on the Havre overflow, Manning silty, and Rhoades thin claypan range sites (Goetz 1975b).

Needle and thread was a major species on the Manning silty and Vebar sandy range sites (tables 28 and 29). Nitrogen fertilization increased the crude protein content during the early portion of the growing season. Crude protein content of the early growth stages of needle and thread on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 3.8%, 22.0%, and 25.0% greater on the Manning silty site; and 3.6%, 16.5%, and 23.7% greater on the Vebar sandy site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased progressively throughout the growing season as the plants matured. The rate of decline was greater on the fertilization treatments than on the unfertilized treatments. A statistically significant decrease in crude protein was evident by early July on the Manning silty and Vebar sandy range sites (Goetz 1975b). Fertilization treatments generally maintained a slightly higher crude protein level than the unfertilized treatment until early August when the differences became quite small. The mean percent crude protein on the 100 lbs N/ac treatment was significantly greater than that on the unfertilized treatment on the Vebar sandy range site. There was no significant differences between the 33 lbs N/ac and 67 lbs N/ac treatments and the unfertilized treatment. No significant differences were found between treatment means on the Manning silty range site (Goetz 1975b).

Green needlegrass was a major species on the Havre overflow range site (table 27). Nitrogen fertilization increased the crude protein content during the early portion of the growing season. Crude protein content of the early growth stages of green needlegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 0.9% lower, and 8.8% and 23.2% greater on the Havre overflow site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased progressively throughout the growing season as the plants matured. The rate of decline was greater on the fertilization treatments than on the unfertilized treatments. A statistically significant decrease in crude protein was evident by early July on the Havre overflow range site (Goetz 1975b). Fertilization treatments generally maintained a slightly higher crude protein level than the unfertilized treatment until early August when the differences became quite small. No significant differences were found between treatment means on the Havre overflow range site (Goetz 1975b).

Blue grama was a major species on the Manning silty, Vebar sandy, and Rhoades thin claypan range sites (tables 28, 29, and 30). Nitrogen fertilization increased the crude protein content during the early portion of the growing season. Crude protein content of the early growth stages of blue grama on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 15.9%, 27.5%, and 33.3% greater on the Manning silty site; 5.2%, 25.0%, and 31.0% greater on the Vebar sandy site; and 7.6%, 20.4%, and 32.2% greater on the Rhoades thin claypan site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased progressively throughout the growing season as the plants matured. The rate of decline was greater on the fertilization treatments than on the unfertilized treatments. The decline in crude protein content was slower for blue grama, a warm season grass, than for the cool season grasses (Goetz 1975b). The mean percent crude protein on the 67 lbs N/ac and 100 lbs N/ac treatments was significantly greater than that on the unfertilized treatments on the Manning silty and Vebar sandy range sites. There was no significant differences between the 33 lbs N/ac treatments and the unfertilized treatments. No significant differences were found between treatment means on the Rhoades thin claypan range site (Goetz 1975b).

Sandberg bluegrass was a major species on the Rhoades thin claypan range site (table 30). Nitrogen fertilization increased the crude protein content during the early portion of the growing season. Early season response to nitrogen fertilization was high (Goetz 1975b). Crude protein content of the early growth stages of sandberg bluegrass on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 22.4%, 43.4%, and 47.7% greater on the Rhoades thin clypan site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased rapidly because of the extremely short life span of the leaf material. Differences in crude protein content between the fertilization treatments and the unfertilized treatment were small by early July. No significant differences were found between treatment means on the Rhoades thin claypan range site (Goetz 1975b).

Threadleaf sedge was a major species on the Vebar sandy range site (table 29). Nitrogen fertilization increased the crude protein content during the early portion of the growing season.

Crude protein content of the early growth stages of threadleaf sedge on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 8.7%, 27.0%, and 32.3% greater on the Vebar sandy site than the crude protein content on the unfertilized treatment, respectively. Crude protein content decreased progressively throughout the growing season as a result of severe leaf drying. The rate of decline was greater on the fertilization treatments than on the unfertilized treatment. A statistically significant decrease in crude protein was evident by early July on the Vebar sandy range site (Goetz 1975b). Differences in crude protein content between the fertilization treatments and the unfertilized treatment were small before early August because of the high loss of leaf material. The mean percent crude protein on the 67 lbs N/ac and 100 lbs N/ac treatments was significantly greater than that on the unfertilized treatment on the Vebar sandy range site. There was no significant differences between the 33 lbs N/ac treatment and the unfertilized treatment (Goetz 1975b).

This six year study showed that nitrogen fertilization of native rangeland resulted in greater total herbage yield than that produced on unfertilized rangeland. The response to nitrogen fertilization was not the same for different range sites. Nitrogen fertilization caused a shift in plant species composition with an increase in herbage weight, percent composition, and basal cover of mid grasses and a decrease in percent composition and basal cover of short grasses. Nitrogen fertilization caused an increase in herbage weight, percent composition, and basal cover of undesirable perennial forbs and increases in individual forb plant size. Root weight increased slightly as a result of nitrogen fertilization with the percent root weight increasing greatly in the shallow soil depths and decreasing in the deeper soil depths.

Nitrogen fertilization increased leaf height about 13%. Unfertilized plants of most major species had active growth during 70% of the growing season. Fertilized plants had faster growth rates for about 55% of this unfertilized plant active growth period and unfertilized plants had faster growth rates for about 45% of the time. Fertilized plants had a greater rate of growth in leaf height during a short period in the early portion of the growing season. Unfertilized plants had a longer period of leaf height growth; during the early portion, the rate of growth in leaf height was slower than that of fertilized plants, and during the latter portion of the growing season, the rate of growth in leaf height was greater than that of fertilized plants. Phenological development was not affected by nitrogen fertilization. Flowering dates occurred within the normal range. Rates of leaf drying on the fertilization treatments were a little different than those on the unfertilized treatments. The early stages of leaf drying were started about 6.3 days later by plants on fertilized treatments than by plants on the unfertilized treatments. Plants on the fertilized treatments reached the advanced stages of leaf drying about 5 days earlier than the unfertilized plants.

Nitrogen fertilization increased the available mineral nitrogen in soil during the early portion of the growing season. The quantity of increase was greater with the higher rates. Peak available mineral nitrogen was reached 30 to 35 days after fertilizer application at the same time the first peak was reached on the unfertilized treatment around mid May prior to rapid plant growth. The quantity of available mineral nitrogen decreased quickly during rapid spring plant growth. Beginning in early June, the quantity of mineral nitrogen on the fertilized treatments was the same as that on the unfertilized treatment. The second peak occurred at the end of the active growing season in mid to late July. The third peak occurred in late autumn following plant development for the subsequent year’s growth. The low points in available mineral nitrogen occurred during periods of active plant growth. The quantity of soil water use was greater on the fertilized treatments than on the unfertilized treatment with greater quantities of soil water extracted from the heavier application rates.

Nitrogen fertilization increased the crude protein content of aboveground plant material about 18.3% during early growth stages. Crude protein content decreased with advancement in plant maturity. The rate of decline was greater on the fertilized treatments than on the unfertilized treatment and the crude protein content was not different on unfertilized and fertilized treatments in early August. After which, the rate of decline in crude protein accelerated on the fertilized treatments.

Nitrogen fertilization plot study IV

The precipitation during the growing seasons of 1970 to 1978 was normal or greater than normal (table 31). During 1970, 1971, 1972, 1973, 1974, 1975, 1976, and 1978, 17.90 inches (132.10% of LTM), 18.58 inches (137.12% of LTM), 18.57 inches (137.05% of LTM), 11.83 inches (87.31% of LTM), 12.45 inches (91.88% of LTM), 15.26 inches (112.62% of LTM), 10.84 inches (80.00% of LTM), 18.65 inches (137.64% of LTM), and 15.17 inches (111.96% of LTM) of precipitation were received, respectively. April, May, and July of 1970 were wet months and each received 246.85%, 271.37%, and 173.87% of LTM precipitation, respectively. September received normal precipitation at 112.03% of LTM. June was a dry month and received 55.77% of LTM precipitation. August and October were very dry months and received 16.76% and 42.11% of the LTM precipitation, respectively. Perennial plants were under water stress conditions during August and October, 1970 (Manske 2008). April, June, September, and October of 1971 were wet months and each received 209.09%, 212.39%, 263.91%, and 334.74% of LTM precipitation, respectively. May, July, and August were very dry months and received 37.18%, 11.26%, and 13.87% of LTM precipitation, respectively. Perennial plants were under water stress conditions during May, July, and August, 1971 (Manske 2008). May, August, and October of 1972 were wet months and each received 217.52%, 167.63%, and 164.21% of LTM precipitation, respectively. April, June, and July received normal precipitation at 88.81%, 120.85%, and 122.52% of LTM. September was a dry month and received 55.64% of LTM precipitation. Perennial plants were under water stress conditions during September, 1972 (Manske 2008). April and September of 1973 were wet months and each received 224.48% and 167.67% of LTM precipitation, respectively. June received normal precipitation at 85.63% of LTM. May and October were dry months and received 55.56% and 70.53% of LTM precipitation. July and August were very dry months and received 40.99% and 27.17% of the LTM precipitation, respectively. Perennial plants were under water stress conditions during July, August, and October, 1973 (Manske 2008). April and May of 1974 were wet months and each received 197.20% and 177.35% of LTM precipitation, respectively. June, July, August, and October were dry months and received 56.34%, 67.57%, 52.02%, and 54.74% of LTM precipitation. September was a very dry month and received 42.11% of the LTM. Perennial plants were under water stress conditions during July, August, September, and October, 1974 (Manske 2008). April, May, and October of 1975 were wet months and each received 297.20%, 142.74%, and 149.47% of LTM precipitation, respectively. June received normal precipitation at 120.28% of LTM. September was a dry month and received 60.15% of LTM. July and August were very dry months and received 28.83% and 31.21% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July, August, and September, 1975 (Manske 2008). April and September of 1976 were wet months and each received 147.55% and 133.08% of LTM precipitation, respectively. June received normal precipitation at 105.35% of LTM. May and October were dry months and received 60.68% and 68.42% of LTM. July and August were very dry months and received 33.78% and 23.12% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July and August, 1976 (Manske 2008). June, September, and October of 1977 were wet months and each received 151.55%, 434.59%, and 227.37% of LTM precipitation, respectively. May and August received normal precipitation at 111.11% and 87.86 % of LTM. April and July were very dry months and received 9.09% and 48.65% of LTM precipitation, respectively. Perennial plants were under water stress conditions during April and July, 1977 (Manske 2008). April, May, and September of 1978 were wet months and each received 126.57%, 170.51%, and 192.48% of LTM precipitation, respectively. July and August received normal precipitation at 108.56% and 116.18% of LTM. June was a dry month and received 59.15% of LTM. October was a very dry month and received 30.53% of LTM precipitation. Perennial plants were under water stress conditions during October, 1978 (Manske 2008).

Total herbage biomass production increased on the fertilization treatments applied every other year (EOY), every year (EY), and one time (OT) (Whitman 1975, 1978). Mean herbage biomass total yield for the upland range site on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertitilization treatments was 12.1%, 32.1%, 27.3%, 38.5%, 7.7%, 27.2%, and 25.1% greater than the mean total herbage yield produced on the unfertilized treatment, respectively (table 32). The 100 lbs N/ac EY and 67 lbs N/ac EY treatments had the greatest increases in total herbage yield. The 200 lbs N/ac OT and 67 lbs N/ac EOY treatments had the lowest increases in total herbage yield. Nitrogen in combination with phosphorus produced slightly greater mean total herbage yield than the respective rate of nitrogen alone (Goetz 1984). Application of either phosphorus or potassium alone resulted in no appreciable change in total herbage yield, with no increase of cool season species and no decrease of short warm season species (Whitman 1976, Goetz et al. 1978).

The heavy one time application of 200 lbs N/ac, 300 lbs N/ac, and 400 lbs N/ac treatments had herbage yields 40.6%, 66.8%, and 59.2% greater than those on the unfertilized treatment, respectively, during the first 3 years after application (1970 to 1972) and had herbage yields 8.3% lower, and 5.6% and 9.6% greater than those on the unfertilized treatment, respectively, during the fourth through the ninth year after application (1973 to 1978) (Whitman 1978). One time application of heavy rates of nitrogen were regarded to be viable treatments during the early portions of the study (Whitman 1970, 1971, 1972). The mediocre production on the heavy one time treatments during the latter two thirds of the study resulted because of the rapid immobilization of nitrogen by the soil-plant system (Goetz 1975a). The solution to this problem was considered to be annually applied low rates of supplemental nitrogen fertilizer that would satisfy the needs of the existing plants for continuation of increased herbage yields (Whitman 1972).

The plant species composition shifted with an increase of mid grasses and a decrease of short grasses as a result of the nitrogen fertilization treatments during this nine year study (Whitman 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978). The mean herbage weight of mid grasses on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 14.8%, 54.8%, 43.5%, 68.3%, 20.5%, 42.2%, and 39.1% greater than the mean mid grass weight produced on the unfertilized treatment, respectively, on the upland range site (table 32). The 100 lbs N/ac EY and 67 lbs N/ac EY treatments had the greatest increases in mid grass herbage yield. The 67 lbs N/ac EOY and 200 lbs N/ac OT treatments had the lowest increases in mid grass herbage yield.

The percent composition of weight yields for mid grasses was greater on the nitrogen fertilization treatments than those on the unfertilized treatments (Whitman 1978) (table 33). The percent composition for mid grasses on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments increased 2.4%, 17.1%, 12.7%, 21.5%, 11.9%, 11.7%, and 11.2%, respectively. The 100 lbs N/ac EY and 67 lbs N/ac EY treatments had the greatest increases in percent composition of mid grasses. The 67 lbs N/ac EOY treatment had the lowest increase in percent composition of mid grasses.

The herbage weight produced by the mid grasses on all of the fertilization treatments was more than double the herbage weight produced by the short grasses (Whitman 1971). The mean herbage weight of short grasses for the upland range site on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 15.2%, 26.6%, 29.5%, 27.2%, 20.2%, 7.4%, and 16.7% lower than the mean short grass weight produced on the unfertilized treatment, respectively (table 32). The 100 lbs N/ac EOY, 100 lbs N/ac EY, and 67 lbs N/ac EY treatments had the greatest decreases in short grass herbage yield. The 300 lbs N/ac OT, 67 lbs N/ac EOY, and 400 lbs N/ac OT treatments had the lowest decreases in short grass herbage yield.

The percent composition of weight yields for short grasses was lower on the nitrogen fertilization treatments than those on the unfertilized treatments (Whitman 1978) (table 33). The percent composition for short grasses on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments decreased 24.4%, 44.5%, 44.6%, 47.4%, 25.9%, 27.2%, and 33.4%, respectively. The reductions in percent composition of short grasses was substantial on all nitrogen fertilization treatments. The reductions were greater on the 67 lbs N/ac EY, 100 lbs N/ac EOY, and 100 lbs N/ac EY treatments.

Herbage biomass production of perennial forbs increased on the fertilization treatments (Whitman 1978). Perennial forb dry matter weight produced on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 101.6%, 117.9%, 133.3%, 110.7%, 34.4%, 75.3%, and 102.4% greater than the perennial forb weight produced on the unfertilized treatment, respectively (table 32) and percent composition of perennial forbs was 79.8%, 65.0%, 83.2%, 52.1%, 24.7%, 37.8%, and 61.5% greater than that on the unfertilized treatment, respectively (table 33). The 100 lbs N/ac EOY, 67 lbs N/ac EOY, and 100 lbs N/ac EY treatments had the greatest increases in perennial forb weight production. The 100 lbs N/ac EOY, 67 lbs N/ac EOY, and 67 lbs N/ac EY treatments had the greatest increases in percent composition of perennial forb weight. The 200 lbs N/ac OT treatment had the lowest increase in herbage biomass weight and percent composition of perennial forbs. Herbage weight of the perennial forb component greatly increased on all nitrogen fertilization treatments (Whitman 1975, 1978). Annual forb herbage weight did not contribute significantly to the total production yield on any of the nitrogen fertilization treatments (Whitman 1970, 1978).

Total basal cover decreased on the fertilization treatments (Whitman 1978, Goetz et al. 1978). Mean total basal cover of grasses and forbs for the upland range site on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 9.1%, 21.5%, 16.0%, 19.8%, 15.2%, 25.9%, and 21.0% lower than the total basal cover on the unfertilized treatment, respectively (table 34). The 300 lbs N/ac OT, 67 lbs N/ac EY, 400 lbs N/ac OT, and 100 lbs N/ac EY treatments had the greatest decreases in total basal cover. The 67 lbs N/ac EOY treatment had the lowest decrease in total basal cover.

Basal cover of cool season grasses, including mid and short grasses, increased on the fertilization treatments (Whitman 1975, 1978; Goetz et al.1978). Cool season grass basal cover on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 25.7%, 14.9%, 31.7%, 57.2%, 46.9%, 5.5%, and 34.6% greater than the cool season grass basal cover on the unfertilized treatment, respectively (table 34). The 100 lbs N/ac EY and 200 lbs N/ac OT treatments had the greatest increases in cool season grasses. Basal cover of the mid cool season grasses was not distinct on the biennial and most of the one time application fertilization treatments (Goetz et al. 1978). The 100 lbs N/ac EY, 200 lbs N/ac OT, and 67 lbs N/ac EY treatments had increases in mid cool season grass basal cover 25.2%, 20.8%, and 10.6% greater than those on the unfertilized treatment, respectively. Substantial increases in short cool season grass basal cover of 135.1%, 111.9%, 110.5%, 94.0%, and 92.9% occurred on the 100 lbs N/ac EY, 100 lbs N/ac EOY, 200 lbs N/ac OT, 400 lbs N/ac OT, and 67 lbs N/ac EOY treatments, respectively.

Basal cover of short warm season grasses decreased substantially on the fertilization treatments (Whitman 1975, 1978; Goetz et al. 1978). Short warm season grass basal cover on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 200 lbs N/ac OT, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 42.1%, 67.6%, 51.2%, 77.7%, 46.9%, 49.1%, and 55.4% lower than the short warm season grass basal cover on the unfertilized treatment, respectively (table 34). The 100 lbs N/ac EY, 67 lbs N/ac EY, and 400 lbs N/ac OT treatments had the greatest decreases in short warm season grass basal cover.

Basal cover of domesticated and introduced grasses was low on the unfertilized treatment and was substantially increased on the fertilization treatments, except not on the 200 lbs N/ac OT treatment (table 34). Domesticated and introduced grass basal cover on the 67 lbs N/ac EOY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 100 lbs N/ac EY, 300 lbs N/ac OT, and 400 lbs N/ac OT fertilization treatments was 655.6%, 988.9%, 211.1%, 288.9%, 544.4%, and 111.1% greater than the basal cover of domesticated and introduced grasses on the unfertilized treatment, respectively.

Basal cover of perennial forbs increased on the fertilization treatments with annual and biennial applications but decreased on the heavy one time application of fertilizer treatments (table 34). Perennial forb basal cover increased 75.0%, 66.4%, 47.1%, and 26.0% on the 100 lbs N/ac EY, 67 lbs N/ac EY, 100 lbs N/ac EOY, 67 lbs N/ac EOY treatments and decreased 23.1%, 16.4%, and 11.5% on the 300 lbs N/ac OT, 400 lbs N/ac OT, and 200 lbs N/ac OT treatments, respectively.

Available mineral nitrogen increased on the nitrogen fertilization treatments during the early portion of the growing season (Whitman 1975). The available mineral nitrogen was depleted quickly and was at low levels soon after active plant growth commenced in the spring (Whitman 1975). Quantities of mineral nitrogen increased and decreased in a cyclic phenomenon during the growing season. The first peak occurred in early spring ahead of active plant growth. The second peak occurred following the start of summer dormancy and before active initiation of new growth shortly before winter freeze up (Whitman 1975). The third peak occurred following plant development for the subsequent year's growth (Goetz 1975a).

Nitrogen fertilization treatments increased the crude protein content of grasses during early growth stages. The crude protein content declined with advancement in plant maturity. Crude protein content in warm season grasses decreased at a slower rate than that in cool season grasses. The rate of decline was more rapid on the fertilization treatments and the crude protein content dropped below livestock requirements earlier in the growing season than the crude protein content of grasses on the unfertilized treatment (Whitman 1975).

Whitman determined that the annual application of 67 lbs N/ac was the most productive treatment even though the 100 lbs N/ac EY treatment produced greater mean herbage weight. The 67 lbs N/ac EY treatment was the most efficient and used the lowest amount of nitrogen and the lowest amount of soil water for each pound of additional herbage produced beyond the herbage weight produced on the unfertilized treatment (Whitman 1970, 1971, 1972, 1975, 1976, 1978).

Whitman (1976) considered the application of nitrogen fertilizer to native rangeland to be a beneficial practice because, in a short period, it changed the plant composition from being dominated by short warm season grasses to being dominated by higher producing mid cool season grasses, it increased the annual herbage weight produced, it increased the crude protein content of grasses during early growth stages, and the water use efficiency was improved. The negative aspects of nitrogen fertilization treatments and the resulting shift in plant composition from multiple stemmed high cover species to single stalked low cover species were identified as decreased plant basal ground cover, reduced litter cover, increased soil erosion, increased undesirable perennial forbs and annual grasses, and greater fluctuations in individual plant numbers (Goetz et al. 1978).

This nine year study showed that nitrogen fertilization of native rangeland resulted in greater total herbage yield than that produced on unfertilized rangeland. Nitrogen fertilization caused a shift in plant species composition with an increase in herbage weight and percent composition of mid grasses and a decrease in herbage weight and percent composition of short grasses. Basal cover of mid and short cool season grasses increased and basal cover of short warm season grasses decreased on nitrogen fertilized treatments. Herbage weight and percent composition of undesirable perennial forbs greatly increased on all nitrogen fertilization treatments. Basal cover of perennial forbs increased on fertilization treatments with annual and biennial applications.

Nitrogen fertilization increased the available mineral nitrogen in soil during the early portion of the growing season. The available mineral nitrogen was depleted quickly and was at low levels soon after active plant growth commenced in the spring. A second peak occurred following the start of summer dormancy in mid to late July. The third peak occurred in late autumn. The low points in available mineral nitrogen occurred during the periods of active plant growth.

Nitrogen fertilization increased the crude protein content of grasses during early growth stages. Crude protein content decreased with advancement in plant maturity. The rate of decline was greater on the fertilized treatments than on the unfertilized treatment. The crude protein content of grasses on fertilized treatments dropped below livestock requirements earlier than that of grasses on unfertilized treatments.

The effectiveness of the nitrogen fertilization treatments evaluated during the fertilization plot studies conducted from 1957 to 1978 by Dr. Warren C. Whitman and Dr. Harold Goetz were not equal. The causes for some of the differences in treatment effectiveness were related to changes in available soil water during the numerous study years and variation in soil characteristics of the several study sites.

The effectiveness of the biennial application treatments was less than that of the annual application treatments. The every other year (EOY) application of 67 lbs N/ac and 100 lbs N/ac treatments had lower mean total herbage yield, lower herbage weight produced per pound of nitrogen, and greater cost for the additional treatment produced herbage than those on the 67 lbs N/ac EY treatment. However, the every other year treatments did slow the rate of change in plant composition. The increase in mid and short cool season grasses and the decrease in short warm season grasses were lower than that on the respective every year (EY) treatments.

The effectiveness of the single application treatments was less than that on the annual application treatments. The heavy one time (OT) applications of nitrogen treatments had lower mean total herbage yield than the 67 lbs N/ac EY treatment. The available mineral nitrogen was immobilized in the soil rapidly and the heavy one time treatments were not effective after the first three years following nitrogen application. During the first three years, the 300 lbs N/ac OT treatment was more effective than the 200 lbs N/ac OT and 400 lbs N/ac treatments.

Annual application of nitrogen fertilizer at low, medium, and high rates compared to unfertilized controls has been the primary objective of the nitrogen fertilization plot studies. The first study had a one year duration that produced a framework for what could be expected from further studies. The annually applied treatment rates in the next three studies were 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments. Generally, the heavier rates have produced greater herbage yield with an average increase of 22%, 53%, and 58% greater than the herbage yields produced on the unfertilized treatment, respectively. The relationships of these average increases in herbage production were not linear as would be expected if the effectiveness of the fertilizer treatments were equal. This means that total herbage yield data does not have diagnostic value to evaluate fertilizer treatment effectiveness. Effectiveness of fertilization treatments can be evaluated though comparisons of the mean pounds of herbage weight produced above that produced on the unfertilized treatment per pound of nitrogen applied per acre. The mean herbage weight produced per pound of nitrogen applied on the 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac treatments was 9.10 lbs, 12.23 lbs, and 8.76 lbs per pound of nitrogen applied on the fertilization plot study sites during 1962 to 1978 (table 35, figure 1). The descending order of treatment effectiveness was the 67 lbs N/ac, 33 lbs N/ac, and 100 lbs N/ac application rates. The 100 lbs N/ac treatment produced the greatest total herbage yield, however, it had the lowest treatment effectiveness and produced the lowest herbage weight per pound of nitrogen applied.

Related Results

Scientists at other research centers in the Northern Plains conducted studies that evaluated fertilization treatments on native rangeland for improvement of productivity and the botanical composition of grasslands and to determine the factors affecting nutrient uptake and distribution within the soil-plant system.

Rogler and Lorenz (1957) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in herbage production and plant species composition at the ARS Research Center, Mandan, ND from 1951 to 1957. Plots were replicated three times and were located in a heavily grazed pasture and a moderately grazed pasture. The treatments included 0 lbs N/ac, 30 lbs N/ac, and 90 lbs N/ac rates in ammonium nitrate applied annually in October. The mean total herbage dry matter production on the 30 lbs N/ac and 90 lbs N/ac rates were 77.3% and 203.6% greater than that on the unfertilized treatment in the heavily grazed pasture, respectively, and were 100.3% and 206.0% greater than that on the unfertilized treatment in the moderately grazed pasture, respectively. Plant species composition shifted with an increase in western wheatgrass basal cover and a decrease in blue grama basal cover.

Smika et al. (1961) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in chemical properties of the soil and moisture extraction at the ARS Research Center, Mandan, ND from 1951 to 1959. Plots were replicated three times. The treatments included 0 lbs N/ac, 30 lbs N/ac, and 90 lbs N/ac rates with ammonium nitrate applied annually in October. After 9 years of annual treatment, the proportion of the applied nitrogen remaining in the 6 foot soil profile was 88.9% and 69.1% for the 30 lbs N/ac and 90 lbs N/ac rates, respectively. The proportion of the applied nitrogen incorporated into the aboveground herbage was 11.1% and 18.8% for the 30 lbs N/ac and 90 lbs N/ac rates, respectively. During an average growing season, the dispersion of the applied nitrogen for the 30 lbs N/ac rate was 26.7 lbs N/ac immobilized in the soil and 3.3 lbs N/ac incorporated into the aboveground herbage; the dispersion of nitrogen for the 90 lbs N/ac rate was 62.2 lbs N/ac immobilized in the soil, 16.9 lbs N/ac incorporated into the aboveground herbage, and 10.9 lbs N/ac not accounted for that could have been incorporated into the root material or volatilized into the air. The greatest use of the applied nitrogen resulting from increased root activity occurred at the 24 to 36 inch soil depth. Ammonium nitrate and urea fertilizers increase soil acidity. The 30 lbs N/ac rate changed soil pH from 6.5 to 6.1 (a decrease of 6.2%) and the 90 lbs N/ac rate changed soil pH from 6.5 to 5.9 (a decrease of 9.2%) at the 0 to 6 inch soil depth. Phosphate solubility increases at soil pH values higher or lower than pH 7.0. The amount of available phosphorus in the surface soils increased with increases in soil acidity caused by nitrogen fertilization. The quantity of soil moisture withdrawal increased in all soil depths with the addition of nitrogen fertilizer.

Smika et al. (1965) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in herbage production, water use, water use efficiency, and recovery of nitrogen fertilizer by native grass at the ARS Research Center, Mandan, ND from 1958 to 1961. Plots were replicated three times. The treatments included 0 lbs N-35 lbs P/ac, 20 lbs N-35 lbs P/ac, 40 lbs N-35 lbs P/ac, 80 lbs N-0 lbs P/ac, 80 lbs N-35 lbs P/ac, and 160 lbs N-35 lbs P/ac rates with superphosphate applied one time the first year and ammonium nitrate applied annually in late fall. Aboveground herbage production increased with nitrogen fertilization. The mean total herbage dry matter production on the 20, 40, 80, and 160 pounds of nitrogen per acre rates were 51.3%, 120.5%, 184.6%, and 289.7% greater than that on the unfertilized treatment, respectively. Total water use was related to the available water supply. Under natural conditions, nearly all the available water was used on the unfertilized and fertilized treatments. A greater proportion of the water use on the unfertilized treatments may have been lost through evaporation. Under high moisture conditions, nitrogen fertilization treatments increased water use. Water use efficiency (pounds of herbage production per inch of water use) increased with increased rates of nitrogen fertilizer when sufficient water was available. The quantity of available water required for maximum water use efficiency for fertilizer rates greater than 40 lbs N/ac does not occur under natural conditions in the Northern Plains. The proportion of the applied nitrogen used by native plants under natural moisture conditions was low (17% to 25%). The proportion of the applied nitrogen incorporated into the aboveground herbage increased (27% to 35%) with greater amounts of available soil moisture. A high proportion of the applied nitrogen fertilizer was immobilized in the soil (40% to 53%). The remaining portions of the applied nitrogen were incorporated into the root material or volatilized into the air (27% to 42%).

Lorenz (1970) and Lorenz and Rogler (1972) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in herbage production and botanical composition at the ARS Research Center, Mandan, ND from 1958 to 1965. Plots were replicated three times and were located in a pasture that had previously been moderately grazed. The treatments included 0 lbs N-0 lbs P/ac, 0 lbs N-18 lbs P/ac, 0 lbs N-36 lbs P/ac, 40 lbs N-0 lbs P/ac, 40 lbs N-18 lbs P/ac, 40 lbs N-36 lbs P/ac, 80 lbs N-0 lbs P/ac, 80 lbs N-18 lbs P/ac, 80 lbs N-36 lbs P/ac, 160 lbs N-0 lbs P/ac, 160 lbs N-18 lbs P/ac, and 160 lbs N-36 lbs P/ac rates with ammonium nitrate and treble superphosphate applied annually in mid October. The mean total herbage dry matter production on the 40 lbs N/ac, 80 lbs N/ac and 160 lbs N/ac rates were 48.3%, 90.5%, and 105.5% greater than that on the unfertilized treatments, respectively. The response to fertilizer varied greatly from year to year as a result of variable effective precipitation, soil moisture supply, and other environmental factors. The response to phosphate applied without nitrogen was small. The response to phosphate increased as rate of nitrogen increased. Plant species composition shifted. Western wheatgrass density increased with increasing nitrogen rates and with phosphate applied with the 160 lbs N/ac rate. Blue grama basal cover decreased with increasing nitrogen rates.

Lorenz (1970) and Lorenz and Rogler (1973) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in growth rate at the ARS Research Center, Mandan, ND from 1958 to 1965. Plots were replicated three times. The treatments included 0 lbs N-0 lbs P/ac, 0 lbs N-18 lbs P/ac, 40 lbs N/ac, 80 lbs N/ac, 80 lbs N-18 lbs P/ac, and 160 lbs N/ac rates with ammonium nitrate and treble superphosphate applied annually in mid October. Herbage on the fertilized treatments had greater growth rates than that on the unfertilized treatments during the early portion of the growing season from early May to early July. The period with the greatest rate of growth for both the fertilized and unfertilized treatments occurred between 15 June and 1 July. Most treatments decreased in aboveground herbage weight between 15 July and 1 August.

Power (1970), Power and Alessi (1971), and Power (1972) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in mid summer cumulative aboveground herbage weight and nitrogen content, grass species abundance, annual spring soil mineral nitrogen content, and root weight and nitrogen content at the ARS Research Center, Mandan, ND from 1963 to 1968. Plots were replicated three times. The treatments included 0 lbs N/ac and total nitrogen rates of 30, 60, 120, 240, and 480 lbs N/ac applied in early spring as ammonium nitrate one time in the first year, one third of the total applied in each of three years, and one sixth of the total applied in each of six years. Cumulative 6 year aboveground herbage production increased with increased rates of nitrogen fertilization. Herbage production on treatments with a total of 30 lbs N/ac applied one, three, and six times was not significantly different from the herbage production on the unfertilized treatments. Year to year variations in herbage production existed as a result of variation in available water supply. The treatments with the same rates of total nitrogen applied one, three, and six times produced essentially the same total 6 year cumulative aboveground herbage dry matter with a slight lag on the treatments applied six times. Moderate and high nitrogen fertilization rates resulted in changes in plant species composition with an increased abundance of the mid cool season grasses, primarily western wheatgrass, and a decreased abundance of the short warm season grasses, primarily blue grama. The abundance of prairie Junegrass decreased. Mineral nitrogen (ammonium and nitrate) was available above the 3 foot soil depth in the spring at greater amounts than on the unfertilized treatments on only a few fertilization treatments: the 480 lbs N/ac and 240 lbs N/ac rates applied one time, the 160 lbs N/ac rate applied three times, and, after four treatments, the 80 lbs N/ac rate applied six times. Only about 17 to 28 lbs N/ac of fertilizer nitrogen from the high rates was assimilated into the aboveground herbage per year. About 178 lbs N/ac were immobilized or lost during the first year of treatment. The immobilized nitrogen was assimilated into grass roots, soil organic matter, and microbial tissue. The lost nitrogen was ammonium fixed by adsorption onto clay particles, or lost in gaseous form into the atmosphere by volatilization of ammonia, or by removing oxygen in denitrification forming nitrous oxide or N_2 gas. None of the nitrogen was lost by leaching. The immobilized quantity of nitrogen increased to around 285 lbs N/ac to 339 lbs N/ac within three or four years after the start of fertilization treatments and remained near that range thereafter. About half of the immobilized nitrogen was found in the grass roots. The nitrogen content of the grass roots on the high fertilization treatments was about 0.5% greater than that of unfertilized grass roots. The immobilized nitrogen in organic forms could be mineralized later by soil microorganisms and recirculated through the ecosystem. Mineralization is the enzymatic hydrolysis of the peptide bonds of organic materials which liberates and degrades amino acids into ammonia and carbon dioxide, or other low molecular weight carbon compounds. The ammonia released is oxidized to the nitrite form, then to the nitrate form, and is added to the plant available inorganic (mineral) nitrogen pool in the soil. The nitrogen immobilization capacity in grassland soils was somewhat variable and was influenced by soil texture, vegetation type, root growth, lignin content of organic matter, amount and minerology of clay material, and environmental parameters of soil temperature, soil oxygen, and soil water. An hypothesis on the operation of the nitrogen cycle in grassland soils was developed by Power along with implications for management. Considerable quantities of the fertilizer nitrogen were immobilized by components of the soil-plant system in addition to the amounts used for aboveground herbage growth. Once sufficient fertilizer nitrogen was applied to saturate the nitrogen immobilizing capacity of the soil-plant system, the excess quantity of fertilizer nitrogen remained in the soil in mineral form. Application of sufficient fertilizer nitrogen to grassland soils that saturated the immobilizing capacity would eliminate nitrogen as a growth limiting factor. As a result, semiarid grasslands would produce at the maximum level for whatever water was available if a small amount of annually applied fertilizer nitrogen plus the quantity of inorganic nitrogen mineralized by soil microorganisms equaled the amount of nitrogen immobilized and lost each growing season.

Wight and Black (1972) conducted a fertilization on native rangeland plot study that evaluated changes in herbage production, plant species composition, precipitation use efficiency, and energy fixation at the ARS Research Center, Sidney, MT from 1969 to 1970. Plots were arranged in a split plot design with two replicated blocks. Treatments included 0 lbs P/ac, 100 lbs P/ac, and 200 lbs P/ac as main plots and 0 lbs N/ac, 100 lbs N/ac, 300 lbs N/ac, and 900 lbs N/ac as subplots with superphosphate and ammonium nitrate applied one time in the early spring of 1969. Total herbage yield was greater on fertilized treatments than on unfertilized treatments. Herbage yield increased with increasing nitrogen on the 100 lbs N/ac and 300 lbs N/ac treatments. Herbage yield increased during the second year on the 900 lbs N and 200 lbs P/ac treatment. Phosphorus applied without nitrogen had no effect on herbage yield. Phosphorus increased total herbage production when applied with nitrogen. Herbage weight of western wheatgrass increased with increased rates of nitrogen when applied without phosphorus or with the 200 lbs P/ac rate. Stem density of western wheatgrass greatly increased during the second year on the treatments with high rates of nitrogen and phosphorus. Herbage weight of forbs increased on the 100 lbs N/ac and 300 lbs N/ac treatments. Threadleaf sedge herbage weight increased on the 100 lbs N/ac treatment. Needle and thread herbage weight increased on the 100 lbs N/ac and 300 lbs N/ac treatments. Herbage weights of blue grama and prairie Junegrass were not affected by the fertilization treatments. Fertilization treatments of high rates of nitrogen and phosphorus improved herbage precipitation use efficiency (pounds of herbage produced per inch of precipitation received). Total soil water use was greater on fertilized treatments than on unfertilized treatments. Energy fixation in native rangelands managed by traditional grazing practices captures low quantities of the sun's energy for use by man. The total amount of energy fixed by chlorophyllous plants on rangeland ecosystems is not limited by the availability of radiant energy from the sun or by the availability of atmospheric carbon dioxide (CO_2) but is limited by the low availability of mineral nitrogen and phosphorus. The availability of water, which is an essential requirement for plant growth and has a dominant role in physiological processes, does not limit herbage production on rangeland ecosystems to the extent that nutrient availability does. Nutrient cycling in Northern Plains rangeland ecosystems is inadequate to supply the nitrogen necessary for maximum herbage production. These rangelands are functioning at levels that cycle nitrogen at a rate of about 59 pounds of mineral nitrogen per acre per year or less (usually less) and produce only one half to one third of the potential quantity of herbage. Increasing herbage production to maximum yields would require nitrogen cycling at rates of about 100 to 165 pounds of available mineral nitrogen per acre per year.

Black and Wight (1972) conducted a fertilization on native rangeland plot study that evaluated changes in interactions of soil nitrogen and phosphorus at high fertilizations rates at the ARS Research Center, Sidney, MT from 1969 to 1970. Plots were arranged in a split plot design with two replicated blocks. Treatments included 0 lbs P/ac, 100 lbs P/ac, and 200 lbs P/ac as main plots and 0 lbs N/ac, 100 lbs N/ac, 300 lbs N/ac, and 900 lbs N/ac as subplots with superphosphate and ammonium nitrate applied one time in the early spring of 1969. Only 50% to 70% of the applied nitrogen was measured as nitrate during each of the two years. Nitrification of the ammonium form of nitrogen in the fertilizer may require more than one or two growing seasons. High rates of nitrogen fertilizer lowered soil pH an average of 7.6% in the top six inches. Soluble phosphorus increased greatly as a result of the decrease in pH caused by the applied nitrogen. Fertilization with high nitrogen rates increased the nitrogen content of aboveground plant material in mid July. The increase in the nitrogen content of the plant material was less the second year. Application of phosphorus had no influence on plant nitrogen content. The increased total herbage production and increased plant nitrogen content resulted in an increase in total production of crude protein. High nitrogen rates applied without phosphorus increased plant phosphorus uptake the first year but plant phosphorus content was below livestock requirements the second year. Phosphorus applied with nitrogen increased plant phosphorus content. The percentages of applied nitrogen and phosphorus recovered in aboveground plant material were extremely low. The quantities of soil available mineral nitrogen and soluble phosphorus were at very low levels. Plant-soil nutrient cycling systems of rangeland have a large proportion of the soil nitrogen and phosphorus required for plant growth tied up in the organic phase in relatively unavailable forms. This is corroborated by the low herbage yield and low quality of unfertilized range plants in this study. The effects of range management techniques on nutrient cycling and availability have not been fully determined.

Wight and Black (1979) conducted a fertilization on native rangeland plot study that evaluated the long-term effects on herbage yield and species composition at the ARS Research Center, Sidney, MT from 1967 to 1976. The treatments included low rates of ammonium nitrate and superphosphate applied annually for ten years in early spring on plots replicated four times. High rates of nitrogen and phosphorus were applied one time in early spring on split plots replicated two times with the treatments started during 1969, 1970, and 1971. Nitrogen was established as a major growth limiting factor in the Northern Plains. Nitrogen and phosphorus deficiencies on rangelands reduced potential herbage production around 44%. Applications of nitrogen and nitrogen plus phosphorus increased herbage yield. Magnitude of response varied with both the annual climate and application rate. Phosphorus increased yields only when applied with nitrogen and when nitrogen was nonlimiting. Most of the yield response to nitrogen occurred at the lower rates with only small increases in yield per added pound of nitrogen as nitrogen rate increased beyond 35 to 45 lbs N/ac rates. The most effective nitrogen fertilization treatments were the lower rates. Almost all of the nitrogen applied above the low rates remained in the soil profile, usually above the three foot depth, because very little water moves through soil profiles of semiarid rangelands under cover of perennial vegetation. Low rates of annually applied nitrogen may require four years to overcome the soil nitrogen-sink effect. Species composition varied considerably among years. The percent composition of perennial grasses varied inversely with forbs. The effects from nitrogen fertilization were relatively minor over the ten year study. Generally, the cool season species increased the most with nitrogen fertilization. Blue grama was not affected by low rates of nitrogen but the percent composition decreased as herbage yields of other species increased with nitrogen rates. High nitrogen rates caused blue grama herbage yields to decrease. Upland sedges responded little to fertilization treatments but the percent composition decreased as herbage yields of other species increased with nitrogen rates. During growing seasons with above normal precipitation, forbs like goatsbeard and fringed sage increased on nitrogen treatments and annual forbs like tansy mustard increased on high nitrogen and phosphorus treatments. Pounds of herbage produced per inch of precipitation received was called precipitation use efficiency. The pounds of herbage produced per inch of precipitation were greater on the nitrogen fertilized treatments than on the unfertilized treatments. Nitrogen fertilization effectively removed the nutrient induced limitations on herbage yield. The ten year annual precipitation during the study averaged 13% above the long-term mean and the ambient deficiency of available mineral nitrogen in the unfertilized rangeland ecosystems caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the herbage produced per inch of precipitation in the fertilized rangeland ecosystems without a deficiency of available mineral nitrogen.

Black and Wight (1979) conducted a fertilization on native rangeland plot study that evaluated changes in plant uptake of nitrogen and phosphorus and recovery of the nutrients after eight years at the ARS Research Center, Sidney, MT from 1969 to 1976. Plots were arranged in a split plot design with two replicated blocks. Treatments included 0 lbs P/ac, 100 lbs P/ac, and 200 lbs P/ac as main plots and 0 lbs N/ac, 100 lbs N/ac, 300 lbs N/ac, and 900 lbs N/ac as subplots with superphosphate and ammonium nitrate applied one time in the early spring of 1969. Aboveground herbage samples were collected in mid July. Plant nitrogen content was not influenced by phosphorus fertilizer. Variations in plant nitrogen content were influenced by the applied rate of nitrogen and years (climate). By the third year after application, plant nitrogen content was no longer influenced by rate of nitrogen application and plant nitrogen content became more related to available water supplies and to the quantity of herbage produced. During wetter years with high herbage production, the plant nitrogen content decreased. During lower precipitation years with reduced herbage production, the plant nitrogen content increased. Plant phosphorus content in grasses decreased as nitrogen rates increased without phosphorus fertilization. The higher rates of nitrogen fertilization depressed plant phosphorus content far below the required levels for livestock. Plant phosphorus content in nongrasses was controlled by the applied rate of phosphorus and secondarily by years (climate). By the third year after application, plant phosphorus content was no longer influenced by rate of phosphorus application and was controlled by available water supplies. During wetter years, plant phosphorus content was relatively high. During lower precipitation years, plant phosphorus content was low. Plant nitrogen uptake was greater on nitrogen fertilization treatments than on the unfertilized treatments. Plant phosphorus uptake was not affected by the application rate of phosphorus. Plant phosphorus uptake increased with the increased rates of nitrogen fertilizer. Recovery of applied nitrogen in the harvested aboveground herbage during the eight years after application was 51.4%, 37.1%, and 19.6% without phosphorus added and was 48.6%, 50.5%, and 27.1% with phosphorus added for the 100 lbs N/ac, 300 lbs N/ac, and 900 lbs N/ac, respectively. Recovery of applied phosphorus in the harvested aboveground herbage during the eight years after application was 27% and 15% for the 100 lbs P/ac and 200 lbs P/ac rates, respectively. Five years after application of the 300 lbs N/ac rate, the distribution of accountable nitrogen (94%) was 34 lbs N/ac in the soil, 103 lbs N/ac in the roots, and 145 lbs N/ac in the aboveground herbage. The nitrogen not accounted for was 18 lbs N/ac, which may have volatilized into the air. The unfertilized treatments had 18,464 lbs/ac of root material in the top foot of soil. The 300 lbs N/ac with 200 lbs P/ac treatment had 21,685 lbs/ac of root material in the top foot of soil five years after application. The root material on the fertilized treatment contained 103 lbs/ac more nitrogen and 6.9 lbs/ac more phosphorus than the roots on the unfertilized treatment. This increased nutrient content of the root material showed that rangeland ecosystems have the potential to immobilize large quantities of nitrogen and phosphorus in the belowground root system.

Taylor (1976) conducted a nitrogen fertilization on native rangeland plot study that evaluated changes in herbage production, plant species composition, and effects from climatic factors at the ARS Research Center, Havre, MT from 1959 to 1973. Plots were replicated three times. The treatments included 0 lbs N/ac and 100 lbs N/ac rates with ammonium nitrate applied annually in late fall for three years, 1959, 1960, and 1961. Herbage samples separated into plant groups were clipped to ground level in early July, 1962 to 1969, 1972 to 1973. Herbage weight and percent composition increased for mid cool season grasses (primarily needle and thread) and herbage weight increased slightly and percent composition decreased for other grasses (primarily blue grama) on the nitrogen fertilization treatments. These changes were not significant because of the wide variations within the annual vegetation production. The climatic factors that explained the variation in plant productivity more than any other climatic factors was the January to peak herbage (June) available plant moisture index which integrated monthly precipitation and potential evapotranspiration. Even though this study was conducted over a 15 year period, the author considered the longevity of response monitoring to be too short because residual effects of nitrogen fertilization were still occurring 12 years after the treatments had stopped. Premature termination of rangeland research studies has contributed many incomplete and erroneous concepts to grassland resource management in the Northern Plains (Jack Taylor 1976).

Discussion

The grazingland natural resources in the Northern Plains had been degraded during the homestead period and beyond as a result of the persistently used naive traditional grazing management practices that repetitively grazed too early, too late, too long, and too heavy. Dr. Warren C. Whitman and Dr. Harold Goetz conducted four nitrogen fertilization of native rangeland plot studies at the Dickinson Research Extension Center from 1957 to 1978 to find and develop cultural management practices that could be used to correct the deteriorated condition of low productivity and botanical composition imbalance on the grazinglands in the Northern Plains. The major findings from these studies follow.

- Nitrogen fertilization of native rangeland resulted in greater total herbage yield than the aboveground herbage produced on unfertilized rangeland manged with traditional grazing practices. Annual applications of 33, 67, and 100 lbs N/ac increased herbage production 22%, 53%, and 58%, respectively. Biennial applications of 67 and 100 lbs N/ac increased herbage production 12% and 27%, respectively. Heavy one time applications of 200, 300, and 400 lbs N/ac were not effective after three years and increased herbage production 8%, 27%, and 25%, respectively. The vegetation responses to nitrogen fertilization were not the same on different range sites as a result of the variations in soil characteristics, soil water content, and plant health status.

- Nitrogen fertilization of native rangeland resulted in a shift in plant species composition. The transformation of the plant community started during the first year of treatment and progressed annually. Herbage weight and percent composition of mid grasses increased and herbage weight and percent composition of short grasses decreased. Basal cover of mid and short cool season grasses increased and basal cover of short warm season grasses decreased. Basal cover, herbage weight, and percent composition of undesirable perennial forbs increased and individual forb plant size greatly increased. The increases in undesirable perennial forbs were greater on range sites in poorer condition. The changes in plant composition were slower on biennially applied treatments. The increases in perennial forbs and the great reductions in blue grama were not beneficial for grassland ecosystems. This plant species shift was also a morphological change in plant community structure with an increase in single stalked low cover species and a decrease in multiple stemmed high cover species resulting in a decrease in total basal cover and an increase in the proportion of soil exposed to potential erosion and open to invasion by opportunistic "weedy" plant species. Basal cover of domesticated cool season grasses and introduced perennial and annual grasses increased slowly. The seriousness of the problems developing with these increasing intrusive grasses was not recognized during these early research projects because their density remained relatively low even after 6, 9, and 11 years of nitrogen fertilization treatments.

- Nitrogen fertilization of native rangeland resulted in an increase in average leaf height of about 13%. Unfertilized plants of most major grass species had active growth during 70% of the growing season. Fertilized plants had faster growth rates for about 55% of this unfertilized plant active growth period and unfertilized plants had faster growth rates for about 45% of the time. Fertilized plants had a greater rate of growth in leaf height during a short period in the early portion of the growing season. Unfertilized plants had a longer period of leaf height growth; during the early portion, the rate of growth in leaf height was slower than that of fertilized plants, and during the latter portion of the growing season, the rate of growth in leaf height was greater than that of fertilized plants. Development of phenological growth stages was not affected by nitrogen fertilization. Flowering (anthesis) occurred within the normal range of dates. Rate of leaf senescence was different for fertilized plants with the early stages of leaf drying starting a little later than for unfertilized plants. Once started, the rate of leaf drying was greater for fertilized plants and the leaves reached advanced stages of drying much earlier than for unfertilized plants.

- Nitrogen fertilization of native rangeland resulted in an increase in the crude protein content of aboveground plant material of about 18% during early growth stages. Crude protein content decreased with advancement in plant maturity. The rate of decline was greater for fertilized plants than for unfertilized plants. The crude protein content of grasses on fertilized treatments dropped below livestock requirements earlier in the growing season than the crude protein content of grasses on unfertilized treatments.

- Nitrogen fertilization of native rangeland resulted in a slight increase in total root weight with the percent root weight increasing greatly in the shallow soil depths and decreasing in the deeper soil depths.

- Nitrogen fertilization of native rangeland resulted in some improvement in soil water use efficiency with a slightly greater amount of herbage weight produced from an inch of soil water. The quantity of total soil water use was greater on the fertilized treatments than on the unfertilized treatments with considerably greater quantities of soil water extracted by the heavier nitrogen application rates.

- Nitrogen fertilization of native rangeland resulted in an increase in available mineral nitrogen in soil during the early portion of the growing season. The quantity of increase was greater with the heavier rates. The quantity of available mineral nitrogen is not at a constant level during the growing season. Low points in available mineral nitrogen occurred during periods of active plant growth and peaks occurred during periods of low plant growth. The first peak in available mineral nitrogen was reached 30 to 35 days after fertilizer application at the same time around mid May that the first peak was reached on the unfertilized treatment prior to rapid plant growth. The quantity of available mineral nitrogen was depleted quickly and was at low levels soon after active plant growth commenced in the spring. Beginning in early June, the quantity of mineral nitrogen on the fertilized treatments was the same as that on the unfertilized treatments. The second peak occurred at the end of the active growing season in mid to late July. The third peak occurred in late autumn following development of fall tillers and fall tiller buds that produce the plant growth during the subsequent growing season.

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Table 1. Precipitation in inches for growing-season months and the annual total precipitation for 1957, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1957	2.59	2.10	6.61	3.46	1.49	1.98	1.94	20.17	22.15
% of LTM	181.12	89.74	186.20	155.86	86.13	148.87	204.21	148.86	138.44

Table 2. Dry matter weight in pounds per acre for fertilization treatments on a heavily grazed site, 1957.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		540	1096	1636			145	1781
50 lbs N		924	1417	2341			115	2456
100 lbs N		1268	2255	3523			242	3765
150 lbs N		706	2259	2965			255	3220

Data from Whitman 1957.

Table 3. Percent composition of weight yield for fertilization treatments on a heavily grazed site, 1957.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		30.3	61.5	91.9			8.1	1781
50 lbs N		37.6	57.7	95.3			4.7	2456
100 lbs N		33.7	59.9	93.6			6.4	3765
150 lbs N		21.9	70.2	92.1			7.9	3220

Data from Whitman 1957.

Table 4. Precipitation in inches for growing-season months and the annual total precipitation for 1962-1969, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1962	1.12	6.18	2.07	3.22	2.52	0.75	0.55	16.41	18.34
% of LTM	78.32	264.10	58.31	145.05	145.66	56.39	57.89	121.11	114.63
1963	3.79	3.69	4.24	1.86	1.04	1.35	0.20	16.17	18.94
% of LTM	265.03	157.69	119.44	83.78	60.12	101.50	21.05	119.34	118.38
1964	1.38	1.86	6.12	4.42	2.87	0.62	0.01	17.28	18.74
% of LTM	96.50	79.49	172.39	199.10	165.90	46.62	1.05	127.53	117.13
1965	3.41	6.07	4.25	3.08	1.64	1.63	0.00	20.08	21.63
% of LTM	238.46	259.40	119.72	138.74	94.80	122.56	0.00	148.19	135.19
1966	0.82	2.16	4.94	2.19	3.41	0.93	0.48	14.93	16.69
% of LTM	57.34	92.31	139.15	98.65	197.11	69.92	50.53	110.18	104.31
1967	3.87	2.79	1.63	0.72	0.41	2.48	0.61	12.51	14.24
% of LTM	270.63	119.23	45.92	32.43	23.70	186.47	64.21	92.32	89.00
1968	1.02	1.25	3.38	2.83	3.99	0.43	0.91	13.81	15.73
% of LTM	71.33	53.42	95.21	127.48	230.64	32.33	95.79	101.92	98.31
1969	0.72	1.32	6.13	4.40	0.52	0.31	0.86	14.26	16.37
% of LTM	50.35	56.41	172.68	198.20	30.06	23.31	90.53	105.24	102.31
1962-1969	2.02	3.17	4.10	2.84	2.05	1.06	0.45	15.68	17.59
% of LTM	141.26	135.47	115.49	127.93	118.50	79.70	47.37	115.72	109.94

Table 5. Dry matter weight in pounds per acre for fertilization treatments on a creek terrace site, 1962-1963.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		385.50a	943.00a	1328.50a	67.00a	125.50a	192.50a	1521.00a
33 lbs N		542.00a	1138.50a	1680.50a	32.50b	219.50a	252.00a	1932.50ab
67 lbs N		640.00a	1493.00a	2133.00a	101.00c	206.00a	307.00a	2440.00ab
100 lbs N		517.00a	1566.50a	2083.50a	70.50a	277.50a	348.00a	2431.50b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).
Data from Whitman 1962, 1963.

Table 6. Percent composition of weight yield for fertilization treatments on a creek terrace site, 1962-1963.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		25.35	62.00	87.34	4.40	8.25	12.66	1521.00
33 lbs N		28.05	58.91	86.96	1.68	11.36	13.04	1932.50
67 lbs N		26.23	61.19	87.42	4.14	8.44	12.58	2440.00
100 lbs N		21.26	64.43	85.69	2.90	11.41	14.31	2431.50

Data from Whitman 1963.

Table 7. Dry matter weight in pounds per acre for fertilization treatments on an upland slope site, 1962-1963.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		132.00a	745.50a	877.50a	280.50a	200.00a	480.50a	1358.00a
33 lbs N		212.50ab	954.50a	1167.00a	424.50a	233.50b	658.00ab	1825.00ab
67 lbs N		160.50a	1155.50a	1316.00a	518.50a	398.50c	917.00b	2233.00bc
100 lbs N		398.50b	1071.50a	1470.00a	350.00a	440.00c	790.00b	2260.00c

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1962, 1963.

Table 8. Percent composition of weight yield for fertilization treatments on an upland slope site, 1962-1963.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		9.72	54.90	64.62	20.66	14.73	35.38	1358.00
33 lbs N		11.64	52.30	63.95	23.26	12.79	36.00	1825.00
67 lbs N		7.19	51.75	58.93	23.22	17.85	41.07	2233.00
100 lbs N		17.63	47.41	65.04	15.49	19.47	34.96	2260.00

Data from Whitman 1963.

Table 9. Dry matter weight in pounds per acre for fertilization treatments on the Havre overflow range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		2068.50a	17.33a	2085.83a	424.50a	3.90a	428.50a	2514.33a
33 lbs N		2284.50a	15.67ab	2300.17a	351.33a	4.00a	355.33a	2655.50a
67 lbs N		2953.83a	5.00a	2959.00a	407.83a	1.17a	409.00a	3368.00a
100 lbs N		2817.83a	43.17b	2861.00a	215.00a	3.17a	218.17a	3079.17a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 10. Percent composition of weight yield for fertilization treatments on the Havre overflow range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		82.65a	0.72ab	83.37a	16.47a	0.15a	16.63a	2514.33a
33 lbs N		85.73a	0.57ab	86.28a	13.57a	0.13a	13.72a	2655.50a
67 lbs N		87.15a	0.13a	87.33a	12.63a	0.05a	12.67a	3368.00a
100 lbs N		90.93a	1.47b	92.42a	7.50a	0.08a	7.58a	3079.17a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 11. Dry matter weight in pounds per acre for fertilization treatments on the Manning silty range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		306.17a	946.67a	1252.67a	248.67a	30.50a	279.17a	1533.50a
33 lbs N		336.83a	1058.67a	1395.33a	316.50a	31.50a	348.00a	1743.17a
67 lbs N		482.00a	1451.83b	1933.83b	497.83a	45.83a	543.67a	2477.33b
100 lbs N		601.67a	1577.83b	2179.50b	687.83a	42.17a	730.00a	2909.33b

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 12. Percent composition of weight yield for fertilization treatments on the Manning silty range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		20.03a	61.98a	82.00a	15.95a	1.93a	17.90a	1533.50a
33 lbs N		19.88a	61.05a	80.93a	17.13a	1.93a	19.08a	1743.17a
67 lbs N		20.38a	59.35a	79.73a	18.17a	2.05a	20.28a	2477.33b
100 lbs N		22.02a	55.22a	77.22a	21.20a	1.65a	22.78a	2909.33b

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 13. Dry matter weight in pounds per acre for fertilization treatments on the Vebar sandy range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized	44.67a	266.67a	696.67a	1007.83a	246.33a	77.50a	323.83a	1331.67a
33 lbs N	58.83a	230.67a	968.00a	1257.67a	367.00ab	41.50a	408.50a	1665.83a
67 lbs N	29.33a	414.17a	1232.50a	1676.17a	567.33b	47.00a	614.33a	2287.00a
100 lbs N	80.67a	436.17a	1221.67a	1738.33a	570.50b	22.00a	592.50a	2331.00a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 14. Percent composition of weight yield for fertilization treatments on the Vebar sandy range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized	3.53a	20.08a	51.65a	75.30a	19.82a	4.88a	24.70a	1331.67a
33 lbs N	3.65a	17.83a	57.33a	75.17a	22.47a	2.40a	24.87a	1665.83a
67 lbs N	1.47a	18.22a	51.90a	71.58a	25.93a	2.73a	28.65a	2287.00a
100 lbs N	3.32a	18.40a	51.57a	73.28a	25.63a	1.07a	26.72a	2331.00a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 15. Dry matter weight in pounds per acre for fertilization treatments on the Rhoades thin claypan range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		429.60a	447.80a	877.20a	47.20a	86.60a	132.00a	1011.20a
33 lbs N		605.20a	516.00ab	1121.20ab	42.60a	85.80a	128.40a	1249.60a
67 lbs N		702.80a	605.00b	1307.60ab	115.00a	51.40a	166.40a	1474.00a
100 lbs N		735.00a	590.00ab	1324.80b	70.80a	128.60a	199.40a	1524.20a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 16. Percent composition of weight yield for fertilization treatments on the Rhoades thin claypan range site, 1964-1969.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		41.18a	46.80a	87.98a	4.48a	7.54a	11.88a	1011.20a
33 lbs N		45.78a	44.16a	89.92a	3.28a	6.78a	10.08a	1249.60a
67 lbs N		45.84a	43.26a	89.12a	7.20a	3.72a	10.88a	1474.00a
100 lbs N		46.26a	40.90a	87.14a	4.74a	8.12a	12.86a	1524.20a

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Whitman 1964, 1965, 1966, 1967, 1968, 1969.

Table 17. Average basal cover of plant categories for fertilization treatments on native rangeland sites, 1964-1966.

Range Sites Treatments	Tall Grasses	Mid Grasses	Short Grasses	Sedge	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Basal Cover
Havre overflow range site									
unfertilized		18.55	2.33		20.88	0.68		0.68	22.26
33 lbs N		21.99	1.85		23.84	1.11		1.11	26.06
67 lbs N		24.28	2.16		26.44	2.58		2.58	28.36
100 lbs N		21.92	1.56		23.48	0.74		0.74	25.55
Manning silty range site									
unfertilized		1.58	35.33	7.04	43.95	0.73	0.0	0.73	44.88
33 lbs N		1.35	35.13	8.97	45.45	0.82	0.0	0.82	46.38
67 lbs N		1.39	35.33	8.21	44.93	1.04	0.03	1.07	46.20
100 lbs N		1.51	35.60	9.57	46.68	1.70	0.0	1.70	48.62
Vebar sandy range site									
unfertilized	0.17	2.15	33.30	3.84	39.46	0.36	0.07	0.43	40.15
33 lbs N	0.22	2.04	32.10	4.55	38.91	0.34	0.02	0.36	39.33
67 lbs N	0.37	2.94	29.92	4.34	37.57	0.37	0.0	0.37	38.22
100 lbs N	0.33	2.25	29.73	4.70	37.01	0.34	0.0	0.34	37.47
Rhoades thin claypan range site									
unfertilized		1.50	36.36	0.43	38.29	0.50	0.13	0.63	39.37
33 lbs N		1.60	33.57	0.67	35.84	0.65	0.05	0.70	36.70
67 lbs N		2.43	34.35	0.63	37.41	0.18	0.0	0.18	37.98
100 lbs N		2.22	34.58	0.60	37.40	0.13	0.10	0.23	38.48

Data from Goetz 1969a.

Table 18. Root weight in grams per soil sample depth for fertilization treatments on native rangeland sites, 1964-1966.

Range Site Treatment	Soil Depth in inches 0-6	6-12	12-18	18-24	24-36	36-48	Total root weight
Havre overflow range site							
unfertilized	0.885a	0.411a	0.251a	0.219ab	0.490a	0.172a	2.428a
33 lbs N	0.946a	0.245a	0.269a	0.140a	0.297a	0.240a	2.137ab
67 lbs N	1.559b	0.446a	0.349a	0.241a	0.444a	0.285a	3.324ab
100 lbs N	1.483b	0.517a	0.270a	0.264b	0.442a	0.403a	3.379b
Manning silty range site							
unfertilized	1.448a	0.247a	0.153a				1.848a
33 lbs N	1.603a	0.275a	0.138a				2.016a
67 lbs N	1.559a	0.249a	0.158a				1.966a
100 lbs N	1.429a	0.363b	0.184a				1.976a
Vebar sandy range site							
unfertilized	1.783a	0.254a	0.206a	0.148a	0.109ab	0.070a	2.570a
33 lbs N	2.881b	0.530a	0.398b	0.299b	0.143b	0.088a	4.339b
67 lbs N	1.964a	0.300a	0.157a	0.057c	0.080b	0.034a	2.592a
100 lbs N	1.819a	0.454a	0.178a	0.104ac	0.126ab	0.092a	2.773a
Rhoades thin claypan range site							
unfertilized	0.830a	0.161a	0.330a	0.009a	0.002a	0.001a	1.333a
33 lbs N	1.414ab	0.260a	0.045ab	0.016a	0.006a	0.002a	1.743a
67 lbs N	2.162b	0.244a	0.068b	0.025a	0.003a	0.001a	2.503a
100 lbs N	2.474b	0.267a	0.064b	0.019a	0.005a	0.001a	2.830a

Means in the same column of each range site and followed by the same letter are not significantly different ($P<0.05$).
Data from Goetz 1969b.

Table 19. Average leaf height in inches for fertilization treatments on the Havre overflow range site, 1964-1966.

Grasses Treatments	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Average Height
Western wheatgrass											
unfertilized	2.05	2.99	5.51	8.27	10.63	13.39	15.47	11.81	11.02	11.02	15.47
33 lbs N	1.18	2.83	5.51	9.06	10.51	12.91	17.32	15.35	14.57	14.96	17.36
67 lbs N	1.73	3.27	5.91	8.54	12.24	14.17	16.34	16.50	14.13	14.13	16.50
100 lbs N	2.01	3.35	5.91	9.45	11.65	14.76	17.60	17.68	17.32	16.97	17.68
Needle and thread											
unfertilized	1.14	2.01	4.33	6.30	8.39	9.29	11.30	10.24	9.65	9.65	11.38
33 lbs N	1.22	2.24	4.72	6.30	9.57	10.12	10.75	9.45	9.06	9.06	10.79
67 lbs N	1.57	2.52	4.57	6.30	9.65	10.98	11.69	9.06	8.66	8.66	11.77
100 lbs N	1.22	2.28	4.37	6.61	11.61	12.60	13.50	13.58	13.54	13.54	13.58
Green needlegrass											
unfertilized	1.54	3.54	5.12	10.24	14.49	17.24	19.88	17.72	17.32	17.32	19.88
33 lbs N	1.93	3.66	5.51	11.02x	14.02	16.73x	22.13x	19.69x	18.90	19.29	22.17x
67 lbs N	2.20	3.82	5.51	11.42x	16.30	20.47x	23.58x	22.83x	22.83	22.83	23.62x
100 lbs N	2.09	3.82	5.51	11.81x	14.84	18.11x	23.23x	23.27x	23.23	23.23	23.27x

Asterisk (x) indicates difference between unfertilized and fertilized treatments is significant ($P<0.05$).
Data from Goetz 1970.

Table 20. Average leaf height in inches for fertilization treatments on the Manning silty range site, 1964-1966.

Grasses Treatments	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Average Height
Western wheatgrass											
unfertilized	2.56	2.91	4.33	5.91	9.09	10.28	11.89	11.85	11.73	11.73	11.93
33 lbs N	2.56	2.87x	4.33	5.91x	9.45x	10.71	11.69	11.69	11.61	11.61	11.85
67 lbs N	2.56	3.15x	5.12	7.83x	10.35x	11.22	11.69	13.70	12.13	13.70	13.70
100 lbs N	2.56	3.27x	5.87	7.09x	10.67x	11.93	12.48	13.90	13.07	13.07	13.90
Needle and thread											
unfertilized	1.18	2.01	4.33	6.30	8.39	9.29	11.30	10.24	9.65	9.65	11.38
33 lbs N	0.98	1.46x	2.76x	5.39x	6.93x	7.68x	8.35x	8.03x	8.07	8.07	8.58x
67 lbs N	0.98	1.50x	3.35x	5.55x	7.60x	8.54x	9.45x	10.83x	10.16	10.08	10.83x
100 lbs N	0.98	1.38x	3.35x	4.33x	7.80x	9.13x	9.57x	10.43x	9.69	9.69	10.43x
Blue grama											
unfertilized	0.39	0.47	0.79	2.44	2.95	3.43	4.69	4.76	4.69	4.69	4.76
33 lbs N	0.39	0.67	1.14	1.77x	3.15x	3.78x	5.59x	5.79x	5.00x	5.00x	5.79x
67 lbs N	0.39	0.39	1.54	2.05x	3.11x	4.61x	5.16x	5.71x	5.67x	5.67x	6.50x
100 lbs N	0.39	0.91	1.61	2.17x	2.91x	4.76x	5.55x	7.24x	6.22x	6.26x	7.24x
Threadleaf sedge											
unfertilized	1.18	1.50	1.97	3.58	4.61	4.61	4.57	4.53	4.53	4.53	4.65
33 lbs N	1.18	1.30	2.72	3.39x	4.57x	4.76x	5.16x	4.76x	4.72x	4.72x	5.43x
67 lbs N	1.18	1.46	2.87	3.94x	4.96x	5.16x	4.92x	5.00x	5.08x	5.08x	5.20x
100 lbs N	1.18	1.46	2.56	4.25x	5.16x	5.43x	5.20x	5.39x	5.43x	5.43x	5.55x
Needleleaf sedge											
unfertilized	0.79	1.69	2.76	3.82	4.25	4.57	4.80	4.76	4.69	4.69	4.80
33 lbs N	0.79	1.57	2.76	3.70x	4.45x	4.84	5.43	5.16	5.04	5.04	5.43
67 lbs N	0.79	1.77	2.76	3.54x	4.80x	5.31	5.47	5.39	5.35	5.35	5.59
100 lbs N	0.79	1.57	2.76	4.21x	5.00x	5.63	5.94	5.94	5.94	5.94	6.02

Asterisk (x) indicates difference between unfertilized and fertilized treatments is significant (P<0.05).
Data from Goetz 1970.

Table 21. Average leaf height in inches for fertilization treatments on the Vebar sandy range site, 1964-1966.

Grasses Treatments	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Average Height
Western wheatgrass											
unfertilized	1.77	2.52	4.72	5.91	6.54	8.90	8.94	8.98	8.98	8.98	8.98
33 lbs N	1.77	2.76	4.72	6.61	7.56	8.11x	8.90x	8.90x	8.90x	8.90x	9.06x
67 lbs N	0.79	2.24	4.96	6.30	8.15	9.13x	9.41x	10.75x	10.98x	10.98x	10.98x
100 lbs N	1.77	3.19	4.53	6.69	8.46	8.86x	12.48x	12.87x	12.87x	12.87x	12.87x
Needle and thread											
unfertilized	0.98	1.57	2.36	3.54	6.46	7.83	10.43	10.43	10.43	10.43	10.51
33 lbs N	0.98	1.97x	2.76x	3.94x	7.52x	8.90x	10.59x	10.59x	10.59x	10.55x	10.63
67 lbs N	0.98	2.60x	3.15x	5.51x	8.35x	9.72x	11.26x	11.26x	11.26x	11.26x	11.46
100 lbs N	0.98	2.24x	3.15x	5.51x	8.86x	9.92x	10.83x	11.10x	11.10x	11.10x	11.10
Blue grama											
unfertilized	0.20	0.59	0.98	1.77	3.15	3.98	4.45	4.57	4.57	4.53	4.57
33 lbs N	0.20	0.51x	0.98	1.97x	3.27x	4.45x	3.90x	4.92x	4.92x	4.92x	4.92x
67 lbs N	0.20	0.51x	1.18	2.36x	3.78x	5.12x	6.10x	6.10x	6.10x	6.10x	6.42x
100 lbs N	0.20	0.59x	1.18	2.13x	3.86x	5.12x	6.22x	6.22x	6.18x	6.18x	7.01x
Threadleaf sedge											
unfertilized	0.98	1.85	2.99	4.33	5.67	5.16	5.12	5.12	5.12	5.12	5.71
33 lbs N	0.98	1.81	2.36x	5.16	5.55x	6.65	5.47x	5.67	5.67	5.63	6.65
67 lbs N	0.98	1.93	3.15x	4.96	6.26x	5.28	6.50x	6.50	6.50	6.46	6.54
100 lbs N	0.98	2.09	3.15x	4.96	6.14x	5.16	6.26x	6.26	6.22	6.22	6.93
Needleleaf sedge											
unfertilized	0.79	1.42	1.97	3.15	3.74	4.88	5.08	5.08	5.04	5.04	5.12
33 lbs N	0.79	1.26	2.95	3.90	4.96	2.91x	5.12x	5.12	5.12	5.12	5.20
67 lbs N	0.79	1.97	3.54	3.94	4.57	5.47x	5.75x	5.75	5.75	5.75	5.75
100 lbs N	0.79	1.69	2.76	3.62	4.65	3.62x	3.62x	3.62	3.58	3.58	4.84

Asterisk (x) indicates difference between unfertilized and fertilized treatments is significant ($P<0.05$).
Data from Goetz 1970.

Table 22. Average leaf height in inches for fertilization treatments on the Rhoades thin claypan range site, 1964-1966.

Grasses Treatments	15 Apr	30 Apr	15 May	31 May	15 Jun	30 Jun	15 Jul	31 Jul	15 Aug	31 Aug	Maximum Average Height
Western wheatgrass											
unfertilized	1.54	1.85	3.39	3.54	5.91	7.32	8.78	8.78	8.78	8.78	8.78
33 lbs N	1.02	1.89	3.58	3.94x	6.57x	7.48x	8.62x	8.62x	8.62x	8.62x	8.62x
67 lbs N	0.59	1.61	3.27	4.29x	6.77x	8.07x	9.84x	9.84x	9.84x	9.76x	9.84x
100 lbs N	0.83	2.28	3.50	4.37x	6.93x	7.48x	10.16x	10.16x	10.16x	10.16x	10.16x
Blue grama											
unfertilized	0.12	0.24	0.79	1.38	2.24	2.87	3.46	3.58	3.58	3.58	3.58
33 lbs N	-	-	0.79	1.38	2.09x	2.44x	3.54x	3.66x	3.66x	3.66x	3.66x
67 lbs N	0.04	0.20	0.79	1.57	2.48x	3.43x	4.65x	4.72x	4.72x	4.72x	4.72x
100 lbs N	0.04	0.79	1.57	2.64	3.58x	4.76x	4.76x	4.76x	4.76x	4.76x	4.88x
Sandberg bluegrass											
unfertilized	0.04	1.34	1.54	1.69	2.17	2.80	3.19	3.19	3.19	3.19	3.19
33 lbs N	0.04	1.34	1.61	1.77	2.48x	3.07x	3.46x	3.46x	3.46x	3.46x	3.46x
67 lbs N	0.47	1.54	1.73	1.97	2.56x	3.35x	3.03x	3.03x	2.95x	2.87x	3.78x
100 lbs N	0.63	1.54	1.77	1.97	2.95x	3.43x	3.62x	3.62x	3.58x	3.54x	3.78x
Needleleaf sedge											
unfertilized	0.79	1.42	2.09	2.52	3.19	3.27	3.39	3.39	3.39	3.39	3.39
33 lbs N	0.79	1.69	2.40	2.60x	3.35x	3.58x	3.94x	3.94x	3.94x	3.94x	4.25x
67 lbs N	0.63	1.22	2.76	2.76x	3.46x	4.06x	4.13x	4.13x	4.09x	4.06x	4.29x
100 lbs N	0.75	1.06	2.40	2.76x	3.94x	4.49x	4.88x	4.88x	4.84x	4.80x	4.88x

Asterisk (x) indicates difference between unfertilized and fertilized treatments is significant ($P<0.05$).
Data from Goetz 1970.

Table 23. Average date of first flowering and of leaf senescence percentage for fertilization treatments on the Havre overflow range site, 1964-1966

Grasses Treatments	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25-50% Dry	Leaf 50-75% Dry
Western wheatgrass					
unfertilized	11 Jul	10 Jun	9 Jul	7 Sep	1 Oct
33 lbs N	12 Jul	11 Jun	31 Jul	7 Sep	
67 lbs N	22 Jul	26 Jun	31 Jul	9 Sep	
100 lbs N	22 Jul	26 Jun	31 Jul	9 Sep	
Needle and thread					
unfertilized	24 Jun	26 Jun	6 Aug	17 Aug	9 Sep
33 lbs N	19 Jun	6 Jul	6 Aug	7 Sep	19 Sep
67 lbs N	19 Jun	30 Jun	31 Jul	24 Aug	9 Sep
100 lbs N	29 Jun	30 Jun	31 Jul	24 Aug	9 Sep
Green needlegrass					
unfertilized	29 Jun	7 Jun	1 Jul	23 Aug	12 Sep
33 lbs N	24 Jun	7 Jun	19 Jul	20 Aug	
67 lbs N	24 Jun	8 Jun	14 Jul	24 Aug	
100 lbs N	24 Jun	8 Jun	19 Jul	17 Aug	
Plains reedgrass					
unfertilized	7 Jul	2 Jul	30 Jul	9 Aug	
33 lbs N	7 Jul	21 Jun	14 Aug	23 Aug	
67 lbs N	7 Jul	2 Jul	27 Jul	2 Aug	
100 lbs N	7 Jul	2 Jul	2 Aug	24 Aug	
Blue grama					
unfertilized	23 Jul	10 Jul	14 Aug		
33 lbs N	23 Jul	6 Jul	14 Aug		
67 lbs N	27 Jul	7 Jul	30 Aug		
100 lbs N	27 Jul	22 Jun	16 Aug		

Data from Goetz 1970.

Table 24. Average date of first flowering and of leaf senescence percentage for fertilization treatments on the Manning silty range site, 1964-1966.

Grasses Treatments	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25-50% Dry	Leaf 50-75% Dry
Western wheatgrass					
unfertilized	17 Jul	7 Jun	31 Jul		1 Oct
33 lbs N	17 Jul	7 Jun	31 Jul		1 Oct
67 lbs N	17 Jul	7 Jun	25 Jul	9 Sep	25 Sep
100 lbs N	17 Jul	7 Jun	25 Jul	29 Aug	9 Sep
Needle and thread					
unfertilized	6 Jul	7 Jun	11 Aug	15 Aug	1 Oct
33 lbs N	6 Jul	7 Jun	12 Aug	15 Aug	1 Oct
67 lbs N	6 Jul	15 Jun	15 Aug	29 Aug	
100 lbs N	17 Jul	7 Jun	25 Jul	29 Aug	9 Sep
Plains reedgrass					
unfertilized	18 Jun	9 Jun	13 Jul	9 Sep	1 Oct
33 lbs N	18 Jun	9 Jun	25 Jul	1 Oct	
67 lbs N	18 Jun	9 Jun	11 Jul	9 Sep	1 Oct
100 lbs N		9 Jun	11 Jul	9 Sep	
Prairie Junegrass					
unfertilized	23 Jun	24 Jun	27 Jul		
33 lbs N	23 Jun	24 Jun	27 Jul		
67 lbs N	21 Jun	24 Jun	27 Jul		
100 lbs N	23 Jun	26 Jun	27 Jul	1 Oct	
Blue grama					
unfertilized	20 Jul	22 Jun	6 Aug	6 Sep	9 Sep
33 lbs N	20 Jul	22 Jun	6 Aug	5 Sep	9 Sep
67 lbs N	20 Jul	20 Jun	28 Jul	25 Aug	9 Sep
100 lbs N	20 Jul	29 Jun	31 Jul	25 Aug	9 Sep
Threadleaf sedge					
unfertilized	5 May	26 May	9 Jun	30 Jul	31 Jul
33 lbs N	4 May	26 May	7 Jun	7 Jul	17 Jul
67 lbs N	4 May	22 May	7 Jun	1 Jul	6 Aug
100 lbs N	4 May	21 May	7 Jun	13 Jul	13 Aug
Needleleaf sedge					
unfertilized	5 May	31 May	7 Jun	30 Jun	13 Jul
33 lbs N	5 May	26 May	7 Jun	30 Jun	27 Jul
67 lbs N	5 May	22 May	7 Jun	6 Jul	27 Jul
100 lbs N	5 May	21 May	7 Jun	13 Jul	27 Jul

Data from Goetz 1970.

Table 25. Average date of first flowering and of leaf senescence percentage for fertilization treatments on the Vebar sandy range site, 1964-1966.

Grasses Treatments	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25-50% Dry	Leaf 50-75% Dry
Western wheatgrass					
unfertilized	17 Jul	14 Jun	6 Aug		1 Oct
33 lbs N	17 Jul	16 Jun	22 Aug		1 Oct
67 lbs N	11 Jul	14 Jun	19 Jul		1 Oct
100 lbs N	11 Jul	16 Jun	14 Jul	8 Sep	
Needle and thread					
unfertilized	26 Jun	25 Jun	19 Aug	9 Sep	1 Oct
33 lbs N	19 Jun	15 Jun	21 Jul	9 Sep	1 Oct
67 lbs N	30 Jun	10 Jun	1 Aug	21 Aug	
100 lbs N	3 Jul	10 Jun	18 Jul	21 Aug	
Plains reedgrass					
unfertilized	29 Jun	8 Jun	16 Jul	25 Aug	1 Oct
33 lbs N	29 Jun	22 Jun	22 Jul	25 Aug	1 Oct
67 lbs N	22 Jun	13 Jun	19 Jul	8 Sep	1 Oct
100 lbs N	26 Jun	15 Jun	19 Jul	8 Sep	1 Oct
Prairie Junegrass					
unfertilized	24 Jun	3 Jul	27 Jul	9 Sep	
33 lbs N	21 Jun	28 Jun	24 Jul	22 Aug	1 Oct
67 lbs N	24 Jun	28 Jun	22 Jul	9 Sep	
100 lbs N	16 Jun	29 Jun	28 Jul	9 Sep	
Blue grama					
unfertilized	16 Jul	19 Jun	4 Aug	29 Aug	1 Oct
33 lbs N	16 Jul	15 Jun	4 Aug	28 Aug	1 Oct
67 lbs N	16 Jul	15 Jun	26 Jul	25 Aug	
100 lbs N	16 Jul	15 Jun	1 Aug	27 Aug	
Threadleaf sedge					
unfertilized	4 May	5 Jun	19 Jun	30 Jun	27 Jul
33 lbs N	4 May	5 Jun	14 Jun	13 Jul	27 Jul
67 lbs N	4 May	2 Jun	11 Jun	13 Jul	2 Aug
100 lbs N	4 May	18 Jun	20 Jun	13 Jul	2 Aug
Needleleaf sedge					
unfertilized	4 May	1 Jun	15 Jun	3 Jul	25 Jul
33 lbs N	4 May	5 Jun	14 Jun	3 Jul	21 Jul
67 lbs N	4 May	5 Jun	13 Jun	26 Jul	22 Jul
100 lbs N	4 May	5 Jun	15 Jun	3 Jul	22 Jul

Data from Goetz 1970.

Table 26. Average date of first flowering and of leaf senescence percentage for fertilization treatments on the Rhoades thin claypan range site, 1964-1966.

Grasses Treatments	Anthesis	Leaf Tip Dry	Leaf 0-25% Dry	Leaf 25-50% Dry	Leaf 50-75% Dry
Western wheatgrass					
unfertilized	12 Jul	1 Jun	1 Jul	5 Aug	2 Sep
33 lbs N	12 Jul	1 Jun	4 Jul	2 Aug	2 Sep
67 lbs N	12 Jul	14 Jun	8 Jul	9 Aug	7 Sep
100 lbs N	15 Jul	22 Jun	23 Jul	9 Aug	23 Aug
Prairie Junegrass					
unfertilized	24 Jun	7 Jul	18 Jul	25 Aug	
33 lbs N			7 Jul	25 Aug	
67 lbs N	24 Jun		11 Jun	25 Aug	
100 lbs N			7 Jul	25 Aug	
Blue grama					
unfertilized	18 Jul	16 Jun	31 Jul	20 Aug	9 Sep
33 lbs N	16 Jul	16 Jun	1 Aug	20 Aug	9 Sep
67 lbs N	15 Jul	16 Jun	18 Jul	11 Sep	
100 lbs N	18 Jul	16 Jun	7 Aug	11 Sep	
Sandberg bluegrass					
unfertilized	21 Jun	10 Jun	14 Jun	18 Jun	6 Jul
33 lbs N	8 Jun	12 Jun	4 Jun	10 Jul	6 Jul
67 lbs N	21 Jun	12 Jun	29 Jun	12 Jul	16 Jul
100 lbs N	21 Jun	12 Jun	5 Jul	7 Jul	16 Jul
Needleleaf sedge					
unfertilized	5 May	22 May	6 Jun	28 Jun	27 Jul
33 lbs N	4 May		8 Jun	16 Jun	13 Jul
67 lbs N	4 May		9 Jun	7 Jul	27 Jul
100 lbs N	30 May		6 Jun	24 Jun	27 Jul

Data from Goetz 1970.

Table 27. Percent crude protein of grass species for fertilization treatments on the Havre overflow range site, 1964-1969.

Treatments	1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Western wheatgrass								
unfertilized	17.1	15.7	12.2	11.7	10.1	9.0	8.8	12.1
33 lbs N	17.6	14.9	11.7	11.4	9.8	7.8	8.9	11.7
67 lbs N	19.3	16.2	11.7	12.6	9.0	8.4	8.8	12.3
100 lbs N	19.7	17.7	13.7	14.1	8.2	8.5	9.9	13.1
Green Needlegrass								
unfertilized	14.9	12.5	9.7	9.1	6.8	7.1	7.3	9.6
33 lbs N	15.6	12.5	8.9	9.1	6.8	6.4	7.6	9.6
67 lbs N	15.7	14.6	10.2	9.8	7.7	7.5	7.6	10.4
100 lbs N	19.3	15.6	11.4	11.0	8.2	8.0	8.2	11.7

Data from Goetz 1975b.

Table 28. Percent crude protein of grass species for fertilization treatments on the Manning silty range site, 1964-1969.

Treatments	1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Western wheatgrass								
unfertilized	15.2	11.7	12.3	9.7	8.3	6.5	6.3	10.0
33 lbs N	16.2	13.2	11.0	10.6	8.6	6.5	6.2	10.3
67 lbs N	18.1	15.5	12.6	10.8	8.9	7.0	6.2	11.3
100 lbs N	20.0	16.3	13.2	11.9	9.4	7.4	7.2	12.2
Needle and thread								
unfertilized	12.3	9.9	7.7	7.9	6.9	6.7	6.1	8.2
33 lbs N	12.5	10.2	8.6	7.8	6.6	6.3	6.1	8.3
67 lbs N	15.3	13.9	9.0	8.4	6.6	6.8	6.7	9.5
100 lbs N	16.5	12.6	10.0	8.6	7.5	6.9	7.3	9.9
Blue grama								
unfertilized	12.0	10.9	8.8	8.9	9.2	6.7	7.1	9.1
33 lbs N	11.0	11.6	12.8	10.7	8.6	7.1	7.3	9.9
67 lbs N	13.6	13.4	13.9	10.3	10.0	8.2	7.9	11.0
100 lbs N	15.6	15.0	11.5	12.0	9.7	10.1	8.8	11.8

Data from Goetz 1975b.

Table 29. Percent crude protein of grass species for fertilization treatments on the Vebar sandy range site, 1964-1969.

Treatments	1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Needle and Thread								
unfertilized	14.2	13.8	7.9	8.1	6.7	6.4	5.9	9.0
33 lbs N	14.8	12.4	9.5	8.1	6.8	6.8	6.4	9.3
67 lbs N	17.1	14.2	10.1	9.3	7.3	7.2	7.8	10.4
100 lbs N	18.2	15.4	10.3	10.1	9.5	8.7	7.9	11.4
Blue grama								
unfertilized	11.5	11.2	10.0	9.2	8.2	7.6	7.2	9.3
33 lbs N	12.8	12.7	9.5	9.3	8.8	7.7	8.4	9.9
67 lbs N	15.0	14.8	12.1	10.7	10.2	8.7	7.5	11.3
100 lbs N	15.4	16.0	13.4	10.4	10.8	9.2	8.5	12.0
Threadleaf sedge								
unfertilized	12.4	11.2	8.8	8.5	7.4	6.4	7.0	8.8
33 lbs N	13.6	12.6	9.4	9.0	6.9	6.9	8.0	9.5
67 lbs N	15.3	14.1	11.8	10.6	9.2	8.6	10.6	11.5
100 lbs N	15.7	14.8	12.4	11.0	10.1	8.8	11.3	12.0

Data from Goetz 1975b.

Table 30. Percent crude protein of grass species for fertilization treatments on the Rhoades thin claypan range site, 1964-1969.

Treatments	1 Jun	15 Jun	1 Jul	15 Jul	1 Aug	15 Aug	1 Sep	Mean
Western wheatgrass								
unfertilized	16.2	13.3	14.6	12.9	8.0	8.6	8.7	11.8
33 lbs N	17.1	15.3	12.4	14.9	9.5	10.2	8.0	12.5
67 lbs N	19.0	15.8	13.9	14.7	9.8	10.1	8.6	13.1
100 lbs N	21.0	15.0	14.6	14.9	11.5	6.6	9.9	13.4
Blue grama								
unfertilized	11.7	14.1	11.6	11.1	10.0	10.3	9.2	11.1
33 lbs N	14.1	13.9	10.4	13.5	12.4	10.0	9.1	11.9
67 lbs N	15.2	15.7	14.5	12.8	13.5	9.9	10.4	13.1
100 lbs N	15.9	16.2	17.4	14.2	16.6	9.8	11.0	14.4
Sandberg bluegrass								
unfertilized	11.5	9.4	7.3				4.9	8.3
33 lbs N	15.2	12.7	7.3	5.7			5.6	9.3
67 lbs N	17.5	14.8	8.8	8.8			5.7	11.1
100 lbs N	18.0	16.0	8.5	14.2			5.7	12.5

Data from Goetz 1975b.

Table 31. Precipitation in inches for growing-season months and the annual total precipitation for 1970-1978, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1970	3.53	6.35	1.98	3.86	0.29	1.49	0.40	17.90	20.16
% of LTM	246.85	271.37	55.77	173.87	16.76	112.03	42.11	132.10	126.00
1971	2.99	0.87	7.54	0.25	0.24	3.51	3.18	18.58	21.25
% of LTM	209.09	37.18	212.39	11.26	13.87	263.91	334.74	137.12	132.81
1972	1.27	5.09	4.29	2.72	2.90	0.74	1.56	18.57	20.76
% of LTM	88.81	217.52	120.85	122.52	167.63	55.64	164.21	137.05	129.75
1973	3.21	1.30	3.04	0.91	0.47	2.23	0.67	11.83	13.53
% of LTM	224.48	55.56	85.63	40.99	27.17	167.67	70.53	87.31	84.56
1974	2.82	4.15	2.00	1.50	0.90	0.56	0.52	12.45	14.15
% of LTM	197.20	177.35	56.34	67.57	52.02	42.11	54.74	91.88	88.44
1975	4.25	3.34	4.27	0.64	0.54	0.80	1.42	15.26	17.71
% of LTM	297.20	142.74	120.28	28.83	31.21	60.15	149.47	112.62	110.69
1976	2.11	1.42	3.74	0.75	0.40	1.77	0.65	10.84	12.68
% of LTM	147.55	60.68	105.35	33.78	23.12	133.08	68.42	80.00	79.25
1977	0.13	2.60	5.38	1.08	1.52	5.78	2.16	18.65	23.13
% of LTM	9.09	111.11	151.55	48.65	87.86	434.59	227.37	137.64	144.56
1978	1.81	3.99	2.10	2.41	2.01	2.56	0.29	15.17	17.63
% of LTM	126.57	170.51	59.15	108.56	116.18	192.48	30.53	111.96	110.19
1970-1978	2.46	3.23	3.82	1.57	1.03	2.16	1.21	15.47	17.89
% of LTM	172.03	138.03	107.61	70.72	59.54	162.41	127.37	114.17	111.81

Table 32. Dry matter weight in pounds per acre for fertilization treatments on the upland range site, 1970-1978.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		1254.23	746.33	2000.56	207.00	45.00	252.00	2252.56
67 lbs N EOY		1439.50	633.13	2072.63	417.25	35.75	453.00	2525.63
67 lbs N EY		1940.89	547.67	2488.56	451.00	36.33	487.33	2975.89
100 lbs N EOY		1799.71	525.86	2325.57	482.86	59.57	542.43	2868.00
100 lbs N EY		2111.00	543.56	2654.56	436.22	28.56	464.78	3119.34
200 lbs N OT		1511.56	595.56	2107.12	278.11	41.33	319.44	2426.56
300 lbs N OT		1782.89	691.11	2474.00	362.78	28.89	391.67	2865.67
400 lbs N OT		1745.11	621.44	2366.55	418.22	33.56	451.78	2818.33

Data from Annual Reports 1970-1978.

Table 33. Percent composition of weight yield for fertilization treatments on the upland range site, 1970-1978.

Treatments	Tall Grasses	Mid Grasses	Short Grasses	Total Grasses	Perennial Forbs	Annual Forbs	Total Forbs	Total Yield
Unfertilized		55.68	33.13	88.81	9.19	2.00	11.19	2252.56
67 lbs N EOY		57.00	25.06	82.06	16.52	1.42	17.94	2525.63
67 lbs N EY		65.22	18.40	83.62	15.16	1.22	16.38	2975.89
100 lbs N EOY		62.75	18.34	81.09	16.84	2.07	18.91	2868.00
100 lbs N EY		67.67	17.43	85.10	13.98	0.92	14.90	3119.34
200 lbs N OT		62.30	24.54	86.84	11.46	1.70	13.16	2426.56
300 lbs N OT		62.21	24.12	86.33	12.66	1.01	13.67	2865.67
400 lbs N OT		61.92	22.05	83.97	14.84	1.19	16.03	2818.33

Data from Annual Reports 1970-1978.

Table 34. Basal cover of plant categories for fertilization treatments on the upland range site, 1970-1976.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Domesticated and Introduced Grasses	Total Grass	Total Forbs	Total Basal Cover
Unfertilized	0.03	14.15	2.47	4.07	2.68	5.71	0.09	29.20	1.04	30.25
67 lbs N EOY	0.10	8.20	1.86	4.56	5.17	5.61	0.68	26.18	1.31	27.49
67 lbs N EY	0.08	4.58	3.61	3.62	3.36	5.78	0.98	22.01	1.73	23.74
100 lbs N EOY	0.02	6.90	1.55	4.91	5.68	4.54	0.28	23.88	1.53	25.41
100 lbs N EY	0.04	3.16	2.91	5.28	6.30	4.41	0.35	22.45	1.82	24.27
200 lbs N OT	0.02	7.51	1.36	6.54	5.64	3.65	0.01	24.73	0.92	25.65
300 lbs N OT	0.02	7.20	2.60	4.43	2.70	4.09	0.58	21.62	0.80	22.42
400 lbs N OT	0.07	6.31	1.50	5.71	5.20	4.04	0.19	23.02	0.87	23.89

Data from Goetz et al. 1978, Goetz 1984.

Table 35. Herbage weight in pounds per acre per pound of nitrogen fertilizer applied, 1962-1978.

	Nitrogen Fertilization Rates		
Study Sites	33 lbs N/ac	67 lbs N/ac	100 lbs N/ac
Creek terrace site	12.47	13.72	9.11
Upland slope site	14.15	13.06	9.02
Havre overflow range site	4.28	12.74	5.65
Manning silty range site	6.35	14.09	13.76
Vebar sandy range site	10.13	14.26	9.99
Rhoades thin claypan range site	7.22	6.91	5.13
Upland range site		10.80	8.67
Mean lbs herbage/lb nitrogen	9.10	12.23	8.76

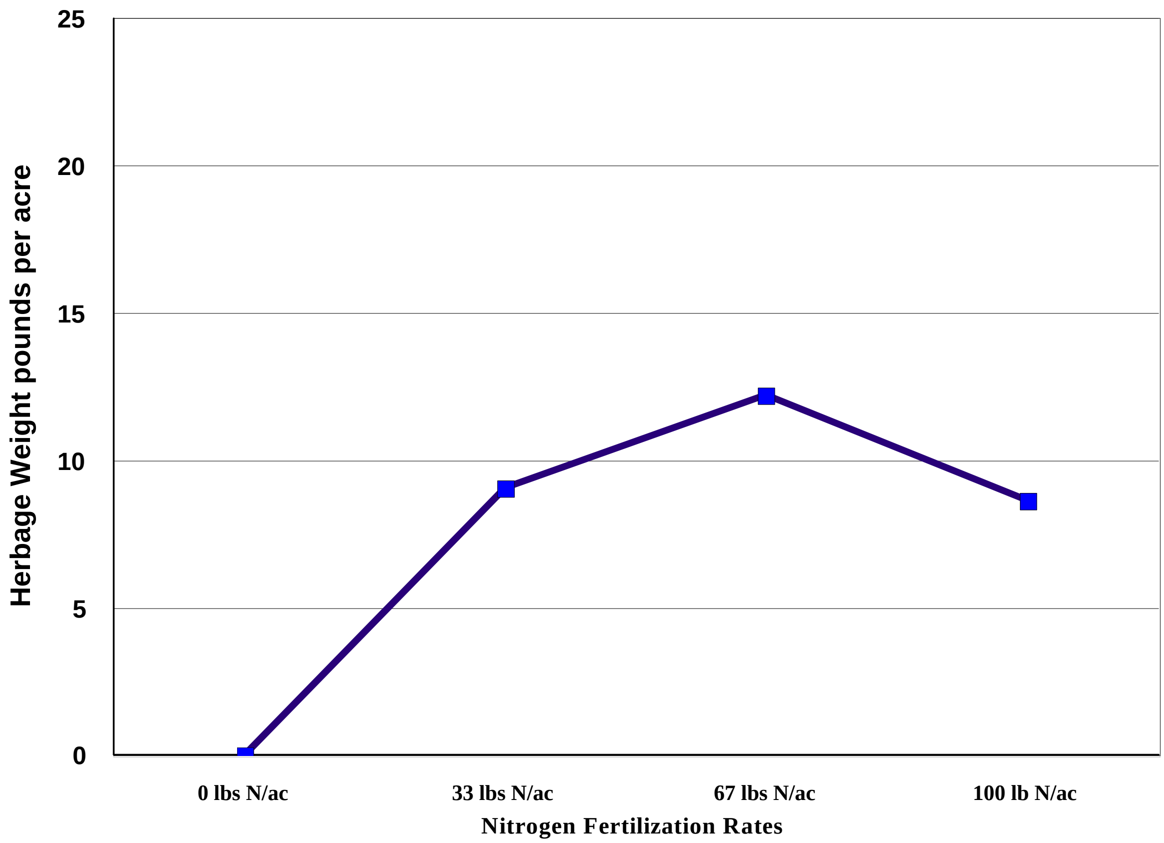

Figure 1. Herbage weight in pounds per acre per pound nitrogen fertilizer applied.

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Nitrogen Fertilization on Native Rangeland with Ammonium Nitrate and Urea

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Numerous nitrogen fertilization of native rangeland plot studies were conducted in the Northern Plains during the 1950's through the 1970's. The source of the fertilizer nitrogen for these studies was usually ammonium nitrate. Reductions in its availability had occurred as a result of serious problems with the manufacture and storage of ammonium nitrate fertilizer. During the manufacture of ammonium nitrate, emissions of nitrous oxides were released into the atmosphere and the high costs for industrial controls of these pollutants were prohibitive (Power 1974). Moreover, ammonium nitrate had explosive characteristics that presented potentially dangerous problems for fertilizer suppliers to handle and store this type of fertilizer.

Urea rapidly overtook ammonium sulfate as the predominant replacement source of fertilizer nitrogen. In order to be able to predict the usefulness of urea for cultural practices on native rangeland, the effects of the replacement fertilizer needed to be compared to the effects determined for ammonium nitrate fertilizer during the previous three decades of research projects.

Presumably, each pound of mineral (inorganic) nitrogen in the soil should yield similar results regardless of source. However, when urea is hydrolyzed to ammonia and carbon dioxide, usually some of the ammonia is volatilized into the atmosphere (Power 1974). The quantity of lost ammonia increases when soil conditions have neutral or alkaline pH, limited water supply, warm temperatures, and/or the presence of organic mulches. In a review of the literature, Power (1974) found that urea at higher rates greater than 100 lbs N/ac was not as effective as ammonium nitrate and that production of aboveground herbage on grasslands was generally from 5% to 40% less on the high rates of urea treatments than on the same rates of ammonium nitrate. This lower effectiveness and the greater proportions of the applied urea nitrogen not accounted for in the ecosystem was attributed to greater volatilization of ammonia from surface broadcast application of high rates of urea than with ammonium nitrate. The relationships of effectiveness at lower rates of ammonium nitrate and urea were not evaluated but were considered to be similar (Power 1974).

Previous studies determined that nitrogen fertilization of native rangeland caused a shift in plant species composition with an increase in mid cool season grasses, primarily western wheatgrass, and a decrease in short warm season grasses, primarily blue grama. Early studies considered these changes to be beneficial (Rogler and Lorenz 1957; Lorenz and Rogler 1972; Whitman 1957, 1976). Later studies (Goetz et al. 1978) found these shifts in plant composition to be undesirable because the resulting reduction in ground cover increased the amount of soil exposed to erosion and increased the amount of open spaces available for invasion by undesirable perennial forbs, domesticated cool season grasses, and introduced annual and perennial grasses.

The objectives of the nitrogen fertilization of native rangeland plot study V were to evaluate the effectiveness of similar low rates of ammonium nitrate and urea and to evaluate the degree of differences in annual and biennial applications of ammonium nitrate and urea fertilizers (Manske and Goetz 1985b).

Procedure

Nitrogen fertilization of native rangeland plot study V (1982-1987) was conducted by Dr. Harold Goetz and Dr. Llewellyn L. Manske on 2.6 acres located on the SW¼, SW¼, NW¼, sec. 16, T. 143 N., R. 96 W., at the Dickinson Research Extension Center ranch near Manning, ND. The 30 X 60 foot plots were arranged in a randomized block design with three replications separated by 10 foot wide alleyways. The soil was Moreau silty clay, Typic Haploboroll, with a loam texture in the top 12 inches and a silty clay loam texture from the 12 inch to 48 inch depths. This clayey range site was enclosed with a barbed wire fence constructed to exclude cattle grazing on the plots until after all of the data for that season had been collected. The treatments included controls of 0 lbs N/ac and fertilization rates of 40 lbs N/ac and 60 lbs N/ac applied annually (EY) and biennially (EOY) and 100 lbs N/ac applied biennially (EOY). For each treatment rate, ammonium nitrate and urea fertilizers were surface broadcast applied in granular form in early spring on 4 May, 1982 to 1985 for the annual treatments and on 4 May, 1982 and 1984 for the biennial treatments (Goetz and Manske 1982, 1983, 1984; Manske and Goetz 1985a). The total four year weight of applied nitrogen was 80, 120, 160, 200, and

240 lbs N/ac for the 40 lbs N/ac EOY, 60 lbs N/ac EOY, 40 lbs N/ac EY, 100 lbs N/ac EOY, and 60 lbs N/ac EY treatments, respectively. The annual spring application of 60 lbs N/ac of ammonium nitrate and urea were continued in 1986 and mid summer treatments of 60 lbs N/ac of ammonium nitrate and urea were applied on 15 August, 1985 and 1986 (Manske 1986, 1987). Results from these additive treatments were not included in this report.

Traditionally, values from single herbage clips at peak aboveground herbage biomass were compared in fertilization studies. Peak herbage biomass normally occurs during the latter portion of July. Aboveground herbage biomass production was sampled by the clipping method four times during late May through August, 1982 to 1987. Vegetation in six quarter-meter frames were hand clipped to ground level for each treatment on each sample period. Herbage was separated into seven biotype categories: cool short, warm short, cool mid, western wheatgrass, warm mid, sedges, and forbs. The plant material was oven dried and weighed (Goetz and Manske 1982, 1983, 1984; Manske and Goetz 1985a).

Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method during the period of mid July to mid August, 1982 to 1987. A total of 1500 points were read annually for each treatment (Manske and Goetz 1985a). Forb and shrub densities were additionally sampled by the use of one-tenth meter square quadrats. Stems rooted within each frame were counted annually by species in 30 quadrats per treatment (Manske and Goetz 1985a).

Available soil water was determined by the gravimetric procedure from soil samples collected with the 1 inch Veihmeyer soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at monthly intervals during June through August, 1982 to 1987. Two replications of soil core samples were collected at three locations, north, central, and south, with one set from each of the two alleyways (Manske and Goetz 1985a).

Available soil mineral nitrogen was determined from soil core samples collected on each plot with the 1 inch Veihmeyer soil tube from 0-6, 6-12, 12-24, 24-36, and 36-48 inch depths at monthly intervals during June through August, 1982 to 1985. Individual soil core samples from each depth were immediately frozen and kept frozen until analysis could be made by the soils laboratory at North Dakota State University (Manske and Goetz 1985a).

Results

The precipitation during the growing seasons of 1982 to 1985 was normal or greater than normal (table 1). During 1982, 1983, 1984, and 1985, 21.09 inches (150.97% of LTM), 13.59 inches (97.28% of LTM), 11.69 inches (83.68% of LTM), and 12.80 inches (91.62% of LTM) of precipitation were received, respectively. June, July, and October of 1982 were wet months and each received 133.96%, 142.17%, and 438.93% of LTM precipitation, respectively. April, May, August, and September received normal precipitation at 95.80%, 112.55%, 99.43%, and 122.46% of LTM. Perennial plants did not experience water stress conditions during 1982 (Manske 2008). August of 1983 was a wet month and received 252.84% of LTM precipitation. June and July received normal precipitation at 101.56% and 102.81% of LTM. May, September, and October were dry months and received 64.02%, 62.32%, and 54.96% of LTM precipitation, respectively. April was a very dry month and received 14.69% of LTM precipitation. Perennial plants were under water stress conditions during April and September, 1983 (Manske 2008). April and June of 1984 were wet months and each received 200.70% and 165.11% of LTM precipitation, respectively. August received normal precipitation at 109.09% of LTM. October was a dry month and received 73.28% of LTM precipitation. May, July, and September were very dry months and received 0.00%, 4.42%, and 38.41% of LTM precipitation, respectively. Perennial plants were under water stress conditions during May, July, and September, 1984 (Manske 2008). May and October of 1985 were wet months and each received 135.98% and 162.60% of LTM precipitation, respectively. April, August, and September received normal precipitation at 86.71%, 104.55%, and 122.46% of LTM. June and July were very dry months and received 49.22% and 42.97% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July, 1985 (Manske 2008).

Mean January to July precipitation averaged 108.22% of LTM for 1982 and 1984 when both the annual and biennial fertilization treatments were applied and mean January to July precipitation averaged 75.07% of LTM (near drought conditions) for 1983 and 1985 when only the annual fertilization treatments were applied. These disproportional climatic conditions favored the biennially applied treatments and disfavored the annually applied treatments.

The period in days between application of fertilization treatments (4 May) and the first measurable precipitation was 3, 2, 33, and 9 days for 1982, 1983, 1984, and 1985, respectively. Volatilization of the ammonia from ammonium nitrate and urea fertilizers would be expected to be minor in 1982 and 1983, and possibly a little greater in 1985. Volatilization would be expected to be fairly substantial for both ammonium nitrate and urea fertilizers during 1984. The divergent conditions of 1982 and 1984 when both annual and biennial fertilization treatments were applied presented ideal circumstances in which to evaluate differences in volatilization characteristics of ammonium nitrate and urea fertilizers.

The available soil water in the top 24 inches decreased progressively from 1982 to 1985 (table 2) similar to the progressive decrease in the April to August precipitation from 1982 to 1985 (table 1). The available soil water from the 24 inch to 48 inch depths changed little during the study.

The available soil mineral nitrogen during June, July, and August was low at 62 lbs/ac on the unfertilized treatment (table 3). The available mineral nitrogen on the ammonium nitrate and urea fertilization treatments diminished to low levels during June, July and August and was not significantly different ($P<0.05$) than that on the unfertilized treatment, except the 100 lbs N EOY urea treatment had significantly greater ($P<0.05$) mineral nitrogen at the 0-48 inch soil core depth and at the 6-12 inch depth than that on the unfertilized treatment. Goetz (1975) also found that the available mineral nitrogen from similar fertilization treatment rates diminished rapidly because of nitrogen immobilization by the soil-plant system and that during the growing season from early June the amounts of mineral nitrogen on the fertilization treatments were essentially the same as the amounts on the unfertilized treatment.

Soil pH ranged between 6.8 and 8.0 in the top 6 inches of soil and was not significantly different ($P<0.05$) among any of the ammonium nitrate and urea fertilization treatments and the unfertilized treatment. Low rates of nitrogen fertilizer did not change soil pH in four years.

Herbage weight of mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 4, 5, 6, and 7). Warm season grass herbage weight on the fertilization treatments were not significantly different ($P<0.05$) than that on the unfertilized treatment.

Percent composition for mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition on the fertilization treatments were significantly lower ($P<0.05$) for mid warm season grasses on the ammonium nitrate treatment of 60 lbs N EOY during July, and on the urea treatments of 60 lbs N EY and 100 lbs N EOY during May, and 40 lbs N EY and 60 lbs N EOY during August, and for short warm season grasses on the ammonium nitrate and urea treatments of 40 lbs N EY during June than on the unfertilized treatment.

Basal cover of mid and short warm season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Mid warm season grass basal cover was significantly lower ($P<0.05$) on the ammonium nitrate treatment of 60 lbs N EOY and on the urea treatment of 40 lbs N EOY than on the unfertilized treatment. Short warm season grass basal cover on the fertilization treatments were not significantly different ($P<0.05$) from that on the unfertilized treatment.

Herbage weight of western wheatgrass and mid and short cool season grasses were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of western wheatgrass was significantly greater ($P<0.05$) on the urea treatment of 40 lbs N EY during May and June than on the unfertilized treatment. Herbage weight of mid cool season grasses was significantly greater ($P<0.05$) on the ammonium nitrate treatments of 40 lbs N EY, 60 lbs N EOY, and 60 lbs N EY during May and June, and on the urea treatments of 60 lbs N EY during May, 60 lbs N EOY during June, and 100 lbs N EOY during May, June, and July than on the unfertilized treatment. Herbage weight of short cool season grasses on the fertilization treatments were not significantly different ($P<0.05$) from that on the unfertilized treatment.

Percent composition for western wheatgrass and mid cool season grasses were generally greater and percent composition for short cool season grasses were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for western wheatgrass was significantly greater ($P<0.05$) on the urea treatment of 40 lbs N EY during May and July than on the unfertilized treatment. Percent composition for mid cool season grasses was significantly greater ($P<0.05$) on the ammonium nitrate treatment of 40 lbs N EY during May, and on the urea treatments of 60 lbs N EOY and 60 lbs N EY during May than on the unfertilized treatment. Percent composition for short cool season grasses on the fertilization treatments was not significantly different ($P<0.05$) from that on the unfertilized treatment.

Basal cover of western wheatgrass and mid cool season grasses were generally greater and basal cover of short cool season grasses was generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Basal cover of western wheatgrass, and mid and short cool season grasses on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight of upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, the sedge herbage weight was consistently lower than the weight on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of sedges were significantly greater (P<0.05) on the ammonium nitrate treatments of 60 lbs N EY during June and 100 lbs N EOY during May, and on the urea treatments of 60 lbs N EOY and 60 lbs N EY during May, and 100 lbs N EOY during May and June than on the unfertilized treatment. Herbage weight of sedges were significantly lower (P<0.05) on the ammonium nitrate treatments of 40 lbs N EY during June, and on the urea treatment of 40 lbs N EY during May and June than on the unfertilized treatment.

Percent composition for upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, percent composition was consistently lower than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for sedges was significantly greater (P<0.05) on the ammonium nitrate treatment of 60 lbs N EOY during August, and on the urea treatments of 60 lbs N EOY during August, and 100 lbs N EOY during May than on the unfertilized treatment. Percent composition for sedges was significantly lower (P<0.05) on the ammonium nitrate treatment of 40 lbs N EY during June and July, and on the urea treatment of 40 lbs N EY during May, June, July, and August than on the unfertilized treatment.

Basal cover of upland sedges were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 40 lbs N EY, basal cover was consistently lower than on the unfertilized treatment (table 12). Sedge basal cover on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight of forbs were generally greater on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment, except on the ammonium nitrate and urea treatments of 60 lbs N EOY, the forb herbage weight was consistently lower, but not significantly (P<0.05), than the forb weight on the unfertilized treatment (tables 4, 5, 6, and 7). Herbage weight of forbs was significantly greater (P<0.05) on the ammonium nitrate and urea treatments of 40 lbs N EY during May than on the unfertilized treatment.

Percent composition for forbs were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (tables 8, 9, 10, and 11). Percent composition for forbs was significantly lower (P<0.05) on the urea treatment of 60 lbs N EY during May than on the unfertilized treatment.

Basal cover of forbs were generally lower on the ammonium nitrate and urea fertilization treatments than on the unfertilized treatment (table 12). Forb basal cover on the fertilization treatments were not significantly different (P<0.05) from that on the unfertilized treatment.

Herbage weight, percent composition, and basal cover were generally lower for mid and short warm season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight, percent composition, and basal cover were generally greater for western wheatgrass and mid cool season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight was generally greater, and percent composition and basal cover were generally lower for short cool season grasses on the annual and biennial fertilization treatments than on the unfertilized treatment. Herbage weight, percent composition, and basal cover were generally greater for upland sedges on the annual and biennial fertilization treatments, except on the ammonium nitrate and urea treatments of 40 lbs N EY herbage weight, percent composition, and basal cover were lower, than on the unfertilized treatment. Herbage weight was generally greater; except on the ammonium nitrate and urea treatments of 60 lbs N EOY herbage weight was lower; and percent composition and basal cover were generally lower for forbs on the annual and biennial fertilization treatments than on the unfertilized treatment. General trends of the plant species shift on the annual and biennial fertilization treatments during the four years of this plot study V were the same as the shift in plant species composition found on previous nitrogen fertilization of native rangeland studies.

Peak aboveground herbage biomass usually occurs during the last two weeks in July. Most of the previous fertilization of native rangeland studies sampled herbage weight one time per year during late July or early August and compared these solitary herbage weights produced on the fertilization treatments. This study sampled aboveground herbage weight during May, June, July, and August to evaluate for differences in quantities and rates of herbage produced by plant categories on the fertilization treatments throughout the growing season.

Production of herbage weight by plant categories on the fertilization treatments did not occur in the same quantities during the growing season months as the quantity of herbage produced by plant categories on the unfertilized treatment (table 13 a, b, c). Peak herbage weights on the unfertilized treatment for cool season grasses, warm season grasses, total grasses, and total yield occurred during August, for sedges it occurred during May, and for forbs peak herbage occurred during July. During this four year study, peak herbage weight of total yield on the fertilized and unfertilized treatments occurred during July in 1982 and 1983 the same as peak herbage weight would occur during other typical growing seasons. During the growing seasons of 1984 and 1985, precipitation in July was well below normal (23.69% of long-term mean) followed by above average precipitation in August (106.82% of long-term mean) resulting in a shift in the occurrence of peak herbage biomass to August. The resulting four year mean herbage weight for total yield on the fertilization treatments were quite similar during July and August. Peak herbage weights on the fertilization treatments for cool season grasses, total grasses, and total yield occurred during July and August, for warm season grasses peak herbage occurred during August, for sedges it occurred during May, and for forbs peak herbage occurred during July or during August. The peak herbage weight of plant categories on fertilization treatments tended to occur earlier during the growing season than that on the unfertilized treatment (table 13 a, b, c).

Production of herbage weight by plant categories on the fertilization treatments did not occur at the same rates during the growing season months as the rate of herbage production by plant categories on the unfertilized treatment (table 14 a, b, c). Plant categories on the unfertilized treatment (0 lbs N) had greatest herbage weight for cool season grasses, warm season grasses, total grasses, and total yield during August, for sedges it occurred during May, and for forbs the greatest herbage weight occurred during July.

The urea treatment of 40 lbs N EOY (80 lbs N) had greater growth of warm season grasses, total grasses, and total yield during August. The ammonium nitrate treatment of 40 lbs N EOY (80 lbs N) and the ammonium nitrate and urea treatments of 60 lbs N EOY (120 lbs N) had greater growth of cool season grasses, total grasses, and total yield during July. The ammonium nitrate treatment of 40 lbs N EY (160 lbs N) had greater growth of warm season grasses, total grasses, and total yield during July. The urea treatment of 40 lbs N EY (160 lbs N) had greater growth of warm season grasses and total grasses during July and greater growth of cool season grasses and total yield during June. The ammonium nitrate and urea treatments of 100 lbs N EOY (200 lbs N) and 60 lbs N EY (240 lbs N) had greater growth of cool season grasses, total grasses, and total yield during June. Greater growth in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied (table 14 a, b, c).

Growth of herbage weight on the ammonium nitrate and urea fertilization treatments and on the unfertilized treatment occurred at different times and at different rates (table 15). The greatest herbage weight occurred during August on the unfertilized treatment. The greatest percent increase in herbage weight occurred during August on the urea treatment of 40 lbs N EOY. The greatest percent increase in herbage weight occurred during July on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 40 lbs N EY, and on the urea treatment of 60 lbs N EOY. The greatest percent increase in herbage weight occurred during June on the ammonium nitrate treatments of 100 lbs N EOY and 60 lbs N EY, and on the urea treatments of 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY. The greatest percent increase in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied (table 15).

The ammonium nitrate treatments of 40 lbs N EOY and 60 lbs N EY consistently out performed the respective urea treatments during each of the growing season months, except the August percent herbage increase on the urea treatment of 40 lbs N EOY was greater than that on the ammonium nitrate treatment. The urea treatment of 100 lbs N EOY consistently out performed the respective ammonium nitrate treatment during each of the growing season months (table 15).

The urea treatments of 60 lbs N EOY, 40 lbs N EY, and 100 lbs N EOY had greater percent increases in herbage weight during the early portions of the growing season than the respective ammonium nitrate treatments, and the ammonium nitrate treatments of 60 lbs N EOY and 40 lbs N EY had greater percent increases in herbage weight during the latter portions of the growing season than the respective urea treatments. The urea treatment of 40 lbs N EY had greater percent increases in herbage weight of 21.75% and 41.94% during May and June than the May and June percent increases in herbage weight of 18.91% and 37.28% on the ammonium nitrate treatment of 40 lb N EY. The ammonium nitrate treatment of 40 lbs N EY had greater percent increases in herbage weight of 43.78% and 27.80% during July and August than the July and August percent increases in herbage weight of 33.43% and

19.41% on the urea treatment of 40 lbs N EY (table 15).

Peak herbage weight of plant categories tended to occur earlier during the growing season on fertilization treatments than on the unfertilized treatment. Greater growth in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied. The greatest percent increase in herbage weight occurred earlier in the growing season with increases in total weight of nitrogen fertilizer applied. The greatest percent increase in herbage weight did not occur at the same time as the greatest aboveground herbage biomass. The greatest percent increase in herbage weight on the urea treatments tended to occur during the early portions of the growing season and the greatest percent increase in herbage weight on the ammonium nitrate treatments tended to occur later in the growing season than on the urea treatments.

The quantity and rate of growth in herbage weight was differentially affected by the quantity and type of nitrogen applied, making impartial comparisons of treatments with multiple nitrogen sources difficult to accomplish from single herbage sample dates per year. The mean herbage weight data from the June, July, and August growing season sample dates were used to remove the unintentional bias that results from single herbage sample date data (table 16). Mean cool season grass herbage weight was 1.6% and 15.7% greater on the urea treatments of 40 lbs N EY and 100 lbs N EOY than on the respective ammonium nitrate treatments, and was 17.8%, 23.5%, and 0.3% greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. Mean warm season grass herbage weight was 5.2% greater on the urea treatment of 40 lbs N EOY than on the respective ammonium nitrate treatment, and was 9.5%, 17.3%, 17.6%, and 38.0% greater on the ammonium nitrate treatments of 60 lbs N EOY, 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The annual urea treatments of 40 lbs N/ac and 60 lbs N/ac were detrimental to warm season grass herbage production. Mean total yield herbage weight was 11.5% greater on the urea treatment of 100 lbs N EOY than on the respective ammonium nitrate treatment, and was 7.6%, 10.4%, 5.4%, and 15.0% greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, 40 lbs N EY, and 60 lbs N EY than on the resepctive urea treatments. Generally, the herbage weight produced by the ammonium nitrate treatments was 5% to 38% greater than that produced by the respective urea treatments, except the urea treatment of 100 lbs N EOY out produced the respective ammonium nitrate treatment in cool season grasses, sedges, and total yield herbage weight consistently. The five ammonium nitrate treatments produced 4.9% greater mean cool season grass herbage weight, 15.5% greater mean warm season grass herbage weight, and 5.4% greater mean total yield herbage weight than the five urea treatments (table 16).

Differences in the pounds of herbage biomass produced per pound of nitrogen applied were used to evaluate production differences between ammonium nitrate and urea fertilization treatments (table 17). The pounds of cool season grass weight produced per pound of nitrogen ranged from 6 to 16 pounds of herbage for ammonium nitrate treatments and from 6 to 11 pounds of herbage for urea treatments. The pounds of warm season grass weight produced per pound of nitrogen ranged from less than 1 pound to 3 pounds of herbage for ammonium nitrate treatments and from a loss of 0.5 pound to a gain of 1.7 pounds of herbage for urea treatments. The pounds of total herbage yield weight produced per pound of nitrogen ranged from 9.5 to 17 pounds of herbage for ammonium nitrate treatments and from 6 to 14 pounds of herbage for urea treatments (table 17).

The pounds of cool season grass herbage produced per pound of nitrogen was 0.3 and 2.0 pounds greater on the urea treatments of 40 lbs N EY and 100 lbs N EOY than on the respective ammonium nitrate treatments, and was 5.8, 5.1, and 0.03 pounds greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The pounds of warm season grass herbage produced per pound of nitrogen was 0.9 pounds greater on the urea treatment of 40 lbs N EOY than on the respective ammonium nitrate treatment, and was 1.1, 1.4, 1.2, and 2.1 pounds greater on the ammonium nitrate treatments of 60 lbs N EOY, 40 lbs N EY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments. The pounds of total herbage yield produced per pound of nitrogen was 3.2 pounds greater on the urea treatment of 100 lbs N EOY than on the respective ammonium nitrate treatment, and was 5.2, 4.8, 1.9, and 3.4 pounds greater on the ammonium nitrate treatments of 40 lbs N EOY, 60 lbs N EOY, 40 lbs N EY, and 60 lbs N EY than on the respective urea treatments. Generally, the pounds of herbage biomass produced per pound of nitrogen by the ammonium nitrate treatments were 0.03 to 5.8 pounds of herbage greater than that produced by the respective urea treatments, except the urea treatment of 100 lbs N EOY produced 2.0 pounds greater cool season grass herbage and 3.2 pounds greater total herbage yield than the respective ammonium nitrate treatment. The five ammonium nitrate treatments produced 1.7 pounds of cool season grass herbage, 1.0 pound of warm season grass herbage, and 2.4 pounds of total herbage yield per pound of nitrogen applied greater than the five urea treatments (table 17).

Both the annual and biennial fertilization treatments were applied in 1982 and 1984. The April to June precipitation was 8.36 inches and 8.17 inches during 1982 and 1984, respectively. The period in days between application of fertilizer (4 May) and the first measurable precipitation was 3 days in 1982 and 33 days in 1984. These divergent conditions of 1982 and 1984 were used to evaluate differences in volatilization characteristics of ammonium nitrate and urea fertilizer (table 18). The difference in the percent herbage weight gain between 1982 and 1984 was considered to be the percent lost herbage weight due to volatilization of the ammonia from the ammonium nitrate and urea fertilizers resulting from the differences between 3 and 33 days with no precipitation following fertilizer application in 1982 and 1984, respectively. The mean percent lost herbage weight for the ammonium nitrate treatments was 72.9%, 27.4%, and 53.3% for cool season grasses, warm season grasses, and total herbage yield, respectively. The mean percent lost herbage weight for the urea treatments was 79.1%, 22.9%, and 56.1% for cool season grasses, warm season grasses, and total herbage yield, respectively (table 18).

The percent lost cool season grass herbage weight was 8.7% and 30.0% greater on the ammonium nitrate treatments of 40 lbs N EOY and 60 lbs N EY than on the respective urea treatments, and was 45.3%, 17.7%, and 6.8% greater on the urea treatments of 60 lbs N EOY, 40 lbs N EY, and 100 lbs N EOY than on the respective ammonium nitrate treatments. The percent lost warm season grass herbage weight was 38.7% and 1.2% greater on the ammonium nitrate treatments of 40 lbs N EY and 100 lbs N EOY than on the respective urea treatments, and was 0.7%, 10.6%, and 5.9% greater on the urea treatments of 40 lbs N EOY, 60 lbs N EOY, and 60 lbs N EY than on the respective ammonium nitrate treatments. The percent lost total yield herbage weight was 7.4%, 1.3%, and 15.1% greater on the ammonium nitrate treatments of 40 lbs N EOY, 100 lbs N EOY, and 60 lbs N EY than on the respective urea treatments, and was 29.2% and 8.7% greater on the urea treatments of 60 lbs N EOY and 40 lbs N EY than on the respective ammonium nitrate treatments. The five ammonium nitrate treatments had 4.5% greater percent lost warm season grass herbage weight than the five urea treatments. The five urea treatments had 6.2% greater percent lost cool season grass herbage weight and 2.8% greater percent lost total herbage yield weight than the five ammonium nitrate treatments (table 18). The percent lost herbage weight was generally similar for ammonium nitrate and urea fertilizers between 1982 and 1984.

Herbage growth during the monthly periods of the growing season was affected by the quantity and the source of nitrogen applied. Plants on the ammonium nitrate treatments had greater percent growth during monthly periods than unfertilized plants 48% of the growing season. Plants on the urea treatments had greater percent growth during monthly periods than unfertilized plants 49% of the growing season. Plants on the unfertilized treatment had greater percent growth during monthly periods than plants on the ammonium nitrate treatments 52% of the growing season and greater percent growth than plants on the urea treatments 51% of the growing season (table 19 a, b, c).

Fertilized cool season grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during May and June, 100 lbs N EOY during June, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during June, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than cool season grasses on the unfertilized treatment. Unfertilized cool season grasses had greater percent growth than fertilized cool season grasses on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during July and August, 100 lbs N EOY during May, July, and August, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during May, July, and August, 100 lbs N EOY during July and August, and 60 lbs N EY during July and August (table 19 a, b, c). Figure 1 shows the greater percent growth of cool season grasses during May and June on the ammonium nitrate treatment of 60 lbs N EY and the greater percent growth during July and August on the unfertilized treatment.

Fertilized warm season grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June, July, and August, and 60 lbs N EY during June, July, and August, and on the urea treatments of 40 lbs N EOY during June, July, and August, 60 lbs N EOY during June and August, 40 lbs N EY during July, 100 lbs N EOY during June and July, and 60 lbs N EY during July and August than warm season grasses on the unfertilized treatment. Unfertilized warm season grasses had greater percent growth than fertilized warm season grasses on the ammonium nitrate treatments of 40 lbs N EOY during May, July, and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and

August, 100 lbs N EOY during May, and 60 lbs N EY during May, and on the urea treatments of 40 lbs N EOY during May, 60 lbs N EOY during May and July, 40 lbs N EY during May, June, and August, 100 lbs N EOY during May and August, and 60 lbs N EY during May and June (table 19 a, b, c).

Fertilized total grasses had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during June and July, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than total grasses on the unfertilized treatment. Unfertilized total grasses had greater percent growth than fertilized total grasses on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and August, 100 lbs N EOY during May, July, and August, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during May and August, 100 lbs N EOY during July and August, and 60 lbs N EY during July and August (table 19 a, b, c).

Fertilized total herbage yield had greater percent growth on the ammonium nitrate treatments of 40 lbs N EOY during June and July, 60 lbs N EOY during June and July, 40 lbs N EY during June and July, 100 lbs N EOY during June and August, and 60 lbs N EY during May and June, and on the urea treatments of 40 lbs N EOY during June and August, 60 lbs N EOY during May, June, and July, 40 lbs N EY during May and June, 100 lbs N EOY during May and June, and 60 lbs N EY during May and June than total herbage yield on the unfertilized treatment. Unfertilized total herbage yield had greater percent growth than fertilized total herbage yield on the ammonium nitrate treatments of 40 lbs N EOY during May and August, 60 lbs N EOY during May and August, 40 lbs N EY during May and August, 100 lbs N EOY during May and July, and 60 lbs N EY during July and August, and on the urea treatments of 40 lbs N EOY during May and July, 60 lbs N EOY during August, 40 lbs N EY during July and August, 100 lbs N EOY during July and August, and 60 lbs N EY during July and August (table 19 a, b, c). Cool season grasses, warm season grasses, and upland sedges had greater percent growth during May on the urea treatments than on the ammonium nitrate treatments. Cool season grasses, warm season grasses, and upland sedges had greater percent growth during June on the ammonium nitrate treatments than on the urea treatments.

Fertilized plants had a greater rate of growth in herbage weight during a short period in the early portion of the growing season, usually May and June. The rapid growth period occurred earlier for plants fertilized with urea than with ammonium nitrate and the rapid growth period occurred earlier with increased quantities of nitrogen applied. Unfertilized plants had a longer period of herbage weight growth; during the early portion, the rate of growth in herbage weight was lower than that of fertilized plants, and during the latter portion of the growing season, usually July and August, the rate of growth in herbage weight was greater than that of fertilized plants.

Percent growth of cool season grasses during May and June on the ammonium nitrate and urea treatments was 10.6% and 10.8% greater, respectively, than that on the unfertilized treatment. Percent growth of cool season grasses during July and August on the unfertilized treatment was 15.1% and 13.9% greater than those on the ammonium nitrate and urea treatments, respectively. Percent growth of total grasses during May and June on the ammonium nitrate and urea treatments was 7.7% and 7.5% greater, respectively, than that on the unfertilized treatment. Percent growth of total grasses during July and August on the unfertilized treatment was 7.7% and 7.5% greater than those on the ammonium nitrate and urea treatments, respectively. Percent growth of total herbage yield during May and June on the ammonium nitrate and urea treatments was 5.5% and 6.5% greater, respectively, than that on the unfertilized treatment. Percent growth of total herbage yield during July and August on the unfertilized treatment was 6.5% and 6.5% greater than those on the ammonium nitrate and urea treatments, respectively (tables 20 and 21). Percent growth of total grasses and total herbage yield on the urea treatment of 40 lbs N EOY was lower during May and June and greater during July and August than those on the unfertilized treatment (tables 20 and 21). During May and June, percent growth of cool season grasses, total grasses, and total herbage yield was greater on the fertilized treatments than those on the unfertilized treatment, and during July and August, percent growth was greater on the unfertilized treatment than those on the fertilized treatments.

Discussion

Nitrogen fertilization of native rangeland plot study V (1982-1987) was conducted to evaluate the effectiveness of low rates of urea fertilizer compared to the same rates of ammonium nitrate and to determine the degree of differences in annual and biennial applications of ammonium nitrate and urea fertilizers. The major findings from this study follow.

- Nitrogen fertilization of native rangeland resulted in greater production of herbage weight than the quantity of aboveground herbage produced on unfertilized rangeland. Annual applications of 40 lbs N/ac and 60 lbs N/ac increased herbage production 35.7% and 41.4% on the ammonium nitrate treatments and 30.3% and 26.4% on the urea treatments, respectively. Biennial applications of 40 lbs N/ac, 60 lbs N/ac, and 100 lbs N/ac increased herbage production 21.2%, 37.1%, and 40.9% on the ammonium nitrate treatments, and 13.6%, 26.7%, and 52.4% on the urea treatments, respectively. The biennial applications of ammonium nitrate and urea fertilizers produced 74.5% and 73.0% of the total herbage weight produced on the annual applications of the respective fertilizers. The years when both the annual and biennial treatments were applied received 33% more precipitation than the years when only the annual treatments were applied causing disproportionally favorable results on the biennial treatments. The biennial applications of ammonium nitrate treatments in plot study IV (1970-1978) realistically produced 54.3% of the total herbage weight produced on the annual application treatments.

- Nitrogen fertilization of native rangeland caused general trends of a shift in plant species composition the same as the shift in plant species composition found on previous nitrogen fertilization of native rangeland studies. Composition of warm season grasses was reduced and composition of mid cool season grasses was increased on annual and biennial applications of ammonium nitrate and urea fertilization treatments.

- Native rangeland soils increase in available soil water during early spring to July under normal precipitation conditions and then decrease in soil water during July to the end of the growing season as a result of greater evapotranspiration demand than precipitation infiltration. Range plants experienced water stress during 25% of the growing season months during the study period of 1982 to 1985 which was lower than the normal long-term conditions with plants under water stress during 33% of the growing season months. Soil water below the 24 inch depth changed little during the study period indicating few grass roots in the lower depths of the soil profile, probably a result of the heavy seasonlong grazing management during past decades. Previous nitrogen fertilization of native rangeland studies have found that soil water use was greater on the fertilized treatments than on the unfertilized treatment and that greater amounts of soil water were used from the treatments with heavier rates of nitrogen fertilizer.

- Nitrogen fertilization of native rangeland with low rates of annual and biennial applications of ammonium nitrate and urea fertilizers did not change soil pH in four years, 1982 to 1985. Smika et al. (1961) found that annual applications of ammonium nitrate fertilizer could reduce soil pH 6% to 9% after 9 years and that the increase in soil acidity increased the solubility and availability of phosphate.

- Nitrogen fertilization of native rangeland with low rates of annual and biennial applications of ammonium nitrate and urea fertilizers did not increase available mineral nitrogen in soil from mid June to the end of the growing season, except the urea treatment of 100 lbs N EOY had significantly greater total available mineral nitrogen of 114 lbs N/ac in the soil profile to the 48 inch depth and consistently produced greater quantities of aboveground herbage throughout the study. Goetz (1975) found that as soil warmed in early spring, the available mineral nitrogen increased. This first peak in available mineral nitrogen occurred around mid May on unfertilized treatments and on fertilized treatments with nitrogen applications in early to mid April. Nitrogen applications in early May may shift the first peak to later in May. The quantity of available mineral nitrogen during the first peak was greater on the treatments with higher nitrogen rates. Differences in the amount of available mineral nitrogen diminished rapidly early in the growing season because of nitrogen immobilization by the soil-plant system. During the remainder of the growing season from early or mid June, the amounts of mineral nitrogen on the fertilization treatments was essentially the same as the amount available on the unfertilized treatment.

- Nitrogen fertilization of native rangeland resulted in the peak herbage weight of plant categories on fertilization treatments to occur earlier in the growing season than peak herbage on the unfertilized treatment. Peak herbage weight on unfertilized native rangeland usually occurs during the last two weeks in July. An exception to these standard conditions occurred during the growing seasons with below normal precipitation in July followed by above average precipitation in August. Peak herbage weights for cool season grasses, warm season grasses, total grasses, and total herbage yield occurred during August on the unfertilized treatment. Peak herbage weights for cool season grasses, total grasses, and total herbage yield occurred earlier during the growing season on the fertilization treatments than on the unfertilized treatment even with the changes in precipitation pattern. The increases in herbage weight occurred earlier in the growing season on the urea treatments than on the ammonium nitrate treatments.

- Nitrogen fertilization of native rangeland resulted in the greater rates of growth in herbage weight and the greatest percent increase in herbage weight to occur earlier in the growing season with increases in total weight of nitrogen fertilizer applied during the four years of the study. The greatest herbage weight on the unfertilized treatment occurred during August. Urea nitrogen applied at 80 lbs/ac resulted in greater herbage growth in August. Ammonium nitrate nitrogen applied at 80 lbs/ac and ammonium nitrate and urea nitrogen applied at 120 lbs/ac and 160 lbs/ac resulted in greater herbage growth in July. Ammonium nitrate and urea nitrogen applied at 200 lbs/ac and 240 lbs/ac resulted in greater growth in June. The greater the total weight of nitrogen fertilizer applied, the earlier in the growing season the greatest increase in herbage weight occurred. The greater rate of growth and the greatest percent increase in herbage weight did not occur at the same time as the greatest aboveground herbage biomass.

- Nitrogen fertilization of native rangeland reduced the time period of active growth. Fertilized plants had a high rate of growth in herbage weight during a short period in the early portion of the growing season and had a low rate of growth or a loss of weight during the latter portion of the growing season. Unfertilized plants had a longer period of active herbage weight growth. The rate of growth for unfertilized plants was lower than the growth rate for fertilized plants during the early portion of the growing season and the rate of growth was greater than the growth rate for fertilized plants during the latter portion of the growing season.

- Nitrogen fertilization of native rangeland resulted in greater herbage weight produced on the ammonium nitrate treatments than on the urea treatments. The herbage weight produced on the ammonium nitrate treatments with low rates of 100 lbs N/ac or less ranged from 5% to 38% greater than the herbage produced on urea treatments with the respective low rates. These differences in herbage production between ammonium nitrate and urea fertilizers at low rates were similar to the differences in herbage production at high rates greater than 100 lbs N/ac that were reported (Power 1974) to range from 5% to 40% greater on ammonium nitrate treatments than on the same rates of urea treatments. The five ammonium nitrate treatments produced a mean 5.4% greater herbage weight than the five urea treatments. Pounds of herbage weight produced per pound of nitrogen ranged from 9.5 to 17 pounds of herbage on the ammonium nitrate treatments and from 6 to 14 pounds of herbage on the urea treatments. The five ammonium nitrate treatments produced a mean 2.4 pounds of herbage weight per pound of nitrogen greater than the pounds of herbage produced per pound of nitrogen on the five urea treatments.

- Nitrogen fertilization of native rangeland resulted in a high loss of herbage weight from nitrogen volatilization that occurred during 33 days with no precipitation following broadcast application of ammonium nitrate and urea fertilizers in 1984. Hydrolyzed nitrogen fertilizers are broken down to ammonia and carbon dioxide. Under some conditions, a portion of the ammonia is volatilized into the atmosphere. This lost quantity of nitrogen is not available to plants for herbage growth. The greater the rate of volatilization, the greater the loss in herbage weight production. The amount of lost herbage weight on the ammonium nitrate and urea treatments was 72.9% and 79.1% of the cool season grasses, 27.4% and 22.9% of the warm season grasses, and 53.3% and 56.1% of the total herbage weight, respectively.

The urea treatments lost 1.5% greater herbage weight than the ammonium nitrate treatments as a result of volatilization of the ammonia.

- Nitrogen fertilization of native rangeland resulted in greater herbage growth rates during May and June on the fertilization treatments and greater herbage growth rates during July and August on the unfertilized treatment. Plants on the ammonium nitrate and urea treatments had greater percent herbage growth during 48% and 49% of the monthly periods than the plants on the unfertilized treatment, respectively, and plants on the unfertilized treatment had greater percent herbage growth during 52% and 51% of the monthly periods than the plants on the ammonium nitrate and urea treatments, respectively. Cool season grasses, warm season grasses, and upland sedges had greater percent herbage growth during May on the urea treatments than on the ammonium nitrate treatments, and had greater percent growth during June on the ammonium nitrate treatments than on the urea treatments. Percent growth of cool season grasses, total grasses, and total herbage weight was greater on the ammonium nitrate and urea fertilization treatments during May and June than on the unfertilized treatment, and percent herbage growth was greater on the unfertilized treatment during July and August than on the fertilization treatments.

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Table 1. Precipitation in inches for growing-season months and the annual total precipitation for 1982-1985, DREC Ranch, Manning, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1982-2007	1.43	2.39	3.21	2.49	1.76	1.38	1.31	13.97	16.77
1982	1.37	2.69	4.30	3.54	1.75	1.69	5.75	21.09	25.31
% of LTM	95.80	112.55	133.96	142.17	99.43	122.46	438.93	150.97	150.92
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.69	64.02	101.56	102.81	252.84	62.32	54.96	97.28	92.73
1984	2.87	T	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	200.70	0.00	165.11	4.42	109.09	38.41	73.28	83.68	76.80
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	14.78
% of LTM	86.71	135.98	49.22	42.97	104.55	122.46	162.60	91.62	88.13
1982-1985	1.42	1.87	3.61	1.82	2.49	1.19	2.39	14.79	17.13
% of LTM	99.30	78.24	112.46	73.09	141.48	86.23	182.44	105.87	102.15

Table 2. Mean soil water in inches per sample depth for fertilization treatments on the Moreau clayey range site, 1982-1985.

	Soil Depth in inches					
Years	0-6	6-12	12-24	24-36	36-48	0-48
1982	1.22a	1.10a	2.10a	1.71ab	1.54a	7.66a
1983	1.06b	0.87b	1.90b	1.94a	1.81a	7.59a
1984	0.89c	0.86b	1.32c	1.51b	1.70a	6.29b
1985	0.65d	0.61c	1.14c	1.29b	1.59a	5.28c

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 3. Mean soil mineral nitrogen content in pounds per acre for fertilization treatments on the Moreau clayey range site, 1982-1985.

	Soil Depth in inches					
Treatments	0-6	6-12	12-24	24-36	36-48	0-48
Unfertilized	8.34ab	7.05a	12.77ab	15.84ab	17.62a	61.61a
Ammonium nitrate						
40 lbs N EOY	9.29ab	6.41a	12.98a	14.53ab	17.14a	60.35a
40 lbs N EY	9.77ab	7.03a	13.64ab	15.36ab	15.62a	61.41a
60 lbs N EOY	8.86a	6.39a	11.62a	12.42a	14.99a	54.28a
60 lbs N EY	15.21b	9.09a	13.82a	13.78ab	13.47a	65.37a
100 lbs N EOY	10.50ab	14.27ab	17.33ab	15.40ab	19.69a	77.18ab
Urea						
40 lbs N EOY	8.61a	6.21a	12.37a	12.29a	15.88a	55.35a
40 lbs N EY	11.05ab	7.67a	13.75a	13.57ab	12.69a	58.73a
60 lbs N EOY	9.28ab	6.16a	11.74a	13.64a	12.61a	53.42a
60 lbs N EY	15.98b	9.23a	14.84ab	15.52ab	16.52a	72.07ab
100 lbs N EOY	29.28ab	22.44b	20.73b	24.17b	17.24a	113.85b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 4. Dry matter weight in pounds per acre for fertilization treatments 30 May on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	22.00a	179.10a	69.69a	149.21a	170.39a	140.35a	730.73a	150.75a	881.49a
Ammonium nitrate									
40 lbs N EOY	9.53a	145.49a	100.29ab	179.97a	177.22a	182.79abc	795.30a	146.71ab	942.01a
40 lbs N EY	4.36a	99.91a	170.27ab	256.31b	192.48a	105.46abc	828.79a	219.43bc	1048.22a
60 lbs N EOY	2.97a	124.31a	129.46ab	235.90b	189.91a	192.68ab	875.23a	130.65ab	1005.88a
60 lbs N EY	7.94a	172.26a	139.35ab	251.54b	263.44a	222.21ab	1056.74a	189.30abc	1246.04a
100 lbs N EOY	2.97a	123.50a	159.79ab	207.34ab	210.34a	246.19b	950.13a	147.27ab	1097.40a
Urea									
40 lbs N EOY	1.00a	178.59a	82.86a	173.04ab	180.55a	146.48a	762.53a	133.41ab	895.94a
40 lbs N EY	2.00a	130.84a	239.67b	193.88ab	183.35a	70.16c	819.89a	253.33c	1073.22a
60 lbs N EOY	6.53a	166.68a	166.94ab	261.87ab	138.95a	271.18b	1012.16a	124.46ab	1136.62a
60 lbs N EY	0.00a	155.42a	137.99ab	248.17b	207.36a	226.78b	975.72a	160.17abc	1135.89a
100 lbs N EOY	0.59a	121.11a	204.75ab	333.20b	200.22a	323.51b	1183.40a	189.72ab	1373.12a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 5. Dry matter weight in pounds per acre for fertilization treatments 23 June on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	6.04a	262.18a	85.43a	217.95a	246.96a	147.07a	928.86a	217.85a	1146.70a
Ammonium nitrate									
40 lbs N EOY	10.85a	275.96a	124.16a	336.59ab	290.06a	236.96a	1215.33b	181.20a	1396.53b
40 lbs N EY	20.20a	175.44a	190.78a	497.62b	345.77a	103.06b	1307.10b	267.13a	1574.23b
60 lbs N EOY	5.05a	279.71a	220.79a	483.78b	303.15a	136.77a	1395.05b	195.03a	1590.08b
60 lbs N EY	22.31a	314.74a	189.90a	477.71b	316.33a	252.74c	1510.54b	237.42a	1747.96b
100 lbs N EOY	13.23a	296.77a	245.13a	360.83ab	345.04a	216.65ac	1423.49b	234.15a	1657.64b
Urea									
40 lbs N EOY	57.98a	228.46a	107.61a	299.71ab	268.34a	112.23ab	1046.26a	249.89a	1296.15a
40 lbs N EY	3.73a	167.96a	320.25a	436.45ab	290.62a	74.94b	1275.21a	352.37a	1627.58b
60 lbs N EOY	4.75a	263.14a	198.23a	445.42b	218.08a	224.57ac	1298.04b	211.56a	1509.59ab
60 lbs N EY	5.07a	212.34a	171.02a	422.83ab	345.33a	232.94ac	1331.30b	173.09a	1504.39ab
100 lbs N EOY	10.12a	294.93a	203.06a	573.98b	349.20a	266.79c	1631.38b	218.29a	1849.67b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 6. Dry matter weight in pounds per acre for fertilization treatments 23 July on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	13.22a	277.57a	118.33a	289.98a	242.79a	171.28a	1070.35a	295.45a	1365.80a
Ammonium nitrate									
40 lbs N EOY	24.84a	280.58a	171.72ab	457.43ab	391.75a	178.00a	1459.81a	386.70a	1846.49a
40 lbs N EY	19.64a	382.98a	265.10ab	489.32ab	349.81a	91.42a	1575.41a	388.33a	1963.71a
60 lbs N EOY	0.60a	341.61a	301.22ab	557.20ab	334.61a	230.55a	1708.15a	235.49a	1943.66a
60 lbs N EY	98.73a	289.90a	136.03ab	580.23ab	388.72a	220.05a	1658.64a	319.03a	1977.67a
100 lbs N EOY	22.76a	357.84a	241.99ab	439.88ab	376.84a	252.94a	1629.01a	270.66a	1899.67a
Urea									
40 lbs N EOY	30.92a	292.74a	147.23a	335.42ab	296.69a	140.95a	1208.71a	309.66a	1518.37a
40 lbs N EY	25.44a	369.10a	341.66b	428.63ab	273.40a	69.98a	1490.71a	331.66a	1822.38a
60 lbs N EOY	13.69a	248.88a	238.60ab	588.12ab	259.43a	224.58a	1517.15a	284.57a	1801.74a
60 lbs N EY	1.34a	287.64a	265.47ab	512.29ab	299.54a	164.14a	1489.39a	244.70a	1734.09a
100 lbs N EOY	19.78a	406.91a	247.49ab	592.43b	328.90a	264.63a	1793.97a	314.74a	2108.70a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 7. Dry matter weight in pounds per acre for fertilization treatments 23 August on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	65.94a	363.79a	155.28a	303.08a	290.27a	184.94a	1317.06a	294.27a	1611.33a
Ammonium nitrate									
40 lbs N EOY	37.75a	408.54a	217.83a	397.39a	325.57a	192.26a	1531.27a	224.00a	1755.27a
40 lbs N EY	100.22a	393.67a	291.68a	482.73a	345.49a	118.94a	1703.00a	356.24a	2059.24a
60 lbs N EOY	38.20a	426.87a	271.79a	526.26a	389.78a	269.39a	1854.94a	266.45a	2121.39a
60 lbs N EY	38.95a	568.65a	154.49a	431.89a	360.52a	272.37a	1758.77a	346.54a	2105.32a
100 lbs N EOY	73.73a	506.01a	403.01a	456.70a	315.78a	233.11a	1930.06a	322.74a	2252.80a
Urea									
40 lbs N EOY	59.02a	421.08a	232.92a	307.88a	369.12a	222.01a	1556.52a	313.80a	1870.32a
40 lbs N EY	5.36a	349.65a	381.65a	518.70a	298.81a	87.59a	1619.86a	304.15a	1924.02a
60 lbs N EOY	0.00a	467.29a	308.49a	416.84a	258.09a	259.06a	1645.01a	269.11a	1914.12a
60 lbs N EY	38.35a	412.88a	252.04a	455.79a	306.11a	284.05a	1678.20a	295.67a	1973.87a
100 lbs N EOY	62.29a	445.37a	283.33a	561.69a	358.30a	246.00a	1895.47a	430.07a	2325.54a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 8. Percent composition of weight yield for fertilization treatments 30 May on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	2.49a	20.05a	7.88a	16.84a	19.11a	16.19a	82.56a	17.44a	881.49
Ammonium nitrate									
40 lbs N EOY	1.05ab	15.69a	10.27a	19.12ab	17.97a	20.22abc	84.31a	15.69a	942.01
40 lbs N EY	0.46ab	10.41a	14.95ab	24.96b	16.39a	11.71abc	78.88a	21.12a	1048.22
60 lbs N EOY	0.35ab	13.34a	12.79a	24.49ab	16.95a	19.02a	86.94a	13.06a	1005.88
60 lbs N EY	0.73ab	15.22a	10.36a	21.29ab	18.52a	19.15ac	85.27a	14.73a	1246.04
100 lbs N EOY	0.35ab	12.60a	13.93ab	18.95ab	17.64a	23.66ac	87.12a	12.88a	1097.40
Urea									
40 lbs N EOY	0.12a	21.06a	8.67a	19.58ab	18.86a	16.98abc	85.28a	14.72a	895.94
40 lbs N EY	0.22a	12.79a	22.14b	17.40ab	15.31a	7.06b	74.92a	25.08a	1073.22
60 lbs N EOY	0.59ab	16.01a	14.23a	22.68b	11.15a	24.34ac	89.06a	10.94a	1136.62
60 lbs N EY	0.00b	15.17a	11.91a	21.87b	16.14a	21.17ac	86.25a	13.75a	1135.89
100 lbs N EOY	0.03b	9.13a	13.95ab	25.02ab	12.61a	24.06c	84.79a	15.21a	1373.12

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 9. Percent composition of weight yield for fertilization treatments 23 June on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	0.55a	22.89a	7.68a	18.86a	21.68a	12.36a	80.92a	19.08a	1146.70
Ammonium nitrate									
40 lbs N EOY	0.82a	19.74a	8.77a	24.32a	20.21a	17.88ab	87.27ab	12.73ab	1396.53
40 lbs N EY	1.37a	11.45b	11.61a	32.84a	21.11a	6.78b	83.46ab	16.54ab	1574.23
60 lbs N EOY	0.34a	17.78ab	13.92a	31.02a	18.30a	8.99ab	88.10ab	11.90ab	1590.08
60 lbs N EY	1.30a	18.86ab	10.87a	28.12a	16.75a	14.78a	86.98ab	13.02ab	1747.96
100 lbs N EOY	1.16a	17.90ab	14.43a	22.56a	19.13a	14.99ab	86.43ab	13.58ab	1657.64
Urea									
40 lbs N EOY	4.76a	17.74a	7.94a	24.00a	19.79a	9.39ab	81.27ab	18.74ab	1296.15
40 lbs N EY	0.31a	10.62b	18.21a	29.56a	16.30a	5.00b	78.76ab	21.25ab	1627.58
60 lbs N EOY	0.28a	17.86ab	12.58a	29.74a	13.32a	17.05a	86.57ab	13.43ab	1509.59
60 lbs N EY	0.45a	14.81ab	11.11a	27.95a	21.37a	17.31a	88.65b	11.35b	1504.39
100 lbs N EOY	0.77a	16.12ab	11.11a	31.17a	17.78a	15.77a	88.79ab	11.21ab	1849.67

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 10. Percent composition of weight yield for fertilization treatments 23 July on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	0.89a	21.04a	8.25a	21.10a	18.33a	12.49a	78.97a	21.04a	1365.80
Ammonium nitrate									
40 lbs N EOY	1.27ab	15.04a	9.37a	24.64a	21.66a	11.75a	80.79a	19.21a	1846.49
40 lbs N EY	1.24a	20.45a	13.12ab	26.22a	17.44a	5.61bc	82.67a	17.33a	1963.71
60 lbs N EOY	0.03b	18.02a	15.62ab	28.93a	16.16a	13.51a	88.88a	11.12a	1943.66
60 lbs N EY	5.66ab	15.15a	6.63a	30.31a	17.63a	13.06a	85.18a	14.82a	1977.67
100 lbs N EOY	1.56ab	19.98a	12.42a	23.85a	17.53a	15.45a	86.91a	13.09a	1899.67
Urea									
40 lbs N EOY	1.76ab	19.88a	9.48a	22.37a	18.85a	10.40ab	80.13a	19.87a	1518.37
40 lbs N EY	1.43ab	21.02a	18.32b	25.57a	13.88a	3.97c	83.18a	16.82a	1822.38
60 lbs N EOY	1.10ab	14.87a	13.14ab	32.96a	12.70a	16.04a	86.79a	13.21a	1801.74
60 lbs N EY	0.07ab	17.07a	14.24ab	31.29a	16.17a	10.26a	86.55a	13.45a	1734.09
100 lbs N EOY	0.84ab	19.02a	11.11ab	30.39a	13.80a	15.12a	86.51a	13.50a	2108.70

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 11. Percent composition of weight yield for fertilization treatments 23 August on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Yield
Unfertilized	3.63a	23.61a	8.78a	19.05a	19.93a	9.00a	81.86a	18.14a	1611.33
Ammonium nitrate									
40 lbs N EOY	2.19ab	21.39a	11.57a	22.74a	20.49a	9.77abc	87.54a	12.46a	1755.27
40 lbs N EY	4.41ab	20.59a	13.60a	24.69a	17.01a	5.01ac	84.05a	15.95a	2059.24
60 lbs N EOY	1.17ab	20.09a	12.57a	25.72a	18.74a	13.48b	88.39a	11.61a	2121.39
60 lbs N EY	1.12ab	28.38a	6.55a	20.78a	17.57a	13.07ab	84.20a	15.80a	2105.32
100 lbs N EOY	2.73ab	22.84a	16.92a	20.68a	13.80a	11.60abc	85.66a	14.34a	2252.80
Urea									
40 lbs N EOY	3.21ab	23.73a	11.96a	16.25a	20.74a	10.96ab	84.09a	15.91a	1870.32
40 lbs N EY	0.38b	18.06a	19.40a	29.32a	14.89a	3.98c	85.02a	14.98a	1924.02
60 lbs N EOY	0.00b	22.23a	16.98a	21.55a	13.62a	14.29b	88.09a	11.91a	1914.12
60 lbs N EY	1.22ab	21.11a	12.88a	23.19a	15.89a	14.76ab	85.35a	14.66a	1973.87
100 lbs N EOY	2.57ab	20.68a	11.29a	24.30a	13.70a	10.60ab	80.50a	19.50a	2325.54

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 12. Basal cover of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Mid Warm	Short Warm	Western Wheatgrass	Mid Cool	Short Cool	Sedge	Total Grass	Total Forbs	Total Basal Cover
Unfertilized	1.38a	15.80ab	1.39a	4.08a	3.97a	3.70a	30.31a	4.34a	34.65a
Ammonium nitrate									
40 lbs N EOY	1.18a	14.85ab	1.02a	4.47a	3.88a	4.37a	29.77a	3.37a	33.13a
40 lbs N EY	0.70a	14.00a	2.09a	5.39a	5.45a	3.45a	31.07a	4.40a	35.47a
60 lbs N EOY	0.25b	16.19ab	1.59a	5.37a	3.29a	3.97a	30.63a	3.70a	34.33a
60 lbs N EY	0.40ab	17.30ab	1.95a	4.28a	3.80a	5.65a	33.38a	3.79a	37.17a
100 lbs N EOY	0.82a	13.49a	2.49a	5.83a	4.00a	4.93a	31.55a	4.10a	35.65a
Urea									
40 lbs N EOY	0.45b	20.53b	1.98a	4.72a	3.93a	4.39a	36.01a	4.41a	40.41a
40 lbs N EY	0.39ab	15.02ab	3.08a	4.78a	4.82a	1.85a	29.93a	4.90a	34.84a
60 lbs N EOY	1.42a	13.23a	1.97a	5.42a	3.72a	6.15a	31.90a	4.36a	36.26a
60 lbs N EY	1.17a	15.47ab	1.97a	5.62a	5.39a	3.75a	33.35a	3.78a	37.13a
100 lbs N EOY	0.59ab	17.92b	2.20a	5.20a	2.97a	6.33a	35.20a	2.10a	37.30a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 13a. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	389.29	201.10	140.35	730.73	150.75	881.49
23 Jun	550.34	268.22	110.30	928.86	217.85	1146.70
23 Jul	651.10	290.79	128.46	1070.35	295.45	1365.80
23 Aug	748.63	429.73	138.70	1317.06	294.27	1611.33
Ammonium nitrate 40 lbs N EOY						
30 May	457.48	155.02	182.79	795.30	146.71	942.01
23 Jun	750.81	286.81	177.71	1215.33	181.20	1396.53
23 Jul	1020.90	305.42	133.50	1459.82	386.70	1846.52
23 Aug	940.79	446.29	144.19	1531.27	224.00	1755.27
40 lbs N EY						
30 May	619.06	104.27	105.46	828.79	219.43	1048.22
23 Jun	1034.17	195.64	77.29	1307.10	267.13	1574.23
23 Jul	1104.23	402.62	68.57	1575.41	388.33	1963.74
23 Aug	1119.90	493.89	89.21	1703.00	356.24	2059.24
60 lbs N EOY						
30 May	555.27	127.28	192.68	875.23	130.65	1005.88
23 Jun	1007.72	284.76	102.57	1395.05	195.03	1590.08
23 Jul	1193.03	342.21	172.91	1708.15	235.49	1943.66
23 Aug	1187.83	465.07	202.04	1854.94	266.45	2121.39

Table 13b. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	654.33	180.20	222.21	1056.74	189.30	1246.04
23 Jun	983.94	337.05	189.55	1510.54	237.42	1747.96
23 Jul	1104.98	388.63	165.03	1658.64	319.03	1977.67
23 Aug	946.90	607.60	204.28	1758.78	346.54	2105.32
100 lbs N EOY						
30 May	577.47	126.47	246.19	950.13	147.27	1097.40
23 Jun	951.00	310.00	162.49	1423.49	234.15	1657.64
23 Jul	1058.71	380.60	189.70	1629.01	270.66	1899.67
23 Aug	1175.49	579.74	174.83	1930.06	322.74	2252.80
Urea 40 lbs N EOY						
30 May	436.45	179.59	146.48	762.53	133.41	895.94
23 Jun	675.66	286.44	84.16	1046.26	249.89	1296.15
23 Jul	779.34	323.66	105.71	1208.71	309.66	1518.37
23 Aug	909.92	480.10	166.50	1556.52	313.80	1870.32
40 lbs N EY						
30 May	616.90	132.84	70.16	819.89	253.33	1073.22
23 Jun	1047.32	171.69	56.20	1275.21	352.37	1627.58
23 Jul	1043.69	394.54	52.49	1490.72	331.66	1822.38
23 Aug	1199.16	355.01	65.69	1619.86	304.15	1924.02

Table 13c. Mean herbage biomass in pounds per acre of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	567.76	173.22	271.18	1012.16	124.46	1136.62
23 Jun	861.73	267.89	168.42	1298.04	211.56	1509.59
23 Jul	1086.15	262.57	168.43	1517.15	284.57	1801.74
23 Aug	983.42	467.29	194.30	1645.01	269.11	1914.12
60 lbs N EY						
30 May	593.52	155.42	226.78	975.72	160.17	1135.89
23 Jun	939.18	217.41	174.71	1331.30	173.09	1504.39
23 Jul	1077.30	288.98	123.11	1489.39	244.70	1734.09
23 Aug	1013.94	451.23	213.03	1678.20	295.67	1973.87
100 lbs N EOY						
30 May	738.18	121.71	323.51	1183.40	189.72	1373.12
23 Jun	1126.24	305.05	200.09	1631.38	218.29	1849.67
23 Jul	1168.82	426.69	198.46	1793.97	314.73	2108.70
23 Aug	1203.32	507.66	184.49	1895.47	430.07	2325.54

Table 14a. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	389.29	201.10	140.35	730.73	150.75	881.48
23 Jun	550.34	268.22	110.30	928.86	217.85	1146.70
23 Jul	651.10	290.79	128.46	1070.35	295.45	1365.80
23 Aug	748.63	429.73	138.70	1317.06	294.27	1611.33
Ammonium nitrate 40 lbs N EOY						
30 May	17.52	-22.91	30.24	8.84	-2.68	6.87
23 Jun	36.43	6.93	61.12	30.84	-16.82	21.79
23 Jul	56.80	5.03	3.92	36.39	30.89	35.20
23 Aug	25.67	3.85	3.96	16.26	-23.88	8.93
40 lbs N EY						
30 May	59.02	-48.15	-24.86	13.42	45.56	18.91
23 Jun	87.91	-27.06	-29.93	40.72	22.62	37.28
23 Jul	69.59	38.46	-46.62	47.19	31.44	43.78
23 Aug	49.59	14.93	-35.68	29.30	21.06	27.80
60 lbs N EOY						
30 May	42.64	-36.71	37.29	19.77	-13.33	14.11
23 Jun	83.11	6.17	-7.01	50.19	-10.47	38.67
23 Jul	83.23	17.68	34.60	59.59	-20.29	42.31
23 Aug	58.67	8.22	45.67	40.84	-9.45	31.65

Table 14b. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	68.08	-10.39	58.33	44.61	25.57	41.36
23 Jun	78.79	25.66	71.85	62.62	8.98	52.43
23 Jul	69.71	33.65	28.47	54.96	7.98	44.80
23 Aug	26.48	41.39	47.28	33.54	17.76	30.66
100 lbs N EOY						
30 May	48.34	-37.11	75.41	30.02	-2.31	24.49
23 Jun	72.80	15.58	47.32	53.25	7.48	44.56
23 Jul	62.60	30.88	47.67	52.19	-8.39	39.09
23 Aug	57.02	34.91	26.05	46.54	9.67	39.81
Urea 40 lbs N EOY						
30 May	12.11	-10.70	4.37	4.35	-11.50	1.64
23 Jun	22.77	6.79	-23.70	12.64	14.71	13.03
23 Jul	19.70	11.30	-17.71	12.93	4.81	11.17
23 Aug	21.54	11.72	20.04	18.18	6.64	16.07
40 lbs N EY						
30 May	58.47	-33.94	-50.01	12.20	68.05	21.75
23 Jun	90.30	-35.99	-49.05	37.29	61.75	41.94
23 Jul	60.30	35.68	-59.14	39.27	12.26	33.43
23 Aug	60.18	-17.39	-52.64	22.99	3.36	19.41

Table 14c. Percent increase or decrease in herbage production of plant categories for fertilization treatments different than for the unfertilized treatment on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	45.84	-13.86	93.22	38.51	-17.44	28.94
23 Jun	56.58	-0.12	52.69	39.75	-2.89	31.65
23 Jul	66.82	-9.70	31.11	41.74	-3.68	31.92
23 Aug	31.36	8.74	40.09	24.90	-8.55	18.79
60 lbs N EY						
30 May	52.46	-22.72	61.58	33.53	6.25	28.86
23 Jun	70.65	-18.94	58.40	43.33	-20.55	31.19
23 Jul	65.46	-0.62	-4.16	39.15	-17.18	26.97
23 Aug	35.44	5.00	53.59	27.42	0.48	22.50
100 lbs N EOY						
30 May	89.62	-39.48	130.50	61.95	25.85	55.77
23 Jun	104.64	13.73	81.41	75.63	0.20	61.30
23 Jul	79.51	46.73	54.49	67.61	6.53	54.39
23 Aug	60.74	18.13	33.01	43.92	46.15	44.32

Table 15. Herbage weight (lbs/ac) for total yield category and percent difference from unfertilized treatment during growing season months on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac		30 May	23 Jun	23 Jul	23 Aug
Unfertilized	0	lbs/ac	881.49	1146.70	1365.80	1611.33
Ammonium nitrate						
40 lbs N EOY	80	lbs/ac	942.01	1396.53	1846.49	1755.27
		%	6.87	21.79	35.19	8.93
60 lbs N EOY	120	lbs/ac	1005.88	1590.08	1943.66	2121.39
		%	14.11	38.67	42.31	31.65
40 lbs N EY	160	lbs/ac	1048.22	1574.23	1963.71	2059.24
		%	18.91	37.28	43.78	27.80
100 lbs N EOY	200	lbs/ac	1097.40	1657.64	1899.67	2252.80
		%	24.49	44.56	39.09	39.81
60 lbs N EY	240	lbs/ac	1246.04	1747.96	1977.67	2105.32
		%	41.36	52.43	44.80	30.66
Urea						
40 lbs N EOY	80	lbs/ac	895.91	1296.15	1518.37	1870.32
		%	1.64	13.03	11.17	16.07
60 lbs N EOY	120	lbs/ac	1136.62	1509.59	1801.74	1914.12
		%	28.94	31.65	31.92	18.79
40 lbs N EY	160	lbs/ac	1073.22	1627.58	1822.38	1924.02
		%	21.75	41.94	33.43	19.41
100 lbs N EOY	200	lbs/ac	1373.12	1849.67	2108.70	2325.54
		%	55.77	61.30	54.39	44.32
60 lbs N EY	240	lbs/ac	1135.89	1504.39	1734.09	1973.87
		%	28.86	31.19	26.97	22.50

Table 16. Four year mean June, July, and August herbage weight (lbs/ac) for fertilization treatments and percent difference from unfertilized treatment on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized	0						
lbs/ac		650.02		329.58		1374.61	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
lbs/ac		904.16	788.31	346.17	363.40	1666.11	1561.66
% difference		39.10	21.27	5.03	10.26	21.21	13.61
60 lbs N EOY	120						
lbs/ac		1129.53	977.10	364.01	332.58	1885.04	1741.81
% difference		73.77	50.32	10.45	0.91	37.13	26.71
40 lbs N EY	160						
lbs/ac		1086.10	1096.73	364.05	307.08	1865.74	1791.33
% difference		67.09	68.72	10.46	-6.83	35.73	30.32
100 lbs N EOY	200						
lbs/ac		1061.73	1163.62	471.26	413.13	1936.70	2094.64
% difference		63.33	79.01	42.99	25.35	40.89	52.38
60 lbs N EY	240						
lbs/ac		1011.94	1010.14	444.42	319.21	1943.65	1737.45
% difference		55.68	55.40	34.85	-3.15	41.40	26.40

Table 17. Herbage weight difference (lbs/ac) for fertilization treatments from unfertilized treatment and pounds of herbage per pound of nitrogen on the Moreau clayey range site, 1982-1985.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized	0						
lbs/ac		650.02		329.58		1374.61	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
lbs/ac difference		254.14	138.29	16.59	33.82	291.50	187.05
lbs/lb N		12.71	6.91	0.83	1.69	14.58	9.35
60 lbs N EOY	120						
lbs/ac difference		479.51	327.08	34.43	3.00	510.43	367.20
lbs/lb N		15.98	10.90	1.15	0.10	17.01	12.24
40 lbs N EY	160						
lbs/ac difference		436.08	446.71	34.47	-22.50	491.13	416.72
lbs/lb N		10.90	11.17	0.86	-0.56	12.28	10.42
100 lbs N EOY	200						
lbs/ac difference		411.71	513.60	141.68	83.55	562.09	720.03
lbs/lb N		8.23	10.27	2.83	1.67	11.24	14.40
60 lbs N EY	240						
lbs/ac difference		361.92	360.12	114.84	-10.37	569.04	362.84
lbs/lb N		6.03	6.00	1.91	-0.17	9.48	6.05

Table 18. Percent difference of mean June, July, and August herbage weight for fertilization treatments from unfertilized treatment produced in 1982 and 1984 and percent lost from 33 days with no precipitation in 1984 on the Moreau clayey range site.

Treatments	Total Nitrogen lbs/ac	Cool Season		Warm Season		Total Yield	
Unfertilized							
1982 lbs/ac		624.10		276.93		1184.23	
1984 lbs/ac		930.07		480.53		2054.43	
Fertilized		Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	80						
1982 %		77.86	63.03	20.22	20.46	51.35	39.63
1984 %		15.69	9.55	10.72	10.23	10.43	6.06
% Lost		-62.17	-53.48	-9.50	-10.23	-40.92	-33.57
60 lbs N EOY	120						
1982 %		104.71	120.97	31.77	25.35	65.33	79.58
1984 %		45.27	16.28	15.20	-1.86	22.67	7.71
% Lost		-59.44	-104.69	-16.57	-27.21	-42.66	-71.87
40 lbs N EY	160						
1982 %		91.32	93.71	55.26	15.91	72.03	68.66
1984 %		40.05	24.76	0.33	-0.29	21.01	8.97
% Lost		-51.27	-68.95	-54.93	-16.20	-51.02	-59.69
100 lbs N EOY	200						
1982 %		147.14	160.73	63.28	63.46	100.27	110.57
1984 %		26.60	33.40	30.92	32.33	20.40	31.99
% Lost		-120.54	-127.33	-32.36	-31.13	-79.87	-78.58
60 lbs N EY	240						
1982 %		103.46	75.92	57.19	19.26	80.02	46.96
1984 %		32.21	34.70	33.58	-10.24	27.99	10.02
% Lost		-71.25	-41.22	-23.61	-29.50	-52.03	-36.94

Table 19a. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
Unfertilized						
30 May	52.00	46.80	83.17	55.48	51.02	54.71
23 Jun	21.51	15.62	-17.81	15.04	22.71	16.46
23 Jul	13.46	5.25	10.76	10.74	26.27	13.60
23 Aug	13.03	32.33	6.07	18.73	-0.40	15.24
Ammonium nitrate 40 lbs N EOY						
30 May	44.81	34.74	94.47	51.94	37.94	51.02
23 Jun	28.73	29.53	-2.63	27.43	8.92	24.62
23 Jul	26.46	4.17	-22.85	15.97	53.14	24.37
23 Aug	-7.85	31.56	5.53	4.67	-42.07	-4.94
40 lbs N EY						
30 May	55.28	21.11	83.63	48.67	56.51	50.90
23 Jun	37.07	18.50	-22.34	28.09	12.28	25.54
23 Jul	6.26	41.91	-6.92	15.76	31.21	18.91
23 Aug	1.40	18.48	16.37	7.49	-8.26	4.64
60 lbs N EOY						
30 May	46.54	27.37	65.95	47.18	49.03	47.42
23 Jun	37.92	33.86	-30.84	28.02	24.16	27.54
23 Jul	15.53	12.35	24.08	16.88	15.18	16.67
23 Aug	-0.44	26.42	9.97	7.91	11.62	8.38

Table 19b. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EY						
30 May	59.22	29.66	84.99	60.08	54.63	59.19
23 Jun	29.83	25.81	-12.49	25.80	13.89	23.84
23 Jul	10.95	8.49	-9.38	8.42	23.55	10.91
23 Aug	-14.31	36.04	15.01	5.69	7.94	6.06
100 lbs N EOY						
30 May	49.13	21.81	90.05	49.23	45.63	48.71
23 Jun	31.78	31.66	-30.61	24.53	26.92	24.87
23 Jul	9.16	12.18	9.95	10.65	11.31	10.74
23 Aug	9.93	34.35	-5.44	15.60	16.14	15.68
Urea 40 lbs EOY						
30 May	47.97	37.41	64.02	48.99	42.51	47.90
23 Jun	26.29	22.26	-27.24	18.23	37.12	21.40
23 Jul	11.39	7.75	9.42	10.44	19.05	11.88
23 Aug	14.35	32.58	26.56	22.34	1.32	18.82
40 lbs N EY						
30 May	51.29	33.67	84.17	50.61	71.89	55.78
23 Jun	35.79	9.85	-16.75	28.11	28.11	28.81
23 Jul	-0.30	56.48	-4.45	13.30	-5.88	10.12
23 Aug	12.93	-10.02	15.83	7.97	-7.81	5.28

Table 19c. Percent herbage growth and senescence of plant categories for fertilization treatments on the Moreau clayey range site, 1982-1985.

Dates Treatments	Cool Season	Warm Season	Sedge	Total Native Grass	Forbs	Total Yield
60 lbs N EOY						
30 May	52.27	36.65	91.29	61.53	43.74	59.38
23 Jun	27.07	20.03	-34.59	17.38	30.61	19.49
23 Jul	20.66	-1.13	0.00	13.32	25.66	15.26
23 Aug	-9.46	43.32	8.71	7.77	-5.43	5.87
60 lbs N EY						
30 May	55.09	34.44	71.61	58.14	54.17	57.55
23 Jun	32.09	13.74	-16.44	21.19	4.37	18.67
23 Jul	12.82	15.86	-16.30	9.42	24.22	11.64
23 Aug	-5.88	35.96	28.39	11.25	17.24	12.15
100 lbs N EOY						
30 May	61.34	23.97	100.00	62.43	44.11	59.05
23 Jun	32.25	36.12	-38.15	23.63	6.64	20.49
23 Jul	3.54	23.96	-0.50	8.58	22.43	11.14
23 Aug	2.87	15.95	-4.32	5.35	26.82	9.32

Table 20. Percent herbage growth occurring during May and June for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Cool Season Grass		Total Native Grass		Total Yield	
Unfertilized	73.5		70.5		71.2	
Fertilized	Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	73.5	74.3	79.4	67.2	75.6	69.3
40 lbs N EY	92.4	87.1	76.8	78.7	76.4	84.6
60 lbs N EOY	84.5	79.3	75.2	78.9	75.0	78.9
60 lbs N EY	89.1	87.2	85.9	79.3	83.0	76.2
100 lbs N EOY	80.9	93.6	73.8	86.1	73.6	79.5

Table 21. Percent herbage growth occurring during July and August for fertilization treatments on the Moreau clayey range site, 1982-1985.

Treatments	Cool Season Grass		Total Native Grass		Total Yield	
Unfertilized	26.5		29.5		28.8	
Fertilized	Ammonium nitrate	Urea	Ammonium nitrate	Urea	Ammonium nitrate	Urea
40 lbs N EOY	18.6	25.7	20.6	32.8	19.4	30.7
40 lbs N EY	7.7	12.6	23.3	21.3	23.6	15.4
60 lbs N EOY	15.1	11.2	24.8	21.1	25.1	21.1
60 lbs N EY	-3.4	6.9	14.1	20.7	17.0	23.8
100 lbs N EOY	19.1	6.4	26.3	13.9	26.4	20.5

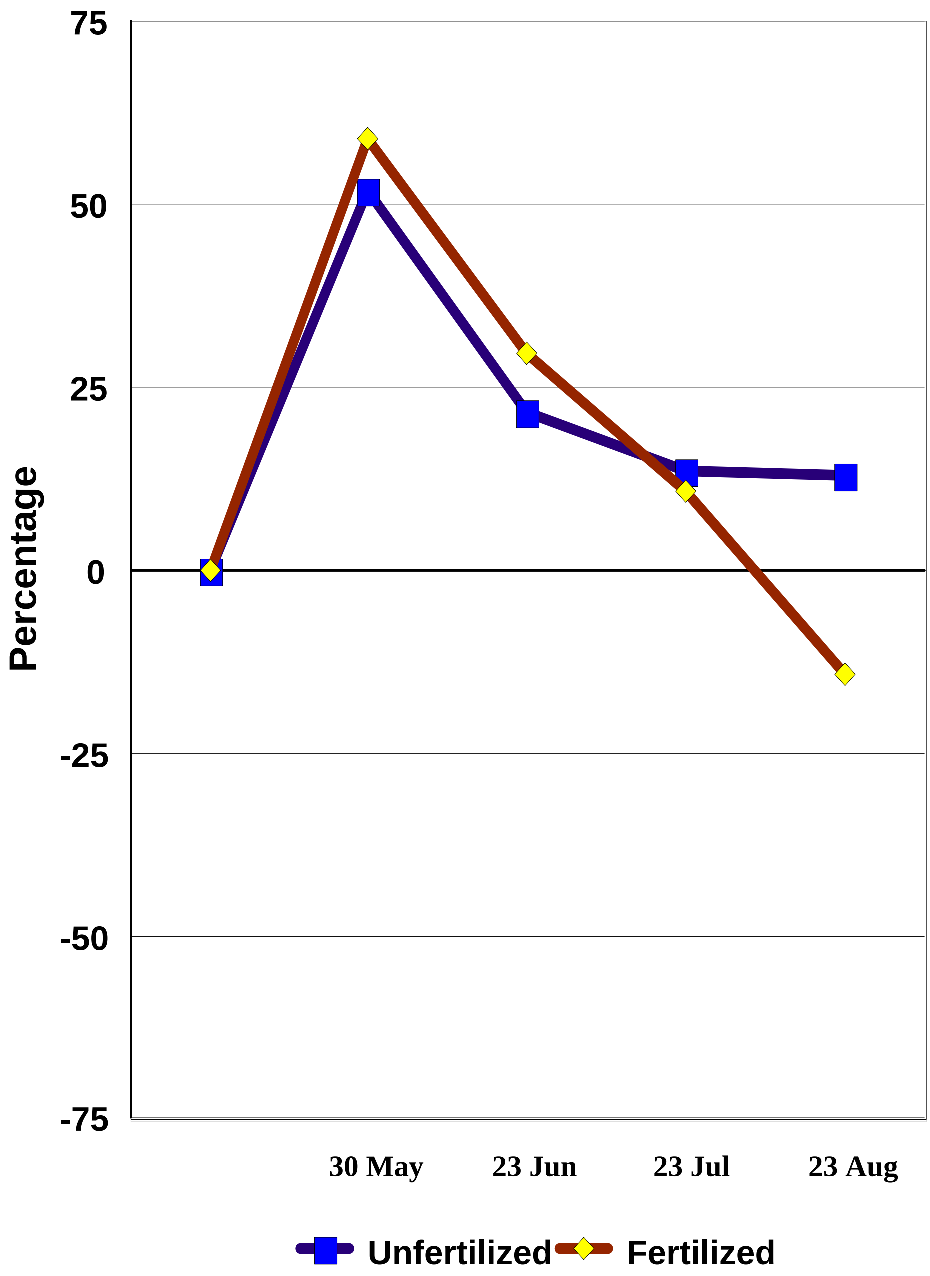

Figure 1. Percent herbage growth and senescence of cool season grasses for 60 lbs N EY and unfertilized treatments on the Moreau clayey range site, 1982-1985.

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Cost of Herbage Weight for Nitrogen Fertilization Treatments on Native Rangeland

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All of the nitrogen fertilization of native rangeland treatments increased total aboveground herbage weight to some degree. The nitrogen treatments increased herbage weight of mid cool season grasses and decreased herbage weight of warm season grasses. Native rangeland response to nitrogen fertilization was differentially affected by the quantity and source of nitrogen applied, and the vegetative communities on different range sites were affected by variation in soil characteristics, soil water content, plant species composition, and health status of the ecosystem. The fertilization treatments with the greatest production of total herbage weight may not be the treatments that are the most effective or lowest cost. This report evaluates the nitrogen fertilization treatments from five native rangeland plot studies for treatment effectiveness and herbage costs.

Procedure

Five nitrogen fertilization of native rangeland plot studies were conducted at the Dickinson Research Extension Center between 1957 and 1987. Plot study I (1957) was conducted on a heavily grazed site with an unfertilized control and ammonium nitrate treatments of 50 lbs N/ac, 100 lbs N/ac, and 150 lbs N/ac applied annually. Plot study II (1962-1963) was conducted on a creek terrace site and an upland slope site with an unfertilized control and ammonium nitrate treatments of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac applied annually. Plot study III (1964-1969) was conducted on a Havre overflow, Manning silty, Vebar sandy, and Rhoades thin claypan range sites with an unfertilized control and ammonium nitrate treatments of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac applied annually. Plot study IV (1970-1978) was conducted on an upland range site with an unfertilized control and ammonium nitrate treatments of 67 lbs N/ac and 100 lbs N/ac applied annually, 67 lbs N/ac and 100 lbs N/ac applied biennially, and 200 lbs N/ac, 300 lbs N/ac, and 400 lbs N/ac applied one time. Plot study V (1982-1987) was conducted on a Moreau clayey range site with an unfertilized control and ammonium nitrate and urea treatments of 40 lbs N/ac and 60 lbs N/ac applied annually, and 40 lbs N/ac, 60 lbs N/ac, and 100 lbs N/ac applied biennially.

Nitrogen fertilizer costs were the actual costs paid during plot study V with ammonium nitrate at $0.24 per pound of nitrogen, and urea at $0.25 per pound of nitrogen. Land rent value for grazinglands in North Dakota taken from the North Dakota Agricultural Statistics Service, 1998, was the mean rent in fifteen western counties at $8.76 per acre.

Herbage cost was compared and evaluated from the cost of herbage weight per ton. Herbage cost per ton on the unfertilized treatments was determined first, by dividing the grazingland rent cost per acre by the mean total herbage weight produced on the unfertilized treatment to derive cost per pound of herbage; then, cost per pound was multiplied by 2000 pounds to derive cost per ton of unfertilized herbage. Herbage cost per ton on the fertilized treatments was determined in three stages: first, the nitrogen cost per acre was determined by multiplying the nitrogen cost per pound by the quantity of nitrogen applied annually (or half the biennial rate); next, the nitrogen cost per acre was divided by the weight difference in mean total herbage weight produced on the fertilization treatments from the mean total herbage weight produced on the unfertilized treatments to derive cost per pound of herbage; then, cost per pound was multiplied by 2000 pounds to derive cost per ton for the additional herbage produced by the nitrogen treatments.

Treatment effectiveness was compared and evaluated from the herbage weight produced per pound of nitrogen applied. Pounds of herbage per pound of nitrogen was determined by dividing the quantity of nitrogen applied annually (or half the biennial rate) by the weight difference in mean total herbage weight produced on the fertilization treatments from the mean total herbage weight produced on the unfertilized treatments.

Results and Discussion

The mean total herbage weight produced on the fertilization treatments was 594.80 pounds greater than the mean total herbage weight produced on the unfertilized treatments. The weight difference in mean total herbage weight produced on the fertilization treatments was 300.3 lbs, 819.0 lbs, and

876.0 lbs greater for ammonium nitrate annually applied at treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac, respectively, and this increase in herbage weight on the fertilization treatments was 21.6%, 52.9%, and 57.5% greater, respectively, than the total herbage weight produced on the unfertilized treatments. Ammonium nitrate treatments applied biennially produced about 54.3% of the total herbage weight produced on the annually applied treatments. Ammonium nitrate treatments produced a mean 5.4% greater total herbage weight than produced on the urea treatments (tables 1-6).

Cost of unfertilized herbage weight per ton on plot study I, plot study II, III, and IV, and plot study V was $9.84, $11.59, and $12.75 per ton of herbage, respectively. The mean cost of herbage weight on the fertilization treatments was $51.39 per ton. Cost of fertilized herbage weight on most of the plot study sites and fertilization treatment rates ranged between $32.00 and $84.00 per ton, with the lowest cost at $24.19 per ton, and the highest cost at $112.21 per ton. The mean cost of herbage weight on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was $62.34, $41.58, and $60.40 per ton, respectively. The cost of herbage weight on the ammonium nitrate treatments applied biennially were in the same range of costs per ton as the costs of herbage weight on the annually applied treatments. The cost of herbage weight on the urea treatments was about $13.23 per ton greater than the cost of herbage weight on the ammonium nitrate treatments (tables 7-8).

The mean percent increase in cost of fertilized herbage weight was 373.56% greater than the cost of herbage weight on the unfertilized treatments. The percent increase in the cost of fertilized herbage weight for most of the fertilization treatments ranged between 160% and 600% greater than the cost of unfertilized herbage weight. More than 80% of the fertilization treatments had herbage weight costs that were greater than 200% of the unfertilized herbage cost. None of the fertilization treatments had herbage weight costs that were less than 120% greater then the herbage weight costs on the unfertilized treatments. The mean percent increase in cost of fertilized herbage weight on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was 502.01%, 279.06%, and 471.28% greater, respectively, than the cost of unfertilized herbage weight. The biennially applied ammonium nitrate treatments had an increase of 184.76% on the 67 lbs N/ac rate and had a reduction of 138.41% on the 100 lbs N/ac rate in cost of herbage weight from the cost of herbage weight on the respective annually applied treatments. The percent increase in the cost of herbage weight on the urea treatments was 104.18% greater than the percent increase in the cost of herbage weight on the ammonium nitrate treatments (tables 9-10).

On native rangeland grazinglands, about 50% of the produced herbage is required by the plants to remain healthy and productive and about 50% of the produced herbage is not needed by the plants and is expendable. About 50% of the plant expendable herbage is lost from the plant by leaf senescence and by grazing of insects and wildlife. The other 50% of the plant expendable herbage is ingested as forage by grazing livestock. About 25% of the produced herbage weight is captured through grazing by livestock as forage. The cost of forage weight is four times greater than the cost of herbage weight. Fertilization treatments with herbage weight costs of $32.00 and $84.00 per ton would have forage weight costs of $128.00 and $336.00 per ton, respectively.

Cost of herbage weight per ton on all of the annual and biennial ammonium nitrate and urea fertilization treatments were too great to be cost effective. More than 62% of the fertilization treatments had herbage weight costs greater than $40 per ton, or forage weight costs greater than $160 per ton. Only one fertilization treatment had herbage weight costs less than $30 per ton or forage weight costs of less than $120 per ton.

Unfertilized treatments with herbage weight costs of $11.59 per ton would have forage weight costs of $46.36 per ton. Cost of herbage weight per ton on unfertilized treatments were not excessive and could be cost effective.

The primary reason for the high herbage weight costs on the fertilization treatments was low pounds of herbage produced per pound of nitrogen applied. The mean weight of herbage produced per pound of nitrogen applied was 10.55 pounds of herbage. The herbage weight produced per pound of nitrogen on most of the fertilization treatments ranged between 8.0 and 14.6 pounds of herbage, with the lowest at 4.3 pounds of herbage and the greatest at 17.0 pounds of herbage. The mean pounds of herbage per pound of nitrogen on the ammonium nitrate annually applied treatment rates of 33 lbs N/ac, 67 lbs N/ac, and 100 lbs N/ac was 9.1 lbs, 12.2 lbs, and 8.8 lbs of herbage. The pounds of herbage per pound of nitrogen on the ammonium nitrate treatments applied biennially were in the same range of pounds of herbage per pound of nitrogen as on the annually applied treatments. The ammonium nitrate treatments produced 2.43 pounds of herbage per pound nitrogen greater than that produced on the urea treatments (tables 11-12).

With few pounds of herbage produced per pound of nitrogen, each pound of herbage had a high cost and each ton of herbage produced on the fertilization treatments cost substantially more than the cost of herbage produced on the unfertilized treatments. Based on the cost of the additional herbage weight produced on the fertilization treatments, the practice of nitrogen fertilization of native rangeland will not be profitable.

Acknowledgment

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Table 1. Mean nitrogen costs and herbage costs of fertilization treatments on a heavily grazed site, plot study I, 1957.

Treatments	Total Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @$0.24/lb $/ac	Herbage Cost $/ton
Unfertilized	1781.00					9.84
50 lbs N	2456.00	675.00	37.90	13.50	12.00	35.56
100 lbs N	3765.00	1984.00	111.40	19.84	24.00	24.19
150 lbs N	3220.00	1439.00	80.80	9.59	36.00	50.03

Table 2. Mean nitrogen costs and herbage costs of fertilization treatments on two range sites, plot study II, 1962-1963.

Treatments	Total Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @$0.24/lb $/ac	Herbage Cost $/ton
Creek terrace site						
Unfertilized	1521.00					11.52
33 lbs N	1932.50	411.50	27.05	12.47	7.92	38.49
67 lbs N	2440.00	919.00	60.42	13.72	16.08	34.99
100 lbs N	2431.50	910.50	59.86	9.11	24.00	52.72
Upland slope site						
Unfertilized	1358.00					12.90
33 lbs N	1825.00	467.00	34.39	14.15	7.92	33.92
67 lbs N	2233.00	875.00	64.43	13.06	16.08	36.75
100 lbs N	2260.00	902.00	66.42	9.02	24.00	53.22
Mean of two sites						
Unfertilized	1439.50					12.17
33 lbs N	1878.75	439.25	30.51	13.31	7.92	36.06
67 lbs N	2336.50	897.00	62.31	13.39	16.08	35.85
100 lbs N	2345.75	906.25	62.96	9.06	24.00	52.97

Table 3. Mean nitrogen costs and herbage costs of fertilization treatments on four range sites, plot study III, 1964-1969.

Treatments	Total Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @$0.24/lb $/ac	Herbage Cost $/ton
Havre overflow range site						
Unfertilized	2514.33					6.97
33 lbs N	2655.50	141.17	5.61	4.28	7.92	112.21
67 lbs N	3368.00	853.67	33.95	12.74	16.08	37.67
100 lbs N	3079.17	564.84	22.46	5.65	24.00	84.98
Manning silty range site						
Unfertilized	1533.50					11.42
33 lbs N	1743.17	209.67	13.67	6.35	7.92	75.55
67 lbs N	2477.33	943.83	61.55	14.09	16.08	34.07
100 lbs N	2909.33	1375.83	89.72	13.76	24.00	34.89
Vebar sandy range site						
Unfertilized	1331.67					13.16
33 lbs N	1665.83	334.16	25.09	10.13	7.92	47.40
67 lbs N	2287.00	955.33	71.74	14.26	16.08	33.66
100 lbs N	2331.00	999.33	75.04	9.99	24.00	48.03
Rhoades thin claypan range site						
Unfertilized	1011.20					17.33
33 lbs N	1249.60	238.40	23.58	7.22	7.92	66.44
67 lbs N	1474.00	462.80	45.77	6.91	16.08	69.49
100 lbs N	1524.20	513.00	50.73	5.13	24.00	93.57
Mean of four range sites						
Unfertilized	1597.68					10.97
33 lbs N	1828.53	230.85	14.45	7.00	7.92	68.62
67 lbs N	2401.58	803.90	50.32	12.00	16.08	40.00
100 lbs N	2460.93	863.25	54.03	8.63	24.00	55.60

Table 4. Mean nitrogen costs and herbage costs of fertilization treatments on the upland range site, plot study IV, 1970-1978.

Treatments	Total Yield	Weight Difference from Unfertilized	Percent Difference from Unfertilized	Herbage Weight per Pound of Nitrogen	Nitrogen Cost @$0.24/lb	Herbage Cost
	lbs/ac	lbs/ac	%	lbs	$/ac	$/ton
Unfertilized	2252.56					7.81
67 lbs N EOY	2525.63	273.07	12.12	8.15	8.04	58.89
67 lbs N EY	2975.89	723.33	32.11	10.80	16.08	44.46
100 lbs N EOY	2868.00	615.44	27.32	10.77	13.71	44.57
100 lbs N EY	3119.34	866.78	38.48	8.67	24.00	55.38
200 lbs N OT	2426.56	174.00	7.72	7.83	5.33	61.26
300 lbs N OT	2865.67	613.11	27.22	18.40	8.00	26.10
400 lbs N OT	2818.33	565.77	25.12	12.73	10.67	37.72

Table 5. Mean nitrogen costs and herbage costs of ammonium nitrate fertilization treatments on the Moreau clayey range site, plot study V, 1982-1985.

Treatments	Total Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @$0.24/lb $/ac	Herbage Cost $/ton
Unfertilized	1374.61					12.75
Ammonium nitrate						
40 lbs N EOY	1666.11	291.50	21.21	14.58	4.80	32.93
40 lbs N EY	1865.74	491.13	35.73	12.28	9.60	39.09
60 lbs N EOY	1885.04	510.43	37.13	17.01	7.20	28.21
60 lbs N EY	1943.65	569.04	41.40	9.48	14.40	50.61
100 lbs N EOY	1936.70	562.09	40.89	11.24	12.00	42.70

Table 6. Mean nitrogen costs and herbage costs of urea fertilization treatments on the Moreau clayey range site, plot study V, 1982-1985.

Treatments	Total Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %	Herbage Weight per Pound of Nitrogen lbs	Nitrogen Cost @$0.25/lb $/ac	Herbage Cost $/ton
Unfertilized	1374.61					12.75
Urea						
40 lbs N EOY	1561.66	187.05	13.61	9.35	5.00	53.46
40 lbs N EY	1791.33	416.72	30.32	10.42	10.00	47.99
60 lbs N EOY	1741.81	367.20	26.71	12.24	7.50	40.85
60 lbs N EY	1737.45	362.84	26.40	6.05	15.00	82.68
100 lbs N EOY	2094.64	720.03	52.38	14.40	12.50	34.72

Table 7. Cost of herbage weight per ton on annual and biennial ammonium nitrate fertilization treatments and on unfertilized treatments.

Study Sites	0 lbs N/ac $/ton	33 lbs N/ac $/ton	67 lbs N/ac $/ton	100 lbs N/ac $/ton
	Treatment Rates			
Annual Treatments				
Creek terrace site	11.52	38.49	34.99	52.72
Upland slope site	12.90	33.92	36.75	53.22
Havre overflow range site	6.97	112.21	37.67	84.98
Manning silty range site	11.42	75.55	34.07	34.89
Vebar sandy range site	13.16	47.40	33.66	48.03
Rhoades thin claypan range site	17.33	66.44	69.49	93.57
Upland range site	7.81	-	44.46	55.38
Mean	11.59	62.34	41.58	60.40
Biennial Treatments				
Upland range site	7.81	-	58.89	44.57

Table 8. Cost of herbage weight per ton on annual and biennial ammonium nitrate and urea fertilization treatments and on the unfertilized treatment.

Study Sites	0 lbs N/ac $/ton	40 lbs N/ac $/ton	60 lbs N/ac $/ton	100 lbs N/ac $/ton
	Treatment Rates			
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	12.75	39.09	50.61	-
Urea	12.75	47.99	82.68	-
Biennial Treatments				
Ammonium nitrate	12.75	32.93	28.21	42.70
Urea	12.75	53.46	40.85	34.72

Table 9. Percent increase in cost of herbage weight per ton on annual and biennial ammonium nitrate fertilization treatments and cost of herbage weight per ton on unfertilized treatments.

	Treatment Rates			
Study Sites	0 lbs N/ac $/ton	33 lbs N/ac %	67 lbs N/ac %	100 lbs N/ac %
Annual Treatments				
Creek terrace site	11.52	234.11	203.73	357.64
Upland slope site	12.90	162.95	184.88	312.56
Havre overflow range site	6.97	1509.90	440.46	1119.23
Manning silty range site	11.42	561.56	198.34	205.52
Vebar sandy range site	13.16	260.18	155.78	264.97
Rhoades thin claypan range site	17.33	283.38	300.98	439.93
Upland range site	7.81	-	469.27	609.09
Mean	11.59	502.01	279.06	471.28
Biennial Treatments				
Upland range site	7.81	-	654.03	470.68

Table 10. Percent increase in cost of herbage weight per ton on annual and biennial ammonium nitrate and urea fertilization treatments and cost of herbage weight per ton on the unfertilized treatment.

	Treatment Rates			
Study Sites	0 lbs N/ac $/ton	40 lbs N/ac %	60 lbs N/ac %	100 lbs N/ac %
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	12.75	206.59	296.94	-
Urea	12.75	276.39	548.47	-
Biennial Treatments				
Ammonium nitrate	12.75	158.27	121.25	234.90
Urea	12.75	319.29	220.39	172.31

Table 11. Herbage weight (in pounds per acre) per pound of nitrogen fertilizer applied and herbage weight on unfertilized treatments.

Study Sites	Treatment Rates 0 lbs N/ac lbs/ac	33 lbs N/ac lbs/ac/lb N	67 lbs N/ac lbs/ac/lb N	100 lbs N/ac lbs/ac/lb N
Annual Treatments				
Creek terrace site	1521.00	12.47	13.72	9.11
Upland slope site	1358.00	14.15	13.06	9.02
Havre overflow range site	2514.33	4.28	12.74	5.65
Manning silty range site	1533.50	6.35	14.09	13.76
Vebar sandy range site	1331.67	10.13	14.26	9.99
Rhoades thin claypan range site	1011.20	7.22	6.91	5.13
Upland range site	2252.56	-	10.80	8.67
Mean	1646.04	9.10	12.23	8.76
Biennial Treatments				
Upland range site	2252.56	-	8.15	10.77

Table 12. Herbage weight (in pounds per acre) per pound of nitrogen fertilizer applied and herbage weight on the unfertilized treatment.

Study Sites	Treatment Rates 0 lbs N/ac lbs/ac	40 lbs N/ac lbs/ac/lb N	60 lbs N/ac lbs/ac/lb N	100 lbs N/ac lbs/ac/lb N
Moreau clayey range site				
Annual Treatments				
Ammonium nitrate	1374.61	12.28	9.48	-
Urea	1374.61	10.42	6.05	-
Biennial Treatments				
Ammonium nitrate	1374.61	14.58	17.01	11.24
Urea	1374.61	9.35	12.24	14.40

Evaluation of Grazing Fertilized Native Rangeland Pastures

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Fertilization of native rangeland plot studies showed that application of nitrogen fertilizers increased total herbage yield (Rogler and Lorenz 1957; Whitman 1957, 1963, 1969, 1978; Smika et al. 1965; Power and Alessi 1971; Lorenz and Rogler 1972; Wight and Black 1972, 1979; Taylor 1976) and increased aboveground herbage crude protein content during the early portion of the growing season (Black and Wight 1972, Whitman 1975, Goetz 1975).

A fertilization of native rangeland grazing study with two grazing trials was conducted at the Dickinson Research Extension Center from 1972 to 1982 to test the performance of herbage and livestock on unfertilized native rangeland and fertilized rangeland pastures. Grazing trial I experimented with yearling steers and was conducted from 1972 to 1976 by Dr. Warren C. Whitman and Dr. Harold Goetz. Data from grazing trial I was reported by Nyren et al. 1983. A transition period occurred during 1977. Grazing trial II experimented with cow-calf pairs and was conducted from 1978 to 1981 by Paul E. Nyren and Dr. Harold Goetz and continued during 1981 to 1982 by Dr. Llewellyn L. Manske and Dr. Harold Goetz. Data from grazing trial II was reported by Nyren et al. 1984 and by Manske et al. 1984.

This report reevaluates the original data collected during grazing trials I and II and compares livestock weight gains, ungrazed and grazed total herbage production, and costs and returns on unfertilized and fertilized native rangeland pastures.

Procedure

The nitrogen fertilization of native rangeland grazing study was conducted from 1972 to 1982 as two grazing trials. The research pastures were located on the SW½, sec. 23, T. 140 N., R. 97 W., at the Dickinson Research Extension Center. The native rangeland plant community was strongly rolling upland mixed grass prairie. The soils were Vebar, Parshall, and Flasher fine sandy loams. The control pasture was 18 acres of untreated native rangeland. The fertilized pasture was 12 acres of native rangeland fertilized annually with ammonium nitrate fertilizer (33-0-0) broadcast applied in granular form at a rate of 50 lbs N/ac in early spring, usually around early to mid April, for eleven years from 1972 to 1982.

Steer performance during grazing trial I and cow and calf performance during grazing trial II were determined by mean weight gains or losses. The cattle were weighed upon entering and leaving each pasture.

Aboveground herbage biomass production was sampled by the clipping method. During grazing trial I, herbage samples were collected at the end of each grazing period and during grazing trial II, herbage samples were collected at the beginning and end of each grazing period. Vegetation was hand clipped to ground level in rectangular quadrats located both inside and outside exclosure cages. The plant material was oven dried and weighed. The difference between the aboveground herbage biomass values collected inside and outside the exclosure cages was the forage utilized. The forage use per acre included the forage ingested by the cattle, the loss in vegetation weight caused by senescence, and the loss in vegetation weight caused by parts broken from the plant, soiled by animal waste, consumed by insects and wildlife, and lost to other natural processes.

In 1982, the last year of the fertilization of native rangeland grazing study, the unfertilized and fertilized pasture herbage weight was sampled by clipping to ground level the vegetation from inside and outside exclosure cages during five monthly periods throughout the growing season. The plant material was separated into five categories: warm season grasses, cool season grasses, sedges, introduced grasses, and forbs.

Costs and returns for grazing trial I and grazing trial II were determined from total pasture and forage costs and value of steer and calf weight gain during the grazing periods and followed the methods developed by Manske et al. (2007). Nitrogen fertilizer costs were the actual costs paid during 1982-1985 with ammonium nitrate at $0.24 per pound of nitrogen. Land rent value for grazinglands in North Dakota taken from the North Dakota Agricultural Statistics Service, 1998, was the mean rent in fifteen western counties at $8.76 per acre. Differences between means from treatment years were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results

Grazing Trial I (1972-1976)

The precipitation during the growing seasons of 1972 to 1976 was normal or greater than normal (table 1). During 1972, 1973, 1974, 1975, and 1976, 18.57 inches (137.05% of LTM), 11.83 inches (87.31% of LTM), 12.45 inches (91.88% of LTM), 15.26 inches (112.62% of LTM), and 10.84 inches (80.00% of LTM) of precipitation were received, respectively. May, August, and October of 1972 were wet months and each received 217.52%, 167.63%, and 164.21% of LTM precipitation, respectively. April, June, and July received normal precipitation at 88.81%, 120.85%, and 122.52% of LTM, respectively. September was a dry month and received 55.64% of LTM precipitation . Perennial plants were under water stress conditions during September, 1972 (Manske 2009). April and September of 1973 were wet months and each received 224.48% and 167.67% of LTM precipitation, respectively. June received normal precipitation at 85.63% of LTM. May and October were dry months and received 55.56% and 70.53% of LTM precipitation, respectively. July and August were very dry months and received 40.99% and 27.17% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July, August, and October, 1973 (Manske 2009). April and May of 1974 were wet months and each received 197.20% and 177.35% of LTM precipitation, respectively. June, July, August, and October were dry months and received 56.34%, 67.57%, 52.02%, and 54.74% of LTM precipitation, respectively. September was a very dry month and received 42.11% of LTM precipitation. Perennial plants were under water stress conditions during July, August, September, and October, 1974 (Manske 2009). April, May, and October of 1975 were wet months and each received 297.20%, 142.74%, and 149.47% of LTM precipitation, respectively. June received normal precipitation at 120.28% of LTM. September was a dry month and received 60.15% of LTM precipitation. July and August were very dry months and received 28.83% and 31.21% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July, August, and September, 1975 (Manske 2009). April and September of 1976 were wet months and each received 147.55% and 133.08% of LTM precipitation, respectively. June received normal precipitation at 105.35% of LTM. May and October were dry months and received 60.68% and 68.42% of LTM precipitation, respectively. July and August were very dry months and received 33.78% and 23.12% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July and August, 1976 (Manske 2009).

The native rangeland and fertilized rangeland pastures of steer grazing trial I were grazed during one period for an average of 59 days from 30 June to 27 August. The grazing periods varied from 46 to 71 days in length and occurred between 21 June and 3 September. The pastures were grazed by 12 yearling steers of which 50% were Hereford and 50% were Angus-Hereford. The mean stocking rate on the native rangeland pasture was 1.08 acres per animal unit equivalent month (AUEM) with a range from 0.88 acres to 1.24 acres per AUEM. The mean stocking rate on the fertilized pasture was 0.73 acres per AUEM with a range from 0.60 acres to 0.84 acres per AUEM. The stocking rate on the fertilized pasture was 48.9% greater than, and significantly different ($P<0.05$) from, the stocking rate on the native rangeland pasture (table 2).

Post study determination of hindsight stocking rates was made from measured standing herbage biomass and animal unit equivalent of the June steer live weight (table 3). The determined stocking rate on the native rangeland pasture was 0.92 acres per AUEM and was not significantly different ($P<0.05$) from the stocking rate used. The determined stocking rate on the fertilized pasture was 0.64 acres per AUEM and was not significantly different ($P<0.05$) from the stocking rate used (tables 2 and 3). The determined stocking rate on the fertilized pasture was 43.8% greater than, but not significantly different ($P<0.05$) from, the determined stocking rate on the native rangeland pasture (table 3).

Steer performance on the native rangeland and fertilized pastures managed with one grazing period on grazing trial I were compared using gain per head, gain per day, and gain per acre data (table 4). Steer gain per head on the fertilized pasture was 5.6% greater than, but not significantly different ($P<0.05$) from, steer gain per head on the native rangeland pasture. Steer gain per day on the fertilized pasture was 7.9% greater than, but not significantly different ($P<0.05$) from, steer gain per day on the native rangeland pasture. Steer gain per acre on the fertilized pastures was 58.6% greater than, but not significantly different (P<0.05) from, steer gain per acre on the native rangeland pasture (table 4).

Early growing season steer daily gain on the fertilized pasture was greater during mid June to late July than steer daily gain on the native rangeland pasture. Late growing season steer daily gain on the native rangeland pasture was greater during early August to mid September than steer daily gain on the fertilized pasture (table 5).

Aboveground herbage biomass on the native rangeland and fertilized pastures managed with one grazing period on grazing trial I was compared from ungrazed and grazed total herbage production sampled at the end of the grazing period, and by the quantity of forage used per acre during the grazing period (table 6). Ungrazed herbage biomass at the end of the grazing period on the fertilized pasture was 49.8% greater than, but not significantly different (P<0.05) from, the ungrazed herbage biomass at the end of the grazing period on the native rangeland pasture. Grazed herbage biomass remaining at the end of the grazing period on the fertilized pasture was 40.7% greater than, but not significantly different (P<0.05) from, the grazed herbage biomass remaining at the end of the grazing period on the native rangeland pasture. The forage used during the grazing period on the fertilized pasture was 64.7% greater than, but not significantly different (P<0.05) from, the quantity of forage used per acre on the native rangeland pasture (table 6).

Costs and returns on the native rangeland and fertilized pastures on grazing trial I were compared using pasture costs and value of steer weight gain (table 7). On the native rangeland pasture managed with one grazing period, a steer required 2.04 acres per period, at a cost of $17.87 for the 59-day period, or $0.30 per day. Steer weight gain was 1.40 lbs per day and 56.18 lbs per acre; accumulated weight gain was 85.70 lbs. When steer accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $59.99 per steer, and the net returns after pasture costs were $42.12 per steer and $20.80 per acre. The cost of steer weight gain was $0.26 per pound. On the fertilized pasture managed with one grazing period, a steer required 1.38 acres per period, at a cost of $29.30 for the 59-day period, or $0.50 per day. Steer weight gain was 1.51 lbs per day and 89.10 lbs per acre; accumulated weight gain was 90.50 lbs. When steer accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $63.35 per steer, and the net returns after pasture costs were $34.05 per steer and $25.10 per acre. The cost of steer weight gain was $0.40 per pound (table 7).

Pasture costs per grazing period on the fertilized pasture was 64.0% greater than, and significantly different (P<0.05) from, pasture costs on the native rangeland pasture. Value of steer weight gain on the fertilized pasture was 5.6% greater than, but not significantly different (P<0.05) from, steer weight gain value on the native rangeland pasture. Net returns per steer on the native rangeland pasture was 23.7% greater than, but not significantly different (P<0.05) from, net returns per steer on the fertilized pasture. Net returns per acre on the fertilized pasture was 20.7% greater than, but not significantly different (P<0.05) from, net returns per acre on the native rangeland pasture. Cost per pound of steer accumulated weight on the fertilized pasture was 53.8% greater than, but not significantly different (P<0.05) from, cost per pound of steer accumulated weight on the native rangeland pasture (table 7).

Grazing Trial II (1978-1982)

The precipitation during the growing seasons of 1978 to 1982 was normal or greater than normal (table 8). During 1978, 1979, 1980, 1981, and 1982, 15.17 inches (111.96% of LTM), 11.12 inches (82.07% of LTM), 10.73 inches (79.19% of LTM), 14.27 inches (105.31% of LTM), and 22.53 inches (166.27% of LTM) of precipitation were received, respectively. April, May, and September of 1978 were wet months and each received 126.57%, 170.51%, and 192.48% of LTM precipitation, respectively. July and August received normal precipitation at 108.56% and 116.18% of LTM, respectively. June was a dry month and received 59.15% of LTM precipitation. October was a very dry month and received 30.53% of LTM precipitation. Perennial plants were under water stress conditions during October, 1978 (Manske 2009). August of 1979 was a wet month and received 127.75% of LTM precipitation. April, June, July, and September received normal precipitation at 89.51%, 86.20%, 100.00%, and 95.49% of LTM, respectively. May and October were very dry months and received 33.89% and 17.89% of LTM precipitation, respectively. Perennial plants were under water stress conditions during October, 1979 (Manske 2009). August and October of 1980 were wet months and each received 191.33% and 253.68% of LTM precipitation, respectively. June received normal precipitation at 75.21% of LTM. July and September were dry months and received 64.41% and 57.14% of LTM precipitation, respectively. April and May were very dry months and received 2.10%

and 5.13% of LTM precipitation, respectively. The April through July precipitation received in 1980 was 44.5% of the LTM precipitation causing drought conditions. Perennial plants were under water stress conditions during April, May, July, and September, 1980 (Manske 2009). August and September of 1981 were wet months and each received 234.10% and 206.77% of LTM precipitation, respectively. June received normal precipitation at 104.51% of LTM. May and July were dry months and received 55.56% and 70.72% of LTM precipitation, respectively. April and October were very dry months and received 46.15% and 24.21% of LTM precipitation, respectively. Perennial plants were under water stress conditions during July and October, 1981 (Manske 2009). April, May, August, September, and October of 1982 were wet months and each received 129.37%, 184.62%, 152.02%, 133.08%, and 685.26% of LTM precipitation, respectively. June and July received normal precipitation at 96.62% and 90.99% of LTM, respectively. Perennial plants did not experience water stress conditions during 1982 (Manske 2009).

The native rangeland pasture of cow-calf grazing trial II was grazed during one period for an average of 45 days from 21 June to 5 August. The grazing periods varied from 28 to 60 days in length and occurred between 19 June and 20 August. The fertilized rangeland pasture of cow-calf grazing trial II was grazed during one period for an average of 51 days from 25 June to 15 August. The grazing periods varied from 28 to 67 days in length and occurred between 17 June and 15 September. The pastures were grazed by 10 commercial crossbred cow-calf pairs. The mean stocking rate on the native rangeland pasture was 1.38 acres per AUEM with a range from 0.91 acres to 1.90 acres per AUEM. The mean stocking rate on the fertilized pasture was 0.82 acres per AUEM with a range from 0.52 acres to 1.25 acres per AUEM. The stocking rate on the fertilized pasture was 67.1% greater than, but not significantly different ($P<0.05$) from, the stocking rate on the native rangeland pasture (table 9).

Post study determination of hindsight stocking rates was made from measured standing herbage biomass and animal unit equivalent of the June cow live weight (table 10). The determined stocking rate on the native rangeland pasture was 1.93 acres per AUEM which was 39.9% lower than, but not significantly different ($P<0.05$) from, the mean stocking rate used. The determined stocking rate on the fertilized pasture was 1.25 acres per AUEM which was 52.4% lower than, but not significantly different ($P<0.05$) from, the mean stocking rate used (tables 9 and 10). The determined stocking rate on the fertilized pasture was 54.4% greater than, but not significantly different ($P<0.05$) from, the determined stocking rate on the native rangeland pasture (table 10).

During the 1980 drought growing season of grazing trial II, the pastures were managed with one grazing period and the stocking rates were reduced greatly. The stocking rate used during drought conditions on the native rangeland pasture was 4.58 acres per AUEM, which was 231.9% lower than the mean stocking rate used during nondrought growing seasons. The determined stocking rate that could have been used during drought conditions on the native rangeland pasture was 2.64 acres per AUEM, which was 91.3% lower than the mean stocking rate used during nondrought growing seasons. The stocking rate used during drought conditions on the fertilized pasture was 3.12 acres per AUEM, which was 280.5% lower than the mean stocking rate used during nondrought growing seasons. The determined stocking rate that could have been used during drought conditions on the fertilized pasture was 2.42 acres per AUEM, which was 195.1% lower than the mean stocking rate used during nondrought growing seasons (tables 9 and 10).

Cow and calf performance on the native rangeland and fertilized pastures managed with one grazing period on grazing trial II were compared using gain per head, gain per day, and gain per acre data (tables 11, 12, and 13). Cow gain per head on the native rangeland pasture was 105.6% greater than, but not significantly different ($P<0.05$) from, cow gain per head on the fertilized pasture. Cow gain per day on the native rangeland pasture was 104.1% greater than, but not significantly different ($P<0.05$) from, cow gain per day on the fertilized pasture. Cow gain per acre on the native rangeland pasture was 109.4% greater than, but not significantly different ($P<0.05$) from, cow gain per acre on the fertilized pasture (tables 11 and 13). Calf gain per head on the native rangeland pasture was 8.4% greater than, but not significantly different ($P<0.05$) from, calf gain per head on the fertilized pasture. Calf gain per day on the native rangeland pasture was 25.2% greater than, but not significantly different ($P<0.05$) from, calf gain per day on the fertilized pasture. Calf gain per acre on the fertilized pasture was 36.8% greater than, but not significantly different ($P<0.05$) from, calf gain per acre on the native rangeland pasture (tables 12 and 13).

Cow and calf performance during the 1980 drought growing season on the native rangeland and fertilized pastures managed with one grazing period on grazing trial II were compared using gain per head, gain per day, and gain per acre data (tables 11, 12, and 13). Cow gain per head on the native rangeland pasture was 1528.6% greater than cow gain per head on the fertilized pasture. Cow gain per day on the native rangeland pasture was 1675.0% greater than cow gain per day on the fertilized pasture. Cow gain per acre on the native rangeland pasture was 2259.3% greater than cow gain per acre on the fertilized pasture (tables 11 and 13). Calf gain per head on the native rangeland pasture was 21.1% greater than calf gain per head on the fertilized pasture. Calf gain per day on the native rangeland pasture was 21.1% greater than calf gain per day on the fertilized pasture. Calf gain per acre on the fertilized pasture was 23.9% greater than calf gain per acre on the native rangeland pasture (tables 12 and 13).

Early growing season cow daily gain on the fertilized pasture was greater during early to mid July than cow daily gain on the native rangeland pasture. Late growing season cow daily gain on the native rangeland pasture was greater during early to late August than cow daily gain on the fertilized pasture. Calf daily gain on the native rangeland pasture was greater during mid to late June and during mid July to late August than calf daily gain on the fertilized pasture. Calf daily gain on the fertilized pasture was not greater during any biweekly period than calf daily gain on the native rangeland pasture (table 14).

Cow and calf daily gain during the 1980 drought growing season on the native rangeland pasture was greater during early and late July than cow and calf daily gain on the fertilized pasture (table 14).

Aboveground herbage biomass on the native rangeland and fertilized pastures managed with one grazing period on grazing trial II was compared from pregrazed total herbage biomass sampled at the start of the grazing period, ungrazed and grazed total herbage biomass sampled at the end of the grazing period, and by the quantity of forage used per acre during the grazing period (table 15). Pregrazed herbage biomass on the fertilized pasture was 49.6% greater than, but not significantly different ($P<0.05$) from, pregrazed herbage biomass on the native rangeland pasture. Ungrazed herbage biomass at the end of the grazing period on the fertilized pasture was 60.9% greater than, but not significantly different ($P<0.05$) from, ungrazed herbage biomass at the end of the grazing period on the native rangeland pasture. Grazed herbage biomass remaining at the end of the grazing period on the fertilized pasture was 29.8% greater than, but not significantly different ($P<0.05$) from, grazed herbage biomass remaining at the end of the grazing period on the native rangeland pasture. The forage used during the grazing period on the fertilized pasture was 113.4% greater than, but not significantly different ($P<0.05$) from, the quantity of forage used per acre on the native rangeland pasture (table 15).

Aboveground herbage biomass during the 1980 drought growing season on the native rangeland and fertilized pastures managed with one grazing period on grazing trial II were compared from pregrazed total herbage biomass sampled at the start of the grazing period, ungrazed and grazed total herbage biomass sampled at the end of the grazing period, and by the quantity of forage used per acre during the grazing period (table 15). Pregrazed herbage biomass on the fertilized pasture was 5.5% greater than pregrazed herbage biomass on the native rangeland pasture. Ungrazed herbage biomass at the end of the grazing period on the fertilized pasture was 8.7% greater than ungrazed herbage biomass at the end of the grazing period on the native rangeland pasture. Grazed herbage biomass remaining at the end of the grazing period on the native rangeland pasture was 29.0% greater than grazed herbage biomass remaining at the end of the grazing period on the fertilized pasture. The forage used during the grazing period on the fertilized pasture was 142.6% greater than the quantity of forage used per acre on the native rangeland pasture (table 15).

Costs and returns on the native rangeland and fertilized pastures on grazing trial II were compared using pasture costs and value of calf weight gain (table 16). On the native rangeland pasture managed with one grazing period, a cow and calf required 1.83 acres per period, at a cost of $16.01 for the 45-day period, or $0.36 per day. Calf weight gain was 1.89 lbs per day and 44.93 lbs per acre; accumulated weight gain was 83.98 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $58.78 per calf, and the net returns after pasture costs were $42.77 per cow-calf pair and $23.74 per acre. The cost of calf weight gain was $0.21 per pound. On the fertilized pasture managed with one grazing period, a cow and calf required 1.23 acres per period, at a cost of $26.15 for the 51-day period, or $0.51 per day. Calf weight gain was 1.51 lbs per day and 61.45 lbs per acre; accumulated weight gain was 77.45 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $54.22 per calf, and the net returns after pasture costs were $28.06 per cow-calf pair and $23.21 per acre. The cost of calf weight gain was $0.39 per pound (table 16).

Pasture costs per grazing period on the fertilized pasture was 63.3% greater than, and significantly different ($P<0.05$) from, pasture costs on the native rangeland pasture. Value of calf weight gain on the native rangeland pasture was 8.4% greater than, but not significantly different ($P<0.05$) from, calf weight gain value on the fertilized pasture. Net returns per cow-calf pair on the native rangeland pasture was 52.4% greater than, but not significantly different ($P<0.05$) from, net returns per cow-calf pair on the fertilized pasture. Net returns per acre on the native rangeland pasture was 2.3% greater than, but not significantly different (P<0.05) from, net returns per acre on the fertilized pasture. Cost per pound of calf accumulated weight on the fertilized pasture was 85.7% greater than, but not significantly different (P<0.05) from, cost per pound of calf accumulated weight on the native rangeland pasture (table 16).

Costs and returns during the 1980 drought growing season on the native rangeland and fertilized pastures on grazing trial II were compared using pasture costs and value of calf weight gain (table 16). On the native rangeland pasture managed with one grazing period, a cow and calf required 2.38 acres per period, at a cost of $20.85 for the 16-day period, or $1.30 per day. Calf weight gain was 2.01 lbs per day and 12.48 lbs per acre; accumulated weight gain was 32.10 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $22.47 per calf, and the net returns after pasture costs were $1.62 per cow-calf pair and $0.68 per acre. The cost of calf weight gain was $0.65 per pound. On the fertilized pasture managed with one grazing period, a cow and calf required 1.62 acres per period, at a cost of $34.44 for the 16-day period, or $2.15 per day. Calf weight gain was 1.66 lbs per day and 15.46 lbs per acre; accumulated weight gain was 26.50 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $18.55 per calf, and the net returns after pasture costs were a loss of $15.89 per cow-calf pair and a loss of $9.81 per acre. The cost of calf weight gain was $1.30 per pound (table 16).

Pasture costs per grazing period during the 1980 drought growing season on the fertilized pasture was 65.2% greater than pasture costs on the native rangeland pasture. Value of calf weight gain on the native rangeland pasture was 21.1% greater than calf weight gain value on the fertilized pasture. Net returns per cow-calf pair on the native rangeland pasture was 1080.9% greater than net returns per cow-calf pair on the fertilized pasture. Net returns per acre on the native rangeland pasture was 1542.6% greater than net returns per acre on the fertilized pasture. Cost per pound of calf accumulated weight on the fertilized pasture was 100.0% greater than cost per pound of calf accumulated weight on the native rangeland pasture (table 16).

Grazing fertilized native rangeland pastures with steers or with cow-calf pairs did not capture much wealth from the land natural resources because the animal performance responded to the quality of the vegetation. Fertilized plants produced herbage weight at a rapid growth rate over a short period of time that occurred during the early portion of the growing season. Unfertilized plants produced herbage weight at a slower growth rate over a long period of time that continued later into the growing season.

Steers on the fertilized pasture had greater daily gain during mid June to late July than steers on the unfertilized pasture. Steers on the unfertilized pasture had greater daily gain during early August to mid September than steers on the fertilized pasture (table 5).

Cows on the fertilized pasture had similar daily gain to cows on the unfertilized pasture during mid June to mid July. Cows on the fertilized pasture started to lose weight in mid July or early August and lost more weight during the latter portion of the grazing period than they gained during the early portion. Cows on the unfertilized pasture gained weight during mid June to mid August and lost a small amount of weight towards the end of the grazing period. Cows on the unfertilized pasture gained more weight per head than the cows on the fertilized pasture. During drought conditions, cows on the fertilized pasture lost weight and cows on the unfertilized pasture gained weight (table 14).

Calves on the fertilized pasture had similar daily gain to the calves on the unfertilized pasture during mid June to mid July. Calves on the fertilized pasture had lower daily gain after mid July than calves on the unfertilized pasture. Calves on the unfertilized pasture gained more weight per head than the calves on the fertilized pasture. During drought conditions, calves on the unfertilized pasture had greater daily gain than calves on the fertilized pasture (table 14).

Nitrogen fertilization of native rangeland increased the crude protein content of aboveground plant material during early growth stages. Most grass species attained maximum crude protein content in mid May. Crude protein content decreased with advancement of plant maturity. A significant decrease in crude protein was evident on the fertilized treatments during mid June to early July and was not different than that on the unfertilized treatments in early August (Goetz 1975). An accelerated rate of decline progressed rapidly on the fertilized treatments and the crude protein content dropped below livestock requirements earlier in the growing season than the crude protein content of grasses on the unfertilized treatments (Whitman 1975).

The growing season of 1982 was the eleventh year with an application of 50 lbs N/ac on the fertilized native rangeland pasture used during the steer grazing trial I (1972-1976) and the cow-calf grazing trial II (1978-1982). The effects from 11 years of fertilization on native rangeland vegetation were determined from herbage weight clipped during 5 monthly periodic dates and separated into 5 categories. Percent herbage growth and senescence of plants during the monthly periods of the growing season were affected by the fertilizer treatment. Fertilized plants have greater herbage growth during a short period in the early portion of the growing season. Unfertilized plants have active growth during about double the length of time of the fertilized plant growth period and have greater herbage growth during the latter portion. Greater total percent herbage senescence occurred during the latter portion of the growing season on the fertilized pasture than on the unfertilized pasture (table 18).

Cool season grasses and upland sedges on the unfertilized and fertilized pastures gained herbage weight during May, June, and July, and then lost aboveground biomass during August and September (table 17). Percent herbage growth of cool season grasses and upland sedges was greater during May and June on the fertilized pasture and was greater during July on the unfertilized pasture. Total percent cool season grass herbage senescence was greater on the fertilized pasture during August and September (table 18 and figure 1).

Warm season grasses on the unfertilized pasture gained herbage weight during May, June, July, and August, and then lost aboveground biomass during September. Warm season grasses on the fertilized pasture gained herbage weight during May, June, and July, and lost aboveground biomass during August and September (table 17). Percent herbage growth of warm season grasses was greater during May and July on the fertilized pasture and was greater during June and August on the unfertilized pasture. Total percent warm season grass herbage senescence was greater on the unfertilized pasture during September (table 18 and figure 2).

Total native grasses on the unfertilized pasture gained herbage weight during May, June, July, and August, and then lost aboveground biomass during September. Total native grasses on the fertilized pasture gained herbage weight during May, June, and July, and lost aboveground biomass during August and September (table 17). Percent herbage growth of total native grasses was greater during May and June on the fertilized pasture and was greater during July and August on the unfertilized pasture. Total percent herbage senescence of total native grasses was greater on the fertilized pasture during August and September (table 18 and figure 3).

Herbage growth of introduced and domesticated grasses occurred during June and July and herbage senescence occurred during August and September on the fertilized pasture and did not occur on the unfertilized pasture (table 18 and figure 4).

Forbs on the unfertilized pasture gained herbage weight during May, June, and July, and then lost aboveground biomass during August and September. Forbs on the fertilized pasture gained herbage weight during May, June, and July, and August, and lost aboveground biomass during September (table 17). Percent herbage growth of forbs was greater during May and June on the unfertilized pasture and was greater during July and August on the fertilized pasture. Almost all of the forb herbage weight on the fertilized pasture was fringed sage. Total percent forb herbage senescence was greater on the fertilized pasture during September (table 18 and figure 5).

Total herbage yield on the unfertilized pasture gained herbage weight during May, June, July, and August, and then lost aboveground biomass during September. Total herbage yield on the fertilized pasture gained herbage weight during May, June, and July, and lost aboveground biomass during August and September (table 17). Percent herbage growth of total herbage yield was greater during May and June on the fertilized pasture and was greater during July and August on the unfertilized pasture. Total percent herbage senescence of total herbage yield was greater on the fertilized pasture during August and September (table 18 and figure 6).

Discussion

Nitrogen fertilization of native rangeland does result in greater production of herbage weight, primarily mid cool season grasses, and a greater crude protein content during early growth stages. These "improvements" in the vegetation, however, do not translate into improved livestock performance throughout the grazing season.

Fertilized rangeland plants have a short period of rapid growth in leaf height and herbage weight during May and June. This rapid increase period is followed by a period of accelerated senescence, with a rapid decline in crude protein content, an increasing rate of leaf drying, and a high rate of loss in aboveground herbage weight during July, August, and September.

Livestock performance responds to the conditions of the vegetation. Yearling steers grazing fertilized rangeland have a high rate of gain during mid June to late July and a poor rate of gain after early August. Cows grazing fertilized rangeland have a good rate of gain during mid June to mid July and have a high loss of weight after mid July or early August. Calves with cows on fertilized rangeland have a good rate of gain during mid June to mid July, have reduced gains during mid July to early August, and have poor gains after early August.

Unfertilized rangeland plants have an active growth period for about 70% of the growing season, which is about double the length of the fertilized plant active growth period. Unfertilized plant growth in leaf height and herbage weight during May and June is slower than the growth rate of fertilized plants. Unfertilized plant growth during July and August is greater than the growth rate of fertilized plants. After mid August, unfertilized rangeland plants have a period of senescence that usually progresses at a slower rate than senescence of fertilized rangeland plants.

Yearling steers grazing unfertilized rangeland have a good rate of gain during mid June to mid September. After early August, the rate of gain by steers on unfertilized rangeland is greater than the rate of gain by steers on fertilized rangeland. Cows grazing unfertilized rangeland have a good rate of gain during mid June to mid August, and after mid August, cows lose a small amount of weight. Calves with cows on unfertilized rangeland have a good rate of gain during mid June to mid August and have a slightly reduced rate of gain after mid August.

Fertilization of native rangeland does produce a short period of rapid plant growth and greater herbage weight, however, fertilization of rangeland does not produce greater livestock performance and does not result in the capture of greater wealth from the native rangeland natural resources.

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Table 1. Precipitation in inches for growing-season months and the annual total precipitation for 1972-1976, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1972	1.27	5.09	4.29	2.72	2.90	0.74	1.56	18.57	20.76
% of LTM	88.81	217.52	120.85	122.52	167.63	55.64	164.21	137.05	129.75
1973	3.21	1.30	3.04	0.91	0.47	2.23	0.67	11.83	13.53
% of LTM	224.48	55.56	85.63	40.99	27.17	167.67	70.53	87.31	84.56
1974	2.82	4.15	2.00	1.50	0.90	0.56	0.52	12.45	14.15
% of LTM	197.20	177.35	56.34	67.57	52.02	42.11	54.74	91.88	88.44
1975	4.25	3.34	4.27	0.64	0.54	0.80	1.42	15.26	17.71
% of LTM	297.20	142.74	120.28	28.83	31.21	60.15	149.47	112.62	110.69
1976	2.11	1.42	3.74	0.75	0.40	1.77	0.65	10.84	12.68
% of LTM	147.55	60.68	105.35	33.78	23.12	133.08	68.42	80.00	79.25
1972-1976	2.73	3.06	3.47	1.30	1.04	1.22	0.96	13.78	15.77
% of LTM	191.05	130.77	97.75	58.56	60.12	91.73	101.05	101.70	98.56

Table 2. Mean stocking rates for steers on native rangeland treatments, 1972-1976.

Treatments	Grazing Period Dates	Days in Period	Months in Period	Number of Steers	Number of AUEM	AUEM per Acre	Acres per AUEM
One grazing period 1972-1976							
Unfertilized	30 Jun-27Aug	59	1.92	12	16.95a	0.94a	1.08a
Fertilized	30 Jun-27 Aug	59	1.92	12	16.77a	1.40b	0.73b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 3. Stocking rates for steers determined from standing herbage biomass and June animal unit equivalent (AUE), 1972-1976.

Treatments	Mean Standing Herbage (lb/ac)	Mean Forage Available (lb/ac)	June AUE	Forage per Day (lbs)	Forage per Month (lbs)	AUEM per Acre	Acres per AUEM
One grazing period 1972-1976							
Unfertilized	2676.60a	669.15a	0.7657a	19.91a	607.17a	1.10a	0.92a
Fertilized	4010.00a	1002.50a	0.7574a	19.69a	600.65a	1.68a	0.64a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 4. Mean steer performance on native rangeland treatments, 1972-1976.

Treatments	Mean Steer initial weight (lbs)	Mean Steer final weight (lbs)	Mean Steer Gain per Head (lbs)	Mean Steer Gain per Day (lbs)	Mean Steer Gain per Acre (lbs)
One grazing period 1972-1976					
Unfertilized	700.92a	786.62a	85.70a	1.40a	56.18a
Fertilized	690.86a	781.36a	90.50a	1.51a	89.10a

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 5. Biweekly average daily gain for steers on native rangeland treatments, 1972-1976.

Treatments	1-15 Jun	16-30 Jun	1-15 Jul	16-31 Jul	1-15 Aug	16-31 Aug	1-15 Sep	Mean gain per Day
One grazing period 1972-1976								
Unfertilized		1.28	1.51	1.56	1.40	1.49	1.58	1.40
Fertilized		1.75	1.78	1.67	1.28	1.24	1.31	1.51

Table 6. Herbage biomass production and forage utilization on native rangeland treatments, 1972-1976.

Treatments	Aboveground Herbage Biomass Pregrazed (lbs/acre)	Ungrazed (lbs/acre)	Grazed (lbs/acre)	Forage Utilized (lbs/acre)	Percent Utilization (%)	Forage per steer (lbs/day)
One grazing period 1972-1976						
Unfertilized		2676.60a	1660.60a	1016.00a	38.21a	27.26a
Fertilized		4010.00a	2337.20a	1672.80a	42.07a	29.48a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 7. Costs and returns after pasture costs for steers on native rangeland treatments, 1972-1976.

Treatments	Land Area per Period (acres)	Production Cost per Acre ($)	Cost per Period ($)	Steer Weight Gain per Period (lbs)	Steer Weight Value @ $0.70/lb ($)	Net Return per Steer ($)	Net Return per Acre ($)	Cost per Pound Steer Gain ($)
One grazing period 1972-1976								
Unfertilized	2.04a	8.76	17.87a	85.70a	59.99a	42.12a	20.80a	0.26a
Fertilized	1.38b	21.26	29.30b	90.50a	63.35a	34.05a	25.10a	0.40a

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 8. Precipitation in inches for growing season months and the annual total precipitation for 1978-1982, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1978	1.81	3.99	2.10	2.41	2.01	2.56	0.29	15.17	17.63
% of LTM	126.57	170.51	59.15	108.56	116.18	192.48	30.53	111.96	110.19
1979	1.28	0.91	3.06	2.22	2.21	1.27	0.17	11.12	12.81
% of LTM	89.51	38.89	86.20	100.00	127.75	95.49	17.89	82.07	80.06
1980	0.03	0.12	2.67	1.43	3.31	0.76	2.41	10.73	12.58
% of LTM	2.10	5.13	75.21	64.41	191.33	57.14	253.68	79.19	78.63
1981	0.66	1.30	3.71	1.57	4.05	2.75	0.23	14.27	15.76
% of LTM	46.15	55.56	104.51	70.72	234.10	206.77	24.21	105.31	98.50
1982	1.85	4.32	3.43	2.02	2.63	1.77	6.51	22.53	26.58
% of LTM	129.37	184.62	96.62	90.99	152.02	133.08	685.26	166.27	166.13
1978-1982	1.13	2.13	2.99	1.93	2.84	1.82	1.92	14.76	17.07
% of LTM	79.02	91.03	84.23	86.94	164.16	136.84	202.11	108.93	106.69

Table 9. Mean stocking rates for cow-calf pairs on native rangeland treatments, 1978-1982.

Treatments	Grazing Period Dates	Days in Period	Months in Period	Number of Cow-Calf Pairs	Number of AUEM	AUEM per Acre	Acres per AUEM
One grazing period 1978-1979, 1981-1982							
Unfertilized	21 Jun-5Aug	45a	1.47a	10a	14.61a	0.82a	1.38a
Fertilized	25 Jun-15 Aug	51a	1.68a	10a	16.49a	1.37a	0.82a
Drought Season 1980							
Unfertilized	7 Jul-23 Jul	16	0.52	7	3.93	0.22	4.58
Fertilized	7 Jul-23 Jul	16	0.52	7	3.84	0.32	3.12

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 10. Stocking rates for cow-calf pairs determined from monthly standing herbage biomass and June animal unit equivalent (AUE), 1978-1982.

Treatments	Mean Monthly Standing Herbage (lb/ac)	Mean Forage Available (lb/ac)	June AUE	Forage per Day (lbs)	Forage per Month (lbs)	AUEM per Acre	Acres per AUEM
One grazing period 1978-1979, 1981-1982							
Unfertilized	1718.48a	429.62a	1.0433a	27.13a	827.36a	0.52a	1.93a
Fertilized	2824.41a	706.10a	1.0354a	26.92a	821.05a	0.86a	1.25a
Drought Season 1980							
Unfertilized	1296.45	324.11	1.0799	28.08	856.36	0.38	2.64
Fertilized	1386.85	346.71	1.0557	27.45	837.17	0.41	2.42

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 11. Mean cow performance on native rangeland treatments, 1978-1982.

Treatments	Mean Cow initial weight (lbs)	Mean Cow final weight (lbs)	Mean Cow Gain per Head (lbs)	Mean Cow Gain per Day (lbs)	Mean Cow Gain per Acre (lbs)
One grazing period 1978-1979, 1981-1982					
Unfertilized	1058.53a	1087.75a	29.23a	0.74a	15.91a
Fertilized	1047.63a	1045.98a	-1.65a	-0.03a	-1.50a
Drought Season 1980					
Unfertilized	1107.90	1108.60	0.70	0.04	0.27
Fertilized	1075.00	1065.00	-10.00	-0.63	-5.83

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 12. Mean calf performance on native rangeland treatments, 1978-1982.

Treatments	Mean Calf initial weight (lbs)	Mean Calf final weight (lbs)	Mean Calf Gain per Head (lbs)	Mean Calf Gain per Day (lbs)	Mean Calf Gain per Acre (lbs)
One grazing period 1978-1979, 1981-1982					
Unfertilized	217.60a	301.58a	83.98a	1.89a	44.93a
Fertilized	234.20a	311.65a	77.45a	1.51a	61.45a
Drought Season 1980					
Unfertilized	287.90	320.00	32.10	2.01	12.48
Fertilized	286.40	312.90	26.50	1.66	15.46

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 13. Mean cow and calf performance on native rangeland treatments, 1978-1982.

Treatments	COW Gain per Head (lbs)	COW Gain per Day (lbs)	COW Gain per Acre (lbs)	CALF Gain per Head (lbs)	CALF Gain per Day (lbs)	CALF Gain per Acre (lbs)
One grazing period 1978-1979, 1981-1982						
Unfertilized	29.23a	0.74a	15.91a	83.98a	1.89a	44.93a
Fertilized	-1.65a	-0.03a	-1.50a	77.45a	1.51a	61.45a
Drought Season 1980						
Unfertilized	0.70	0.04	0.27	32.10	2.01	12.48
Fertilized	-10.00	-0.63	-5.83	26.50	1.65	15.46

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 14. Biweekly average daily gain for cow-calf pairs on native rangeland treatments, 1978-1982.

Treatments	1-15 Jun	16-30 Jun	1-15 Jul	16-31 Jul	1-15 Aug	16-31 Aug	1-15 Sep	Mean gain per Day
One grazing period 1978-1979, 1981-1982								
Cow								
Unfertilized		1.23	1.23	0.22	0.25	-0.25		0.74
Fertilized		1.23	1.27	0.25	-0.88	-1.79	-2.52	-0.03
Calf								
Unfertilized		1.91	1.91	1.89	1.90	1.77		1.89
Fertilized		1.79	1.91	1.72	1.42	0.96	0.46	1.51
Drought Season 1980								
Cow								
Unfertilized			0.04	0.04				0.04
Fertilized			-0.63	-0.63				-0.63
Calf								
Unfertilized			2.01	2.01				2.01
Fertilized			1.65	1.65				1.65

Table 15. Herbage biomass production and forage utilization on native rangeland treatments, 1978-1982.

Treatments	Aboveground Herbage Biomass Pregrazed (lbs/acre)	Ungrazed (lbs/acre)	Grazed lbs/acre)	Forage Utilized (lbs/acre)	Percent Utilization (%)	Forage per Cow-Calf Pair (lbs/day)
One grazing period 1978-1979, 1981-1982						
Unfertilized	1608.18a	1828.78a	1147.63a	681.15a	36.23a	30.94a
Fertilized	2705.60a	2943.23a	1489.53a	1453.70a	51.53a	39.94a
Drought Season 1980						
Unfertilized	1389.10	1203.80	976.50	227.30	18.90	36.53
Fertilized	1465.30	1308.40	756.90	551.50	42.20	59.09

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 16. Costs and returns after pasture costs for cow-calf pairs on native rangeland treatments, 1978-1982.

Treatments	Land Area per Period (acres)	Production Cost per Acre ($)	Cost per Period ($)	Calf Weight Gain per Period (lbs)	Calf Weight Value @ $0.70/lb ($)	Net Return per Cow-Calf Pair ($)	Net Return per Acre ($)	Cost per Pound Calf Gain ($)
One grazing period 1978-1979, 1981-1982								
Unfertilized	1.83a	8.76	16.01a	83.98a	58.78a	42.77a	23.74a	0.21a
Fertilized	1.23b	21.26	26.15b	77.45a	54.22a	28.06a	23.21a	0.39a
Drought Season 1980								
Unfertilized	2.38	8.76	20.85	32.10	22.47	1.62	0.68	0.65
Fertilized	1.62	21.26	34.44	26.50	18.55	-15.89	-9.81	1.30

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 17. Monthly dry matter weight in pounds per acre for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

Plant Categories Treatments	15 May	15 Jun	15 Jul	15 Aug	15 Sep
Unfertilized					
cool season	429.6	834.9	1506.1	1232.0	1147.7
warm season	9.3	178.1	520.2	965.9	404.4
total native grass	438.9	1013.0	2026.3	2197.9	1552.1
introduced grass	0.0	0.0	0.0	0.0	0.0
forbs	31.4	199.5	231.6	222.6	203.4
total yield	470.3	1212.5	2257.9	2420.5	1755.5
Fertilized					
cool season	1085.4	2690.6	3260.0	2332.8	2233.6
warm season	54.2	71.0	229.8	162.7	126.1
total native grass	1139.6	2761.6	3489.8	2495.5	2359.7
introduced grass	0.0	201.2	895.9	707.1	264.0
forbs	10.7	205.5	480.3	638.0	133.2
total yield	1150.3	3168.3	4866.0	3840.6	2756.9

Table 18. Percent herbage growth and senescence of plant categories for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

Plant Categories Treatments	15 May	15 Jun	15 Jul	15 Aug	15 Sep
Unfertilized					
cool season	28.52	26.91	44.57	-18.20	-5.60
warm season	0.96	17.48	35.42	46.14	-58.13
total native grass	19.97	26.12	46.10	7.81	-29.38
introduced grass	0.0	0.0	0.0	0.0	0.0
forbs	13.56	72.58	13.86	-3.89	-8.29
total yield	19.43	30.66	43.19	6.72	-27.47
Fertilized					
cool season	33.29	49.24	17.47	-28.44	-3.04
warm season	23.59	7.31	69.10	-29.20	-15.93
total native grass	32.66	46.48	20.87	-28.49	-3.89
introduced grass	0.0	22.46	77.54	-21.07	-49.46
forbs	1.68	30.53	43.07	24.72	-79.12
total yield	23.64	41.47	34.89	-21.07	-22.27

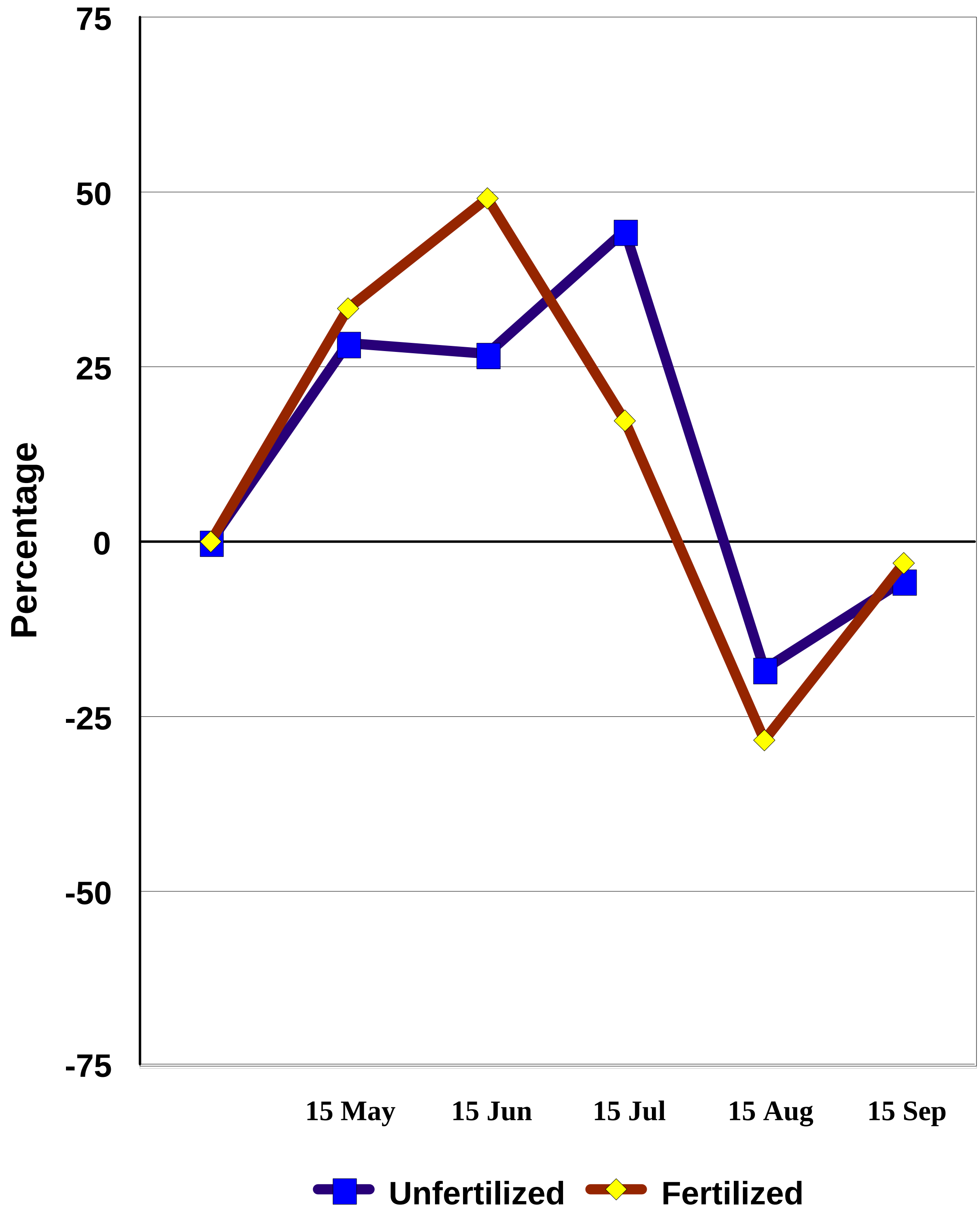

Figure 1. Percent herbage growth and senescence of cool season grasses for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

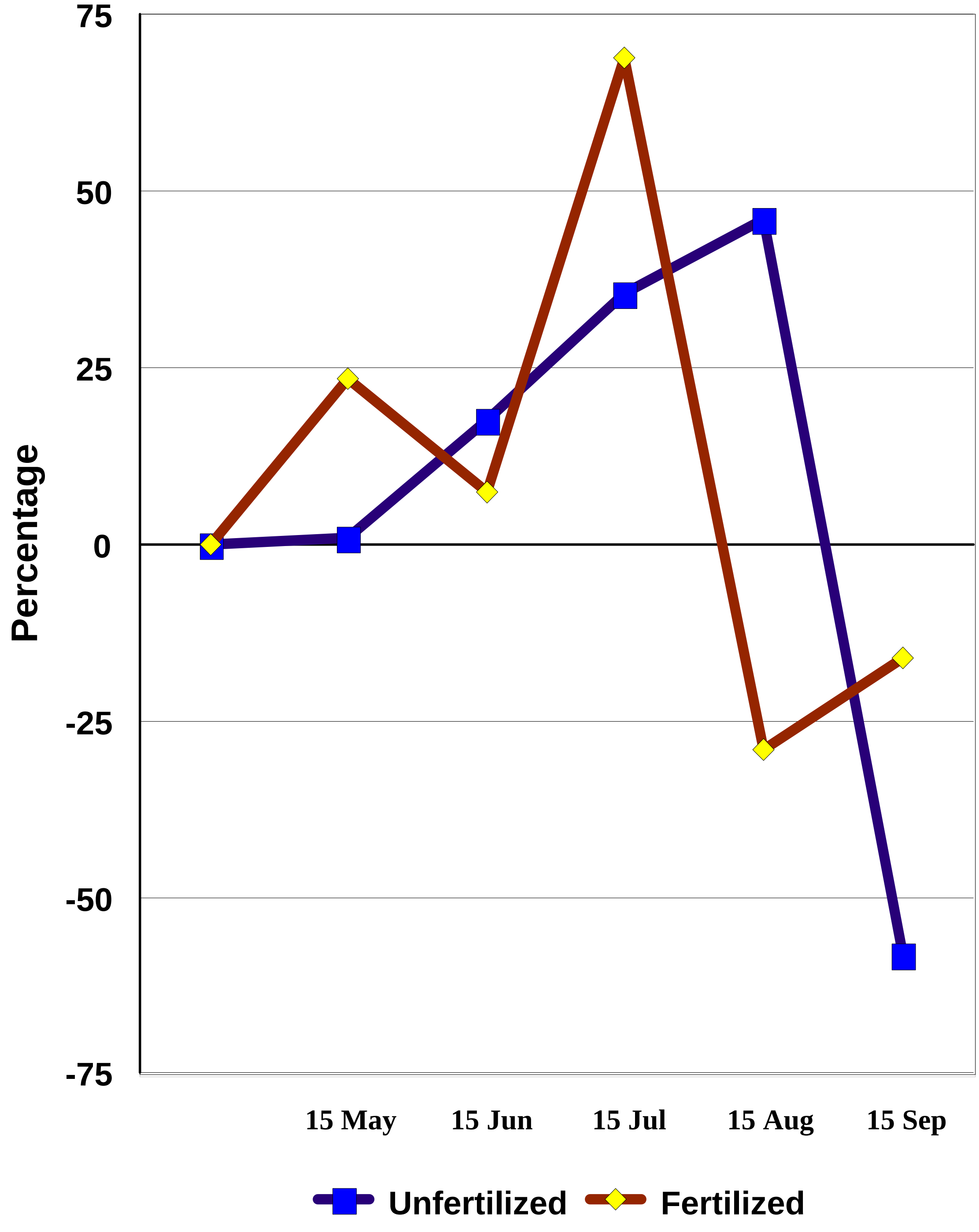

Figure 2. Percent herbage growth and senescence of warm season grasses for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

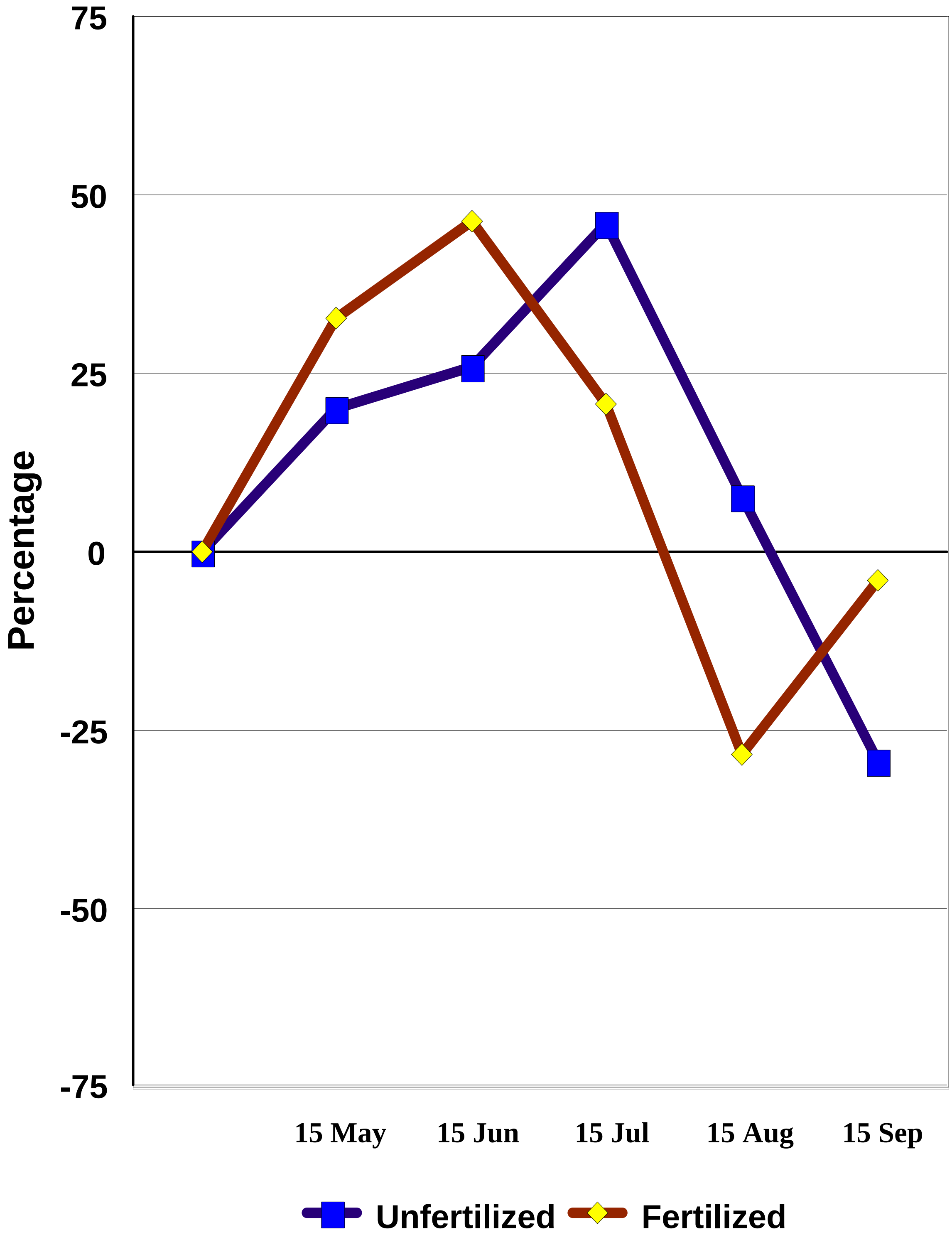

Figure 3. Percent herbage growth and senescence of total native grasses for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

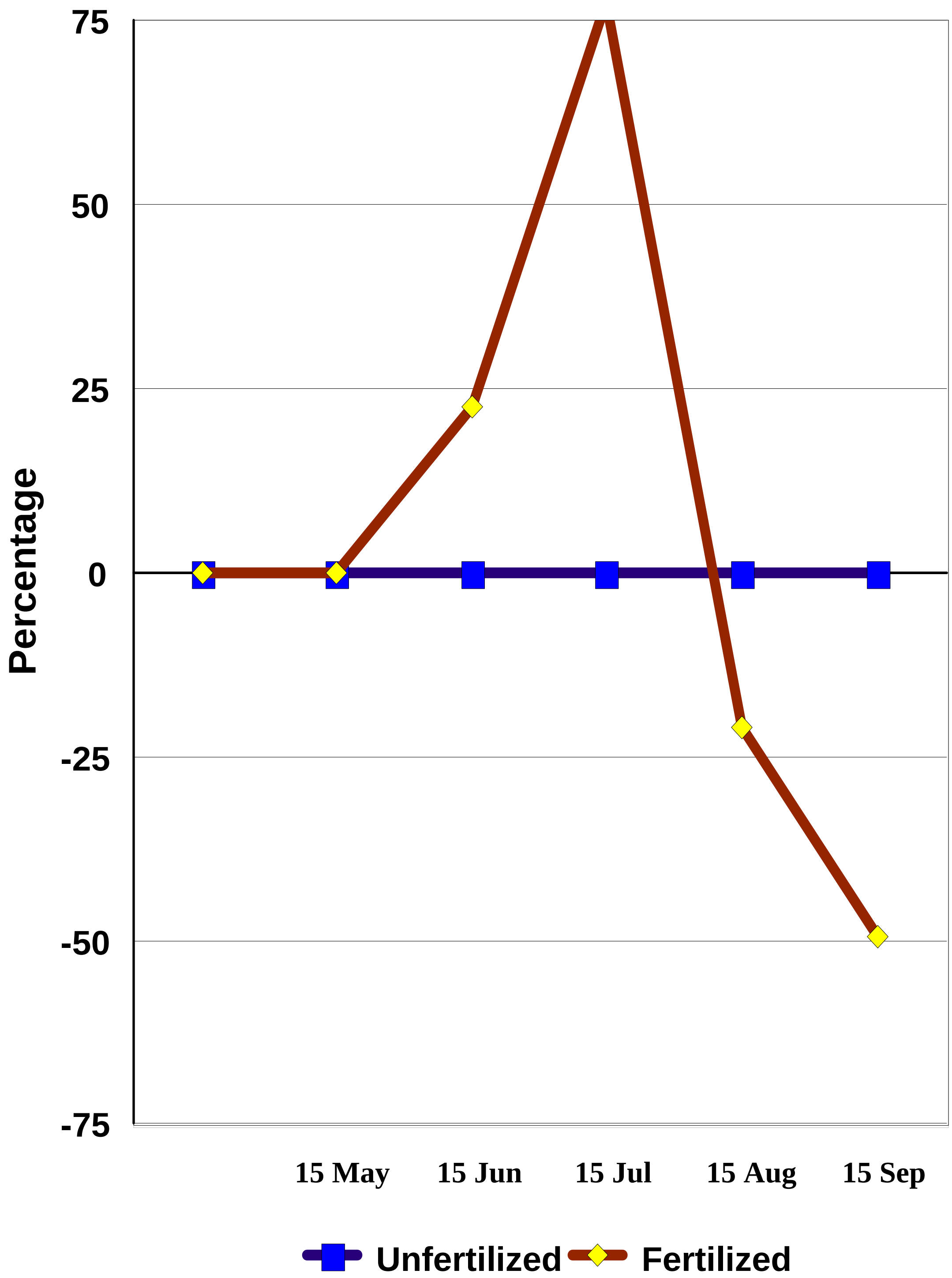

Figure 4. Percent herbage growth and senescence of introduced grasses for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

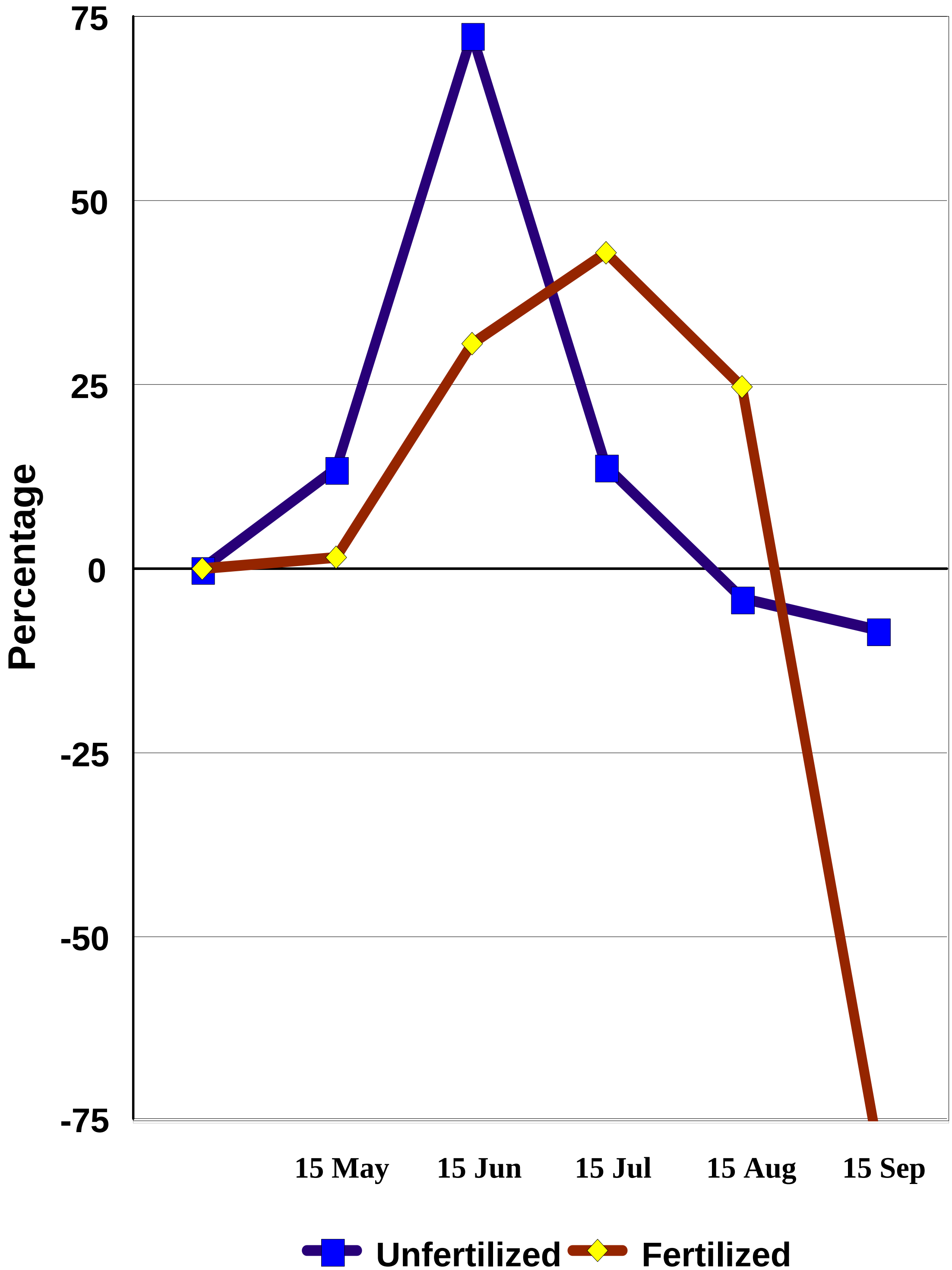

Figure 5. Percent herbage growth and senescence of forbs for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

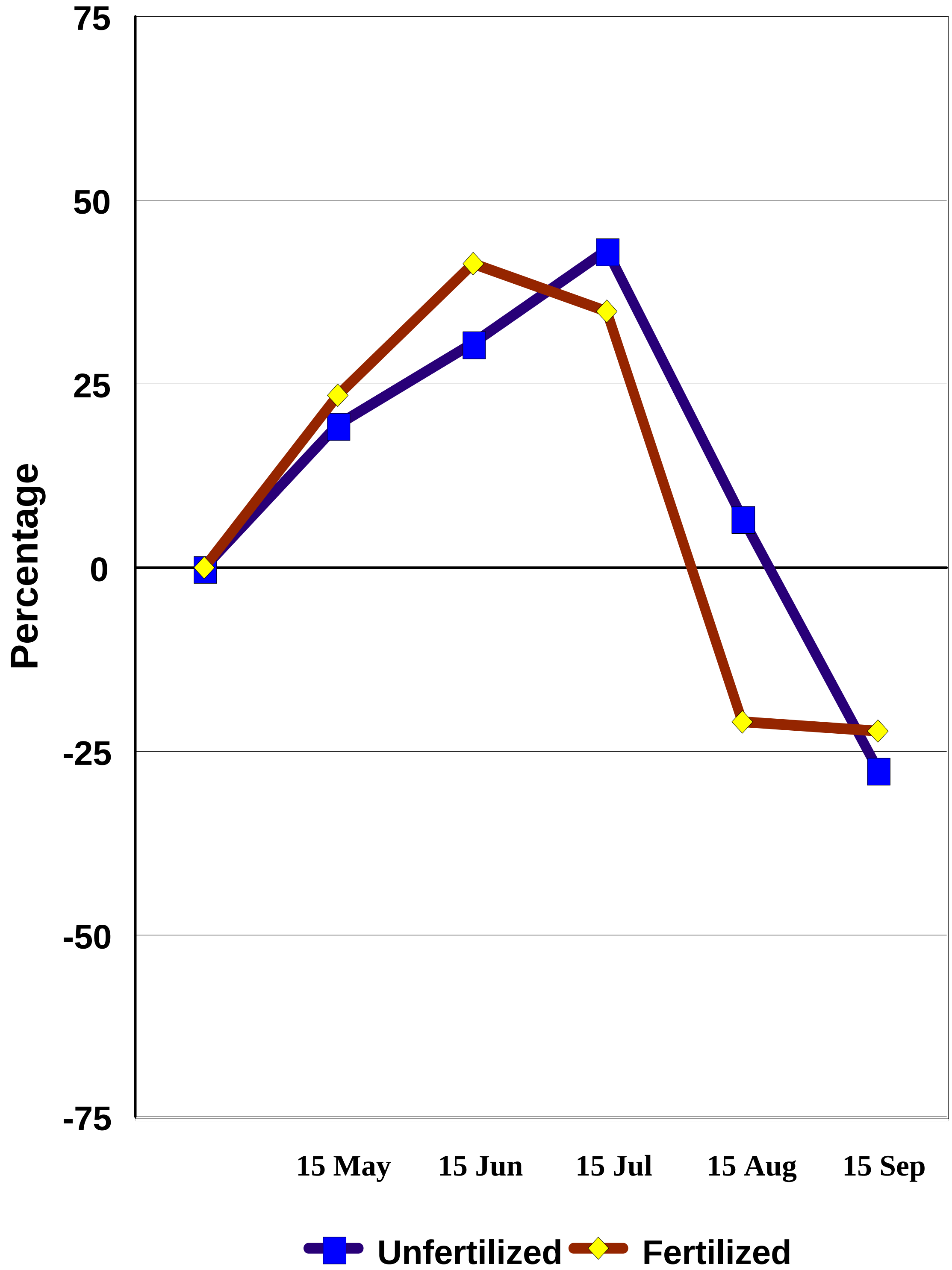

Figure 6. Percent herbage growth and senescence of total yield for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

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Fate of Applied Fertilizer Nitrogen on Native Rangeland

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Residual effects from nitrogen fertilizer in grasslands appear to be much more prolonged than for cultivated soils (Power and Alessi 1971).

The fate of applied fertilizer nitrogen on native rangeland ecosystems is dependent on the immobilization and mineralization of nitrogen by various biotic and abiotic factors called nitrogen sinks. Power (1977) determined the nitrogen content in the various sinks of a grazed semiarid native mixed grass prairie ecosystem near Mandan, ND that had been annually fertilized with 80 lbs N/ac for 11 years by G.A. Rogler and R.J. Lorenz. Power (1977) subtracted the nitrogen content of the various nitrogen sinks of the unfertilized pasture from the nitrogen content of the respective sinks of the fertilized pasture to determine the content and percentage of the applied fertilizer nitrogen in each nitrogen sink. The fate of nitrogen as a percent of applied fertilizer determined by Power (1977) is shown in the left column of table 1. The fate of applied fertilizer nitrogen during one year (50 lbs N/ac per year) and during eleven years (550 lbs N/ac per 11 years) of the fertilization of native rangeland grazing study conducted at the Dickinson Research Extension Center (1972-1982) are shown in the center and right columns of table 1, respectively.

The largest nitrogen sinks after eleven years of fertilization treatments were the soil mineral nitrogen (41%), grass root material (19%), and organic surface litter (16%). Fertilizer nitrogen remaining in the aboveground herbage and grass crowns was only 3% (Power 1977) (table 1). None of the fertilizer nitrogen was lost by leaching through the soil profile (Power 1970). The nitrogen not accounted for was 18%, of which other research suggests 5% was gaseous nitrogen lost to the atmosphere and 13% was immobilized in soil organic matter (Power 1975).

Black and Wight (1972) concluded that the plant-soil nutrient cycling systems of rangeland have a large portion of the soil nitrogen required for plant growth tied up in the organic phase in relatively unavailable forms. A large amount of fertilizer nitrogen was immobilized into grass roots, soil organic matter, and microbial tissue. About half of the immobilized nitrogen was found in the grass roots. The nitrogen immobilization capacity in grassland soils was somewhat variable and was influenced by soil texture, vegetation type, root growth, lignin content of organic matter, amount and mineralogy of clay material, and environmental parameters of soil temperature, soil oxygen, and soil water (Power 1972). The immobilized nitrogen in organic forms could be mineralized later by soil microorganisms and recirculated through the ecosystem. Mineralization breaks down organic materials into ammonia and carbon dioxide, or other low molecular weight carbon compounds. Most of the ammonia released is readily hydrolyzed to the ammonium form. Some of the ammonium is nitrified by oxidation to the nitrite form, then oxidized again to the nitrate form. The ammonium and nitrate produced by the mineralization and nitrification processes are added to the plant available inorganic (mineral) nitrogen pool in the soil (Power 1972).

Soil mineral nitrogen (ammonium NH_4 and nitrate NO_3) was available above the 3 foot soil depth in early spring the first year on high fertilization treatment rates greater than 160 lbs N/ac. Lower fertilization rates, greater than 40 lbs N/ac, required two to six years before increased inorganic nitrogen was available during early spring (Power 1972). Power (1977) determined after 11 years of annual applications of ammonium nitrate that 41% of the applied fertilizer nitrogen was available as soil mineral nitrogen with a small amount in the ammonium form (2%) and most in the nitrate form (39%) (table 1).

Only a small amount of fertilizer nitrogen was assimilated into the aboveground herbage per year. Smika et al. (1961) determined the fertilizer nitrogen fate after 9 years of annual applications of ammonium nitrate that 11.1% of the 30 lbs N/ac rate and that 18.8% of the 90 lbs N/ac rate had been incorporated into the aboveground herbage. Smika et al. (1965) determined the fertilizer nitrogen fate after 4 years of annual applications of ammonium nitrate that under natural moisture conditions 17% to 25% of the applied nitrogen was incorporated into the aboveground herbage. Power (1977) determined the aboveground fertilizer nitrogen fate at the end of the eleventh growing season of a grazed semiarid rangeland pasture with annual applications of ammonium nitrate to be at least a total of 18% and that 2% remained in the live aboveground herbage and 16% remained in the organic surface litter (table 1).

Livestock grazing removes only a small portion of the nitrogen from the aboveground herbage, leaving a significant part of the nitrogen in the remaining live aboveground herbage, the standing dead vegetation, and the litter. Most of the nitrogen consumed by grazing livestock is returned to the soil surface in urine and feces waste. Grazing livestock retain only a small amount of the nitrogen consumed, about 15% in a nonlactating animal and about 30% in a lactating animal (Russelle 1992). Power (1977) determined that about 3% of the applied nitrogen was removed from the grassland pasture as livestock product (table 1).

Some soil mineral nitrogen is immobilized when fixed by adsorption onto clay particles. The type of clay mineral affects the retention of ammonium. Clay materials with expanding lattices, such as montmorillonite, have greater surface area and adsorptive capacity for ammonium than clay minerals with nonexpanding lattices, such as kaolinite (Legg 1975).

Soil nitrogen is lost to the atmosphere through denitrification and ammonia volatilization. Denitrification is the reduction of the nitrite or nitrate mineral nitrogen to form nitrous oxide or dinitrogen gas. Denitrification probably accounts for only a small part of total nitrogen losses from pastures and rangeland because grass plants readily take up mineral nitrogen. Gaseous ammonia forms during mineralization of soil organic nitrogen to ammonium. Under some conditions the ammonia escapes into the atmosphere by volatilization. Ammonia volatilization losses generally increase with increasing aridity. Power (1977) estimated that about 5% of the applied nitrogen was lost to the atmosphere in gaseous form (table 1).

Fertilizer nitrogen applied to native rangeland soils is retained at greater quantities for considerably longer time periods than the same amount of fertilizer nitrogen applied to cropland soils because of the relatively rapid immobilization of mineral nitrogen into organic forms by perennial grass roots and soil microbial activity. These living components of grassland ecosystems can immobilize about 178 lbs N/ac in one growing season and around 285 lbs N/ac to 339 lbs N/ac within three or four years and the amount of nitrogen immobilized in live tissue can remain near that high range thereafter (Power 1972). The turnover rate of immobilized organic root material operates on a 3- to 4-year cycle (Power 1972). Mineralization of some of the organic nitrogen immobilized in perennial grass roots increases the supply of available mineral nitrogen (Power 1977). Rates of immobilization of mineral nitrogen to organic nitrogen and rates of mineralization of organic nitrogen to mineral nitrogen effect the quantity of available mineral nitrogen in grassland soils.

Cropland soils lack perennial grass roots and the ability to preserve a large portion of the mineral nitrogen as immobilized organic nitrogen. Mineral nitrogen in cropland soils is vulnerable to great losses through denitrification and ammonia volatilization.

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Table 1. Fate of applied fertilizer nitrogen on native rangeland pasture, 1972-1982, following first approximation percentages of fertilizer nitrogen fate in grazed semiarid rangeland developed by Power (1977).

Biotic and Abiotic Nitrogen Sinks	Fate of N as Percent of Applied Data from Power 1977 %			Fate of N from 50 lbs N/ac per year lbs N/yr			Fate of N from 550 lbs N/ac per 11 years lbs N/11 yrs		
Retained in Ecosystem			92%			46.0			506.0
Plants		22%			11.0			121.0	
aboveground herbage	2%			1.0			11.0		
crown	1%			0.5			5.5		
roots	19%			9.5			104.5		
Litter		16%			8.0			88.0	
Soil Mineral Nitrogen		41%			20.5			225.5	
ammonium NH_4	2%			1.0			11.0		
nitrate NO_3	39%			19.5			214.5		
Soil Organic Nitrogen unmeasured estimate		13%			6.5			71.5	
Lost to Ecosystem			8%			4.0			44.0
Beef Tissue		3%			1.5			16.5	
Gaseous Losses unmeasured estimate		5%			2.5			27.5	
Leaching		0%			0.0			0.0	

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Evaluation of Plant Species Shift on Fertilized Native Rangeland

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Nitrogen fertilization of native rangeland results in a plant species composition shift with an increase in mid cool season grasses and a decrease in short warm season grasses and these changes have been shown to occur from 30 and 90 lbs N/ac annually applied in fall and monitored for 7 years (Rogler and Lorenz 1957), from 33, 67, and 100 lbs N/ac annually applied to two range sites in spring and monitored for 2 years (Whitman 1963), from 33, 67, and 100 lbs N/ac annually applied to four range sites in spring and monitored for 6 years (Whitman 1969, Goetz 1969), from 30, 60, 120, 240, and 480 lbs N/ac applied over 1 year, 3 years, and 6 years in spring and monitored for 6 years (Power and Alessi 1971), from 40, 80, and 160 lbs N/ac annually applied with and without phosphate in fall and monitored for 8 years (Lorenz and Rogler 1972), from 100 lbs N/ac annually applied for 3 years in fall and monitored for 15 years (Taylor 1976), from 67 and 100 lbs N/ac annually and biennially applied in spring and 200, 300, and 400 lbs N/ac applied one time and monitored for 8 years (Whitman 1978, Goetz et al. 1978), and from low rates of less than 100 lbs N/ac annually applied in spring and high rates of greater than 100 lbs N/ac applied one time and monitored for 10 years (Wight and Black 1979). This shift in plant species composition was, at first, considered to be a beneficial change and a process to restore the natural balance in the botanical species composition of the Northern Plains mixed grass prairie.

The disruption of the natural species composition was caused during the homestead period between 1900 and 1936 by excessively heavy grazing with stocking rates greater than 60% heavier than the biological carrying capacity (Whitman et al. 1943). The resulting deterioration in the Northern Plains mixed grass prairie caused a decrease in herbage biomass production and a disproportional reduction of mid cool season grass species, such as western wheatgrass, and leaving a predominance of short warm season grass species, such as blue grama.

Heavy grazing damages grass species with long shoot tillers to a greater extent than grass species with short shoot tillers. Grass species with long shoots elevate the apical meristem a short distance above ground level by internode elongation while still in the vegetative phase (Dahl 1995) exposing the elevated apical meristem to removal by grazing prior to flowering. Grass species with short shoots do not produce significant internode elongation during vegetative growth and the apical meristem remains below grazing or cutting height until the flower stalk elongates during the sexual reproductive phase (Dahl 1995). Grass species with long shoots are nearly always decreased at greater rates than grass species with short shoots in pastures that are repeatedly grazed heavily (Branson 1953).

Application of nitrogen fertilizer to native rangeland in spring or fall, at low rates, high rates, annually, biennially, or one time all cause a shift in species composition with an increase in mid cool season grasses and a decrease in short warm season grasses. These multiple variables, however, do affect the rates of change differently and the shift in plant species composition does not occur at the same rate under different conditions. Cultural management practices of nitrogen fertilization that seemed to restore the natural species composition balance and appeared to correct existing problems were initially considered to be beneficial.

However, Goetz et al. (1978) found several undesirable aspects related to the changes in plant species composition that have implications of adverse consequences for mixed grass prairie communities. Detrimental complications could develop from synthetically induced changes in plant species because the increasing mid cool season grasses were primarily single stalked, low-cover, plants and the decreasing short warm season grasses were primarily multiple stemmed, high-cover, plants and the shift in plant species would cause a decrease in basal cover and a reduction in live plant material covering the soil and would open an otherwise closed community. The resulting reductions in ground cover would expose greater amounts of soil to erosion and to higher levels of solar radiation, and would create larger areas of open spaces available for potential invasion by undesirable perennial forbs, domesticated cool season grasses, and introduced annual and perennial grasses.

Eventhough, the nitrogen fertilization plot studies conducted in the Northern Plains from the early 1950's to the mid 1980's were comparatively long with 6 to 10 years of monitoring data, none of the studies were conducted long enough to fully document the undesirable changes proposed by Goetz et al. 1978. Taylor (1976) conducted a study for 15 years and found that residual effects from nitrogen fertilization of native rangeland were still occurring 12 years after the treatments had stopped.

This report uses compiled vegetation data from four studies to follow the plant species composition changes in a nitrogen fertilized mixed grass prairie community during 33 years from 1972 to 2004 and corroborates the adverse implications of nitrogen fertilization in native rangeland that were hypothesized to occur by Goetz et al. 1978.

Procedure

The changes in plant species composition evaluated during this investigation occurred in the mixed grass prairie communities of the unfertilized and nitrogen fertilized pastures of the fertilization of native rangeland grazing study. The research pastures were located on the SW½, sec. 23, T. 140 N., R. 97 W., at the Dickinson Research Extension Center. The native rangeland plant community was strongly rolling upland mixed grass prairie. The soils were Vebar, Parshall, and Flasher fine sandy loams. The control pasture was 18 acres of untreated native rangeland. The fertilized pasture was 12 acres of native rangeland fertilized annually with ammonium nitrate fertilizer (33-0-0) broadcast applied in granular form at a rate of 50 lbs N/ac in early spring, usually around early to mid April, for eleven years from 1972 to 1982. The growing season of 1982 was the last year of fertilizer application.

The unfertilized and fertilized native rangeland pastures were grazed by yearling steers from 1972 to 1976 and grazed by cow-calf pairs from 1977 to 1982 during mid June to late August or early September. The fertilized pasture grazing project was not conducted in 1983. A two grazing period study was conducted from 1984 to 1988 on the unfertilized pasture. The unfertilized pasture was grazed by cow-calf pairs for two periods per year with the first period during early to mid June and the second period during mid July to mid August. The fertilized pasture was not fertilized after 1982 and was grazed by cow-calf pairs from 1984 to 1988 one period during mid June to late August or early September. Grazing studies were terminated at this location and the pastures were grazed by cattle that were not in research projects. The pastures were used from 1989 to 2004 for one period usually during early June to late August.

Aboveground herbage biomass production was sampled on the unfertilized and fertilized native rangeland pastures by the clipping method from inside and outside exclosure cages in 1972 to 1982, on the unfertilized pasture from inside and outside exclosure cages in 1984 to 1988, and on the unfertilized and fertilized pastures in 1997 to 2004. The exclosures were steel wire quonset type cages measuring 3 X 7 foot. During 1972 to 1988, the exclosures were distributed in a systematic grid with an average of 20 exclosures per pasture. The exclosure cages were moved within the respective grids every spring. All of the herbage samples were oven dried and weighed. During 1972 to 1976, dry aboveground herbage biomass was sampled by hand clipping to ground level from 2.5 X 5.0 foot (0.75 X 1.5 meter) heavy steel frames with one clip per year at the end of the grazing period during mid August to mid September. The plant material was not separated into categories. During 1977 to 1981, dry aboveground herbage biomass was sampled by hand clipping to ground level from 0.82 X 3.28 foot (0.25 X 1.0 meter) light weight steel frames with two clippings per year at the beginning and end of the grazing period with the first clip during mid June to mid July and the second clip during late July to mid August. The plant material was not separated into categories. During 1982 to 1988, dry aboveground herbage biomass was sampled by hand clipping to ground level from 0.82 X 3.28 foot (0.25 X 1.0 meter) light weight steel frames with four clippings per year with the first clip during early to mid June, the second clip during mid June to mid July, the third clip during mid July to mid August, and the fourth clip during mid August to mid September. The plant material was separated into five categories: warm season grasses, cool season grasses, sedges, introduced grasses, and forbs. An additional clip was conducted during mid May in 1982. Herbage weight data were not collected in 1983.

Herbage samples were not collected between 1989 and 1996. During 1997 to 2004, the unfertilized and fertilized native rangeland pastures were each separated into three equal sized replicated sample zones; west, middle, and east. Dry aboveground herbage biomass was sampled by hand clipping to ground level from three to five 0.82 X 3.28 foot (0.25 X 1.0 meter) light weight steel frames from each of the three replicated zones with one clip per year during late June to mid August. The plant material was separated into five categories: warm season grasses, cool season grasses, sedges, introduced grasses, and forbs. The exclosure cages had been moved to other research pastures and the sites clipped were areas with no or low herbage removed by grazing livestock. Herbage weight data were not collected in 2003.

Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method during the period of mid July to mid August, on the unfertilized and fertilized pastures in 1982, on the unfertilized pasture in 1985 to 1988, and on the unfertilized and fertilized pastures in 1998-2004.

Results

The precipitation during the growing seasons of 1972 to 1976 was normal or greater than normal (table 1). During 1972, 1973, 1974, 1975, and 1976, 18.57 inches (137.05% of LTM), 11.83 inches (87.31% of LTM), 12.45 inches (91.88% of LTM), 15.26 inches (112.62% of LTM), and 10.84 inches (80.00% of LTM) of precipitation were received, respectively. Perennial plants were under water stress conditions during September, 1972; July, August, and October, 1973; July, August, September, and October, 1974; July, August, and September, 1975; and July and August, 1976 (Manske 2009).

The precipitation during the growing seasons of 1977 to 1982 was normal or greater than normal (table 1). During 1977, 1978, 1979, 1980, 1981, and 1982, 18.65 inches (137.64% of LTM), 15.17 inches (111.96% of LTM), 11.12 inches (82.07% of LTM), 10.73 inches (79.19% of LTM), 14.27 inches (105.31% of LTM), and 22.53 inches (166.27% of LTM) of precipitation were received, respectively. Perennial plants were under water stress conditions during April and July, 1977; October, 1978; October, 1979; April, May, July, and September, 1980; and July and October, 1981. The April through July precipitation received in 1980 was 44.5% of the LTM causing drought conditions, and August and October of 1980 were wet months. Perennial plants did not experience water stress conditions during 1982 (Manske 2009).

The precipitation during the growing seasons of 1997 to 2004 was normal or greater than normal (table 2). During 1997, 1998, 1999, 2000, 2001, 2002, 2003, and 2004, 14.74 inches (108.78% of LTM), 20.51 inches (151.37% of LTM), 14.20 inches (104.80% of LTM), 11.91 inches (87.90% of LTM), 17.74 inches (130.92% of LTM), 15.47 inches (114.17% of LTM), 11.45 inches (84.50% of LTM), and 10.26 inches (75.77% of LTM) of precipitation were received, respectively. Perennial plants were under water stress conditions during August and September, 1997; July and October, 1999; August and September, 2000; August and October, 2001; September, 2002; July and August, 2003; and June and August, 2004. The April through August precipitation received in 2004 was 52.8% of the LTM causing mild drought conditions. Perennial plants did not experience water stress conditions during 1998 (Manske 2009).

Trial I (1972-1976)

The unfertilized and fertilized pasture herbage weight samples collected in 1972 to 1976 were clipped to ground level from inside and outside exclosure cages one time per growing season during the clip period of mid August to mid September. Some previous years standing dead were included in the samples collected from inside the exclosure cages. The herbage samples were not separated into categories. The reported data were mean total ungrazed herbage from the one clip period.

Mean aboveground total ungrazed herbage weight during 1972 to 1976 was 2676.60 lbs per acre on the unfertilized pasture and was 4010.00 lbs per acre on the fertilized pasture during the clip period of mid August to mid September (table 3). The total ungrazed herbage weight on the fertilized pasture was 49.8% greater than, but not significantly different ($P<0.05$) from, the total ungrazed herbage weight on the unfertilized native rangeland pasture.

Trial II (1977-1982)

The unfertilized and fertilized pasture herbage weight samples collected in 1977 to 1981 were clipped to ground level from inside and outside exclosure cages two times per growing season during the clip period of mid June to mid July and during the clip period of mid July to mid August. The herbage samples were not separated into categories. The reported data were mean total ungrazed herbage from the two clip periods.

Mean aboveground total ungrazed herbage weight during 1977 to 1979 and 1981 to 1982 was 1733.72 lbs per acre on the unfertilized pasture and was 2623.95 lbs per acre on the fertilized pasture during the two grazing season clip periods between early June and mid September (table 3). The mean total ungrazed herbage weight on the fertilized pasture was 51.3% greater than, but not significantly different ($P<0.05$) from, the mean total ungrazed herbage weight on the unfertilized native rangeland pasture. In 1980, drought conditions occurred from April through July with only 44.5% of the LTM precipitation received. The ungrazed herbage samples were collected 7 and 23 July after 2.67 inches of precipitation was received in June. Mean aboveground total ungrazed herbage weight during 1980 was 1296.45 lbs per acre on the unfertilized pasture and was 1386.85 lbs per acre on the fertilized pasture (table 3). The mean total ungrazed herbage weight on the fertilized pasture was 7.0% greater than, but not significantly different ($P<0.05$) from, the total ungrazed herbage weight on the unfertilized pasture.

The unfertilized and fertilized pasture herbage weight samples collected in 1982 were clipped to ground level from inside and outside exclosure cages five times per growing season. The first clip was during mid May before grasses were phenologically ready for grazing. After grasses were phenologically ready for grazing, the second clip was during the clip period of early to mid June, the third clip was during the clip period of mid June to mid July, the fourth clip was during the clip period of mid July to mid August, and the fifth clip was during the clip period of mid August to mid September. The herbage was separated into five categories: warm season grasses, cool season grasses, sedges, introduced and domesticated grasses, and forbs. The reported data was mean ungrazed herbage for each category and for the total yield of all categories from the four grazing season clip periods between early June and mid September.

The growing season of 1982 was the eleventh and last year with an application of 50 lbs N/ac on the fertilized native rangeland pasture. The effects from 11 years of fertilization on native rangeland vegetation were determined from herbage weight clipped during 5 periodic dates and separated into categories and from plant species composition determined by basal cover.

Cool season grasses on the unfertilized and fertilized pastures gained herbage weight during May, June, and July, and then lost aboveground biomass during August and September (table 4). Mean cool season grass herbage weight during the four grazing season clip periods between early June and mid September was 898.28 lbs per acre, composing 46.99%, on the unfertilized pasture and was 2392.55 lbs per acre, composing 65.41%, on the fertilized pasture. Mean cool season herbage weight on the fertilized pasture was 166.3% greater than mean cool season herbage weight on the unfertilized pasture. Mean sedge herbage weight on the unfertilized pasture was 281.90 lbs per acre, composing 14.75%, and was 236.70 lbs per acre, composing 6.47%, on the fertilized pasture. Mean sedge herbage weight on the fertilized pasture was 16.0% lower than that on the unfertilized pasture (tables 6 and 7).

Warm season grasses, total native grasses, and total yield on the unfertilized pasture gained herbage weight during May, June, July, and August, and lost aboveground biomass during September. Warm season grasses, total native grasses, and total yield on the fertilized pasture gained herbage weight during May, June, and July, and lost aboveground biomass during August and September (table 4). Mean warm season grass herbage weight during the four grazing season clip periods was 517.15 lbs per acre, composing 27.05%, on the unfertilized pasture and was 147.40 lbs per acre, composing 4.03%, on the fertilized pasture. Mean warm season grass herbage weight on the fertilized pasture was 71.5% lower than mean warm season grass herbage weight on the unfertilized pasture (tables 6 and 7).

Forbs on the unfertilized pasture gained herbage weight during May, June, and July, and lost aboveground biomass during August and September. Forbs on the fertilized pasture gained herbage weight during May, June, July, and August, and lost aboveground biomass during September (table 4). Mean forb herbage weight during the four grazing season clip periods was 214.27 lbs per acre, composing 11.21%, on the unfertilized pasture and was 364.25 lbs per acre, composing 9.96%, on the fertilized pasture. Almost all of the forb herbage weight on the fertilized pasture was fringed sage. Mean forb herbage weight on the fertilized pasture was 70.0% greater than mean forb herbage weight on the unfertilized pasture (tables 6 and 7).

Mean total native grass herbage weight on the fertilized pasture was 63.6% greater than mean total native grass herbage weight on the unfertilized pasture. Mean total yield herbage weight was 91.4% greater on the fertilized pasture than on the unfertilized pasture. The greater production of herbage weight on the fertilized pasture resulted from the increase in cool season grass and forb herbage weight and from the additional 517.05 lbs per acre of herbage weight produced by introduced and domesticated grasses that were not measured on the unfertilized pasture (tables 4 and 6).

Mean percent composition of herbage weight on the fertilized pasture was 39.2% greater for cool season grasses, and was 85.1% lower for warm season grasses, 56.1% lower for sedges, and 11.2%

lower for forbs than the percent composition of herbage weight of the respective categories on the unfertilized pasture (tables 5 and 7). Herbage weight of introduced and domesticated grasses, composed 14.1% of the mean total herbage yield on the fertilized pasture.

Mean percent total basal cover of the plant community during 1982 was 22.81% on the unfertilized pasture and was 17.47% on the fertilized pasture. Total basal cover on the fertilized pasture was 23.4% lower than total basal cover on the unfertilized pasture (table 8). Warm season grass basal cover was 9.94% on the unfertilized pasture and was 3.20% on the fertilized pasture. Warm season grass basal cover on the fertilized pasture was 67.8% lower than that on the unfertilized pasture. Basal cover of mid warm season grasses, primarily little bluestem and sideoats grama, had decreased 95.3% and basal cover of short warm season grasses, primarily blue grama, had decreased 65.9% on the fertilized pasture (table 13). Cool season grass basal cover was 4.47% on the unfertilized pasture and was 6.27% on the fertilized pasture. Cool season grass basal cover on the fertilized pasture was 40.3% greater than that on the unfertilized pasture. Basal cover of mid cool season grasses, primarily western wheatgrass and green needlegrass, had increased 94.3% and basal cover of short cool season grasses, primarily prairie Junegrass, had decreased 26.5% on the fertilized pasture (table 13). Sedge basal cover on the unfertilized pasture was 6.64% and was 5.70% on the fertilized pasture. Sedge basal cover on the fertilized pasture was 14.2% lower than that on the unfertilized pasture. Total native grass basal cover on the unfertilized pasture was 21.05% and was 15.17% on the fertilized pasture. Total native grass basal cover on the fertilized pasture was 27.9% lower than that on the unfertilized pasture. Domesticated grass basal cover was 0.36% on the unfertilized pasture and was 1.96% on the fertilized pasture. Domesticated grass basal cover on the fertilized pasture was 444.4% greater than that on the unfertilized pasture. The domesticated grasses were crested wheatgrass with a basal cover of 0.67% and smooth bromegrass with a basal cover of 0.63%. The introduced grasses were Kentucky bluegrass and Canada bluegrass with a combined basal cover of 0.66% (table 13). Forb basal cover on the unfertilized pasture was 1.40% and was 0.34% on the fertilized pasture. Forb basal cover on the fertilized pasture was 75.7% lower than that on the unfertilized pasture (table 8). The typical shift in plant species composition with an increase in mid cool season grasses and a decrease in short warm season grasses occurred as a result of eleven years of 50 lbs N/ac applied each spring. Total basal cover decreased 23.4% on the fertilized pasture because the increasing plants, consisting of native mid cool season grasses, domesticated mid cool season grasses, and introduced mid cool season grasses, were single stalked, low-cover plants and the decreasing plants, consisting of native mid and short warm season grasses, native short cool season grasses, and native upland sedges, were multiple stemmed, high-cover plants.

Trial III (1984-1988)

Herbage weight and basal cover samples were not collected on the fertilized pasture during 1984 to 1988. The unfertilized pasture herbage weight samples collected in 1984 to 1988 were clipped to ground level from inside and outside exclosure cages four times per growing season. The first clip was during the clip period of early to mid June, the second clip was during the clip period of mid June to mid July, the third clip was during the clip period of mid July to mid August, and the fourth clip was during the clip period of mid August to mid September. The herbage was separated into five categories: warm season grasses, cool season grasses, sedges, introduced and domesticated grasses, and forbs. The reported data for 1984 was mean ungrazed herbage for each category and for the total yield of all categories from two clip periods; the clip period of mid June to mid July, and the clip period of mid August and mid September. The reported data for 1985 to 1988 was mean ungrazed herbage for each category and for the total yield of all categories from the four grazing season clip periods conducted between early June and mid September.

Mean aboveground total ungrazed herbage weight during 1984 to 1987 was 1429.72 lbs per acre on the unfertilized pasture during the growing season periods between early June and mid September (tables 3 and 6). Mean warm season herbage weight was 293.45 lbs per acre and composed 20.3% of the total herbage weight. Mean cool season herbage weight was 416.35 lbs per acre and composed 29.1% of the total herbage weight. Mean sedge herbage weight was 581.99 lbs per acre and composed 41.1% of the total herbage weight. Mean total native grass herbage weight was 1291.78 lbs per acre and composed 90.5% of the total herbage weight. Mean forb herbage weight was 137.94 lbs per acre and composed 9.5% of the total herbage weight (tables 6 and 7). In 1988, severe drought conditions occurred during the entire growing season with only 48.4% of the LTM precipitation received from April through October. Mean aboveground total ungrazed herbage weight in 1988 was 451.23 lbs per acre on the unfertilized pasture during the growing season periods between early June and mid September (tables 3 and 6). Mean warm season herbage weight was 92.03 lbs per acre and composed 20.4% of the total herbage weight. Mean cool season herbage weight was 89.54 lbs per acre and composed 19.8% of the total herbage weight. Mean sedge herbage weight was 208.58 lbs per acre and composed 46.2% of the total herbage weight. Mean total native grass herbage weight was 390.15 lbs per acre and composed 86.5% of the total herbage weight. Mean forb herbage weight was 61.08 lbs per acre and composed 13.5% of the total herbage weight (tables 6 and 7).

Mean total basal cover during 1985 to 1987 was 30.59% on the unfertilized pasture (table 8). Mean warm season grass basal cover was 9.95%. Mean cool season grass basal cover was 6.20%. Mean sedge basal cover was 10.47%. Mean total native grass basal cover was 26.62%. Mean forb basal cover was 3.94% (table 8).

Mean total basal cover during the 1988 drought conditions was 26.83% on the unfertilized pasture (table 8). Mean warm season grass basal cover was 8.51%. Mean cool season grass basal cover was 5.21%. Mean sedge basal cover was 7.88%. Mean total native grass basal cover was 21.60%. Mean forb basal cover was 5.23% (table 8).

Trial IV (1997-2004)

The unfertilized and fertilized pasture herbage weight samples collected in 1997 to 2002 and 2004 were clipped to ground level one time per growing season during late June to mid August. The herbage was separated into five categories: warm season grasses, cool season grasses, sedges, introduced and domesticated grasses, and forbs. The pastures were grazed and the clipped herbage samples were collected from ungrazed or lightly grazed areas. The reported data were mean ungrazed herbage or lightly grazed herbage for each category and for the total yield of all categories from the one clip period on each of the three replicated pasture zones.

Mean aboveground total yield herbage weight during 1997 to 1999 and 2001 to 2002 was 1348.47 lbs per acre on the unfertilized pasture and was 2288.09 lbs per acre on the fertilized pasture during the growing season period of early June to mid August (tables 9 and 10). The total herbage weight on the fertilized pasture was 69.7% greater than, and significantly different ($P<0.05$) from, the total herbage weight on the unfertilized pasture. Mean warm season grass herbage weight was 236.77 lbs per acre, composing 18.96%, on the unfertilized pasture and was 71.31 lbs per acre, composing 3.39%, on the fertilized pasture. Warm season grass herbage weight on the fertilized pasture was 69.9% lower than, and significantly different ($P<0.05$) from, mean warm season grass herbage weight on the unfertilized pasture. Mean cool season grass herbage weight was 453.28 lbs per acre, composing 34.74%, on the unfertilized pasture and was 125.74 lbs per acre, composing 6.12%, on the fertilized pasture. Cool season grass herbage weight on the fertilized pasture was 72.3% lower than, and significantly different ($P<0.05$) from, that on the unfertilized pasture. Mean sedge herbage weight on the unfertilized pasture was 319.79 lbs per acre, composing 22.70%, and was 199.81 lbs per acre, composing 9.33%, on the fertilized pasture and were not significantly different ($P<0.05$). Mean total native grass herbage weight was 1009.84 lbs per acre, composing 76.41%, on the unfertilized pasture and was 396.86 lbs per acre, composing 18.83%, on the fertilized pasture. Total native grass herbage weight on the fertilized pasture was 60.7% lower than, and significantly different ($P<0.05$) from, that on the unfertilized pasture. Mean domesticated grass herbage weight was 108.94 lbs per acre, composing 7.53%, on the unfertilized pasture and was 1785.52 lbs per acre, composing 78.04%, on the fertilized pasture. Domesticated grass herbage weight on the fertilized pasture was 1539.0% greater than, and significantly different ($P<0.05$) from, domesticated grass herbage weight on the unfertilized pasture. Mean forb herbage weight on the unfertilized pasture was 229.68 lbs per acre, composing 16.06%, and was 105.71 lbs per acre, composing 4.90%, on the fertilized pasture and were not significantly different ($P<0.05$) (tables 10 and 11).

Mean percent composition of herbage weight for warm season grass, cool season grass, sedge, total native grass, and forbs were significanly lower ($P<0.05$) on the fertilized pasture than on the unfertilized pasture. Mean percent composition of herbage weight for domesticated grass were significantly greater ($P<0.05$) on the fertilized pasture than on the unfertilized pasture (table 11). The herbage weight samples of 2000 were collected from areas that were more than lightly grazed. In 2004, mild drought conditions occurred from April through August with 52.8% of the LTM precipitation received.

Mean percent total basal cover of the plant community during 1998 to 1999 and 2001 to 2003 was 26.37% on the unfertilized pasture and was

21.96% on the fertilized pasture and were not significantly different (P<0.05) (table 12). Mean warm season grass basal cover was 7.92% on the unfertilized pasture and was 2.56% on the fertilized pasture. Warm season grass basal cover on the fertilized pasture was 67.7% lower than, and significantly different (P<0.05) from, mean warm season grass basal cover on the unfertilized pasture. Basal cover of mid warm season grasses had decreased 80.0% and basal cover of short warm season grasses had decreased 63.5% on the fertilized pasture (table 13). Mean cool season grass basal cover was 5.42% on the unfertilized pasture and was 1.34% on the fertilized pasture. Cool season grass basal cover on the fertilized pasture was 75.3% lower than, and significantly different (P<0.05) from, that on the unfertilized pasture. Basal cover of mid cool season grasses had decreased 66.1% and basal cover of short cool season grasses had decreased 86.9% on the fertilized pasture (table 13). Mean sedge basal cover on the unfertilized pasture was 7.18% and was 4.45% on the fertilized pasture and were not significantly different (P<0.05). Mean total native grass basal cover on the unfertilized pasture was 20.52% and was 8.35% on the fertilized pasture. Total native grass basal cover on the fertilized pasture was 59.3% lower than, and significantly different (P<0.05) from, that on the unfertilized pasture. Mean domesticated grass basal cover was 2.45% on the unfertilized pasture and was 12.39% on the fertilized pasture. Domesticated grass basal cover on the fertilized pasture was 405.7% greater than, and significantly different (P<0.05) from, domesticated grass basal cover on the unfertilized pasture. Basal cover of crested wheatgrass had increased 577.6%, basal cover of smooth bromegrass had increased 568.3%, and basal cover of Kentucky bluegrass and Canada bluegrass had increased 451.5% from their respective basal cover in 1982 (table 13). The introduced and domesticated grasses had back filled 81.7% of the open spaces created in the plant community by the decrease in native grass basal cover on the fertilized pasture. Mean forb basal cover on the unfertilized pasture was 3.40% and was 1.22% on the fertilized pasture. Forb basal cover on the fertilized pasture was 64.1% lower than, and significantly different (P<0.05) from, that on the unfertilized pasture (table 12). The basal cover samples of 2000 were collected from areas that were more than lightly grazed. In 2004, mild drought conditions occurred from April through August with 52.8% of the LTM precipitation received.

Introduced and domesticated grasses are apparently capable of occupying open spaces created by native grass reductions in the plant community when soil mineral nitrogen is readily available. The plant community in the fertilized pasture would be expected to continue to change in plant species composition with a decrease in native warm season grasses, cool season grasses, upland sedges, and prairie forbs and an increase in domesticated and introduced mid cool season grasses until the quantity of applied fertilizer nitrogen was no longer readily available as soil mineral nitrogen. The duration of time that the applied fertilizer nitrogen would remain in the ecosystem could be estimated by determination of the fate of the applied fertilizer nitrogen according to the nitrogen fate percentages developed by Power (1977).

The fate of applied nitrogen fertilizer in native rangeland ecosystems is dependent on various biotic and abiotic factors called nitrogen sinks. Power (1977) determined the nitrogen content in the various sinks of a grazed native mixed grass prairie near Mandan, ND. Power (1977) subtracted the nitrogen content of the unfertilized pasture from the nitrogen content of the fertilized pasture to determine the content and percentage of the applied fertilizer nitrogen in each sink.

The fate of nitrogen as a percent of applied fertilizer determined by Power (1977) is shown in the left column of table 14. Power (1977) determined that 8% or 4.0 lbs per acre of the applied nitrogen was lost from the ecosystem per year. At a constant rate of loss at 4.0 lbs of applied nitrogen per acre per year, the applied nitrogen would be used up in 126.5 years from the last year fertilizer was applied and the ecosystem should be devoid of fertilizer nitrogen sometime during the growing season in the year 2109.

Discussion

Nitrogen fertilization of native rangeland with annual applications of 50 lbs N/ac caused the plant species composition to shift. Pasture fertilization increased total herbage weight 49.8% during 1972 to 1976, and increased mean total herbage weight 51.3% during 1977 to 1982. In 1982, after 11 years of fertilization treatments, total herbage weight had increased 91.4% and the plant species composition had changed greatly. Cool season grass herbage weight had increased 166.3%, composition had increased 39.2%, and basal cover had increased 40.3%. Warm season grass herbage weight had decreased 71.5%, composition had decreased 85.1%, and basal cover had decreased 67.8%. Upland sedge herbage weight had decreased 16.0%, composition had decreased 56.1%, and basal cover had decreased 14.2%. Forb herbage weight had increased 70.0%, composition had decreased 11.2%, and basal cover had decreased 75.4%. The quantity of forb plants and the number of forb species had greatly decreased on the fertilized pasture. A few of the remaining plants were fringed sage that had greatly increased in size and weight. Fringed sage composed around 50% of the forb basal cover and almost all of the forb herbage weight. A small amount of domesticated and introduced mid cool season grasses had encroached into the fertilized pasture by 1982. This plant species intrusion was not recognized as a serious problem at that time because the domesticated and introduced grasses had produced only 517.05 lbs per acre of herbage weight and occupied only 1.96% basal cover.

The residual effects from nitrogen fertilization of native rangeland continued to change the plant species composition for an additional twenty two years after the fertilization treatments had stopped. During 1997 to 2004, the total herbage weight was 69.7% greater on the fertilized pasture than on the unfertilized pasture. However, the composition of the herbage weight had greatly changed; domesticated and introduced grasses composed 78.0%, native grasses composed 17.3%, and forbs composed 4.6% of the total herbage weight. Cool season grass herbage weight had decreased 72.3%, composition had decreased 82.4%, and basal cover had decreased 75.3%. Warm season grass herbage weight had decreased 69.9%, composition had decreased 82.1%, and basal cover had decreased 67.7%. Upland sedge herbage weight had decreased 37.5%, composition had decreased 58.9%, and basal cover had decreased 38.0%. Forb herbage weight had decreased 54.0%, composition had decreased 69.5%, and basal cover had decreased 64.1%. Domesticated and introduced grass herbage weight had increased 1539.0%, composition had increased 936.9%, and basal cover had increased 405.7%. The small encroachment of nonnative grasses had transformed into an overwhelming occupation.

After eleven years of fertilization treatments, native mid cool season grasses had greatly increased in herbage weight and basal cover. Herbage weight the other native grasses had decreased less than the mid cool season grasses had increased. Total native grass herbage weight had increased 63.6%, however, total native grass basal cover had decreased 27.9% in eleven years. Twenty two years after treatments had stopped, native grass herbage weight had decreased 82.7% and basal cover had decreased 60.3%. Fertilization of native rangeland caused native warm season grasses, cool season grasses, and upland sedges to decrease greatly, and after 33 years of plant species composition change, the native grasses only composed 17.3% of the total herbage weight and 38.0% of the total basal cover.

Domesticated and introduced grasses started from zero and increased slowly, and after eleven years of fertilization treatments, domesticated and introduced grasses composed 14.1% of the total herbage weight and composed 11.2% of the total basal cover. Twenty two years after treatments had stopped, domesticated and introduced grass herbage weight had increased 342.5% and basal cover had increased 532.1%. Fertilization of native rangeland caused domesticated and introduced grasses to increase greatly, and after 33 years of plant species composition change, the domesticated and introduced grasses composed 78.0% of the total herbage weight and 56.4% of the total basal cover.

Nitrogen fertilization of native rangeland changed the plant species composition from a mixed grass prairie community of warm season grasses, cool season grasses, upland sedges, and prairie forbs to a community dominated by introduced and domesticated mid cool season grasses in 33 years. The residual effects from nitrogen fertilization continue to change the plant species composition of the fertilized rangeland pasture.

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Table 1. Precipitation in inches for growing season months and the annual total precipitation for 1972-1982, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1972	1.27	5.09	4.29	2.72	2.90	0.74	1.56	18.57	20.76
% of LTM	88.81	217.52	120.85	122.52	167.63	55.64	164.21	137.05	129.75
1973	3.21	1.30	3.04	0.91	0.47	2.23	0.67	11.83	13.53
% of LTM	224.48	55.56	85.63	40.99	27.17	167.67	70.53	87.31	84.56
1974	2.82	4.15	2.00	1.50	0.90	0.56	0.52	12.45	14.15
% of LTM	197.20	177.35	56.34	67.57	52.02	42.11	54.74	91.88	88.44
1975	4.25	3.34	4.27	0.64	0.54	0.80	1.42	15.26	17.71
% of LTM	297.20	142.74	120.28	28.83	31.21	60.15	149.47	112.62	110.69
1976	2.11	1.42	3.74	0.75	0.40	1.77	0.65	10.84	12.68
% of LTM	147.55	60.68	105.35	33.78	23.12	133.08	68.42	80.00	79.25
1977	0.13	2.60	5.38	1.08	1.52	5.78	2.16	18.65	23.13
% of LTM	9.09	111.11	151.55	48.65	87.86	434.59	227.37	137.64	144.56
1978	1.81	3.99	2.10	2.41	2.01	2.56	0.29	15.17	17.63
% of LTM	126.57	170.51	59.15	108.56	116.18	192.48	30.53	111.96	110.19
1979	1.28	0.91	3.06	2.22	2.21	1.27	0.17	11.12	12.81
% of LTM	89.51	38.89	86.20	100.00	127.75	95.49	17.89	82.07	80.06
1980	0.03	0.12	2.67	1.43	3.31	0.76	2.41	10.73	12.58
% of LTM	2.10	5.13	75.21	64.41	191.33	57.14	253.68	79.19	78.63
1981	0.66	1.30	3.71	1.57	4.05	2.75	0.23	14.27	15.76
% of LTM	46.15	55.56	104.51	70.72	234.10	206.77	24.21	105.31	98.50
1982	1.85	4.32	3.43	2.02	2.63	1.77	6.51	22.53	26.58
% of LTM	129.37	184.62	96.62	90.99	152.02	133.08	685.26	166.27	166.13
1972-1982	1.77	2.59	3.43	1.57	1.90	1.91	1.51	14.67	17.30
% of LTM	123.78	110.68	96.62	70.72	109.83	143.61	158.95	108.27	108.13

Table 2. Precipitation in inches for growing-season months and the annual total precipitation for 1997-2004, Dickinson, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean 1892-2007	1.43	2.34	3.55	2.22	1.73	1.33	0.95	13.55	16.00
1997	3.29	0.92	2.19	6.36	0.91	0.09	0.98	14.74	23.13
% of LTM	230.07	39.32	61.69	286.49	52.60	6.77	103.16	108.78	144.56
1998	0.85	1.86	6.55	1.82	2.90	2.03	4.50	20.51	17.63
% of LTM	59.44	79.49	184.51	81.98	167.63	152.63	473.68	151.37	110.19
1999	1.48	3.94	1.99	0.99	3.23	2.25	0.32	14.20	12.81
% of LTM	103.50	168.38	56.06	44.59	186.71	169.17	33.68	104.80	80.06
2000	1.38	1.80	3.09	3.45	0.35	1.11	0.73	11.91	12.58
% of LTM	96.50	76.92	87.04	155.41	20.23	83.46	76.84	87.90	78.63
2001	2.08	1.75	7.15	3.99	0.00	2.53	0.24	17.74	15.76
% of LTM	145.45	74.79	201.41	179.73	0.00	190.23	25.26	130.92	98.50
2002	1.39	2.06	4.75	2.98	2.81	0.17	1.31	15.47	26.58
% of LTM	97.20	88.03	133.80	134.23	162.43	12.78	137.89	114.17	166.13
2003	0.69	2.67	2.81	0.93	1.46	2.17	0.72	11.45	12.59
% of LTM	48.25	114.10	79.15	41.89	84.39	163.16	75.79	84.50	78.69
2004	0.96	1.40	0.54	2.42	0.63	1.53	2.78	10.26	15.54
% of LTM	67.13	59.83	15.21	109.01	36.42	115.04	292.63	75.72	97.13
1997-2004	1.52	2.05	3.63	2.87	1.54	1.49	1.45	14.54	17.08
% of LTM	106.29	87.61	102.25	129.28	89.02	112.03	152.63	107.31	106.75

Table 3. Evaluation of mean herbage yield on native rangeland pasture fertilization trial, 1972-1988.

Years	Unfertilized Mean Herbage Yield lbs/ac	Fertilized Mean Herbage Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %
1972	3160.00	4421.00	1261.00	39.91
1973	2367.00	3448.00	1081.00	45.67
1974	3079.00	5270.00	2191.00	71.16
1975	2462.00	4069.00	1607.00	65.27
1976	2315.00	2842.00	527.00	22.76
1977	1640.00	2021.00	381.00	23.23
1978	1998.95	3201.20	1202.25	60.14
1979	1308.90	1976.55	667.65	51.01
1980	1296.45	1386.85	90.40	6.97
1981	1809.15	2263.05	453.90	25.09
1982	1911.60	3657.95	1746.35	91.36
1983				
1984	1115.00			
1985	1279.30			
1986	1702.01			
1987	1622.56			
1988	451.23			

Table 4. Monthly dry matter weight in pounds per acre for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

Plant Categories Treatments	15 May	15 Jun	15 Jul	15 Aug	15 Sep
Unfertilized					
cool season	429.6	834.9	1506.1	1232.0	1147.7
warm season	9.3	178.1	520.2	965.9	404.4
total native grass	438.9	1013.0	2026.3	2197.9	1552.1
introduced grass	0.0	0.0	0.0	0.0	0.0
forbs	31.4	199.5	231.6	222.6	203.4
total yield	470.3	1212.5	2257.9	2420.5	1755.5
Fertilized					
cool season	1085.4	2690.6	3260.0	2332.8	2233.6
warm season	54.2	71.0	229.8	162.7	126.1
total native grass	1139.6	2761.6	3489.8	2495.5	2359.7
introduced grass	0.0	201.2	895.9	707.1	264.0
forbs	10.7	205.5	480.3	638.0	133.2
total yield	1150.3	3168.3	4866.0	3840.6	2756.9

Table 5. Percent composition of weight yield for treatments on the evaluation of native rangeland pasture fertilization trial, 1982.

Plant Categories Treatments	15 May	15 Jun	15 Jul	15 Aug	15 Sep
Unfertilized					
cool season	91.35	68.86	66.70	50.90	65.38
warm season	1.98	14.69	23.04	39.90	23.04
total native grass	93.32	83.55	89.74	90.80	88.41
introduced grass	0.0	0.0	0.0	0.0	0.0
forbs	6.68	16.45	10.26	9.20	11.59
total yield	470.3	1212.5	2257.9	2420.5	1755.5
Fertilized					
cool season	94.36	84.92	67.00	60.74	81.02
warm season	4.71	2.24	4.72	4.24	4.57
total native grass	99.07	87.16	71.72	64.98	85.59
introduced grass	0.0	6.35	18.41	18.41	9.58
forbs	0.93	6.49	9.87	16.61	4.83
total yield	1150.3	3168.3	4866.0	3840.6	2756.9

Table 6. Dry matter weight in pounds per acre for treatments on the evaluation of native rangeland pasture fertilization trial, 1982-1988.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Yield
1982							
unfertilized	517.15	898.28	281.90	1697.33	0.0	214.27	1911.60
fertilized	147.40	2392.55	236.70	2776.65	517.05	364.25	3657.95
1983							
unfertilized							
fertilized							
1984							
unfertilized	222.39	324.14	448.77	995.30	0.0	119.70	1115.00
fertilized							
1985							
unfertilized	231.72	364.06	615.47	1211.25	0.0	68.05	1279.30
fertilized							
1986							
unfertilized	379.73	519.63	587.30	1486.66	0.0	215.35	1702.01
fertilized							
1987							
unfertilized	339.96	457.55	676.40	1473.91	0.0	148.65	1622.56
fertilized							
1988							
unfertilized	92.03	89.54	208.58	390.15	0.0	61.08	451.23
fertilized							

Table 7. Percent composition of weight yield for treatments on the evaluation of native rangeland pasture fertilization trial, 1982-1988.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Yield
1982							
unfertilized	27.05	46.99	14.75	88.79	0.0	11.21	1911.60
fertilized	4.03	65.41	6.47	75.91	14.13	9.96	3657.95
1983							
unfertilized							
fertilized							
1984							
unfertilized	19.95	29.07	40.25	89.26	0.0	10.74	1115.00
fertilized							
1985							
unfertilized	18.11	28.46	48.11	94.68	0.0	5.32	1279.30
fertilized							
1986							
unfertilized	22.31	30.53	34.51	87.35	0.0	12.65	1702.01
fertilized							
1987							
unfertilized	20.95	28.20	41.69	90.84	0.0	9.16	1622.56
fertilized							
1988							
unfertilized	20.40	19.84	46.22	86.46	0.0	13.54	451.23
fertilized							

Table 8. Basal cover of plant categories for treatments on the evaluation of native rangeland pasture fertilization trial, 1982-1988.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Basal Cover
1982							
unfertilized	9.94	4.47	6.64	21.05	0.36	1.40	22.81
fertilized	3.20	6.27	5.70	15.17	1.96	0.34	17.47
1983							
unfertilized							
fertilized							
1984							
unfertilized							
fertilized							
1985							
unfertilized	14.78	4.48	8.93	28.19	0.08	2.48	30.75
fertilized							
1986							
unfertilized	10.11	8.69	12.18	30.98	0.0	4.66	35.64
fertilized							
1987							
unfertilized	4.96	5.42	10.30	20.68	0.0	4.69	25.37
fertilized							
1988							
unfertilized	8.51	5.21	7.88	21.60	0.0	5.23	26.83
fertilized							

Table 9. Evaluation of mean herbage yield on native rangeland pasture fertilization trial, 1997-2004.

Years	Unfertilized Mean Herbage Yield lbs/ac	Fertilized Mean Herbage Yield lbs/ac	Weight Difference from Unfertilized lbs/ac	Percent Difference from Unfertilized %
1997	1442.66a	2238.32b	795.66	55.15
1998	1385.57a	1997.12a	611.55	44.14
1999	1157.94a	2293.04b	1135.10	98.03
2000	696.71a	1132.48b	435.77	62.55
2001	1495.00a	3034.71b	1539.71	102.99
2002	1261.17a	1877.24b	616.07	48.85
2003				
2004	705.75a	1090.86b	385.11	54.57

Means for each year in the same row and followed by the same letter are not significantly different (P<0.05).

Table 10. Dry matter weight in pounds per acre for treatments on the evaluation of native rangeland pasture fertilization trial, 1997-2004.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Yield
1997							
unfertilized	226.21a	279.02a	456.70a	961.94a	159.13a	321.59a	1442.66a
fertilized	238.10a	285.44a	428.87a	952.42a	1063.03b	222.88a	2238.32b
1998							
unfertilized	322.07a	527.35a	305.42a	1154.84a	0.0a	230.73a	1385.57a
fertilized	33.06b	157.47a	204.09a	394.62b	1524.01b	78.50a	1997.12a
1999							
unfertilized	190.30a	501.66a	159.37a	851.33a	168.65a	137.96a	1157.94a
fertilized	27.12b	58.76b	91.82a	177.69b	2031.62b	83.73a	2293.04b
2000							
unfertilized	148.67a	186.49a	165.08a	500.23a	105.37a	91.10a	696.71a
fertilized	40.91a	39.01b	77.78a	157.71b	949.32b	25.45b	1132.48b
2001							
unfertilized	227.64a	465.27a	341.58a	1034.49a	185.06a	275.45a	1495.00a
fertilized	28.31b	44.72b	137.73a	210.75b	2757.11b	66.84b	3034.71b
2002							
unfertilized	217.65a	493.10a	335.87a	1046.61a	31.87a	182.68a	1261.17a
fertilized	29.97b	82.30b	136.54b	248.81b	1551.84b	76.59a	1877.24b
2003							
unfertilized							
fertilized							
2004							
unfertilized	73.50a	286.39a	182.45a	542.34a	51.85a	111.56a	705.75a
fertilized	16.17a	63.99b	135.35a	215.51b	818.50b	56.85a	1090.86b

Means for each year in the same column and followed by the same letter are not significantly different (P<0.05).

Table 11. Percent composition of weight yield for treatments on the evaluation of native rangeland pasture fertilization trial, 1997-2004.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Yield
1997							
unfertilized	16.01a	19.20a	30.68a	65.90a	12.08a	22.03a	1442.66
fertilized	11.18a	13.23a	20.36a	44.77a	44.73a	10.49b	2238.32
1998							
unfertilized	26.84a	37.44a	21.65a	85.92a	0.0a	14.08a	1385.57
fertilized	1.63b	8.20b	10.25b	20.08b	75.97b	3.95b	1997.12
1999							
unfertilized	18.13a	44.46a	12.83a	75.41a	12.32a	12.26a	1157.94
fertilized	1.44b	2.94b	4.02a	8.40b	88.02b	3.58b	2293.04
2000							
unfertilized	22.35a	26.72a	23.09a	72.17a	13.73a	14.10a	696.71
fertilized	4.01b	3.80b	6.65b	14.46b	83.27b	2.27b	1132.48
2001							
unfertilized	16.25a	32.83a	21.88a	70.97a	10.99a	18.04a	1495.00
fertilized	1.12b	1.83b	4.77b	7.72b	89.17b	2.40b	3034.71
2002							
unfertilized	17.57a	39.79a	26.47a	83.83a	2.26a	13.91a	1261.17
fertilized	1.56b	4.40b	7.23b	13.18b	82.73b	4.09b	1877.24
2003							
unfertilized							
fertilized							
2004							
unfertilized	10.42a	40.59a	26.01a	77.02a	7.31a	15.66a	705.75
fertilized	1.61b	5.88b	12.81a	20.29b	74.47b	5.23b	1090.86

Means for each year in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 12. Basal cover of plant categories for treatments on the evaluation of native rangeland pasture fertilization trial, 1997-2004.

Years Treatments	Warm Season Grass	Cool Season Grass	Sedge	Total Native Grass	Domesticated Grass	Forbs	Total Basal Cover
1997							
unfertilized							
fertilized							
1998							
unfertilized	9.93a	3.63a	4.33a	17.93a	1.17a	1.97a	21.07a
fertilized	2.70b	0.85b	3.37a	6.92b	4.67b	0.73a	12.32b
1999							
unfertilized	7.90a	7.16a	5.33a	20.39a	4.09a	2.57a	27.05a
fertilized	2.43b	1.72b	2.02b	6.17b	17.40b	0.71b	24.28a
2000							
unfertilized	7.25a	3.79a	6.17a	17.21a	1.49a	2.61a	21.31a
fertilized	3.25a	0.92b	5.47a	9.64b	10.40b	0.63b	20.67a
2001							
unfertilized	6.87a	6.20a	8.17a	21.24a	2.86a	4.37a	28.47a
fertilized	2.35b	1.73b	5.63a	9.71b	17.90b	0.82a	28.43a
2002							
unfertilized	7.00a	5.81a	9.77a	22.58a	2.87a	5.10a	30.55a
fertilized	2.48b	1.20b	4.52b	8.20b	13.09b	1.65b	22.94b
2003							
unfertilized	7.92a	4.28a	8.28a	20.48a	1.27a	2.98a	24.73a
fertilized	2.85b	1.20b	6.72a	10.77b	8.88b	2.17a	21.82a
2004							
unfertilized	4.48a	4.34a	6.10a	14.92a	6.25a	5.25a	26.42a
fertilized	1.37a	1.45b	6.20a	9.02b	16.64b	1.87b	27.53a

Means for each year in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 13. Basal cover of plant subcategories for treatments on the evaluation of native rangeland pasture fertilization trial, 1982, 1985-1988, 1998-2004.

Years Treatments	Warm Season Grass		Cool Season Grass		Domesticated Grass		
	mid warm	short warm	mid cool	short cool	crested wheatgras s	smooth bromegrass	bluegrass
1982							
unfertilized	0.64	9.30	2.47	2.00	0.00	0.03	0.33
fertilized	0.03	3.17	4.80	1.47	0.67	0.63	0.66
1985-1988							
unfertilized	1.56	8.39	2.83	3.36	0.00	0.03	0.00
fertilized							
1998-2004							
unfertilized	0.95	6.98	3.04	2.37	0.21	1.65	0.59
fertilized	0.19	2.55	1.03	0.31	4.54	4.21	3.64

Table 14. Fate of applied fertilizer nitrogen on native rangeland pasture, 1972-1982, following first approximation percentages of fertilizer nitrogen fate in grazed semiarid rangeland developed by Power (1977).

Biotic and Abiotic Nitrogen Sinks	Fate of N as Percent of Applied Data from Power 1977 %	Fate of N from 50 lbs N/ac per year lbs N/yr	Fate of N from 550 lbs N/ac per 11 years lbs N/11 yrs
Retained in Ecosystem	92%	46.0	506.0
Plants	22%	11.0	121.0
aboveground herbage	2%	1.0	11.0
crown	1%	0.5	5.5
roots	19%	9.5	104.5
Litter	16%	8.0	88.0
Soil Mineral Nitrogen	41%	20.5	225.5
ammonium NH_4	2%	1.0	11.0
nitrate NO_3	39%	19.5	214.5
Soil Organic Nitrogen unmeasured estimate	13%	6.5	71.5
Lost to Ecosystem	8%	4.0	44.0
Beef Tissue	3%	1.5	16.5
Gaseous Losses unmeasured estimate	5%	2.5	27.5
Leaching	0%	0.0	0.0

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Influence of Soil Mineral Nitrogen on Native Rangeland Plant Water Use Efficiency and Herbage Production

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Native rangelands managed by traditional grazing practices are deficient in available soil mineral nitrogen and produce less than potential quantities of herbage biomass (Wight and Black 1972). The biogeochemical processes of these rangeland ecosystems typically function at levels that cycle nitrogen at rates of about 59 pounds or less of mineral nitrogen per acre per year and produce only one half to one third of the potential quantities of herbage biomass (Wight and Black 1972). The remedy for the problem of low herbage production on native rangeland is not repetitive applications of nitrogen fertilizer because the additional herbage produced from nitrogen fertilization has unprofitably high costs (Manske 2009b) and the long-term effects from nitrogen fertilization cause shifts in plant species composition with reductions of the native grass species and increases of the domesticated and introduced grass species (Manske 2009a). However, the results from more than three decades of nitrogen fertilization research on native rangelands provides insight into the underlying causes of the problem of herbage production at below potential quantities on native rangelands managed by traditional grazing practices.

Nitrogen fertilization of native rangeland increases the quantity of available soil mineral nitrogen. Total herbage biomass production on native rangeland increases with the increases in quantity of soil mineral nitrogen (Rogler and Lorenz 1957, Whitman 1957, Whitman 1963, Smika et al. 1965, Goetz 1969, Power and Alessi 1971, Lorenz and Rogler 1972, Goetz 1975, Taylor 1976, Whitman 1976, Goetz et al. 1978, Wight and Black 1979). The greater quantities of available soil mineral nitrogen cause the soil water use efficiency to improve in grassland plants (Smika et al. 1965, Wight and Black 1972, Whitman 1976, 1978). Water use efficiency (pounds of herbage produced per inch of water use) is difficult to measure quantitatively because soil water can be lost through evaporation or transpiration. Precipitation use efficiency (pounds of herbage produced per inch of precipitation received) is less complicated to measure than water use efficiency. Wight and Black (1972) found that precipitation use efficiency of grasslands improved with increased quantities of soil mineral nitrogen and that the pounds of herbage produced per inch of precipitation were greater on the nitrogen fertilized treatments than on the unfertilized treatments. Wight and Black (1979) compared herbage production on traditionally managed rangeland with the typical ambient deficiency of available mineral nitrogen to herbage production on nitrogen fertilized rangeland without a deficiency of available mineral nitrogen. During ten years of study with normal growing season precipitation, the deficiency of mineral nitrogen on the traditionally managed rangeland caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the herbage produced per inch of precipitation on the rangeland without a mineral nitrogen deficiency.

Nitrogen cycling in Northern Plains rangeland ecosystems managed by traditional grazing practices is inadequate to supply the quantity of mineral nitrogen necessary for minimum potential herbage production. A deficiency in available mineral nitrogen causes reductions in grassland plant water use efficiency and reductions in herbage biomass production to below potential levels during growing seasons with normal precipitation and no deficiency in available water. During growing seasons with below normal precipitation, both the deficiency in available water and the deficiency in available mineral nitrogen contribute to the resulting reductions in herbage production. During drought growing seasons, the percent reduction in herbage production is greater than the percent reduction in precipitation because of the additional reductions in water use efficiency and herbage production caused by the deficiency of mineral nitrogen. Semiarid rangelands would produce herbage biomass at the maximum level for whatever soil water was available if the ecosystems were not deficient in mineral nitrogen (Power and Alessi 1971). Herbage production on native rangeland ecosystems at minimum potential herbage yields would require nitrogen cycling at a rate of about 100 pounds of available mineral nitrogen per acre per year and that maximum potential herbage yields would be produced at rates of about 165 pounds of mineral nitrogen per acre per year (Wight and Black 1972).

Native rangeland plants need hydrogen, carbon, and nitrogen to produce herbage biomass. The hydrogen comes from soil water absorbed through the roots. The carbon comes from atmospheric carbon dioxide fixed through photosynthesis in the leaves. The nitrogen comes from the mineral nitrogen mineralized from soil organic nitrogen by rhizosphere microorganisms (Manske 2007). The total amount of energy fixed by chlorophyllous plants on rangeland ecosystems is not limited by the availability of radiant energy from the sun or by the availability of atmospheric carbon dioxide. The availability of water, which is an essential requirement for plant growth and has a dominant role in physiological processes, does not limit herbage production on rangeland ecosystems to the extent that mineral nitrogen availability does (Wight and Black 1972). Available soil mineral nitrogen is the major herbage growth limiting factor in Northern Plains rangelands (Wight and Black 1979). Grassland soils are not deficient of nitrogen and do not require application of additional fertilizer nitrogen. Most of the grassland nitrogen is immobilized in the soil as organic nitrogen in living tissue and nonliving detritus. Grassland soils in the Northern Plains contain about 3 to 8 tons of organic nitrogen per acre. Soil organic nitrogen must be converted into mineral nitrogen through mineralization by soil microorganisms in order to be available to grassland plants. The greater the biomass of soil microorganisms, the greater the quantity of available mineral nitrogen.

Rangelands managed by the twice-over rotation grazing strategy are not deficient in available mineral nitrogen. The biologically effective twice-over rotation grazing management strategy is designed to use partial defoliation of grass tillers at beneficial phenological growth stages to meet the biological requirements of grassland plants and to stimulate rhizosphere organism activity that enhances the biogeochemical processes in grassland ecosystems and increases the quantity of organic nitrogen mineralized into inorganic (mineral) nitrogen at amounts sufficient for herbage production at maximum potential yield levels (Manske 2007).

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Enhancement of the Nitrogen Cycle Improves Native Rangeland

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Available soil mineral nitrogen is the major limiting factor of herbage growth on native rangelands (Wight and Black 1979). Rangeland soils, however, are not deficient of nitrogen. Most of the nitrogen in rangeland ecosystems is in the organic form. A large amount of the organic nitrogen is immobilized in living tissue of microorganisms, plants, and animals as essential constituents of proteins and nucleic acids. An additional large amount of the soil organic nitrogen is contained in the soil organic matter detritus that is at various stages of physical breakdown and decomposition and is derived from dead organisms, excreta, and sloughed material. A small portion of the soil nitrogen is in the mineral form as ammonium, nitrate, and nitrite. The amount of available mineral nitrogen in the soil is affected by the rate of mineralization of the organic nitrogen by soil microorganisms. A minimum rate of mineralization of about 100 pounds of mineral nitrogen per acre per year is required to sustain herbage production at potential levels on native rangeland (Wight and Black 1972). Mineralization at these high rates can not be obtained from traditional grazing practices (Wight and Black 1972). Grazing management specifically designed to enhance soil microorganism activity can be implemented to obtain mineralization rates of 100 pounds of mineral nitrogen per acre per year or greater. Enhancement of the nitrogen cycle, with increases in the quantity of available soil mineral nitrogen, increases herbage growth and production and improves new wealth generation from native rangeland natural resources.

The nitrogen cycle in rangeland ecosystems is complex. Nitrogen is versatile and has several oxidation states and can exist as a gas, a dissolved cation or anion, a precipitated salt, an adsorbed or interlayer ion in clay, and as dissolved or solid organic molecules of varying complexity (Russelle 1992). Nitrogen moves through a variety of biological and chemical pathways and the movement within the cycle is difficult to predict and highly variable among different climatic zones because the nitrogen cycle pathways are directly or indirectly influenced by regional temperature and moisture regimes. Biological pathways are also influenced by metabolic rates of microorganisms, plants, and animals (Russelle 1992). The nitrogen cycle in rangelands is open and has inputs (gains) that transfer in from outside sources and has outputs (losses) that transfer out of the ecosystem.

Nitrogen inputs on rangelands arrive through atmospheric pathways as wet deposits in rain, snow, or hail and as dry deposits of gases or minute particles. Lightning discharges cause atmospheric nitrogen (N_2) and oxygen (O_2) to combine and produce nitrogen oxides, mainly nitric acid (NO) and dinitrogen oxide (N_2O), that are deposited on rangeland in precipitation. Inorganic nitrogen, as ammonium (NH_4) and nitrate (NO_3), and complex organic compounds removed by erosive forces from distant soil surfaces are deposited on rangelands in precipitation, wind, and sometimes overland water movement. The ambient amount of wet and dry nitrogen deposition in temperate regions from natural sources is around 5 to 6 pounds per acre per year (Brady 1974). Nitrogen deposits from other sources are primarily nitrogen oxides expelled in the exhaust emissions from cars, aircraft, and factories. The amount of nitrogen deposits from sources related to anthropogenic activity is highly variable, influenced by distance and direction from population centers, and can range from 0 to 15 pounds per acre per year or greater (Gibson 2009).

Symbiotic and nonsymbiotic fixation of atmospheric nitrogen is an input source of nitrogen for some mesic grasslands but generally not for semiarid rangelands. Strains of symbiotic Rhizobium bacteria form nodules on the roots of legumes and can fix atmospheric dinitrogen gas (N_2) in soil air and synthesize it into complex forms. Some of this fixed nitrogen is required by the bacteria, some of the nitrogen can be available to the host plant, and some of the nitrogen can be passed into the surrounding soil by excretion or by the sloughing off of the roots with nodules (Brady 1974). Legumes are not an abundant component in native rangelands and the legumes that are present in mature soils have low levels of nodulation and may not fix nitrogen (Gibson 2009). A few nonsymbiotic soil microorganisms are able to fix atmospheric dinitrogen (N_2) from soil air into their body tissue (Brady 1974). Nitrogen fixation by free living soil bacteria in semiarid rangelands is not known to be important and considered to be insignificantly low or nonexistent (Legg 1995, Gibson 2009).

Potential outputs for nitrogen from rangeland ecosystems can be lost to the atmosphere through denitrification of mineral nitrogen, ammonia volatilization, and volatilization by fire; lost through transfers by wind and water erosion of surface soil and by hydrologic leaching; and lost through animal production of both domesticated livestock and wildlife.

Denitrification is the reduction of inorganic nitrogen by removal of oxygen from the nitrite (NO_2) and nitrate (NO_3) mineral nitrogen to form gaseous nitrous oxides (NO and N_2O) or nonreactive dinitrogen gas (N_2) and can be mediated both chemically and biologically (Brady 1974). Losses from denitrification in rangelands is greatest in the nitrous oxide form (N_2O), followed by losses in the dinitrogen form (N_2). Losses in the nitric oxide form (NO) occur on rangelands only under acid conditions (Brady 1974). Chemical denitrification is of little importance in native rangelands unless nitrate is present in high concentrations (Russelle 1992). Biological denitrification occurs when soil microorganisms are deficient of oxygen as a result of poor drainage or poor soil structure causing soil saturation or lack of aeration. Denitrification probably accounts for only a small part of the total nitrogen losses from pastures and rangelands (Legg 1975, Gibson 2009).

Ammonia volatilization can occur near the soil surface during mineralization of soil organic nitrogen by soil microorganisms (Foth 1978). Gaseous ammonia (NH_3) forms as an intermediate stage and is usually readily hydrolyzed to form ammonium (NH_4) which is a stable form of mineral nitrogen. However, under conditions of increasing aridity and decreasing availability of hydrogen ions, the hydrolyzation process decreases and the amount of ammonia that escapes into the atmosphere by volatilization increases (Gibson 2009).

Nitrogen contained in aboveground herbage and litter is volatilized when rangelands are burned by prescribed fire and wild fire. Combustion causes nitrogen losses approaching 90%, primarily as ammonia (NH_3), dinitrogen oxide (N_2O), and other nitrogen oxides (Russelle 1992). Little belowground nitrogen is volatilized when the soil is moist during a burn, however, when the soil is dry, belowground temperatures can increase enough to denature protein, killing portions of the grass crowns and root material and volatilizing some belowground nitrogen.

Nitrogen in soil, litter, and organic detritus can be transferred from one area to another through movement by wind and water. The transferred nitrogen is a loss from one area and a gain at the deposition area. Nitrogen losses through erosion removal are variable and influenced by live plant density, litter cover, extent of branching fiberous root systems, and soil infiltration rates. The quantity of nitrogen lost through erosional movement can be decreased with enhancement of the nitrogen cycle and improvement in productivity of the rangeland ecosystem (Russelle 1992).

Soluble nitrate (NO_3) moves downward in the soil profile with soil water. In mesic grasslands, nitrogen can be lost as a result of water movement below the rooting depth (Russelle 1992). None of the mineral nitrogen in western rangelands is lost by hydrologic leaching through the soil profile (Power 1970) because very little water moves below the three foot soil depth and water loss by leaching is low or nonexistent in arid and semiarid rangelands under cover of perennial vegetation (Brady 1974, Wight and Black 1979).

Livestock grazing semiarid rangelands in the Northern Plains consume about 25% of the aboveground herbage, leaving a significant part of the nitrogen absorbed by the growing vegetation in the remaining live aboveground herbage, the standing dead vegetation, and the litter. Most of the nitrogen consumed by grazing livestock and wildlife is returned to the soil surface in urine and feces waste. Almost all of the nitrogen in urine is immediately available to plants. A portion of the urea in urine can be volatilized in warm dry conditions (Gibson 2009). Grazing animals retain only a small amount of the nitrogen consumed, about 15% to 17% in a nonlactating animal and about 30% in a lactating animal (Russelle 1992). The quantity of nitrogen lost as animal product increases as enhancement of the nitrogen cycle improves productivity of the rangeland ecosystem.

Differences in nitrogen inputs and outputs on rangeland soils determine the quantity of net accumulation of nitrogen. The total nitrogen content in soils accumulates gradually over several thousand years. Organic matter accumulation is benefitted in northern soils because little or no chemical oxidation activity of organic matter takes place during the cold periods. The dark surface layer of most soils in the Northern Plains has an accumulation of 2% to 5% organic matter (Larson et al. 1968, Wright et al. 1982). An acre of soil 6 inches deep contains about 1000 pounds of nitrogen for each percent of organic matter (Foth 1978). Nitrogen content and percent organic matter decrease with soil depth. A net accumulation of 2 pounds of nitrogen per acre per year results in a soil with 5 tons of nitrogen per acre in 5000 years.

The nitrogen cycle within rangeland soils functions around the two processes of immobilization and mineralization. These processes take place simultaneously with plant growth, dieback, and decomposition (Legg 1975). Immobilization is the process of tying up nitrogen in organic forms.

Mineralization is the process of converting organic nitrogen into mineral (inorganic) nitrogen.

Biological immobilization of nitrogen occurs when autotrophic plants and soil microorganisms absorb inorganic nitrogen and build essential organic nitrogen compounds of amino acids and nucleic acids. Amino acids are building blocks of proteins that form enzymes, hormones, and important structural components of cells. Nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), are the genetic material that control all cellular functions and heredity. In rangeland soils, nitrogen is tied up in organic forms for three to four years (Power 1972). Biological immobilization of mineral nitrogen by plants and soil microorganisms is beneficial for rangeland ecosystems because about 95% of the total nitrogen is preserved within the soil as organic nitrogen and not subjected to great potential losses through denitrification and ammonia volatilization (Legg 1975, Gibson 2009).

Chemical immobilization of mineral nitrogen by adsorption of ammonium onto clay particles can be an advantage or a disadvantage for rangeland ecosystems depending on the type and amount of clay present. The ammonium ions are apparently the right size to fit into the cavities between crystal units normally occupied by potassium making the ammonium more or less a rigid part of the crystal (Brady 1974, Foth 1978). The type of clay mineral affects the retention of the ammonium. Clay materials with expanding lattices, such as vermiculite, illite, and montmorillonite, have greater surface area and adsorptive capacity for ammonium than clay minerals with nonexpanding lattices, such as kaolinite (Brady 1974, Legg 1975). Chemical immobilization of ammonium to clay material protects that portion of the soil mineral nitrogen from potential losses. The ammonium is slowly released from the clay and made available to plants and soil microorganisms. When the quantity of clay is too high or when the ammonium release rate is too slow, available mineral nitrogen may be too low to maintain ecosystem productivity at potential levels.

Mineralization occurs when organic nitrogen immobilized in living tissue or contained in soil organic matter detritus is processed by soil microorganisms to form mineral nitrogen. Mineralization consists of a series of reactions. Complex proteins and other organic nitrogen compounds are simplified by enzymatic digestion that hydrolyze the peptide bonds and liberate and degrade the amino acids by deamination to produce ammonia (NH_3) and carbon dioxide, or other low molecular weight carbon compounds (Power 1972, Brady 1974). Most of the released ammonia is readily hydrolyzed into ammonium (NH_4) which becomes part of the inorganic nitrogen pool in the soil.

Some of the ammonium produced during the mineralization process by soil microorganisms or the ammonium released from adsorption to clay material is nitrified in a complex two stage process coordinated by two distinct groups of soil bacteria. Ammonium is nitrified by enzyme oxidation that releases energy for the first group of bacteria and produces nitrite (NO_2) and water. In short order, the second group of bacteria oxidize the nitrite by enzyme activity that releases energy and produces nitrate (NO_3) which becomes part of the inorganic nitrogen pool in the soil. The speed of this coordinated two stage nitrification process prevents accumulation of nitrite in the soil. Concentrations of nitrite are toxic to higher plants (Brady 1974).

The quantity of available soil mineral nitrogen varies cyclically with changes in soil temperature, soil microorganism biomass, and plant phenological growth and development during the growing season (Whitman 1975) and is the net difference between the total quantity of organic nitrogen mineralized by soil microorganisms and the quantity of mineral nitrogen immobilized by plants (Brady 1974, Legg 1975). The relationships between soil microorganism activity and phenology of plant growth activity results in a dynamic cycle of available mineral nitrogen (Goetz 1975). When soil microorganism activity is greater than plant growth activity, the quantity of available mineral nitrogen increases. When plant growth activity is greater than soil microorganism activity, the quantity of available mineral nitrogen decreases. This cycle in available soil mineral nitrogen results in three peaks and three low periods during the growing season (Whitman 1975). The quantity of mineral nitrogen increases an average of 25% to 50% between the low periods and the peaks in the cycle with some variations occurring on different range sites and at different soil depths (Goetz 1975).

Mineralization and nitrification processes of soil microorganism activity start slowly in the spring when the soil temperature permits formation of liquid water around 30° F. Available mineral nitrogen increases with increases in soil temperature and microorganism biomass reaching the first peak in mineral nitrogen around mid May just prior to start of rapid plant growth. The quantity of mineral nitrogen decreases rapidly with increasing plant growth rates during spring reaching the first low period during June and the first two weeks of July. The second peak in mineral nitrogen is reached at the end of the active growing season usually around late July or early August. A second low period in mineral nitrogen occurs from around mid August to mid or late September when plants have slow growth rates and during growth and development of fall tillers and fall tiller buds that will produce the early plant growth during the subsequent growing season. The third peak in mineral nitrogen occurs around mid October just prior to the end of the perennial plant growing season during autumn. Mineral nitrogen declines during the third low period as winter freeze up approaches (Goetz 1975, Whitman 1975).

The greater the quantity of mineral nitrogen available during periods of active plant growth, the greater the quantity of herbage biomass production. Rangeland ecosystem biogeochemical processes that cycle nitrogen need to function at rates that provide 100 pounds of mineral nitrogen per acre to produce the minimum potential quantity of herbage biomass and need to provide 165 pounds of mineral nitrogen per acre to produce the maximum potential quantity of herbage biomass (Wight and Black 1972) (table 1).

Traditional management practices, like 6.0 month seasonlong, repeated seasonal, and deferred grazing, were designed to use rangelands as a source of grazable forage for livestock and, even when operated with strong land stewardship ethics, traditional practices do not provide mineral nitrogen at quantities great enough to produce the potential quantity of herbage. Rangelands managed for about 35 years with a moderately stocked 6.0 month seasonlong grazing practice provided 62 pounds of mineral nitrogen per acre (Manske 2009), rangelands managed with an unspecified traditional grazing practice provided 59 pounds of mineral nitrogen per acre (Wight and Black 1972), and rangelands managed for 35 years with a low to moderately stocked 4.5 to 5.0 month deferred grazing practice provided 31 pounds of mineral nitrogen per acre (Manske 2008) (table 1). Rangelands managed with traditional grazing practices provide mineral nitrogen at deficiency rates of less than 100 pounds per acre causing decreases in plant water use efficiency and reducing herbage biomass production an average of 49.6% per inch of precipitation (Wight and Black 1979) (table 1). As a consequence of traditional grazing practices providing low quantities of mineral nitrogen and producing less than potential quantities of herbage biomass, native rangelands are incorrectly considered to be low producing, low income generating, resources.

Grazing management that is designed to meet the biological requirements of the plants and soil microorganisms and to stimulate ecosystem biogeochemical processes provide greater quantities of mineral nitrogen than do traditional practices. During the seventh grazing season, rangelands managed with a three pasture twice-over rotation grazing system provided 178 pounds of mineral nitrogen per acre (Manske 2008) (table 1). The greater quantity of mineral nitrogen resulted from greater soil microorganism activity. The twice-over rotation grazing system stimulated soil microorganism activity in the rhizosphere by increasing the quantity of plant fixed carbon exudated through grass roots into the rhizosphere. Removal of 25% to 33% of the leaf material by grazing livestock after the three and a half new leaf stage and before the flowering (anthesis) stage increased plant carbon exudates (Manske 2007). Soil microorganism growth and activity is limited by available carbon. Rhizosphere organisms increase in biomass and activity with increases in carbon. The rhizosphere volume on traditional grazing practices after twenty years of 6.0 month seasonlong and 4.5 month seasonlong was 50 and 68 cubic feet per acre, respectively (table 1). The rhizosphere volume was 227 cubic feet per acre on a twice-over rotation grazing system after twenty years (Manske 2008) (table 1). The greater rhizosphere organism biomass on rangelands managed with a twice-over rotation system had increased activity that mineralized and nitrified a greater quantity of organic nitrogen into mineral nitrogen. The greater quantity of available soil mineral nitrogen permitted the production of maximum potential herbage biomass, the growth of greater pounds of calf weight per acre, the generation of greater wealth per acre, and the improvement of native rangeland natural resources (Manske et al. 2008).

Table 1. Grazing management effects on mineral nitrogen and rhizosphere volume in native rangelands.

Standards for Mineral Nitrogen		Mineral Nitrogen	Source
Minimum potential herbage biomass		100 lbs/ac	Wight and Black 1972
Maximum potential herbage biomass		165 lbs/ac	Wight and Black 1972
Mineral nitrogen deficiency of less than 100 lbs/ac results in 49.6% reduction in herbage production per inch of precipitation.			Wight and Black 1979
Grazing Management		**Mineral Nitrogen**	
4.5-5.0 month Deferred	35 yrs	31 lbs/ac	Manske 2008
Traditional, not specified	long-term	59 lbs/ac	Wight and Black 1972
6.0 month Seasonlong	35 yrs	62 lbs/ac	Manske 2009
4.5 month Seasonlong	6 yrs	112 lbs/ac	Manske 2008
Twice-over Rotation	6 yrs	178 lbs/ac	Manske 2008
Grazing Management		**Rhizosphere Volume**	
6.0 month Seasonlong	20 yrs	50 ft^3/ac	Manske 2008
4.5 month Seasonlong	20 yrs	68 ft^3/ac	Manske 2008
Twice-over Rotation	20 yrs	227 ft^3/ac	Manske 2008

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Halogeton,
A Poisonous Plant Recently Introduced into North Dakota Rangelands

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Several small and medium sized patches of halogeton, a plant toxic to sheep, cattle, and herbivorous wildlife, have been located in the Badlands Area of western North Dakota, on both sides of the Little Missouri River and north of Interstate Highway 94, by Carmen Waldo, Natural Resources Specialist (Minerals) with the US Forest Service in the Medora Ranger District.

Halogeton, previously unknown to occur in North Dakota, was initially introduced during the 1930's into North America from the cold desert region of Eurasia. The plant spread rapidly and quickly became a serious problem weed in the Intermountain Great Basin Region of western United States. The plant thrives on the arid alkaline and saline soils in Nevada, Utah, Wyoming, Idaho, Oregon, and Colorado. Halogeton is listed as a noxious weed in the states of Arizona, California, Colorado, Hawaii, New Mexico, and Oregon.

Halogeton (Halogeton glomeratus (M. Bieb.) C.A. Mey.) is a member of the Goosefoot family and is an introduced, warm season, summer annual herb with horizontal spreading branches that curve upward to around 2 feet in height. The taproot can grow to about 20 inches in depth. Immature plants appear similar to young Russian thistle and kochia plants. Mature plants have red stems with small, round, fleshy, blue-green leaves about a half inch long with a single hair protruding out of the end. The leaf resembles a miniature sausage or wiener on a stick. Plants have small, inconspicuous yellow flowers during July through September and produce enormous quantities of seed, averaging around 75 seeds per inch of stem. Two types of seeds are produced each year. The black winged seeds, developed after mid August, can remain viable for about 1 year, and have a short after-ripening period that permits quick germination. The black seeds can imbibe water and germinate in less than 1 hour. The brown wingless seeds, developed before mid August, are dormant at maturity permitting the seeds to survive in soil for 10 years or more. The seeds are dispersed by wind, water, human activities, through the digestive tract of sick animals, and when dry plants break off at ground level and tumble with the wind. Germination of most seeds occurs during late fall or early spring.

Halogeton plants contain unusually heavy concentrations of soluble oxalates which are bound primarily as sodium salts. Concentrations of the soluble oxalates are highest in the leaves (14 to 25%) and lowest in the stems (1 to 4%) and seeds (2%). Most of the sodium oxalates in the stems are insoluble and thus nonpoisonous. The content of the soluble sodium oxalates tends to be relatively high during midsummer and may exceed 30% in leaf samples from late August to frost. Dead plants remain almost as poisonous as the living plants. After ingestion, soluble sodium oxalates are readily absorbed into the circulatory system. The sodium ions are replaced by calcium withdrawn from blood serum. This calcium reduction disrupts blood coagulation, and nerve and muscle function resulting in staggering and muscular spasms similar to milk fever. These calcium oxalates formed in the blood are precipitated in the liver and kidneys, which then interferes with normal function of these organs. A lethal dose of foliage at 0.3 to 0.5% of the animal's body weight can cause death within 24 hours. About 1.5 lbs of foliage can kill a sheep and about 3 to 5 lbs can kill a cow. As little as 12 oz of foliage can be fatal to animals in poor condition. Cattle generally develop subacute symptoms from halogeton poisoning when abundant good forage is available because the bitter taste of halogeton discourages consumption of large enough quantities of foliage to cause acute symptoms and death.

Halogeton competes poorly with healthy, established perennial vegetation, however, open areas with bare saline-alkali soils facilitate its invasion and establishment. Control can be troublesome because of the large quantity of seeds produced annually and the long survival period of the brown seeds. Three herbicides have been shown to effectively manage halogeton in the Great Basin Region. Control of young plants during June, prior to the start of flowering, is possible with 2, 4-D applied at 1.0 to 2.0 lbs acid equivalent (ae) (1.1 to 2.1 qt product) per acre and, when plants are mature, application of 2.0 to 6.0 lbs ae (2.1 to 6.3 qt product) per acre is effective. One application of tebuthiuron (Spike 20P) at 0.5 lb active ingredient (ai) (2.5 lb product) per acre should provide control for 3 to 5 years. Metsulfuron (Ally XP, Cimarron, Cimarron X-tra, and Cimarron Max) is effective at 0.2 oz ai (0.33 lb product) per acre. There are no currently registered biocontrol agents for halogeton, however, there are a few experimental agents ready for field testing.

Halogeton has the biological ability to develop into a very troublesome noxious poisonous plant in our western rangelands, however, during these early stages of invasion, eradication from North Dakota soils still is possible if decisive action is implemented before the plant population reaches crisis level.

CDFA/BCSP

Distribution of *Halogeton glomeratus* (M. Bieb.) C. A. Mey.

Map from http://www.cdfa.ca.gov/PHPPS/ipc/weedinfo/usedimages/halogetonmap.html

Sheri Hagwood@USDA-NRCS PLANTS Database

Grass Plant Responses to Defoliation

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Management of grassland ecosystems has customarily been applied from the perspective of the "use" of the grassland creating conflict among competing user groups and imposing antagonistic effects on grassland plants and soil organisms that cause degradation of biogeochemical processes, reduction of available mineral nitrogen, reduction of grass tiller density, and reduction of grassland productivity (Manske 2007a). Management strategies that place priority with the living components of the ecosystem meet the biological requirements of grassland plants and soil organisms, and are beneficial for biogeochemical processes, thereby increasing soil mineral nitrogen and enhancing health and productivity of grassland ecosystems (Manske 2007b).

Implementation of biologically effective management strategies that are beneficial for grassland ecosystems requires knowledge of grass plant responses to defoliation resulting from activation of the defoliation resistance mechanisms developed in grass plants during coevolution with herbivores (McNaughton 1979, 1983; Coleman et al. 1983; Briske 1991; Briske and Richards 1995; Manske 1999). The defoliation resistance mechanisms help grass tillers withstand and recover from partial defoliation by grazing and are: herbivore-induced compensatory physiological processes (McNaughton 1979, 1983; Briske 1991); stimulation of vegetative reproduction of secondary tillers from axillary buds (Mueller and Richards 1986, Richards et al. 1988, Murphy and Briske 1992, Briske and Richards 1994, Briske and Richards 1995); and stimulation of rhizosphere organism activity and the increased conversion of inorganic nitrogen from soil organic nitrogen (Coleman et al. 1983, Ingham et al. 1985).

Compensatory physiological processes within grass plants enable rapid recovery of defoliated tillers through: increased growth rates of replacement leaves and shoots that produces larger leaves with greater mass (Langer 1972, Briske and Richards 1995); increased photosynthetic capacity of remaining mature leaves and rejuvenated portions of older leaves not completely senescent (Atkinson 1986, Briske and Richards 1995); and increased allocation of carbon and nitrogen from remaining leaf and shoot tissue, not from material stored in the roots (Richards and Caldwell 1985, Briske and Richards 1995, Coyne et al. 1995). Compensatory physiological processes are activated by seasonable partial defoliation by grazing of grass tillers during phenological growth between the three and a half new leaf stage and the flowering (anthesis) stage (Manske 2007b).

Vegetative reproduction by tillering is the asexual process of growth and development of tillers from axillary buds (Dalh 1995). The meristematic activity in axillary buds and the subsequent development of vegetative secondary tillers is regulated by auxin, a growth-inhibiting hormone produced in the apical meristem and young developing leaves of lead tillers (Briske and Richards 1995). Auxin interferes with the metabolic function of cytokinin, a growth hormone (Briske and Richards 1995). Partial defoliation temporarily reduces the production of the blockage hormone, auxin (Briske and Richards 1994). This abrupt reduction of plant auxin in the lead tiller allows for cytokinin synthesis or utilization in multiple axillary buds, stimulating the development of vegetative tillers (Murphy and Briske 1992, Briske and Richards 1994). Vegetative growth of secondary tillers from axillary buds can be stimulated by partial defoliation of young leaf material from grass tillers at phenological growth between the three and a half new leaf stage and the flowering (anthesis) stage (Manske 2007b).

The rhizosphere is the narrow zone of soil around active roots of perennial grassland plants and is comprised of bacteria, protozoa, nematodes, springtails, mites, endomycorrhizal fungi (Anderson et al. 1981, Curl and Truelove 1986) and ectomycorrhizal fungi (Caesar-TonThat et al. 2001, Manske and Caesar-TonThat 2003). Active rhizosphere organisms are required in grassland ecosystems for the conversion of plant usable inorganic nitrogen from soil organic nitrogen. Rhizosphere organism biomass and activity are limited by access to simple carbon chains (Curl and Truelove 1986) because the microflora trophic levels lack chlorophyll and have low carbon (energy) content. Partial defoliation of grass plants at vegetative phenological growth stages by large grazing herbivores causes greater quantities of exudates containing simple carbon compounds to be released through the plant roots into the rhizosphere (Hamilton and Frank 2001). With the increase in availability of carbon compounds in the rhizosphere, activity of the microorganisms increases (Anderson et al. 1981, Curl and Truelove 1986, Whipps 1990). The increase in rhizosphere organism activity causes an increase in microorganism biomass and an increase in rhizosphere volume (Gorder, Manske, and Stroh 2004). The elevated rhizosphere organism activity caused by the increase in available carbon compounds results in a greater quantity of organic nitrogen converted into inorganic nitrogen (Coleman et al. 1983, Klein et al. 1988, Burrows and Pfleger 2002, Rillig et al. 2002, Bird et al. 2002, Driver et al. 2005). The increase in inorganic nitrogen available to defoliated grass plants allows the plant to recover more quickly from defoliation, to accelerate the growth rate, to increase vegetative tiller development from axillary buds, and to increase the total herbage biomass production (Manske 1999, 2003).

The defoliation resistance mechanisms not only permit grass plants to tolerate defoliation but to benefit from partial defoliation by grazing at some vegetative phenological growth stages. The activation of the defoliation resistance mechanisms in grass plants on various grazing management strategies from the differences of timing and frequency of defoliation by grazing are not completely understood. The goal of this project was to increase the knowledge of activation of the defoliation resistance mechanisms with grazing management strategies so that partial defoliation by grazing can be intentionally used beneficially to stimulate vegetative tillering from axillary buds in grass plants.

Vegetative tiller development of grass plants as a response to timing and frequency of partial defoliation by grazing has been studied at the North Dakota State University Dickinson Research Extension Center since 1983. This vegetative tiller development as a response to defoliation research project was funded by North Dakota State Board of Agricultural Research and Education (SBARE) and conducted at the Dickinson Research Extension Center in southwestern North Dakota during 2000 and 2001. Detailed data was collected from western wheatgrass tillers to evaluate grass plant response to changes in time of defoliation and differences in severity of defoliation. These data will assist in the refinement of grazing management practices so that the biological requirements of grass plants and soil organisms can be met and increase vegetative tillering from axillary buds.

Study Area

The native rangeland study sites were on the Dickinson Research Extension Center ranch, operated by North Dakota State University and located 20 miles north of Dickinson, in southwestern North Dakota, U.S.A. (47° 14' N. lat., 102° 50' W. long.).

Soils were primarily Typic Haploborolls. Long-term mean annual temperature was 42.4° F (5.8° C). January was the coldest month, with a mean temperature of 14.6° F (-9.7° C). July and August were the warmest months, with mean temperatures of 69.8° F (21.0° C) and 68.8° F (20.4° C), respectively. Long-term annual precipitation was 16.69 inches (423.96 mm). The amount of precipitation received during the growing season (April to October) was 13.90 inches (353.08 mm), 83.28% of annual precipitation (Manske 2009a).

The native rangeland vegetation was the Wheatgrass-Needlegrass Type (Barker and Whitman 1988, Shiflet 1994) of the mixed grass prairie. The dominant native range grasses were western wheatgrass (*Agropyron smithii*) (*Pascopyrum smithii*), needle and thread (*Stipa comata*) (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*), and threadleaf sedge (*Carex filifolia*).

The study sites were managed with three different grazing strategies. The 6.0-month seasonlong management strategy started in mid May. Livestock grazed a single native range pasture for 183 days, until mid November. The 4.5-month seasonlong management strategy started in early June. Livestock grazed a single native range pasture for 137 days, until mid October. The 4.5-month twice-over rotation management strategy started in early June, when livestock were moved to one of three native range pastures. Livestock remained on native range for 137 days, grazing each pasture for two periods, one 15-day period between 1 June and 15 July (when lead tillers of grasses were between the third-leaf stage and flowering stage) and one 30-day period after 15 July (after secondary tillers of grasses reached the third-leaf stage) and prior to mid October. The first pasture grazed in the sequence was the last pasture grazed the previous year.

Procedures

Three study site exclosures were established on native rangeland silty range sites with livestock grazing controlled by three different management strategies: 6.0-month seasonlong (6.0 m SL), 4.5-month seasonlong (4.5 m SL), and 4.5-month twice-over rotation (4.5 m TOR). The silty range sites were located on gently sloping upland terrace landscape positions with deep fine sandy loam soils. Sites with near 10 inch (25 cm) surface horizon depth were reconnoitered prior to the start of the study, however, the exclosure construction crew relocated the 4.5 m SL site to a more level grade but with a shallower surface horizon depth. The depths of the surface horizon on the study sites of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies were 9.6 inches (24.4 cm), 8.1 inches (20.6 cm), and 9.8 inches (24.5 cm), respectively. The surface horizon of the soil on the 4.5 m SL management strategy was significantly shallower than that on the 6.0 m SL and 4.5 m TOR management strategies.

Within each exclosure, 35 microplots were located and seven randomly selected microplots were assigned to each of the five defoliation treatments. Grass tillers within each microplot were separated from the surrounding plant community by inserting into the sample site soil a PVC conduit barrier with a 3 inch (7.62 cm) diameter and 6 inch (15.24 cm) depth that was open at both ends. The PVC barriers prevented lateral movement of soil water, consequently, the only source of soil water in the microplots was precipitation.

Every western wheatgrass tiller within each microplot was individually identified with a distinguishing loop of colored wire that encircled the tiller at its base. New tillers were identified with different colored wire loops as they developed and carry over tillers were remarked at the start of the second year.

The western wheatgrass tillers were categorized as lead tillers, rhizome tillers, crown tillers, or fall tillers during data collection according to biological characteristics observed and relative position in the microplot. However, not all of the tillers classified as lead tillers were actually dominant tillers; some were subordinate secondary tillers. The tillers classified as rhizome tillers, crown tillers, or fall tillers were the type of tiller as classified, however, not all of these tillers were subordinate secondary tillers; some were actually lead tillers. Differentiation of tillers into distinguishable categories of dominant lead tillers and subordinate secondary tillers is not clear-cut. There appears to be a continuum of hierarchical levels within the tiller population from greatest dominance to lowest subordinate.

With the power of hindsight, the study tillers were divided into two synthetic groups based on relative rates of growth and development. Tillers with seemingly rapid or unimpeded growth were reclassified as lead tillers, and tillers with obviously inhibited growth and development were reclassified as secondary tillers. The lead tillers were subdivided into tillers that developed into sexually reproductive flowering stages (reproductive lead tillers) and tillers that remained vegetative at the end of the growing season (vegetative lead tillers). The secondary tillers with inhibited growth rates were subdivided into tillers that remained vegetative at the end of the growing season (slow growth secondary tillers) and tillers that terminated growth during the growing season (early senescent secondary tillers). Tillers that were initiated between mid August and mid October were classified as fall tillers. Vegetative tillers with intact apical meristem tissue that survived the winter period and continued growth and development during the next growing season were classified as carry over tillers.

Four defoliation treatments, based on actual livestock grazing patterns, and a control of no defoliation were applied to the western wheatgrass tillers in the microplots during the first year in each of the three exclosures. Two treatments to evaluate the effect of time of defoliation were conducted at critical phenological stages of development: 1) before apical meristem elevation (mid May), and 2) during apical meristem elevation (mid June). No apical meristem tissue was removed from treated tillers. Two treatments to evaluate the effects of severity of defoliation were conducted: 1) 25%, and 2) 50% removal of current aboveground biomass. The five defoliation treatments were: A) no defoliation, control, B) defoliation, mid May-25%, C) defoliation, mid May-50%, D) defoliation, mid June-25%, and E) defoliation, mid June-50%.

All western wheatgrass tillers within a microplot received the same timing and severity of defoliation treatment. Defoliation treatment clip heights were based on percent height-weight data determined during the week before the date of each defoliation treatment from 40 typical tillers collected at ground level from near the study areas. The typical tillers were cut into segments of 1.0 inch (2.5 cm) height increments from the base upwards. The height increments were oven dried and weighed separately. Percent of mean total tiller weight was determined for each height increment. The height of the tillers in each microplot was measured and the appropriate proportion of height equal to 25% or 50% of the typical tillers weight was removed from each microplot tiller. Defoliation treatments were conducted 11 May and 22 June 2000. The height of the tillers in each microplot was remeasured and a post defoliation tiller height was determined for each microplot (table 1).

Data collection began in early May and continued into October for two years (2000 and 2001). Sample periods occurred weekly during the first year and biweekly during the second year. The data collected for each tiller included number of leaves produced, phenological growth stage, and height of tallest leaf. New tillers were added to the data set as they developed during the growing season or early fall. A standard paired-plot t-test was used to analyze differences among means (Mosteller and Rourke 1973).

Table 1. Defoliation treatment tiller height before and after removal of 25% or 50% of tiller weight.

Date Treatment	Management Strategy	Pretreatment Height cm	Post treatment Height cm	Removed Height cm	Percent Height Removed %
11 May 2000					
May 25%	6.0 m SL	10.9	8.6	2.2	20.5
	4.5 m SL	8.7	6.9	1.8	20.6
	4.5 m TOR	9.2	7.4	1.8	19.4
	mean	9.6	7.7	1.9	20.2
May 50%	6.0 m SL	12.0	7.1	4.9	40.6
	4.5 m SL	9.1	5.5	3.6	39.8
	4.5 m TOR	10.9	6.5	4.4	40.5
	mean	10.8	6.4	4.3	40.3
22 June 2000					
June 25%	6.0 m SL	15.8	12.6	3.2	20.2
	4.5 m SL	13.6	10.9	2.7	19.9
	4.5 m TOR	14.1	11.3	2.8	19.9
	mean	14.5	11.6	2.9	20.0
June 50%	6.0 m SL	15.4	9.2	6.2	40.2
	4.5 m SL	14.9	9.0	5.9	39.4
	4.5 m TOR	17.4	10.4	7.0	40.1
	mean	15.9	9.6	6.4	39.9

Results

The basic design of this study was intended to test a simple straight forward treatment-response relationship between a defoliation event and the grass tiller reaction. However, the western wheatgrass tillers on the three grazing management strategies did not respond similarly to each of the defoliation treatments, disclosing that stimulation of the defoliation resistance mechanisms that help grass tillers withstand and recover from partial defoliation was not simple and was influenced by additional conditions or other factors. Activation of the physiological processes within the grass plants and the biogeochemical processes within the grassland ecosystem that provide resistance to defoliation depend on complex interactions among grazing animals, grass plants, and rhizosphere soil organisms (Manske 2007b).

The quantity of vegetative tiller development in grassland ecosystems and the rate of tiller growth and recovery following partial defoliation are affected by hierarchical dominant tiller regulation, by growing season environmental variables, and by availability of essential elements (Briske and Richards 1995, Manske 1998). Stimulation of vegetative tiller development from axillary buds requires the reduction of the inhibiting hormone, auxin, and growth and development of stimulated vegetative tillers requires procurement of sufficient quantities of essential elements from the surrounding environment. The major elements needed by grass plants are hydrogen, carbon, and nitrogen. The hydrogen comes from soil water (H_20) absorbed through the roots and distributed throughout the plant within the xylem vascular tissue. The source of carbon is atmospheric carbon dioxide ($C0_2$). Plants capture and fix carbon with the hydrogen from soil water during the process of photosynthesis which converts radiant energy from sunlight into chemical energy. The assimilated carbon is combined in several ways to form various types of sugars and starches that collectively are carbohydrates (CH_20). The source of nitrogen is inorganic nitrogen ($N0_3$) mineralized from soil organic nitrogen by rhizosphere organisms. This available mineral nitrogen is transferred from the rhizosphere through the endomycorrhizal fungi to the roots of the host grass plant and is than preferentially moved up to the active axillary bud meristmatic tissue shortly after stimulation by the growth hormone, cytokinin. Phosphorus and minor mineral nutrients are absorbed by grass plant roots from soil with assistance from rhizosphere endomycorrhizal fungi (Manske 2007b).

The amount of vegetative tiller growth and development on grassland ecosystems is not limited by the availability of radiant energy from the sun or by the availability of atmospheric carbon dioxide and these two essential elements were not quantified. The environmental variables of temperature and precipitation were determined for the study area, and the resource availability of mineral nitrogen and the volume of the rhizosphere were determined for the silty range sites on the three grazing management strategies, 6.0 m SL, 4.5 m SL, and 4.5 m TOR.

The average monthly temperature and monthly precipitation data for 1999 to 2001 collected from the Dickinson Research Extension Center ranch were used to characterize growing-season conditions and to identify water-deficiency months. The ombrothermic diagram (figure 1) developed through use of the ombrothermic graph technique reported by Emberger et al. (1963) identified monthly periods with water-deficiency conditions. Water-deficiency periods are indicated when the monthly precipitation data bar drops below the mean monthly temperature data curve. During water-deficiency periods perennial plants experience water stress, a condition that results when plants are unable to absorb adequate water to match the transpiration rate. Water-deficiency periods lasting for a month place plants under water stress severe enough to reduce herbage biomass production. During fall, average monthly temperatures are near or below freezing (32°F, 0°C), and most grass leaves are senescent and contain only a small amount of green tissue; however, plant growth continues at low levels.

The precipitation during the growing seasons of 2000 and 2001 was normal (table 2). During 2000 and 2001, 14.99 inches (107.84% of LTM) and 16.40 inches (117.98% of LTM) of precipitation were received, respectively. August of 2000 was a wet month and received 158.38% of LTM precipitation. April, May, June, July, and October received normal precipitation at 90.00%, 79.17%, 116.36%, 113.99%, and 109.77% of LTM. September was a dry month and received 79.56% of LTM precipitation. Perennial plants were under water stress conditions during September, 2000 (figure 1) (Manske 2009a). April, June, July, and September of 2001 were wet months and each received 192.86%, 196.30%, 200.41%, and 141.61% of LTM precipitation, respectively. May was a very dry month and received 22.08% of LTM precipitation. August and October were extremely dry months and received no precipitation. Perennial plants were under water stress conditions during May, August, and October, 2001 (figure 1) (Manske 2009a).

The availability of water, which is essential in physiological processes, does not limit herbage production on grassland ecosystems to the extent that mineral nitrogen availability does (Wight and Black

1972). Available soil mineral nitrogen is the major herbage growth limiting factor in Northern Plains rangelands (Wight and Black 1979). Available mineral nitrogen was determined from four replicated field soil core samples collected to a depth of 6 inches during mid June from silty range sites in each of the three grazing management strategies at the start of the seventh year of the grazing treatment study. Subsamples of field soil cores were analyzed for total incubated mineralizable nitrogen (N) using procedures outlined by Keeney (1982) and Keeney and Nelsen (1982). The available mineral nitrogen was 178, 112, and 62 lbs/acre-foot on the 4.5 m TOR, 4.5 m SL, and 6.0 m SL management strategies, respectively (table 3) (Manske 2008, 2009b). The quantity of soil mineral nitrogen at the relocated exclosure site of the 4.5 m SL management strategy appears to have been well below 100 lbs/ac. All mineral nitrogen values for the three management strategies were significantly different from each other (table 3).

The rhizosphere volume, which reflects the activity and biomass levels of soil microorganisms, was determined from length and diameter measurements of the rhizosphere soil cylinder around each root of every western wheatgrass tiller located in two replicated soil cores of 3 inches in diameter and 4 inches deep collected during June, July, August, and September from silty range sites in each of the three grazing management strategies during 2002 (Gorder, Manske, and Stroh 2004). The seasonal mean rhizosphere volume was 227, 68, and 50 ft^3/acre-foot on the 4.5 m TOR, 4.5 m SL, and 6.0 m SL management strategies, respectively (table 3) (Manske 2008). The rhizosphere volume on the 4.5 m SL and 6.0 m SL management strategies were not significantly different and the rhizosphere volume on both the seasonlong management strategies were significantly less than the rhizosphere volume on the 4.5 m TOR management strategy (table 3).

Tiller Dynamics

Control Treatment

The first year on the control treatment of the 6.0 month seasonlong management strategy (table 4a) started in early May with 469.9 /m^2 vegetative tillers including 344.6 /m^2 lead tillers and 125.3 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 0.0 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 469.9 /m^2 different tillers were present during the first growing season. During mid season, 219.3 /m^2 lead tillers developed into reproductive flowering stages (46.7% of the tiller population). Before reaching maturity, 31.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 219.3 /m^2 fall tillers developed. During mid October, 438.6 /m^2 live vegetative tillers remained, of which, 125.3 /m^2 were lead tillers, 94.0 /m^2 were secondary tillers, and 219.3 /m^2 were fall tillers. During the winter period, 0.0 /m^2 tillers terminated. The second year on the control treatment (table 4b) started in early May with 783.2 /m^2 vegetative tillers including 501.2 /m^2 lead tillers and 281.9 /m^2 secondary tillers, of which, 438.6 /m^2 were carry over tillers and 344.6 /m^2 were early spring initiated tillers; there were 313.3 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 31.3 /m^2 tillers during the second growing season with 0.0 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 814.5 /m^2 different tillers were present during the second growing season; there were 344.6 /m^2 more total tillers than during the first growing season. During mid season, 156.6 /m^2 lead tillers developed into reproductive flowering stages (19.2% of the tiller population). Before reaching maturity, 250.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 313.3 /m^2 fall tillers developed. During mid October, 720.5 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 188.0 /m^2 were secondary tillers, and 313.3 /m^2 were fall tillers; there were 281.9 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the control treatment of the 4.5 month seasonlong management strategy (table 4a) started in early May with 281.9 /m^2 vegetative tillers including 188.0 /m^2 lead tillers and 94.0 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 0.0 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 281.9 /m^2 different tillers were present during the first growing season. During mid season, 94.0 /m^2 lead tillers developed into reproductive flowering stages (33.3% of the tiller population). Before reaching maturity, 62.7 /m^2 vegetative tillers terminated. Between mid August and mid October, 94.0 /m^2 fall tillers developed. During mid October, 219.3 /m^2 live vegetative tillers remained, of which, 94.0 /m^2 were lead tillers, 31.3 /m^2 were secondary tillers, and 94.0 /m^2 were fall tillers. During the winter period, 0.0 /m^2 tillers terminated. The second year on the control treatment (table 4b) started in early May with 407.2 /m^2 vegetative tillers including 219.3 /m^2 lead tillers and 188.0 /m^2 secondary tillers, of which, 219.3 /m^2 were carry over tillers and 188.0 /m^2 were early spring initiated tillers; there were 125.3 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 125.3 /m^2 tillers during the second growing season with 31.3 /m^2 initiated during May and 94.0 /m^2 initiated during mid season. A total of 532.5 /m^2 different tillers were present during the second growing season; there were 250.6 /m^2 more total tillers than during the first growing season. During mid season, 31.3 /m^2 lead tillers developed into reproductive flowering stages (5.9% of the tiller population). Before reaching maturity, 188.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 156.6 /m^2 fall tillers developed. During mid October, 469.9 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 94.0 /m^2 were secondary tillers, and 156.6 /m^2 were fall tillers; there were 250.6 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the control treatment of the 4.5 month twice-over rotation management strategy (table 4a) started in early May with 877.1 /m^2 vegetative tillers including 626.5 /m^2 lead tillers and 250.6 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 31.3 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 939.8 /m^2 different tillers were present during the first growing season. During mid season, 344.6 /m^2 lead tillers developed into reproductive flowering stages (36.7% of the tiller population). Before reaching maturity, 250.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 250.6 /m^2 fall tillers developed. During mid October, 595.2 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 125.3 /m^2 were secondary tillers, and 250.6 /m^2 were fall tillers. During the winter period, 31.3 /m^2 tillers terminated. The second year on the control treatment (table 4b) started in early May with 1033.8 /m^2 vegetative tillers including 626.5 /m^2 lead tillers and 407.2 /m^2 secondary tillers, of which, 563.9 /m^2 were carry over tillers and 469.9 /m^2 were early spring initiated tillers; there were 156.6 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 250.6 /m^2 tillers during the second growing season with 125.3 /m^2 initiated during May and 125.3 /m^2 initiated during mid season. A total of 1284.4 /m^2 different tillers were present during the second growing season; there were 344.6 /m^2 more total tillers than during the first growing season. During mid season, 375.9 /m^2 lead tillers developed into reproductive flowering stages (29.3% of the tiller population). Before reaching maturity, 438.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 188.0 /m^2 fall tillers developed. During mid October, 657.8 /m^2 live vegetative tillers remained, of which, 250.6 /m^2 were lead tillers, 219.3 /m^2 were secondary tillers, and 188.0 /m^2 were fall tillers; there were 62.7 /m^2 more live vegetative tillers than during mid October of the first growing season.

Mid May 25% Treatment

The first year on the mid May 25% defoliation treatment of the 6.0 month seasonlong management strategy (table 4a) started in early May with 845.8 /m^2 vegetative tillers including 595.2 /m^2 lead tillers and 250.6 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 62.7 /m^2 initiated during mid season. A total of 908.5 /m^2 different tillers were present during the first growing season. During mid season, 156.6 /m^2 lead tillers developed into reproductive flowering stages (17.2% of the tiller population). Before reaching maturity, 94.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 94.0 /m^2 fall tillers developed. During mid October, 751.8 /m^2 live vegetative tillers remained, of which, 313.3 /m^2 were lead tillers, 344.6 /m^2 were secondary tillers, and 94.0 /m^2 were fall tillers. During the winter period, 281.9 /m^2 tillers terminated. The second year on the mid May 25% defoliation treatment (table 4b) started in early May with 626.5 /m^2 vegetative tillers including 375.9 /m^2 lead tillers and 250.6 /m^2 secondary tillers, of which, 469.9 /m^2 were carry over tillers and 156.6 /m^2 were early spring initiated tillers; there were 219.3 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 219.3 /m^2 tillers during the second growing season with 156.6 /m^2 initiated during May and 62.7 /m^2 initiated during mid season. A total of 845.8 /m^2 different tillers were present during the second growing season; there were 62.7 /m^2 fewer total tillers than during the first growing season. During mid season, 188.0 /m^2 lead tillers developed into reproductive flowering stages (22.2% of the tiller population). Before reaching maturity, 219.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 563.9 /m^2 fall tillers developed. During mid October, 1002.4 /m^2 live vegetative tillers remained, of which, 250.6 /m^2 were lead tillers, 188.0 /m^2 were secondary tillers, and 563.9 /m^2 were fall tillers; there were 250.6 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid May 25% defoliation treatment of the 4.5 month seasonlong management strategy (table 4a) started in early May with 626.5 /m^2 vegetative tillers including 532.5 /m^2 lead tillers and 94.0 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 62.7 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 689.2 /m^2 different tillers were present during the first growing season. During mid season, 31.3 /m^2 lead tillers developed into reproductive flowering stages (4.5% of the tiller population). Before reaching maturity, 125.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 281.9 /m^2 fall tillers developed. During mid October, 814.5 /m^2 live vegetative tillers remained, of which, 469.9 /m^2 were lead tillers, 62.7 /m^2 were secondary tillers, and 281.9 /m^2 were fall tillers. During the winter period, 313.3 /m^2 tillers terminated. The second year on the mid May 25% defoliation treatment (table 4b) started in early May with 501.2 /m^2 vegetative tillers including 250.6 /m^2 lead tillers and 250.6 /m^2 secondary tillers, of which, 501.2 /m^2 were carry over tillers and 0.0 /m^2 were early spring initiated tillers; there were 125.3 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 156.6 /m^2 tillers during the second growing season with 94.0 /m^2 initiated during May and 62.7 /m^2 initiated during mid season. A total of 657.8 /m^2 different tillers were present during the second growing season; there were 31.3 /m^2 fewer total tillers than during the first growing season. During mid season, 62.7 /m^2 lead tillers developed into reproductive flowering stages (9.5% of the tiller population). Before reaching maturity, 188.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 501.2 /m^2 fall tillers developed. During mid October, 908.5 /m^2 live vegetative tillers remained, of which, 313.3 /m^2 were lead tillers, 94.0 /m^2 were secondary tillers, and 501.2 /m^2 were fall tillers; there were 94.0 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid May 25% defoliation treatment of the 4.5 month twice-over rotation management strategy (table 4a) started in early May with 657.8 /m^2 vegetative tillers including 407.2 /m^2 lead tillers and 250.6 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 31.3 /m^2 tillers during the first growing season with 31.3 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 689.2 /m^2 different tillers were present during the first growing season. During mid season, 188.0 /m^2 lead tillers developed into reproductive flowering stages (27.3% of the tiller population). Before reaching maturity, 281.9 /m^2 vegetative tillers terminated. Between mid August and mid October, 313.3 /m^2 fall tillers developed. During mid October, 532.5 /m^2 live vegetative tillers remained, of which, 156.6 /m^2 were lead tillers, 62.7 /m^2 were secondary tillers, and 313.3 /m^2 were fall tillers. During the winter period, 0.0 /m^2 tillers terminated. The second year on the mid May 25% defoliation treatment (table 4b) started in early May with 1033.8 /m^2 vegetative tillers including 751.8 /m^2 lead tillers and 281.9 /m^2 secondary tillers, of which, 532.5 /m^2 were carry over tillers and 501.2 /m^2 were early spring initiated tillers; there were 375.9 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 250.6 /m^2 tillers during the second growing season with 31.3 /m^2 initiated during May and 219.3 /m^2 initiated during mid season. A total of 1284.4 /m^2 different tillers were present during the second growing season; there were 595.2 /m^2 more total tillers than during the first growing season. During mid season, 313.3 /m^2 lead tillers developed into reproductive flowering stages (24.4% of the tiller population). Before reaching maturity, 438.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 156.6 /m^2 fall tillers developed. During mid October, 689.2 /m^2 live vegetative tillers remained, of which, 313.3 /m^2 were lead tillers, 219.3 /m^2 were secondary tillers, and 156.6 /m^2 were fall tillers; there were 156.6 /m^2 more live vegetative tillers than during mid October of the first growing season.

Mid May 50% Treatment

The first year on the mid May 50% defoliation treatment of the 6.0 month seasonlong management strategy (table 4a) started in early May with 908.5 /m^2 vegetative tillers including 751.8 /m^2 lead tillers and 156.6 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 0.0 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 908.5 /m^2 different tillers were present during the first growing season. During mid season, 62.7 /m^2 lead tillers developed into reproductive flowering stages (6.9% of the tiller population). Before reaching maturity, 219.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 469.9 /m^2 fall tillers developed. During mid October, 1096.4 /m^2 live vegetative tillers remained, of which, 375.9 /m^2 were lead tillers, 250.6 /m^2 were secondary tillers, and 469.9 /m^2 were fall tillers. During the winter period, 250.6 /m^2 tillers terminated. The second year on the mid May 50% defoliation treatment (table 4b) started in early May with 908.5 /m^2 vegetative tillers including 657.8 /m^2 lead tillers and 250.6 /m^2 secondary tillers, of which, 845.8 /m^2 were carry over tillers and 62.7 /m^2 were early spring initiated tillers; there were no more tillers than during May of the first growing season. Vegetative reproduction produced 125.3 /m^2 tillers during the second growing season with 125.3 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 1033.8 /m^2 different tillers were present during the second growing season; there were 125.3 /m^2 more total tillers than during the first growing season. During mid season, 250.6 /m^2 lead tillers developed into reproductive flowering stages (24.2% of the tiller population). Before reaching maturity, 219.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 501.2 /m^2 fall tillers developed. During mid October, 1065.1 /m^2 live vegetative tillers remained, of which, 438.6 /m^2 were lead tillers, 125.3 /m^2 were secondary tillers, and 501.2 /m^2 were fall tillers; there were 31.3 /m^2 fewer live vegetative tillers than during mid October of the first growing season.

The first year on the mid May 50% defoliation treatment of the 4.5 month seasonlong management strategy (table 4a) started in early May with 344.6 /m^2 vegetative tillers including 313.3 /m^2 lead tillers and 31.3 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 31.3 /m^2 tillers during the first growing season with 31.3 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 375.9 /m^2 different tillers were present during the first growing season. During mid season, 62.7 /m^2 lead tillers developed into reproductive flowering stages (16.7% of the tiller population). Before reaching maturity, 94.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 188.0 /m^2 fall tillers developed. During mid October, 407.2 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 0.0 /m^2 were secondary tillers, and 188.0 /m^2 were fall tillers. During the winter period, 94.0 /m^2 tillers terminated. The second year on the mid May 50% defoliation treatment (table 4b) started in early May with 313.3 /m^2 vegetative tillers including 156.6 /m^2 lead tillers and 156.6 /m^2 secondary tillers, of which, 313.3 /m^2 were carry over tillers and 0.0 /m^2 were early spring initiated tillers; there were 31.3 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 125.3 /m^2 tillers during the second growing season with 94.0 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 438.6 /m^2 different tillers were present during the second growing season; there were 62.7 /m^2 more total tillers than during the first growing season. During mid season, 156.6 /m^2 lead tillers developed into reproductive flowering stages (35.7% of the tiller population). Before reaching maturity, 125.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 94.0 /m^2 fall tillers developed. During mid October, 250.6 /m^2 live vegetative tillers remained, of which, 156.6 /m^2 were lead tillers, 0.0 /m^2 were secondary tillers, and 94.0 /m^2 were fall tillers; there were 156.6 /m^2 fewer live vegetative tillers than during mid October of the first growing season.

The first year on the mid May 50% defoliation treatment of the 4.5 month twice-over rotation management strategy (table 4a) started in early May with 939.8 /m^2 vegetative tillers including 689.2 /m^2 lead tillers and 250.6 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 125.3 /m^2 tillers during the first growing season with 62.7 /m^2 initiated during May and 62.7 /m^2 initiated during mid season. A total of 1065.1 /m^2 different tillers were present during the first growing season. During mid season, 125.3 /m^2 lead tillers developed into reproductive flowering stages (11.8% of the tiller population). Before reaching maturity, 188.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 689.2 /m^2 fall tillers developed. During mid October, 1441.0 /m^2 live vegetative tillers remained, of which, 407.2 /m^2 were lead tillers, 344.6 /m^2 were secondary tillers, and 689.2 /m^2 were fall tillers. During the winter period, 407.2 /m^2 tillers terminated. The second year on the mid May 50% defoliation treatment (table 4b) started in early May with 1378.3 /m^2 vegetative tillers including 532.5 /m^2 lead tillers and 845.8 /m^2 secondary tillers, of which, 1033.8 /m^2 were carry over tillers and 344.6 /m^2 were early spring initiated tillers; there were 438.6 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 156.6 /m^2 tillers during the second growing season with 94.0 /m^2 initiated during May and 62.7 /m^2 initiated during mid season. A total of 1535.0 /m^2 different tillers were present during the second growing season; there were 469.9 /m^2 more total tillers than during the first growing season. During mid season, 250.6 /m^2 lead tillers developed into reproductive flowering stages (16.3% of the tiller population). Before reaching maturity, 750.5 /m^2 vegetative tillers terminated. Between mid August and mid October, 281.9 /m^2 fall tillers developed. During mid October, 845.8 /m^2 live vegetative tillers remained, of which, 281.9 /m^2 were lead tillers, 281.9 /m^2 were secondary tillers, and 281.9 /m^2 were fall tillers; there were 595.2 /m^2 fewer live vegetative tillers than during mid October of the first growing season.

Mid June 25% Treatment

The first year on the mid June 25% defoliation treatment of the 6.0 month seasonlong management strategy (table 4a) started in early May with 469.9 /m^2 vegetative tillers including 375.9 /m^2 lead tillers and 94.0 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 62.7 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 532.5 /m^2 different tillers were present during the first growing season. During mid season, 94.0 /m^2 lead tillers developed into reproductive flowering stages (17.7% of the tiller population). Before reaching maturity, 31.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 125.3 /m^2 fall tillers developed. During mid October, 532.5 /m^2 live vegetative tillers remained, of which, 188.0 /m^2 were lead tillers, 219.3 /m^2 were secondary tillers, and 125.3 /m^2 were fall tillers. During the winter period, 62.7 /m^2 tillers terminated. The second year on the mid June 25% defoliation treatment (table 4b) started in early May with 501.2 /m^2 vegetative tillers including 438.6 /m^2 lead tillers and 62.7 /m^2 secondary tillers, of which, 469.9 /m^2 were carry over tillers and 31.3 /m^2 were early spring initiated tillers; there were 31.3 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 94.0 /m^2 tillers during the second growing season with 0.0 /m^2 initiated during May and 94.0 /m^2 initiated during mid season. A total of 595.2 /m^2 different tillers were present during the second growing season; there were 62.7 /m^2 more total tillers than during the first growing season. During mid season, 188.0 /m^2 lead tillers developed into reproductive flowering stages (31.6% of the tiller population). Before reaching maturity, 94.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 469.9 /m^2 fall tillers developed. During mid October, 783.2 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 94.0 /m^2 were secondary tillers, and 469.9 /m^2 were fall tillers; there were 250.6 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid June 25% defoliation treatment of the 4.5 month seasonlong management strategy (table 4a) started in early May with 438.6 /m^2 vegetative tillers including 250.6 /m^2 lead tillers and 188.0 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 31.3 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 469.9 /m^2 different tillers were present during the first growing season. During mid season, 94.0 /m^2 lead tillers developed into reproductive flowering stages (20.0% of the tiller population). Before reaching maturity, 156.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 125.3 /m^2 fall tillers developed. During mid October, 344.6 /m^2 live vegetative tillers remained, of which, 62.7 /m^2 were lead tillers, 156.6 /m^2 were secondary tillers, and 125.3 /m^2 were fall tillers. During the winter period, 0.0 /m^2 tillers terminated. The second year on the mid June 25% defoliation treatment (table 4b) started in early May with 344.6 /m^2 vegetative tillers including 219.3 /m^2 lead tillers and 125.3 /m^2 secondary tillers, of which, 344.6 /m^2 were carry over tillers and 0.0 /m^2 were early spring initiated tillers; there were 94.0 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 188.0 /m^2 tillers during the second growing season with 62.7 /m^2 initiated during May and 125.3 /m^2 initiated during mid season. A total of 532.5 /m^2 different tillers were present during the second growing season; there were 62.7 /m^2 more total tillers than during the first growing season. During mid season, 125.3 /m^2 lead tillers developed into reproductive flowering stages (23.5% of the tiller population). Before reaching maturity, 156.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 125.3 /m^2 fall tillers developed. During mid October, 375.9 /m^2 live vegetative tillers remained, of which, 188.0 /m^2 were lead tillers, 62.7 /m^2 were secondary tillers, and 125.3 /m^2 were fall tillers; there were 31.3 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid June 25% defoliation treatment of the 4.5 month twice-over rotation management strategy (table 4a) started in early May with 971.1 /m^2 vegetative tillers including 595.2 /m^2 lead tillers and 375.9 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 31.3 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 1033.8 /m^2 different tillers were present during the first growing season. During mid season, 156.6 /m^2 lead tillers developed into reproductive flowering stages (15.1% of the tiller population). Before reaching maturity, 407.2 /m^2 vegetative tillers terminated. Between mid August and mid October, 344.6 /m^2 fall tillers developed. During mid October, 814.5 /m^2 live vegetative tillers remained, of which, 313.3 /m^2 were lead tillers, 156.6 /m^2 were secondary tillers, and 344.6 /m^2 were fall tillers. During the winter period, 188.0 /m^2 tillers terminated. The second year on the mid June 25% defoliation treatment (table 4b) started in early May with 1096.4 /m^2 vegetative tillers including 845.8 /m^2 lead tillers and 250.6 /m^2 secondary tillers, of which, 626.5 /m^2 were carry over tillers and 469.9 /m^2 were early spring initiated tillers; there were 125.3 /m^2 more tillers than during May of the first growing season. Vegetative reproduction produced 188.0 /m^2 tillers during the second growing season with 156.6 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 1284.4 /m^2 different tillers were present during the second growing season; there were 250.6 /m^2 more total tillers than during the first growing season. During mid season, 188.0 /m^2 lead tillers developed into reproductive flowering stages (14.6% of the tiller population). Before reaching maturity, 281.9 /m^2 vegetative tillers terminated.

Between mid August and mid October, 219.3 /m^2 fall tillers developed. During mid October, 1033.8 /m^2 live vegetative tillers remained, of which, 657.8 /m^2 were lead tillers, 156.6 /m^2 were secondary tillers, and 219.3 /m^2 were fall tillers; there were 219.3 /m^2 more live vegetative tillers than during mid October of the first growing season.

Mid June 50% Treatment

The first year on the mid June 50% defoliation treatment of the 6.0 month seasonlong management strategy (table 4a) started in early May with 563.9 /m^2 vegetative tillers including 438.6 /m^2 lead tillers and 125.3 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 31.3 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 626.5 /m^2 different tillers were present during the first growing season. During mid season, 156.6 /m^2 lead tillers developed into reproductive flowering stages (25.0% of the tiller population). Before reaching maturity, 62.7 /m^2 vegetative tillers terminated. Between mid August and mid October, 188.0 /m^2 fall tillers developed. During mid October, 595.2 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 188.0 /m^2 were secondary tillers, and 188.0 /m^2 were fall tillers. During the winter period, 156.6 /m^2 tillers terminated. The second year on the mid June 50% defoliation treatment (table 4b) started in early May with 469.9 /m^2 vegetative tillers including 407.2 /m^2 lead tillers and 62.7 /m^2 secondary tillers, of which, 438.6 /m^2 were carry over tillers and 31.3 /m^2 were early spring initiated tillers; there were 94.0 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 156.6 /m^2 tillers during the second growing season with 125.3 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 626.5 /m^2 different tillers were present during the second growing season; there were the same number of total tillers as during the first growing season. During mid season, 125.3 /m^2 lead tillers developed into reproductive flowering stages (20.0% of the tiller population). Before reaching maturity, 94.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 313.3 /m^2 fall tillers developed. During mid October, 720.5 /m^2 live vegetative tillers remained, of which, 375.9 /m^2 were lead tillers, 31.3 /m^2 were secondary tillers, and 313.3 /m^2 were fall tillers; there were 125.3 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid June 50% defoliation treatment of the 4.5 month seasonlong management strategy (table 4a) started in early May with 375.9 /m^2 vegetative tillers including 281.9 /m^2 lead tillers and 94.0 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 0.0 /m^2 tillers during the first growing season with 0.0 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 375.9 /m^2 different tillers were present during the first growing season. During mid season, 62.7 /m^2 lead tillers developed into reproductive flowering stages (16.7% of the tiller population). Before reaching maturity, 125.3 /m^2 vegetative tillers terminated. Between mid August and mid October, 156.6 /m^2 fall tillers developed. During mid October, 344.6 /m^2 live vegetative tillers remained, of which, 125.3 /m^2 were lead tillers, 62.7 /m^2 were secondary tillers, and 156.6 /m^2 were fall tillers. During the winter period, 125.3 /m^2 tillers terminated. The second year on the mid June 50% defoliation treatment (table 4b) started in early May with 250.6 /m^2 vegetative tillers including 156.6 /m^2 lead tillers and 94.0 /m^2 secondary tillers, of which, 219.3 /m^2 were carry over tillers and 31.3 /m^2 were early spring initiated tillers; there were 125.3 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 94.0 /m^2 tillers during the second growing season with 62.7 /m^2 initiated during May and 31.3 /m^2 initiated during mid season. A total of 344.6 /m^2 different tillers were present during the second growing season; there were 31.3 /m^2 fewer total tillers than during the first growing season. During mid season, 94.0 /m^2 lead tillers developed into reproductive flowering stages (27.3% of the tiller population). Before reaching maturity, 94.0 /m^2 vegetative tillers terminated. Between mid August and mid October, 219.3 /m^2 fall tillers developed. During mid October, 375.9 /m^2 live vegetative tillers remained, of which, 156.6 /m^2 were lead tillers, 0.0 /m^2 were secondary tillers, and 219.3 /m^2 were fall tillers; there were 31.3 /m^2 more live vegetative tillers than during mid October of the first growing season.

The first year on the mid June 50% defoliation treatment of the 4.5 month twice-over rotation management strategy (table 4a) started in early May with 720.5 /m^2 vegetative tillers including 595.2 /m^2 lead tillers and 125.3 /m^2 secondary tillers. An unknown quantity of these tillers were carry over tillers from the previous growing season. Vegetative reproduction produced 62.7 /m^2 tillers during the first growing season with 62.7 /m^2 initiated during May and 0.0 /m^2 initiated during mid season. A total of 783.2 /m^2 different tillers were present during the first growing season. During mid season, 219.3 /m^2 lead tillers developed into reproductive flowering stages (28.0% of the tiller population). Before reaching maturity, 250.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 344.6 /m^2 fall tillers developed. During mid October, 657.8 /m^2 live vegetative tillers remained, of which, 219.3 /m^2 were lead tillers, 94.0 /m^2 were secondary tillers, and 344.6 /m^2 were fall tillers. During the winter period, 219.3 /m^2 tillers terminated. The second year on the mid June 50% defoliation treatment (table 4b) started in early May with 689.2 /m^2 vegetative tillers including 563.9 /m^2 lead tillers and 125.3 /m^2 secondary tillers, of which, 438.6 /m^2 were carry over tillers and 250.6 /m^2 were early spring initiated tillers; there were 31.3 /m^2 fewer tillers than during May of the first growing season. Vegetative reproduction produced 250.6 /m^2 tillers during the second growing season with 156.6 /m^2 initiated during May and 94.0 /m^2 initiated during mid season. A total of 939.8 /m^2 different tillers were present during the second growing season; there were 156.6 /m^2 more total tillers than during the first growing season. During mid season, 281.9 /m^2 lead tillers developed into reproductive flowering stages (30.0% of the tiller population). Before reaching maturity, 156.6 /m^2 vegetative tillers terminated. Between mid August and mid October, 344.6 /m^2 fall tillers developed. During mid October, 845.8 /m^2 live vegetative tillers remained, of which, 438.6 /m^2 were lead tillers, 62.7 /m^2 were secondary tillers, and 344.6 /m^2 were fall tillers; there were 188.0 /m^2 more live vegetative tillers than during mid October of the first growing season.

Tiller Density

The number of total different tillers present were significantly greater during the first year on the control, May 50%, and June 25% treatments and during the second year on the control, May 25%, May 50%, and June 25% treatments and numerically greater during both years on the June 50% treatment of the 4.5 m TOR management strategy (tables 4a and 4b). The number of total different tillers were significantly lower during the first year on the control, May 50%, and June 50% treatments and during the second year on the May 50% and June 50% treatments and numerically lower during the first year on the June 25% treatment and during the second year on the control, May 25%, and June 25% treatments of the 4.5 m SL management strategy (tables 4a and 4b). On the 6.0 m SL management strategy, the number of total different tillers were intermediate during the first year on the control, May 50%, June 25%, and June 50% treatments and during the second year on all five treatments (tables 4a and 4b).

Monthly tiller densities, consisting of lead tillers, secondary tillers, and, from mid August to mid October, fall tillers, were greater during both years on all five treatments (except the first year on the May 25% treatment) of the 4.5 m TOR management strategy; were lower on all five treatments (except the first year on the May 25% treatment) of the 4.5 m SL management strategy; and were intermediate on all five treatments (except the first year on the May 25% treatment) of the 6.0 m SL management strategy (figures 2, 3, 4, 5, and 6). During the first year on the May 25% treatment, the monthly tiller densities were greater on the 6.0 m SL management strategy and were similar on the 4.5 m SL and 4.5 m TOR management strategies; except the vegetative lead tiller density was lower on the 4.5 m TOR management strategy during mid August to mid October (figure 3).

Mean monthly tiller densities, excluding the fall tillers, were significantly greater during the first year on the May 25% treatment of the 6.0 m SL management strategy and were significantly greater during the first year on the control, June 25%, and June 50% treatments and during the second year on the control, May 25%, June 25%, and June 50% treatments of the 4.5 m TOR management strategy (table 5). During both years on the May 50% treatment, there were no significant differences between the mean monthly densities of the 6.0 m SL and 4.5 m TOR management strategies (table 5). Mean monthly densities were significantly lower during the first year on the control, May 50%, June 25%, and June 50% treatments and during the second year on all five treatments of the 4.5 m SL management strategy (table 5). During the first year on the May 25% treatment, there were no significant differences between the mean monthly densities of the 4.5 m SL and 4.5 m TOR management strategies (table 5).

The change in mean monthly tiller densities from the first year to the second year were not significantly different on the control, May 50%, and June 50% treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies and on the June 25% treatments of the 6.0 m SL and 4.5 m SL management strategies (table 5). Mean monthly tiller densities increased significantly during the second year on the May 25% and June 25% treatments of the 4.5 m TOR management strategy and decreased significantly on the May 25% treatments of the 6.0 m SL and 4.5 m SL management strategies (table 5).

The total tiller density for the combined first and second years, excluding the carry over tillers during the second year, were significantly greater on the May 50% and June 25% treatments and numerically greater on the control and June 50% treatments of the 4.5 m TOR management strategy; and were significantly lower on the control, May 50%, June 25%, and June 50% treatments of the 4.5 m SL management strategy (table 6). The total two year tiller densities were intermediate on the control, May 50%, June 25%, and June 50% treatments of the 6.0 m SL management strategy (table 6). There were no significant differences in the total two year tiller densities on the May 25% treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies (table 6).

The 6.0 m SL, 4.5 m SL, and 4.5 m TOR grazing management strategies had been operational prior to the start of this defoliation study for 12 years, 14 years, and 17 years, respectively. The effects from these grazing management strategies would have been established within the respective ecosystems at some proportion related the length of operational time. The quantities of tillers were significantly or numerically greater on the five treatments of the 4.5 m TOR management strategy during both years, except the first year on the May 25% treatment. The quantities of tillers were significantly or numerically lower on the five treatments of the 4.5 m SL management strategy. The quantity of tillers on the five treatments of the 6.0 m SL management strategy were usually intermediate, except the first year on the May 25% treatment. The greater quantity of tillers on the 4.5 m TOR management strategy developed because of the significantly greater quantities of available soil mineral nitrogen that resulted from the greater soil organism activity in the significantly larger rhizosphere volume (table 3). The low quantity of tillers produced on the 4.5 m SL management strategy resulted because of the low quantities of soil mineral nitrogen, the low rhizosphere volume, and the effects from the soil characteristics related to the significantly shallower surface horizon depth. The quantity of tillers on the 6.0 m SL management strategy were lower than the tiller densities on the 4.5 m TOR management strategy because of the lower quantities of soil mineral nitrogen and lower rhizosphere volume, and would be expected to be lower than those on the 4.5 m SL management strategy had both seasonlong management strategies had similar duration of operation and surface horizon depth.

Tiller Initiation

The total number of tillers initiated through vegetative reproduction from axillary buds were significantly greater on the May 50% treatment and numerically greater on the control, May 25%, June 25%, and June 50% treatments of the 4.5 m TOR management strategy; and were significantly lower on the control, May 50%, June 25%, and June 50% treatments and numerically lower on the May 25% treatment of the 4.5 m SL management strategy (table 7). Vegetatively reproduced tillers were intermediate on the five treatments of the 6.0 m SL management strategy (table 7).

The number of vegetative tillers stimulated per lead tiller present at the time of defoliation treatment were significantly greater on the May 25% treatment and numerically greater on the May 50%, June 25%, and June 50% treatments of the 4.5 m TOR management strategy; were significantly lower on the May 50% treatment and numerically lower on the June 25% and June 50% treatments of the 4.5 m SL management strategy and on the May 25% treatment of the 6.0 m SL management strategy; and were intermediate on the May 50%, June 25%, and June 50% treatment of the 6.0 m SL management strategy and on the May 25% treatment of the 4.5 m SL management strategy (table 7).

Significantly greater numbers of vegetative tillers were stimulated on the May 25%, May 50%, and June 25% treatments than on the control treatment and numerically fewer tillers were stimulated on the June 50% treatment than on the control treatment of the 4.5 m TOR management strategy. Significantly fewer tillers were stimulated on the May 50% treatment and numerically fewer tillers were stimulated on the May 25%, June 25%, and June 50% treatments than on the control treatment of the 4.5 m SL management strategy; and numerically fewer tillers were stimulated on the May 25%, May 50%, June 25%, and June 50% treatments than on the control treatment of the 6.0 m SL management strategy (table 7). The defoliated tillers on the traditional 6.0 m SL and 4.5 m SL management strategies produced 141.0 /m^2 and 117.4 /m^2 fewer vegetative tillers than were produced by undefoliated tillers on the respective control treatments. The defoliated tillers produced 198.4 /m^2 more vegetative tillers than were produced by undefoliated tillers on the control treatment of the 4.5 m TOR management strategy.

The total number of initiated vegetative tillers was lower on the treatments of the 4.5 m SL and 6.0 m SL management strategies than the number of initiated tillers on the treatments of the 4.5 m TOR management strategy because of the significantly lower soil mineral nitrogen, and the significantly lower volume of rhizosphere on the two seasonlong management strategies. The number of stimulated vegetative tillers per lead tiller on all four defoliation treatments of the 4.5 m SL and 6.0 m SL management strategies was lower than the number of tillers that developed on the respective control treatments because the defoliated tillers were unable to recover fully from the single event defoliation treatment as a result of the insufficient quantities of soil mineral nitrogen inhibiting the compensatory physiological processes within the grass plants on the two seasonlong management strategies. The defoliated tillers on the June 50% treatment of the 4.5 m TOR management strategy recovered to slightly less than full pretreatment condition and produced slightly fewer tillers per lead tiller than were produced on the control treatment.

The defoliated tillers on the May 25%, May 50%, and June 25% treatments of the 4.5 m TOR management strategy fully recovered from the defoliation treatments and produced more vegetative tillers per lead tiller than were produced on the control treatment. The significantly larger rhizosphere volume and the significantly greater quantities of available soil mineral nitrogen on the 4.5 m TOR management strategy were the essential resources that permitted grass tillers to fully recover by the compensatory physiological processes within the grass plants, to support vegetative tiller growth from several axillary buds, and to increase herbage production following defoliation treatments.

Vegetative tillers initiated during early spring were significantly greater on the control, May 25%, and June 25% treatments and numerically greater on the May 50% and June 50% treatments of the 4.5 m TOR management strategy than on the defoliation treatments of the two seasonlong management strategies (table 8). Vegetative tillers initiated during May were significantly greater on the June 25% and June 50% treatments and numerically greater on the control and May 50% treatments of the 4.5 m TOR management strategy than on the defoliation treatments of the two seasonlong management strategies (table 8). Vegetative tillers initiated during mid season were significantly greater on the June 25% treatment of the 4.5 m SL management strategy and were significantly greater on the control and May 25% treatments and numerically greater on the May 50% and June 50% treatments of the 4.5 m TOR management strategy (table 8). Greater numbers of vegetative tillers were initiated during early spring and May on the treatments of the 4.5 m TOR management strategy than were initiated on the treatments of the 4.5 m SL and 6.0 m SL management strategies showing that grass plants on the 4.5 m TOR management strategy were in better condition and had access to carbohydrates and essential mineral nitrogen in much greater quantities than were available to grass plants on the 4.5 m SL and 6.0 m SL management strategies. The mid season vegetative tiller initiation period occurred simultaneously with the high resource demand period in which the dominant reproductive lead tillers progressed through the flowering stages and produced seeds. Greater numbers of lead tillers flowered and greater numbers of vegetative tillers were initiated during mid season on the treatments of the 4.5 m TOR management strategy than flowered and were initiated on the treatments of the 4.5 m SL and 6.0 m SL management strategies showing that the grass plants on the 4.5 m TOR management strategy were in better condition and had access to greater quantities of essential mineral nitrogen than the grass plants on the 4.5 m SL and 6.0 m SL management strategies.

Vegetative tillers initiated as fall tillers during mid August to mid October were numerically greater on the control and June 25% treatments of the 6.0 m SL management strategy; on the May 25% treatment of the 4.5 m SL management strategy; and on the June 50% treatment of the 4.5 m TOR management strategy (table 8). On the May 25% treatment, there were no significant differences between the fall initiated tiller densities of the 6.0 m SL and 4.5 m TOR management strategies. Vegetative tillers initiated during fall season were significantly lower on the control, May 50%, and June 25% treatments and numerically lower on the June 50% treatment of the 4.5 m SL management strategy (table 8). Greater numbers of vegetative tillers were initiated as fall tillers than were initiated during early spring and May on the five treatments of the 6.0 m SL and 4.5 m SL management strategies (table 8). A greater percentage of the total vegetative tillers were initiated during mid August to mid October as fall tillers on the five treatments of the 6.0 m SL and 4.5 m SL management strategies than the percent of total vegetative tillers initiated as fall tillers on the respective treatments of the 4.5 m TOR management strategy (table 8). The fall tiller initiation period, mid August to mid October, started after the lead tillers had completed most of their active growth and occurred simultaneously with the winter hardening process of perennial grasses. Young vegetative tillers on the 4.5 m SL and 6.0 m SL management strategies appeared to have lower competition for essential elements during this late season period than during the other vegetative tiller initiation periods.

The greatest number of total vegetative tillers initiated from axillary buds on the 4.5 m SL, 6.0 m SL, and 4.5 m TOR management strategies were 1002.4 /m^2 tillers on the May 25% treatment, 1159.1 /m^2 tillers on the May 50% treatment, and 1597.6 /m^2 tillers on the May 50% treatment, respectively. The lowest number of total vegetative tillers initiated on the 4.5 m SL, 6.0 m SL, and 4.5 m TOR management strategies were 438.6 /m^2 tillers on the May 50% treatment, 751.8 /m^2 tillers on the June 50% treatment, and 1221.7 /m^2 tillers on the control treatment, respectively (table 8). The lowest number of vegetative tillers initiated on the treatments of the 4.5 m TOR management strategy (1221.7 /m^2 tillers) was greater than the greatest number of vegetative tillers initiated on the treatments of the 4.5 m SL (1002.4 /m^2 tillers) and 6.0 m SL (1159.1 /m^2 tillers) management strategies (table 8). All of the treatments of the 4.5 m TOR management strategy initiated more vegetative tillers during the growing season than all the treatments of the 4.5 m SL and 6.0 m SL management strategies because of the greater quantities of available essential soil mineral nitrogen that resulted from the greater soil organism activity in the larger rhizosphere volume on the 4.5 m TOR management strategy.

Tiller Termination

The number of total tillers terminated during the growing season were significantly greater on the control and May 50% treatments and numerically greater on the May 25%, June 25%, and June 50% treatments of the 4.5 m TOR management strategy; were significantly lower on the control treatment and numerically lower on the May 25%, May 50%, June 25%, and June 50% treatments of the 4.5 m SL management strategy; and were intermediate on all five treatments of the 6.0 m SL management strategy (table 9). The mean percent of the tiller population terminated was 54.0%. Percent termination of the tiller population was greatest (61.1%) on the May 50% treatments and lowest (50.1%) on the June 25% treatments. There was no significant differences in the percent of total tillers that terminated among all the treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies.

The number of lead tillers terminated after flowering was significantly greater on the control, May 25%, and June 50% treatments and numerically greater on the May 50% and June 25% treatments of the 4.5 m TOR management strategy; was significantly lower on the control, May 25%, and June 50% treatments and numerically lower on the May 50% and June 25% treatments of the 4.5 m SL management strategy; and was intermediate on all five treatments of the 6.0 m SL management strategy (table 9). The percent of the tiller population that produced flower stages was around 33.0% on the control treatments and around 20.3% on the defoliation treatments, with a mean of 17.3% during the first year and a mean of 23.3% during the second year. The percent of the tiller population reaching flowering stages was depressed 48.6% the first year and 29.4% the second year by the defoliation treatments. There was no significant differences in the percent of total tillers that terminated after flowering among all the treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies.

The number of vegetative tillers terminated before reaching maturity was significantly greater on the May 50% and June 25% treatments and numerically greater on the control, May 25%, and June 50% treatments of the 4.5 m TOR management strategy; was significantly lower on the June 25% treatment and numerically lower on the May 25% and June 50% treatments of the 6.0 m SL management strategy and on the control and May 50% treatments of the 4.5 m SL management strategy; and was intermediate on the control and May 50% treatments of the 6.0 m SL management strategy and on the May 25%, June 25%, and June 50% treatments of the 4.5 m SL management strategy (table 9). The percent of the tiller population terminated during the early season, mid and fall season, and winter period was 2.5%, 22.4%, and 8.4%, respectively. There was no significant differences in the percent of total tillers that terminated before reaching maturity during any of the periods among all the treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies.

The relationships among the numbers of tillers terminated on the management strategies were similar to the relationships among the total tiller densities on the management strategies with greater numbers on the treatments of the 4.5 m TOR management strategy, intermediate numbers on the treatments of the 6.0 m SL management strategy, and lower numbers on the treatments of the 4.5 m SL management strategy. The percent of total tillers terminated, percent of lead tillers terminated after flowering, and percent of vegetative tillers terminated before reaching maturity were not different among the management strategies. Termination of lead tillers after reaching flowering stages occurred systematically because the apical meristem tissue was depleted during the process of inflorescence production. Termination of secondary tillers before reaching maturity most likely resulted from insufficient quantities of essential resources reaching those tillers. The allocation of essential elements and photosynthetic products to some tillers and not to other tillers required a controlling process and an hierarchical differentiation of tillers into categories.

Tiller Leaf Height

Mean tiller leaf height of the reproductive lead tillers was 17.5 cm during 2000 and 25.0 cm during 2001 with increases in leaf height on all treatments the second year. The mean monthly reproductive lead tiller leaf heights were not significantly different among the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies on the five treatments during the first and second years, respectively (tables 10a, 10b, and 10c). Mean tiller leaf height of the vegetative lead tillers was 13.6 cm during 2000 and 19.7 cm during 2001 with increases in leaf height on all treatments the second year. The mean monthly vegetative lead tiller leaf heights were not significantly different among the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies on the five treatments during the first and second years, respectively (tables 10a, 10b, and 10c).

Mean tiller leaf height of the slow growth secondary tillers was 7.9 cm during 2000 and 11.9 cm during 2001 with increases in leaf height on all treatments the second year, except on the June 25% and June 50% treatments of the 6.0 m SL management strategy and on the June 50% treatment of the 4.5 m SL management strategy. The mean monthly slow growth secondary tiller leaf heights were not significantly different among the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies on the five treatments during the first and second years, respectively, except on the May 50% treatment of the 4.5 m SL management strategy during 2000 and on the June 50% treatment of the 4.5 m SL management strategy during 2001 (tables 10a, 10b, and 10c). Mean tiller leaf height of the early senescent secondary tillers was 4.5 cm during 2000 and 7.6 cm during 2001 with increases in leaf height on all treatments the second year, except on the May 25% treatment of the 6.0 m SL management strategy and on the June 25% treatment of the 4.5 m TOR management strategy. The mean monthly early senescent secondary tiller leaf heights were not significantly different among the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies on the five treatments during the first and second years, respectively, except on the control and June 25% treatments of the 6.0 m SL management strategy and on the June 50% treatment of the 4.5 m SL management strategy during 2000 (tables 10a, 10b, and 10c).

Grazing management strategy and defoliation treatment did not appear to affect tiller leaf height. Mean tiller leaf height was affected by the relative hierarchical dominance of the tiller categories and by the greater precipitation during June and July of the second year. Both tiller density and tiller leaf height affect the quantity of herbage biomass production. When leaf heights are similar, the management strategy that supports the greatest tiller density will produce the greatest quantity of herbage biomass.

Tiller Growth and Development

Vegetative tillers did not all develop at the same rate. Rates of tiller growth and development were regulated by hormones and availability of essential elements. The dominant tillers with rapid or unimpeded growth were the reproductive lead tillers and vegetative lead tillers and the subordinate tillers with slow or inhibited growth were the slow growth secondary tillers and early senescent secondary tillers.

The reproductive lead tillers had the fastest rate of growth and development. They started with two or three leaves in early May and reached the early flower stages around mid June. Reproductive lead tiller development was significantly rapid on the June 50% treatment of the 6.0 m SL management strategy during 2000 and 2001, and was significantly slower on the May 50% and June 25% treatments of the 6.0 m SL management strategy during 2000 and on the control treatment of the 4.5 m SL management strategy during 2001 (tables 11a and 11b).

Mean percent of the tiller population to develop into reproductive flowering stages on the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies were 23.1%, 19.3%, and 23.4%, respectively, and were not significantly different. The percent of tillers at flower stages were significantly greater on the control treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies during the first year. The defoliation treatments reduced the number of tillers that developed into flower stages by around 38.5%. These reductions were significantly lower on the May 50% treatments of the 6.0 m SL and 4.5 m TOR management strategies and on the May 25% treatment of the 4.5 m SL management strategy. Greater numbers of tillers developed into flower stages during the second year than during the first year on the four defoliation treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies, except on the June 50% treatment of the 6.0 m SL management strategy.

The length of the annual flowering period was affected by the availability of essential elements. The flowering period started shortly after 15 June during the first year and was completed by late June on the control and June 50% treatments of the 6.0 m SL management strategy and on all five treatments of the 4.5 m SL management strategy; was completed by mid July on the May 25% treatment of the 6.0 m SL management strategy and on the May 50% and June 25% treatments of the 4.5 m TOR management strategy; and was completed by mid or late August on the May 50% and June 25% treatments of the 6.0 m SL management strategy and on the control, May 25%, and June 50% treatments of the 4.5 m TOR management strategy.

The flowering period started shortly after 21 June during the second year and was completed by mid July on the control, May 25%, June 25%, and June 50% treatments of the 6.0 m SL management strategy and on the control and May 25% treatments of the 4.5 m SL management strategy; and was completed by mid August on the May 50% treatment of the 6.0 m SL management strategy, on the May 50%, June 25%, and June 50% treatments of the 4.5 m SL management strategy, and on all five treatments of the 4.5 m TOR management strategy.

The flowering periods were extended beyond early August during the first year on two treatments of the 6.0 m SL management strategy and on three treatments of the 4.5 m TOR management strategy, and during the second year on one treatment of the 6.0 m SL management strategy, on three treatments of the 4.5 m SL management strategy, and on five treatments of the 4.5 m TOR management strategy.

The precipitation for June and July during the first year was 115.34% of the LTM (long-term mean) and during the second year was 198.06% of the LTM (table 2). The additional 5.56 inches of precipitation during the second year contributed to the extended length of the flowering periods and to the increased number of tillers that developed into flower stages on the treatments of the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies. The quantity of soil mineral nitrogen available on the 4.5 m TOR management strategy was significantly greater than that on the 6.0 m SL and 4.5 m SL management strategies (table 3). The increase in mineral nitrogen resulted from the increased soil microorganism activity in the significantly greater rhizosphere volume on the 4.5 m TOR management strategy (table 3). The greater quantity of mineral nitrogen and greater volume of the rhizosphere on the 4.5 m TOR management strategy contributed to the greater number of tillers developing flower stages and the longer flowering periods during both years.

The vegetative lead tillers had the second fastest rate of growth and development. They started with one, two, or three leaves in early May and reached the fifth leaf stage by early June and the sixth leaf stage by early July. Vegetative lead tiller development was significantly rapid on the control treatment of the 6.0 m SL management strategy and on the May 50% treatment of the 4.5 m TOR management strategy during 2000 and 2001, and was significantly slower on the May 25% treatment of the 4.5 m SL management strategy during 2000 and 2001 and on the May 50% and June 50% treatments of the 4.5 m SL management strategy during 2001 (tables 11a and 11b).

The slow growth secondary tillers and early senescent secondary tillers were the subordinate tillers and had very slow growth rates. The secondary tillers remained at the second and third leaf stages for more than half of the growing season. After the majority of the reproductive lead tillers had reached the anthesis (flowering) stage, a few of the secondary tillers advanced to the fourth and sometimes the fifth leaf stages. Slow growth secondary tiller development was relatively slow on all treatments. This slow rate of growth was significantly faster on the May 50% treatment of the 4.5 m TOR management strategy, and was significantly slower on the control treatment of the 4.5 m SL management strategy during 2000 and 2001 (tables 12a and 12b). Early senescent secondary tillers usually terminated before mid August. Growth and development of early senescent tillers was slow on all treatments, however, growth was significantly faster on the control treatment of the 4.5 m TOR management strategy during 2000 and on the June 25% treatment of the 6.0 m SL management strategy during 2001 (tables 12a and 12b).

Vegetatively reproduced tillers with three leaves or less were not independent and relied on allocation of essential elements and photosynthetic products from lead tillers. The four leaf stage appeared to be a transition phase between dependence on and independence from other tillers. After the development of the fifth or sixth leaf, vegetatively initiated tillers appeared to be able to procure essential elements independently and possibly could control distribution of essential elements and photosynthetic products to subordinate tillers; indicating that vegetatively produced tillers do not achieve independence from dominant tiller regulation of growth until after development of adequate mature leaf area and root system.

Discussion

Growth and development of grass tillers were affected by availability of essential elements and required energy from sunlight, carbon from atmospheric carbon dioxide, hydrogen from soil water, and nitrogen from soil inorganic nitrogen. Radiant energy from sunlight is usually available in sufficient amounts on rangelands (Wight and Black 1972), even after the reductions in energy due to ambient cloud cover. Availability of sunlight can be a limiting factor in areas where taller woody plants shade the grassland community (Kochy and Wilson 2000). Atmospheric carbon dioxide is readily available on rangelands and carbon is not a limiting factor for grass plants (Wight and Black 1972). Hydrogen from soil water is readily available on rangelands during some periods of the growing season with various degrees of deficiency during other periods, and soil water can be a limiting factor during periodic drought conditions (Manske 2009a). The availability of soil water, which is an essential requirement for plant growth and has a dominant role in physiological processes, does not limit herbage production on rangeland ecosystems to the extent that mineral nitrogen availability does (Wight and Black 1972). Available soil mineral nitrogen is the major limiting factor on native rangeland (Wight and Black 1979). The rate of mineralization of soil organic nitrogen by rhizosphere organisms determines the quantity of mineral nitrogen available on grasslands

(Manske 2008, 2009b). Soil mineral nitrogen available at amounts of less than 100 lbs/ac causes nitrogen deficiencies that limit plant physiological processes and production of herbage (Wight and Black 1972). Deficiencies of mineral nitrogen decrease grass plant soil water use efficiency and cause the weight of herbage produced per inch of precipitation received to be reduced an average of 49.6% below the quantity of herbage produced per inch of precipitation on grasslands with sufficient available mineral nitrogen at 100 lbs/ac or greater (Wight and Black 1979).

Growth and development of grass tillers were affected by grazing because defoliation removes vital leaf material from the plant, disrupts photosynthesis and physiological processes throughout the plant, alters the microclimate around the plant, and changes the soil environment affecting soil organism activity. Grass plants developed defoliation resistance mechanisms in response to grazing during the period of coevolution with herbivores. The defoliation resistance mechanisms help grass tillers withstand and recover from partial defoliation. The defoliation resistance mechanisms consist of three major components that are: compensatory physiological processes within grass plants, vegetative reproduction of secondary tillers from axillary buds, and symbiotic rhizosphere organism activity and the associated conversion of inorganic nitrogen from soil organic nitrogen (Manske 2007b).

Different grazing management strategies produce different effects on grassland ecosystems as a result of the variations with the timing and severity of defoliation events. Depending on the degree of foliage removal and phenological growth stage of the grass tillers, the effects from defoliation can be beneficial or antagonistic to the defoliation resistance mechanisms and to the rate of mineralization of soil organic nitrogen into mineral nitrogen by rhizosphere organisms. Low rates of mineralization occur on grasslands managed with traditional grazing management strategies (Wight and Black 1972). The quantity of available mineral nitrogen on traditionally managed grasslands ranges from a low of 31 lbs/ac on deferred management strategies up to 62 lbs/ac on moderately stocked seasonlong management strategies (Manske 2008, 2009b). High rates of mineralization with mineral nitrogen available at quantities from 164 lbs/ac to 199 lbs/ac can be obtained on grasslands managed with the twice-over rotation management strategy (Manske 2008, 2009b).

The quantity of total tillers present during the growing season was greatest on the 4.5 m TOR management strategy, except the first year on the May 25% treatment, because of the greater quantities of available mineral nitrogen resulting from the increased soil microorganism activity in the larger rhizosphere volume. The quantity of total tillers was intermediate on the 6.0 m SL management strategy, except the first year on the May 25% treatment, because the quantities of available mineral nitrogen and rhizosphere volume were lower than those on the 4.5 m TOR management strategy. The quantity of total tillers was lowest on the 4.5 m SL management strategy because of the low quantities of available mineral nitrogen, the low rhizosphere volume, and the shallower surface soil horizon depth.

Grass plants reproduce by two methods; sexually by seeds developing into seedlings and vegetatively by tillers developing from axillary buds. Seedlings are rare on rangeland ecosystems. Stimulation of vegetative tiller development from axillary buds requires the reduction of the inhibiting hormone, auxin, through partial defoliation of lead tiller leaf area while the tillers are in vegetative growth stages, and requires the availability of sufficient quantities of the essential elements for growth and development of the initiated tillers. All the treatments of the 4.5 m TOR management strategy initiated more vegetative tillers from axillary buds during the growing season than all the treatments of the 4.5 m SL and 6.0 m SL management strategies because of the greater quantities of available mineral nitrogen. The lowest number of vegetative tillers initiated on the 4.5 m TOR management strategy was on the control treatment and was greater than the number of tillers initiated on any of the treatments of the 4.5 m SL and 6.0 m SL management strategies.

Greater numbers of vegetative tillers were stimulated per lead tiller on the defoliation treatments of the 4.5 m TOR management strategy than vegetative tillers per lead tiller on the control treatment, except on the June 50% defoliation treatment. The increased soil organism activity in the large rhizosphere volume and the great quantities of available mineral nitrogen above 100 lbs/ac were the essential resources that permitted the partially defoliated tillers to fully recover, to develop more vegetative tillers per lead tiller, and to increase production following defoliation treatments. Fewer vegetative tillers were stimulated per lead tiller on the June 50% treatment of the 4.5 m TOR management strategy than on the control treatment because the defoliated tillers recovered to slightly less than full pretreatment condition and produced slightly fewer tillers per lead tiller than were produced on the control treatment.

Lower numbers of vegetative tillers were stimulated per lead tiller on the defoliation treatments of the 4.5 m SL and 6.0 m SL management strategies than vegetative tillers per lead tiller on the respective control treatments. The partially defoliated tillers were unable to recover fully from the single event defoliation treatments as a result of the significantly insufficient quantities of available mineral nitrogen on the two traditional seasonlong management strategies.

The numbers of vegetative tillers initiated during the early spring, during May, and during the mid season periods of the growing season were greater on the 4.5 m TOR management strategy than on the 4.5 m SL and 6.0 m SL management strategies. The greater numbers of vegetative tillers initiated during early spring and May showed that the grass plants on the 4.5 m TOR management strategy were in better condition and had access to carbohydrates and essential mineral nitrogen in much greater quantities than were available to grass plants on the 4.5 m SL and 6.0 m SL management strategies. The mid season period occurred simultaneously with the high resource demand period in which the dominant reproductive lead tillers progressed through the flowering stages and produced seeds. The greater numbers of vegetative tillers initiated during mid season showed that the grass plants on the 4.5 m TOR management strategy were in better condition and had access to essential mineral nitrogen in much greater quantities than were available to grass plants on the 4.5 m SL and 6.0 m SL management strategies.

Greater numbers of vegetative tillers were initiated during mid August to mid October as fall tillers than were initiated during early spring and May on the 4.5 m SL and 6.0 m SL management strategies. A greater percent of the total vegetative tillers stimulated were initiated during mid August to mid October as fall tillers on the 4.5 m SL and 6.0 m SL management strategies than the percent of total vegetative tillers initiated as fall tillers on the respective treatments of the 4.5 m TOR management strategy. The fall tiller initiation period, mid August to mid October, started after the lead tillers had completed most of their active growth and occurred simultaneously with the winter hardening process of perennial grasses. There appeared to be lower competition for essential elements during this late season period than during the other vegetative tiller initiation periods, giving the young initiated vegetative tillers access to a greater proportion of the significantly lower quantities of available mineral nitrogen on the 4.5 m SL and 6.0 m SL management strategies.

The total number of tillers terminated during the growing season was greatest on the 4.5 m TOR management strategy, intermediate on the 6.0 m SL management strategy, and lowest on the 4.5 m SL management strategy, which was the same relationship as with the total number of tillers present during the growing season. The mean percent of the tiller population that terminated was 54% and was not different among the management strategies.

The number of lead tillers terminated after flowering was greatest on the 4.5 m TOR management strategy, intermediate on the 6.0 m SL management strategy, and lowest on the 4.5 m SL management strategy. Tillers usually produced vegetative growth during the first growing season and developed into flower stages during the second growing season. Tillers rarely reached flowering stages during the initiation growing season. Termination of lead tillers after reaching the flowering stages occurred because the apical meristem tissue was depleted during the production of the inflorescence. The percent of the tiller population that produced flower stages was around 33% on the control treatments. The defoliation treatments did not remove the apical meristem from any tillers, however, the percent of the tiller population reaching flowering stages was reduced during two growing seasons. The depression in the numbers of tillers developing into flowering stages was 48.6% the first year and 29.4% the second year. The percentage of the tiller population terminated after reaching flower stages was not different among the management strategies.

The number of vegetative tillers terminated before reaching maturity was greatest on the 4.5 m TOR management strategy and was lower on the 4.5 m SL and 6.0 m SL management strategies. The percent of the vegetative tillers terminated during the early season, the mid and fall season, and the winter period was 2.5%, 22.4%, and 8.7%, respectively. The percentage of the tiller population terminated before reaching maturity was not different among the management strategies.

The quantity of available essential elements determined the quantity of tillers that could be sustained on each grazing management strategy with the greatest tiller densities, intermediate densities, and the lowest densities on the 4.5 m TOR, 6.0 m SL, and 4.5 m SL management strategies, respectively. More tillers were initiated than could be supported by the available quantity of essential elements. Some of the lower subordinate tillers terminated before reaching maturity as a result of not receiving sufficient resources. Allocation of essential elements to some tillers and not to other tillers would require a controlling process with a continuum of hierarchical differentiation of tillers into dominant and subordinate levels and would indicate that vegetatively reproduced tillers did not achieve independence at phenological growth stages of three leaves or less, that the fourth leaf stage was a transition phase, and that with the development of the fifth or sixth leaf the tillers could procure essential elements independently and possibly could control distribution of essential elements and photosynthetic products to subordinate secondary tillers.

Tiller leaf height and tiller growth and development did not appear to be affected by grazing management strategy or by defoliation treatment, however, they were strongly affected by the relative hierarchical dominance level of the tiller categories and by the greater precipitation received during June and July of the second year. The dominant lead tillers had greater leaf height and had rapid or unimpeded growth and development. The subordinate secondary tillers had shorter leaf height and had slow or inhibited growth and development. The tiller leaf height increased on all tiller categories during the second year which received 5.56 inches of precipitation during June and July greater than was received during the first year. The reproductive lead tillers started with two or three leaves in early May and reached the early flower stages around mid June. The vegetative lead tillers started with one to three leaves in early May and reached the fifth leaf stage by early June and the sixth leaf stage by early July. The secondary tillers developed relatively slow and remained at the second and third leaf stages for more than half of the growing season. After the majority of the lead tillers had completed most of the active growth, a few of the secondary tillers advanced to the fourth and fifth leaf stages. Some secondary tillers terminated before mid August as a result of not receiving sufficient quantities of essential elements or photosynthetic products. The surviving vegetative lead tillers, slow growth secondary tillers, and initiated fall tillers did not terminate at the end of the growing season; the tillers with intact apical meristems became carry over tillers and continued growth and development during the next growing season, and it appears likely that some vegetative tillers would continue active growth into the third growing season.

The grass plants on the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies did not respond similarly to identical timing and severity defoliation treatments because the defoliation by grazing during the previous growing seasons caused differential effects to the defoliation resistance mechanisms and to the rates of mineralization of soil organic nitrogen on the three management strategies.

Grass plant responses to defoliation were negative on the traditional 4.5 m SL and 6.0 m SL management strategies because the timing and severity of grass tiller defoliation was antagonistic to rhizosphere organism activity resulting in insufficient quantities of available mineral nitrogen that inhibited the defoliation resistance mechanisms from functioning at restorative levels causing incomplete recovery of partially defoliated grass tillers, decreased numbers of vegetatively initiated tillers, low grass tiller densities, and decreased quantities of herbage production.

Grass plant responses to defoliation were positive on the 4.5 m TOR management strategy because the timing and severity of grass tiller defoliation was beneficial to rhizosphere organism activity resulting in great quantities of available mineral nitrogen above 100 lbs/ac that permitted the defoliation resistance mechanisms to function at elevated levels causing full recovery of partially defoliated grass tillers, increased numbers of vegetatively initiated tillers, high grass tiller densities, and increased quantities of herbage production.

Grass plant responses to defoliation were positive or negative depending on the quantity of soil mineral nitrogen and whether the available mineral nitrogen was greater than or less than 100 lbs/ac, respectively.

The defoliation resistance mechanisms are activated following removal of a portion of the leaf material. The defoliation resistance mechanisms, however, do not function at full capacity following a single defoliation event. The functionality of the various processes increase in increments over several years with annually repeated partial defoliation occurring during vegetative phenological growth stages. Successful fulfillment of the defoliation resistance mechanisms requires availability of sufficient quantities of the essential elements and requires sufficient periods of time without further disruption to develop and perform all specific steps for each process. The compensatory physiological processes within the grass plants and the processes for vegetative reproduction of secondary tillers from axillary buds cannot function at elevated levels until the biogeochemical processes of nutrient cycling within the ecosystem that require rhizosphere organism activity are functioning at elevated levels with soil mineral nitrogen available at 100 lbs/ac or greater.

Summary

Northern Plains ranchers who implemented the biologically effective twice-over rotation management strategy found that it required three to five years before grass tiller density increased significantly. An intensive timing and severity defoliation treatment study was conducted with western wheatgrass to determine treatments that activated vegetative reproduction of tillers from axillary buds. Four defoliation treatments and a control with seven microplots each were established on silty range sites in 6.0 month seasonlong (6.0 m SL), 4.5 month seasonlong (4.5 m SL), and 4.5 month twice-over rotation (4.5 m TOR) management strategies. Mean tiller densities were 485.5 /m^2, 759.7 /m^2, 1148.7 /m^2 on the 4.5 m SL, 6.0 m SL, and 4.5 m TOR management strategies, respectively. The defoliated tillers on the traditional 4.5 m SL and 6.0 m SL management strategies produced 117.4 /m^2 and 141.0 /m^2 fewer vegetative tillers than were produced by undefoliated tillers on the respective control treatments. The defoliated tillers produced 198.4 /m^2 more vegetative tillers on the 4.5 m TOR management strategy than were produced by undefoliated tillers on the control treatment. The seasonal mean rhizosphere volume was 50, 68, and 227 ft^3/ac on the 6.0 m SL, 4.5 m SL, and 4.5 m TOR management strategies, respectively, and the available soil mineral nitrogen ranged between 31 and 62 lbs/ac on traditional management strategies and ranged between 164 and 199 lbs/ac on the 4.5 m TOR management strategy. The compensatory physiological processes that enable rapid recovery of defoliated tillers and the processes for vegetative reproduction of secondary tillers from axillary buds were not fully activated on the 6.0 m SL and 4.5 m SL management strategies because the timing and severity of grass tiller defoliation was antagonistic to rhizosphere organism activity causing insufficient quantities of available mineral nitrogen that resulted in incomplete recovery of defoliated tillers, decreased vegetative tillers from axillary buds, low tiller densities, and decreased herbage production. The defoliation resistance mechanisms functioned at elevated levels on the 4.5 m TOR management strategy because the timing and severity of grass tiller defoliation was beneficial to rhizosphere organism activity causing great quantities of available mineral nitrogen that resulted in full recovery of defoliated tillers, increased vegetative tillers from axillary buds, high tiller densities, and increased herbage production. Wight and Black (1979) found that activation of the processes for grass plant water use efficiency required 100 lbs/ac or greater soil mineral nitrogen. This study found that activation of the components of the defoliation resistance mechanisms that help grass tillers withstand and recover from defoliation and that produce vegetative tillers from axillary buds required 100 lbs/ac or greater soil mineral nitrogen. Stimulation of increased rhizosphere organism activity and increased mineralization of soil organic nitrogen into mineral nitrogen available at 100 lbs/ac or greater must occur before the other beneficial components of the defoliation resistance mechanisms can be fully activated.

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Table 2. Precipitation in inches for growing-season months and the annual total precipitation for 1999-2001, DREC Ranch, Manning, North Dakota.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-term mean									
1982-2008	1.40	2.40	3.24	2.43	1.73	1.37	1.33	13.90	16.69
1999	1.10	4.93	1.59	1.80	2.70	2.40	T	14.52	15.56
% of LTM	78.57	205.42	49.07	74.07	156.07	175.18	0.00	104.46	93.23
2000	1.26	1.90	3.77	2.77	2.74	1.09	1.46	14.99	20.23
% of LTM	90.00	79.17	116.36	113.99	158.38	79.56	109.77	107.84	121.21
2001	2.70	0.53	6.36	4.87	0.00	1.94	0.00	16.40	18.03
% of LTM	192.86	22.08	196.30	200.41	0.00	141.61	0.00	117.98	108.03
1999-2001	1.69	2.45	3.91	3.15	1.81	1.81	0.49	15.30	17.94
% of LTM	120.71	102.08	120.68	129.63	104.62	132.12	36.84	110.07	107.49

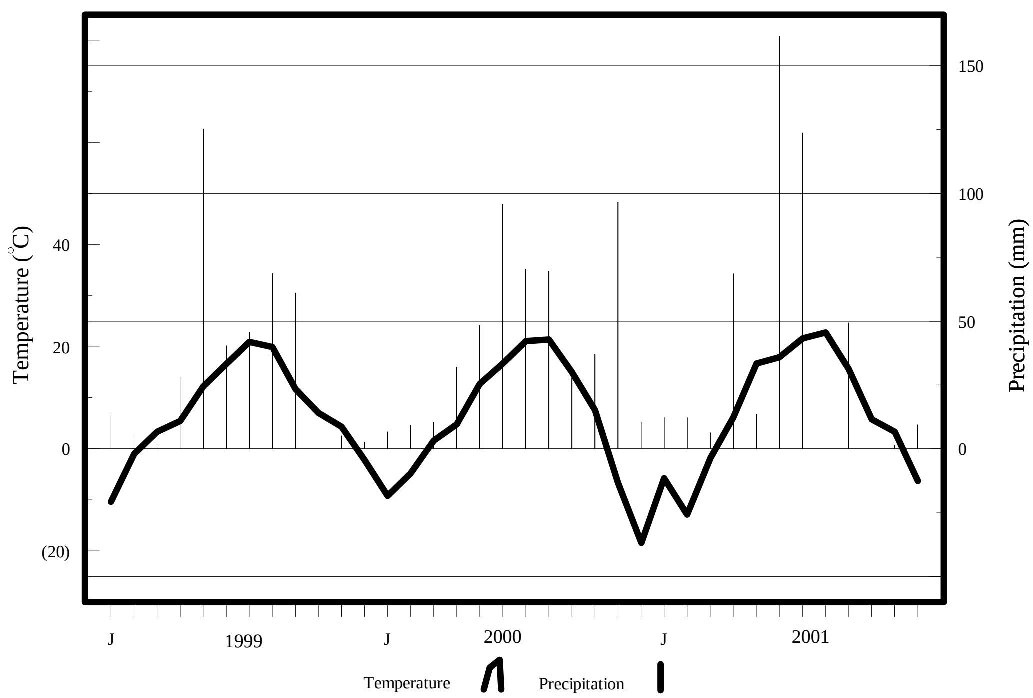

Fig. 1. Ombrothermic diagram of 1999-2001 mean monthly temperature and monthly precipitation at DREC Ranch, Manning, North Dakota.

Table 3. Mineral nitrogen and rhizosphere volume for grazing management strategies.

Grazing Management Strategy	Mineral Nitrogen lbs/acre-foot	Rhizosphere Volume ft^3/acre-foot
6.0-m Seasonlong	62c	50z
4.5-m Seasonlong	112b	68z
4.5-m Twice-over Rotation	178a	227x

Means in the same column and followed by the same letter are not significantly different (P<0.05).
Data from Manske 2008, 2009b.

Table 4a. Density per square meter of tiller types on the defoliation treatments of the management strategies during the first growing season, 2000.

Treatment Management Strategy	Live tillers early May #/m^2	New tillers first season #/m^2	Total first season tillers #/m^2	Tillers at flower stages #/m^2	Dead tillers first season #/m^2	Live tillers fall #/m^2	New fall tillers #/m^2	Total live tillers mid October #/m^2	Dead tillers winter period #/m^2
Control									
6.0 m SL	469.9b	0.0c	469.9b	219.3b	31.3c	219.3b	219.3b	438.6b	0.0c
4.5 m SL	281.9c	0.0c	281.9c	94.0b	62.7b	125.3c	94.0c	219.3c	0.0c
4.5 m TOR	877.1a	62.7b	939.8a	344.6a	250.6b	344.6b	250.6b	595.2b	31.3b
May 25%									
6.0 m SL	845.8b	62.7b	908.5b	156.6b	94.0b	657.8a	94.0c	751.8b	281.9a
4.5 m SL	626.5b	62.7b	689.2b	31.3c	125.3b	532.5b	281.9b	814.5b	313.3a
4.5 m TOR	657.8b	31.3b	689.2b	188.0b	281.9a	219.3b	313.3b	532.5b	0.0c
May 50%									
6.0 m SL	908.5a	0.0c	908.5b	62.7b	219.3b	626.5a	469.9a	1096.4a	250.6b
4.5 m SL	344.6c	31.3b	375.9c	62.7b	94.0b	219.3b	188.0b	407.2b	94.0b
4.5 m TOR	939.8a	125.3a	1065.1a	125.3b	188.0b	751.8a	689.2a	1441.0a	407.2a
June 25%									
6.0 m SL	469.9b	62.7b	532.5b	94.0b	31.3c	407.2b	125.3b	532.5b	62.7b
4.5 m SL	438.6b	31.3b	469.9b	94.0b	156.6b	219.3b	125.3b	344.6b	0.0c
4.5 m TOR	971.1a	62.7b	1033.8a	156.6b	407.2a	469.9b	344.6b	814.5b	188.0b
June 50%									
6.0 m SL	563.9b	62.7b	626.5b	156.6b	62.7b	407.2b	188.0b	595.2b	156.6b
4.5 m SL	375.9c	0.0c	375.9c	62.7b	125.3b	188.0b	156.6b	344.6b	125.3b
4.5 m TOR	720.5a	62.7b	783.2b	219.3b	250.6b	313.3b	344.6b	657.8b	219.3b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 4b. Density per square meter of tiller types on the defoliation treatments of the management strategies during the second growing season, 2001.

Treatment Management Strategy	Carry over tillers #/m^2	New tillers early spring #/m^2	Live tillers early May #/m^2	New tillers second season #/m^2	Total second season tillers #/m^2	Tillers at flower stages #/m^2	Dead tillers second season #/m^2	Live tillers fall #/m^2	New fall tillers #/m^2	Total live tillers mid October #/m^2
Control										
6.0 m SL	438.6b	344.6b	783.2b	31.3c	814.5b	156.6b	250.6b	407.2b	313.3b	720.5b
4.5 m SL	219.3c	188.0b	407.2b	125.3b	532.5b	31.3c	188.0b	313.3b	156.6b	469.9b
4.5 m TOR	563.9b	469.9a	1033.8a	250.6a	1284.4a	375.9a	438.6a	469.9b	188.0b	657.8b
May 25%										
6.0 m SL	469.9b	156.6b	626.5b	219.3b	845.8b	188.0b	219.3b	438.6b	563.9a	1002.4a
4.5 m SL	501.2b	0.0c	501.2b	156.6b	657.8b	62.7c	188.0b	407.2b	501.2a	908.5b
4.5 m TOR	532.5b	501.2a	1033.8a	250.6a	1284.4a	313.3a	438.6a	532.5b	156.6b	689.2b
May 50%										
6.0 m SL	845.8a	62.7b	908.5b	125.3b	1033.8b	250.6b	219.3b	563.9b	501.2a	1065.1a
4.5 m SL	313.3b	0.0c	313.3c	125.3b	438.6c	156.6b	125.3b	156.6c	94.0c	250.6b
4.5 m TOR	1033.8a	344.6b	1378.3a	156.6b	1535.0a	250.6b	720.5a	563.9b	281.9b	845.8b
June 25%										
6.0 m SL	469.9b	31.3b	501.2b	94.0c	595.2b	188.0b	94.0b	313.3b	469.9a	783.2b
4.5 m SL	344.6b	0.0c	344.6c	188.0b	532.5b	125.3b	156.6b	250.6b	125.3c	375.9c
4.5 m TOR	626.5b	469.9a	1096.4a	188.0b	1284.4a	188.0b	281.9b	814.5a	219.3b	1033.8a
June 50%										
6.0 m SL	438.6b	31.3b	469.9b	156.6b	626.5b	125.3b	94.0b	407.2b	313.3b	720.5b
4.5 m SL	219.3c	31.3b	250.6c	94.0c	344.6c	94.0b	94.0b	156.6c	219.3b	375.9c
4.5 m TOR	438.6b	250.6b	689.2b	250.6a	939.8b	281.9a	156.6b	501.2b	344.6b	845.8b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 5. Mean monthly growing season tiller density (excluding the fall tillers) on the defoliation treatments of the management strategies, 2000, 2001.

Treatment Management Strategy	First Growing Season 2000 #/m²	Second Growing Season 2001 #/m²	Change during Second Growing Season #/m²
Control			
6.0 m SL	464.7b	704.9b	+240.2b
4.5 m SL	245.4c	391.6c	+146.2b
4.5 m TOR	814.5a	892.8a	+78.3b
May 25%			
6.0 m SL	840.6a	699.6b	-141.0c
4.5 m SL	610.9b	527.3c	-83.6c
4.5 m TOR	563.9b	1028.6a	+464.7a
May 50%			
6.0 m SL	856.3a	908.5a	+52.2b
4.5 m SL	302.8c	355.1c	+52.3b
4.5 m TOR	976.4a	1148.6a	+172.2b
June 25%			
6.0 m SL	516.9b	522.1b	+5.2b
4.5 m SL	402.0c	391.6c	-10.4b
4.5 m TOR	824.9a	1117.3a	+292.4a
June 50%			
6.0 m SL	584.8b	543.0b	-41.8b
4.5 m SL	349.8c	281.9c	-67.9b
4.5 m TOR	710.1a	788.4a	+78.3b

Means in the same column of each defoliation treatment and followed by the same letter are not significantly different ($P<0.05$).

Table 6. Density per square meter of total growing season tillers on the defoliation treatments of the management strategies, 2000, 2001.

Treatment Management Strategy	First Growing Season Tillers #/m^2	Fall Tillers First Year #/m^2	Total Tillers First Year #/m^2	Carry Over Tillers #/m^2	Second Growing Season Tillers #/m^2	Fall Tillers Second Year #/m^2	Total Tillers Second Year #/m^2	Two Year Total Tillers #/m^2
Control								
6.0 m SL	469.9b	219.3b	689.2b	438.6b	814.5b	313.3b	1127.7b	1378.3b
4.5 m SL	281.9c	94.0c	375.9c	219.3c	532.5b	156.6b	689.2c	845.8c
4.5 m TOR	939.8a	250.6b	1190.4b	563.9b	1284.4a	188.0b	1472.3b	2098.8b
May 25%								
6.0 m SL	908.5b	94.0c	1002.4b	469.9b	845.8b	563.9a	1409.7b	1942.2b
4.5 m SL	689.2b	281.9b	971.1b	501.2b	657.8b	501.2a	1159.1b	1629.0b
4.5 m TOR	689.2b	313.3b	1002.4b	532.5b	1284.4a	156.6b	1441.0b	1910.9b
May 50%								
6.0 m SL	908.5b	469.9a	1378.3a	845.8a	1033.8b	501.2a	1535.0b	2067.5b
4.5 m SL	375.9c	188.0b	563.9b	313.3b	438.6c	94.0c	532.5c	783.2c
4.5 m TOR	1065.1a	689.2a	1754.3a	1033.8a	1535.0a	281.9b	1816.9a	2537.4a
June 25%								
6.0 m SL	532.5b	125.3b	657.8b	469.9b	595.2b	469.9a	1065.1b	1253.0b
4.5 m SL	469.9b	125.3b	595.2b	344.6b	532.5b	125.3c	657.8c	908.5c
4.5 m TOR	1033.8a	344.6b	1378.3a	626.5b	1284.4a	219.3b	1503.6b	2255.5a
June 50%								
6.0 m SL	626.5b	188.0b	814.5b	438.6b	626.5b	313.3b	939.8b	1315.7b
4.5 m SL	375.9c	156.6b	532.5c	219.3c	344.6c	219.3b	563.9c	877.1c
4.5 m TOR	783.2b	344.6b	1127.7b	438.6b	939.8b	344.6b	1284.4b	1973.5b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 7. Vegetative tillers developed per lead tiller on the defoliation treatments of the management strategies.

Treatment Management Strategy	Density of Lead Tillers at Defoliation Treatment #/m²	Density of Total Initiated Vegetative Tillers #/m²	Number of Stimulated Vegetative Tillers per Lead Tiller #	Difference from Management Strategy Control
Control				
6.0 m SL	344.6b	908.5b	2.64a	
4.5 m SL	188.0c	563.9c	3.00a	
4.5 m TOR	595.2b	1221.7b	2.05b	
May 25%				
6.0 m SL	595.2b	1096.4b	1.84b	-0.80b
4.5 m SL	532.5b	1002.4b	1.88b	-1.12b
4.5 m TOR	407.2b	1253.0b	3.08a	+1.03a
May 50%				
6.0 m SL	751.8a	1159.1b	1.54c	-1.10b
4.5 m SL	313.3b	438.6c	1.40c	-1.60c
4.5 m TOR	689.2a	1597.6a	2.32b	+0.27a
June 25%				
6.0 m SL	344.6b	783.2b	2.27b	-0.37b
4.5 m SL	250.6c	469.9c	1.88b	-1.12b
4.5 m TOR	563.9b	1284.4b	2.28b	+0.23a
June 50%				
6.0 m SL	407.2b	751.8b	1.85b	-0.79b
4.5 m SL	281.9c	501.2c	1.78b	-1.22b
4.5 m TOR	626.5b	1253.0b	2.00b	-0.05b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 8. Density per square meter and percent of total for tillers initiated through vegetative reproduction during periods of the growing season.

Treatment Management Strategy	Seasonal Periods: Early Spring #/m²	May #/m²	Mid Season #/m²	Fall Season #/m²	Total Initiated Tillers #/m²	Seasonal Periods: Early Spring %	May %	Mid Season %	Fall Season %
Control									
6.0 m SL	344.6b	0.0c	31.3c	532.5b	908.5b	37.9a	0.0c	3.5b	58.6b
4.5 m SL	188.0b	31.3c	94.0b	250.6c	563.9c	33.3b	5.6c	16.7b	44.4b
4.5 m TOR	469.9a	156.6b	156.6a	438.6b	1221.7b	38.5a	12.8b	12.8b	35.9c
May 25%									
6.0 m SL	156.6b	156.6b	125.3b	657.8b	1096.4b	14.3b	14.3b	11.4b	60.0b
4.5 m SL	0.0c	156.6b	62.7b	783.2b	1002.4b	0.0c	15.6b	6.3b	78.1a
4.5 m TOR	501.2a	62.7b	219.3a	469.9b	1253.0b	40.0a	5.0c	17.5b	37.5c
May 50%									
6.0 m SL	62.7b	125.3b	0.0c	971.1a	1159.1b	5.4b	10.8b	0.0c	83.8a
4.5 m SL	0.0c	125.3b	31.3c	281.9c	438.6c	0.0c	28.6a	7.1b	64.3b
4.5 m TOR	344.6b	156.6b	125.3b	971.1a	1597.6a	21.6b	9.8b	7.8b	60.8b
June 25%									
6.0 m SL	31.3b	62.7b	94.0b	595.2b	783.2b	4.0b	8.0b	12.0b	76.0a
4.5 m SL	0.0c	62.7b	156.6a	250.6c	469.9c	0.0c	13.3b	33.3a	53.3b
4.5 m TOR	469.9a	188.0a	62.7b	563.9b	1284.4b	36.6a	14.6b	4.9b	43.9c
June 50%									
6.0 m SL	31.3b	156.6b	62.7b	501.2b	751.8b	4.2b	20.8a	8.3b	66.7b
4.5 m SL	31.3b	62.7b	31.3c	375.9b	501.2c	6.3b	12.5b	6.3b	75.0a
4.5 m TOR	250.6b	219.3a	94.0b	689.2b	1253.0b	20.0b	17.5b	7.5b	55.0b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 9. Density per square meter and percent of total for vegetative tillers terminated during periods of the growing season before reaching maturity and for lead tillers terminated after flowering.

	Seasonal Periods				Total Terminated Tillers	Seasonal Periods			
Treatment Management Strategy	Early Season #/m^2	Mid and Fall Season #/m^2	Flowering Lead Tillers #/m^2	Winter Period #/m^2	#/m^2	Early Season %	Mid and Fall Season %	Flowering Lead Tillers %	Winter Period %
Control									
6.0 m SL	0.0b	281.9b	375.9b	0.0c	657.8b	0.0b	42.9b	57.1a	0.0c
4.5 m SL	0.0b	250.6b	125.3c	0.0c	375.9c	0.0b	66.7a	33.3b	0.0c
4.5 m TOR	281.9a	407.2b	720.5a	31.3b	1441.0a	19.5a	28.3b	50.0b	2.2c
May 25%									
6.0 m SL	31.3b	281.9b	344.6b	281.9a	939.8b	3.3b	30.0b	36.7b	30.0a
4.5 m SL	62.7b	250.6b	94.0c	313.3a	720.5b	8.7b	34.8b	13.0c	43.5a
4.5 m TOR	62.7b	657.8a	501.2a	0.0c	1221.7b	5.1b	53.9a	41.0b	0.0c
May 50%									
6.0 m SL	0.0b	438.6b	313.3b	250.6b	1002.4b	0.0b	43.7b	31.3b	25.0b
4.5 m SL	62.7b	156.6b	219.3b	94.0b	532.5b	11.8a	29.4b	41.2b	17.6b
4.5 m TOR	0.0b	908.5a	375.9b	407.2a	1691.6a	0.0b	53.7b	22.2c	24.1b
June 25%									
6.0 m SL	0.0b	125.3c	281.9b	62.7b	469.9b	0.0b	26.7c	60.0a	13.3b
4.5 m SL	0.0b	313.3b	219.3b	0.0c	532.5b	0.0b	58.8a	41.2b	0.0c
4.5 m TOR	125.3a	563.9b	344.6b	188.0b	1221.7b	10.3a	46.2b	28.2b	15.3b
June 50%									
6.0 m SL	0.0b	156.6b	281.9b	156.6b	595.2b	0.0b	26.3c	47.4b	26.3b
4.5 m SL	0.0b	219.3b	156.6c	125.3b	501.2b	0.0b	43.8b	31.2b	25.0b
4.5 m TOR	31.3b	375.9b	501.2a	219.3b	1127.7b	2.8b	33.3b	44.4b	19.5b

Means in the same column and followed by the same letter are not significantly different ($P<0.05$).

Table 10a. Mean monthly tiller leaf height (cm) on the defoliation treatments of the management strategies during the first growing season, 2000.

Treatment Management Strategy	Reproductive Lead Tillers cm	Vegetative Lead Tillers cm	Slow Growth Secondary Tillers cm	Early Senescent Secondary Tillers cm	Fall Tillers cm
Control					
6.0 m SL	19.4a	15.5a	8.9a	0.0c	3.9a
4.5 m SL	17.7a	16.7a	8.2a	6.5a	2.7a
4.5 m TOR	17.9a	13.9a	10.5a	6.6a	3.7a
May 25%					
6.0 m SL	18.7a	14.6a	8.2a	9.7a	1.4b
4.5 m SL	18.5a	11.4a	5.9a	5.5a	4.0a
4.5 m TOR	16.9a	14.0a	6.4a	5.5a	3.4a
May 50%					
6.0 m SL	19.4a	16.7a	8.6a	6.0a	2.4b
4.5 m SL	17.3a	12.6a	0.0c	4.0a	4.6a
4.5 m TOR	15.0a	14.0a	9.4a	4.5a	2.9b
June 25%					
6.0 m SL	18.1a	13.0a	10.1a	0.0c	2.5b
4.5 m SL	17.9a	14.9a	9.1a	4.1a	2.9ab
4.5 m TOR	15.9a	12.8a	7.9a	6.6a	4.2a
June 50%					
6.0 m SL	14.6a	10.9a	7.2a	4.7a	3.1ab
4.5 m SL	18.2a	13.8a	9.7a	0.0c	3.7b
4.5 m TOR	16.5a	9.8a	7.7a	3.5a	6.2a

Means in the same column of each defoliation treatment and followed by the same letter are not significantly different ($P<0.05$).

Table 10b. Mean monthly tiller leaf height (cm) on the defoliation treatments of the management strategies during the second growing season, 2001.

Treatment Management Strategy	Reproductive Lead Tillers cm	Vegetative Lead Tillers cm	Slow Growth Secondary Tillers cm	Early Senescent Secondary Tillers cm	Fall Tillers cm
Control					
6.0 m SL	27.1a	18.1a	15.4a	8.1a	2.9b
4.5 m SL	23.0a	20.8a	16.4a	6.6a	9.3a
4.5 m TOR	26.7a	20.6a	15.1a	9.2a	6.1ab
May 25%					
6.0 m SL	22.2a	20.0a	14.5a	5.0a	6.6a
4.5 m SL	24.0a	19.9a	12.3a	6.5a	10.1a
4.5 m TOR	25.9a	20.7a	17.0a	7.7a	6.8a
May 50%					
6.0 m SL	28.0a	18.6a	13.0a	9.1a	8.0a
4.5 m SL	24.9a	19.6a	5.0a	4.8a	2.4a
4.5 m TOR	26.4a	21.3a	13.6a	7.3a	4.3a
June 25%					
6.0 m SL	23.2a	17.4a	8.5a	10.5a	9.0a
4.5 m SL	21.7a	21.1a	12.3a	8.5a	1.8b
4.5 m TOR	25.4a	20.5a	13.4a	5.3a	4.5ab
June 50%					
6.0 m SL	26.2a	18.0a	6.0a	10.1a	3.8a
4.5 m SL	25.2a	19.4a	0.0c	8.3a	3.1a
4.5 m TOR	25.6a	19.2a	15.3a	7.7a	5.8a

Means in the same column of each defoliation treatment and followed by the same letter are not significantly different (P<0.05).

Table 10c. Change in mean monthly tiller leaf height (cm) during the second growing season on the defoliation treatments of the management strategies, 2000, 2001.

Treatment Management Strategy	Reproductive Lead Tillers cm	Vegetative Lead Tillers cm	Slow Growth Secondary Tillers cm	Early Senescent Secondary Tillers cm	Fall Tillers cm
Control					
6.0 m SL	7.7b	2.6c	6.5b	8.1a	-1.0c
4.5 m SL	5.3b	4.1b	8.2b	0.1b	6.6a
4.5 m TOR	8.8b	6.7b	4.6b	2.6b	2.4b
May 25%					
6.0 m SL	3.5c	5.4b	6.3b	-4.7c	5.2b
4.5 m SL	5.5b	8.5a	6.4b	1.0b	6.1a
4.5 m TOR	9.0b	6.7b	10.6a	2.2b	3.4b
May 50%					
6.0 m SL	8.6b	1.9c	4.4b	3.1b	5.6a
4.5 m SL	7.6b	7.0b	5.0b	0.8b	-2.2c
4.5 m TOR	11.4a	7.3b	4.2b	2.8b	1.4b
June 25%					
6.0 m SL	5.1b	4.4b	-1.6c	10.5a	6.5a
4.5 m SL	3.8c	6.2b	3.2b	4.4b	-1.1c
4.5 m TOR	9.5b	7.7b	5.5b	-1.3c	0.3b
June 50%					
6.0 m SL	11.6a	7.1b	-1.2c	5.4b	0.7b
4.5 m SL	7.0b	5.6b	-9.7c	8.3a	-0.6b
4.5 m TOR	9.1b	9.4a	7.6b	4.2b	-0.4b

Means in the same column and followed by the same letter are not significantly different (P<0.05).

Table 11a. Mean monthly leaf stage as a percent of tiller population for lead tillers on the defoliation treatments of the management strategies during the first growing season, 2000.

Treatment Management Strategy	Reproductive Lead Tillers Leaf Stage							Vegetative Lead Tillers Leaf Stage					
	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6-9 %	Flower Stages %	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6-10 %
Control													
6.0 m SL	219.3	0.0	7.2	14.3	7.2	4.8	66.7	125.3	0.0	12.5	8.3	12.5	66.7
4.5 m SL	94.0	5.6	11.1	11.1	0.0	5.6	66.7	94.0	0.0	11.1	27.8	27.8	33.3
4.5 m TOR	344.6	1.5	6.1	10.6	12.1	13.6	56.1	229.7	0.0	11.1	15.1	35.7	38.1
May 25%													
6.0 m SL	156.6	0.0	0.0	20.0	13.3	0.0	66.7	349.8	0.0	11.9	15.1	41.3	31.7
4.5 m SL	31.3	16.7	0.0	16.7	0.0	0.0	66.7	490.8	4.2	24.0	21.4	24.4	26.1
4.5 m TOR	188.0	2.8	8.3	13.9	5.6	8.3	61.1	198.4	0.0	25.9	12.9	12.2	48.9
May 50%													
6.0 m SL	62.7	0.0	16.7	0.0	16.7	16.7	50.0	511.7	0.0	10.6	14.0	25.9	49.6
4.5 m SL	62.7	0.0	16.7	16.7	0.0	0.0	66.7	224.5	10.4	8.9	25.9	19.1	35.7
4.5 m TOR	125.3	0.0	12.5	16.7	4.2	0.0	66.7	454.2	0.0	12.0	10.6	16.3	61.1
June 25%													
6.0 m SL	94.0	0.0	0.0	16.7	11.1	22.2	50.0	235.0	0.0	13.0	20.4	4.2	62.5
4.5 m SL	94.0	0.0	11.1	16.7	5.6	0.0	66.7	114.9	0.0	6.7	23.3	20.0	50.0
4.5 m TOR	146.2	0.0	3.3	16.7	16.7	3.3	60.0	370.7	0.0	9.5	13.6	20.0	56.9
June 50%													
6.0 m SL	156.6	0.0	6.7	13.3	6.7	3.3	70.0	235.0	0.0	16.7	10.4	34.9	38.1
4.5 m SL	62.7	0.0	16.7	16.7	0.0	0.0	66.7	182.8	0.0	26.2	9.9	20.0	43.9
4.5 m TOR	219.3	0.0	0.0	16.7	14.3	7.2	61.9	339.4	0.0	12.5	10.5	34.6	42.4

Table 11b. Mean monthly leaf stage as a percent of tiller population for lead tillers on the defoliation treatments of the management strategies during the second growing season, 2001.

Treatment Management Strategy	Reproductive Lead Tillers Leaf Stage							Vegetative Lead Tillers Leaf Stage					
	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6-9 %	Flower Stages %	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6-10 %
Control													
6.0 m SL	156.6	0.0	13.3	6.7	13.3	3.3	63.3	292.4	0.0	13.6	12.1	7.6	66.7
4.5 m SL	31.3	0.0	16.7	16.7	16.7	0.0	50.0	208.9	8.3	19.4	7.5	12.3	52.4
4.5 m TOR	308.1	7.5	13.4	5.6	9.7	5.6	58.3	349.8	7.4	16.7	12.6	10.0	53.3
May 25%													
6.0 m SL	172.3	0.0	15.8	7.5	6.7	11.7	58.3	250.6	0.0	14.6	14.6	12.5	58.3
4.5 m SL	62.7	0.0	16.7	8.3	8.3	8.3	58.3	281.9	0.0	22.2	7.4	23.3	47.0
4.5 m TOR	308.1	1.9	10.9	12.2	11.7	5.0	58.3	349.8	0.0	14.5	12.8	7.6	65.2
May 50%													
6.0 m SL	245.4	2.4	9.5	4.8	14.6	10.4	58.3	438.6	0.0	14.3	10.7	10.7	64.3
4.5 m SL	151.4	0.0	20.0	10.0	6.7	6.7	56.7	125.3	0.0	27.8	12.2	13.3	46.7
4.5 m TOR	250.6	4.2	2.1	20.8	4.2	14.6	54.2	297.6	0.0	13.0	14.8	7.2	65.0
June 25%													
6.0 m SL	188.0	5.6	8.3	11.1	8.3	2.8	63.9	245.4	6.3	16.7	8.3	6.3	62.5
4.5 m SL	114.9	0.0	27.8	5.6	8.3	0.0	58.3	177.6	0.0	22.2	11.1	13.9	52.8
4.5 m TOR	188.0	0.0	13.9	8.3	11.1	5.6	61.1	657.8	0.0	11.9	15.9	9.5	62.7
June 50%													
6.0 m SL	114.9	8.3	12.5	8.3	0.0	0.0	70.8	370.7	1.5	16.2	12.9	12.5	57.0
4.5 m SL	94.0	5.6	11.1	11.1	5.6	5.6	61.1	135.7	16.7	16.7	6.7	13.3	46.7
4.5 m TOR	255.8	4.2	16.2	5.6	7.4	5.6	61.1	438.6	6.0	16.7	9.5	8.3	59.5

Table 12a. Mean monthly leaf stage as a percent of tiller population for secondary tillers on the defoliation treatments of the management strategies during the first growing season, 2000.

Treatment Management Strategy	Slow Growth Secondary Tillers Leaf Stage						Early Senescent Secondary Tillers Leaf Stage					
	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6 %	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6 %
Control												
6.0 m SL	120.1	52.8	25.0	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.5 m SL	31.3	16.7	83.3	0.0	0.0	0.0	46.7	25.0	25.0	25.0	0.0	0.0
4.5 m TOR	151.4	35.8	37.8	19.5	0.0	6.9	106.5	19.0	14.0	23.0	24.0	0.0
May 25%												
6.0 m SL	308.1	34.6	17.6	45.0	2.9	0.0	31.3	20.0	0.0	60.0	0.0	0.0
4.5 m SL	78.3	52.8	47.2	0.0	0.0	0.0	31.3	0.0	50.0	0.0	0.0	0.0
4.5 m TOR	146.2	47.6	52.4	0.0	0.0	0.0	47.0	8.3	45.8	20.8	0.0	0.0
May 50%												
6.0 m SL	271.5	25.7	30.6	43.7	0.0	0.0	20.9	66.7	0.0	0.0	0.0	0.0
4.5 m SL	0.0	0.0	0.0	0.0	0.0	0.0	23.5	0.0	75.0	0.0	0.0	0.0
4.5 m TOR	381.1	24.4	29.8	19.8	26.1	0.0	23.5	25.0	50.0	0.0	0.0	0.0
June 25%												
6.0 m SL	188.0	44.9	28.2	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.5 m SL	167.1	19.3	48.1	19.7	12.9	0.0	39.2	37.5	37.5	0.0	0.0	0.0
4.5 m TOR	245.4	31.7	34.6	19.6	14.2	0.0	75.2	13.3	33.3	23.3	0.0	10.0
June 50%												
6.0 m SL	182.8	53.7	31.3	12.3	2.8	0.0	20.9	66.7	0.0	0.0	0.0	0.0
4.5 m SL	104.4	36.1	20.8	26.4	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.5 m TOR	135.8	16.7	16.7	55.6	11.1	0.0	23.5	0.0	75.0	0.0	0.0	0.0

Table 12b. Mean monthly leaf stage as a percent of tiller population for secondary tillers on the defoliation treatments of the management strategies during the second growing season, 2001.

Treatment Management Strategy	Slow Growth Secondary Tillers Leaf Stage						Early Senescent Secondary Tillers Leaf Stage					
	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6 %	Tiller Density #/m^2	1-2 %	3 %	4 %	5 %	6 %
Control												
6.0 m SL	156.6	16.7	11.1	17.8	23.1	31.3	119.1	40.0	30.0	10.0	0.0	0.0
4.5 m SL	78.3	16.7	56.9	26.4	0.0	0.0	109.6	38.8	36.3	0.0	0.0	0.0
4.5 m TOR	130.6	16.7	19.0	19.1	23.8	4.8	144.1	5.5	46.7	27.7	0.0	0.0
May 25%												
6.0 m SL	182.8	16.7	34.5	23.0	7.9	17.9	112.8	38.6	34.6	6.6	0.0	0.0
4.5 m SL	104.4	27.8	38.9	23.6	9.7	0.0	117.5	30.0	25.0	10.0	10.0	0.0
4.5 m TOR	235.0	16.7	29.1	10.7	16.4	27.1	162.9	20.9	33.8	15.3	10.0	0.0
May 50%												
6.0 m SL	161.9	21.4	33.9	2.4	13.1	29.2	75.2	0.0	45.0	35.0	0.0	0.0
4.5 m SL	20.9	66.7	0.0	0.0	0.0	0.0	81.4	50.0	30.0	0.0	0.0	0.0
4.5 m TOR	214.1	5.6	28.8	18.2	25.5	22.0	463.6	12.0	30.7	23.8	5.0	8.5
June 25%												
6.0 m SL	62.7	0.0	53.3	20.0	6.7	0.0	43.9	0.0	0.0	10.0	70.0	0.0
4.5 m SL	47.0	0.0	25.0	37.5	12.5	0.0	81.4	25.0	55.0	0.0	0.0	0.0
4.5 m TOR	167.1	29.4	30.6	13.8	17.2	9.1	156.6	22.7	41.7	10.7	0.0	0.0
June 50%												
6.0 m SL	26.1	66.7	0.0	16.7	0.0	0.0	47.0	0.0	12.5	62.5	0.0	0.0
4.5 m SL	0.0	0.0	0.0	0.0	0.0	0.0	62.7	26.7	26.7	0.0	26.7	0.0
4.5 m TOR	43.9	0.0	0.0	50.0	30.0	0.0	86.2	0.0	54.2	20.8	0.0	0.0

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Environmental Factors that Affect Range Plant Growth, 1892-2009

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Environmental factors affect range plant growth. The three most ecologically important environmental factors affecting rangeland plant growth are light, temperature, and water (precipitation). Plant growth and development are controlled by internal regulators that are modified according to environmental conditions. A research project was conducted to describe the three most important environmental factors in western North Dakota and to identify some of the conditions and variables that limit range plant growth. Rangeland managers should consider these factors during the development of long-term management strategies (Manske 2010).

Light is the most important ecological factor affecting plant growth. Light is necessary for photosynthesis, and changes in day length (photoperiod) regulate the phenological development of rangeland plants. Changes in the day length function as the timer or trigger that activates or stops physiological processes initiating growth and flowering and that starts the process of hardening for resistance to low temperatures in fall and winter. The tilt of the earth's axis in conjunction with the earth's annual revolution around the sun produces the seasons and changes the length of daylight in temperate zones. Dickinson (Fig. 1) has nearly uniform day and night lengths (12 hours) during only a few days, near the vernal and autumnal equinoxes, 20 March and 22 September, respectively, when the sun's apparent path crosses the equator as the sun travels north or south, respectively. The shortest day length (8 hours, 23 minutes) occurs at winter solstice, 21 December, when the sun's apparent path is farthest south of the equator. The longest day length (15 hours, 52 minutes) occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. The length of daylight changes during the growing season, increasing from about 13 hours in mid April to nearly 16 hours in mid June, then decreasing to around 11 hours in mid October (Fig. 1).

Temperature, an approximate measurement of the heat energy available from solar radiation, is a significant factor because both low and high temperatures limit plant growth. Most plant biological activity and growth occur within only a narrow range of temperatures, between 32° F (0° C) and 122° F (50° C). The long-term (118-year) mean annual temperature in the Dickinson, North Dakota, area is 40.9° F (4.9° C) (Table 1). January is the coldest month, with a mean temperature of 11.5° F (-11.4° C). July and August are the warmest months, with mean temperatures of 68.8° F (20.4° C) and 67.0° F (19.4° C), respectively. Months with mean monthly temperatures below 32.0° F (0.0° C) are too cold for active plant growth. Low temperatures define the growing season for perennial plants, which is generally from mid April to mid October (6.0 months). Perennial grassland plants are capable of growing for longer than the frost-free period, but to continue active growth, they require temperatures above the level that freezes water in plant tissue and soil. Winter dormancy in perennial plants is not total inactivity but reduced activity.

Water (precipitation) is essential for all plants and is an integral part of living systems. Water is ecologically important because it is a major force in shaping climatic patterns and biochemically important because it is a necessary component in physiological processes. Plant water stress limits growth. Water stress can vary in degree from a small decrease in water potential to the lethal limit of desiccation. The long-term (118-year) annual precipitation for the area of Dickinson, North Dakota, is 16.00 inches (406.50 mm). The growing season precipitation (April to October) is 13.52 inches (343.21 mm), 84.43% of the annual precipitation. June has the greatest monthly precipitation, at 3.55 inches (90.07 mm). The seasonal distribution of precipitation (Table 2) shows the greatest amount of precipitation occurring in the spring (7.29 inches, 45.54%) and the smallest amount occurring in winter (1.55 inches, 9.71%). Total precipitation received in November through March averages less than 2.5 inches (15.63%). The precipitation received in May, June, and July accounts for 50.69% of the annual precipitation (8.11 inches).

Of the past 118 years (1892 to 2009), 14 (11.86%) were drought years, receiving 75% or less of the long-term mean precipitation level. Fifteen (12.71%) were wet years, receiving 125% or more of the long-term mean precipitation level. Eighty-nine years (75.42%) received normal annual precipitation amounts, between 75% and 125% of the long-term mean. Of the past 118 growing seasons, 18 (15.25% were drought growing seasons, 21 (17.80%) were wet growing seasons, and 79 (66.95%) received precipitation at normal levels.

Temperature and precipitation act together to affect the physiological and ecological status of range plants. The balance between rainfall and potential evapotranspiration determines a plant's biological situation. When rainfall is lower than evapotranspiration demand, a water deficiency exists. The ombrothermic graph technique (Emberger et al. 1963), which plots mean monthly temperature and monthly precipitation on the same axis, was used to identify months with water deficiency conditions during 1892-2009 (Manske 2010). The long-term ombrothermic graph for the Dickinson area (Fig. 2) shows near water deficiency conditions for August, September, and October, a finding indicating that range plants generally may have difficulty growing and accumulating biomass during these 3 months. Favorable water relations occur during May, June, and July, a period during which range plants should be capable of growing and accumulating herbage biomass.

Drought years occurred during 11.9% of the past 118 years, and 15.3% of the growing seasons were drought growing seasons. The 118-year period (1892 to 2009) contained a total of 708 growing-season months. Water deficiency conditions occurred during 231.5 of these, a finding indicating that during 32.69% of the growing season months, or for an average of 2.0 months during every 6.0-month growing season, range plants were under water stress and therefore limited in growth and herbage biomass accumulation. Water deficiency occurred in May and June 13.6% and 10.2 % of the time, respectively. Water deficiency conditions occurred in July less than 40% of the time. Water deficiency conditions occurred in August, September, and October more than 50% of the time: 52.5% of the time in August, 50.0 % of the time in September, and 46.6% of the time in October. Water deficiency conditions lasting a month or more cause plants to experience water stress severe enough to reduce herbage production. These levels of water stress are a major factor limiting the quantity and quality of plant growth in western North Dakota and can limit livestock production if not considered during the development and implementation of long-term grazing management strategies.

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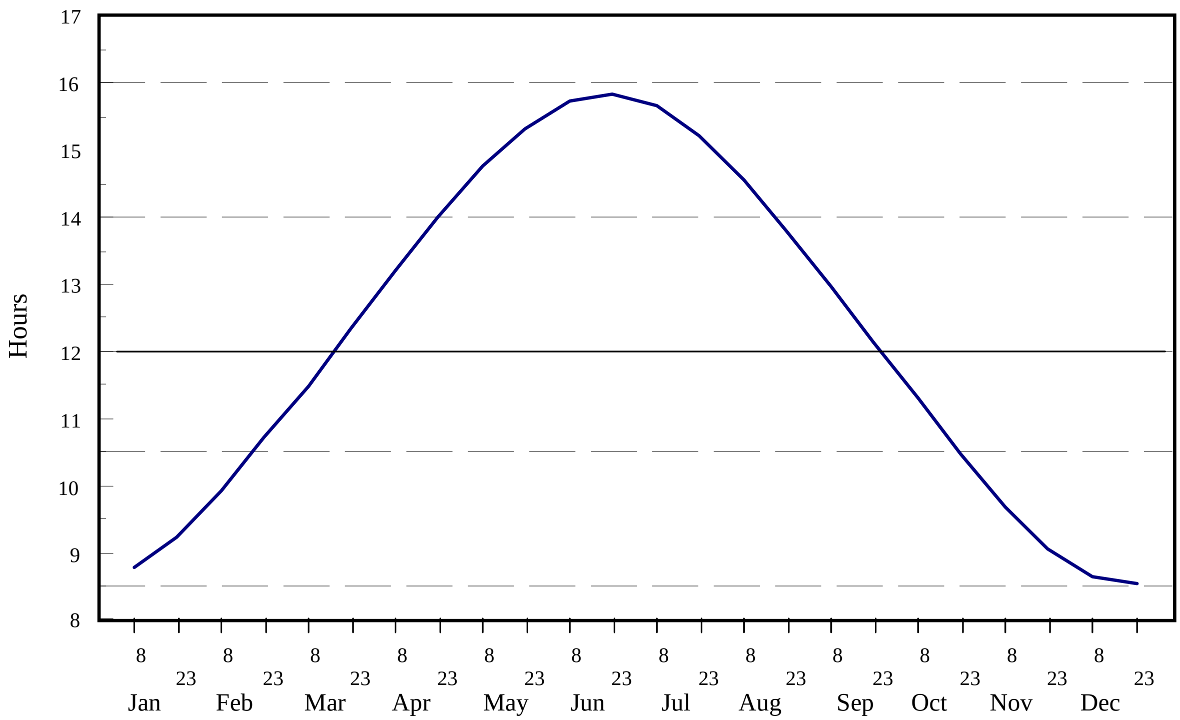

Fig. 1. Annual pattern of daylight duration at Dickinson, North Dakota.

Table 1. Long-term (1892-2009) mean monthly temperature and monthly precipitation at Dickinson, ND.

	º F	º C	in.	mm
Jan	11.47	-11.40	0.41	10.36
Feb	15.28	-9.29	0.41	10.35
Mar	26.18	-3.23	0.74	18.76
Apr	41.54	5.30	1.41	35.84
May	52.79	11.55	2.33	59.21
Jun	61.96	16.65	3.55	90.07
Jul	68.75	20.42	2.23	56.58
Aug	67.00	19.44	1.72	43.58
Sep	56.11	13.39	1.32	33.60
Oct	43.70	6.50	0.96	24.35
Nov	28.45	-1.97	0.53	13.51
Dec	16.94	-8.37	0.41	10.29
	MEAN		**TOTAL**	
	40.85	**4.92**	**16.00**	**406.50**

Table 2. Seasonal percentage of mean annual precipitation distribution (1892-2009).

Season	in.	%
Winter (Jan, Feb, Mar)	1.55	9.71
Spring (Apr, May, Jun)	7.29	45.54
Summer (Jul, Aug, Sep)	5.27	32.91
Fall (Oct, Nov, Dec)	1.90	11.84
TOTAL	16.00	

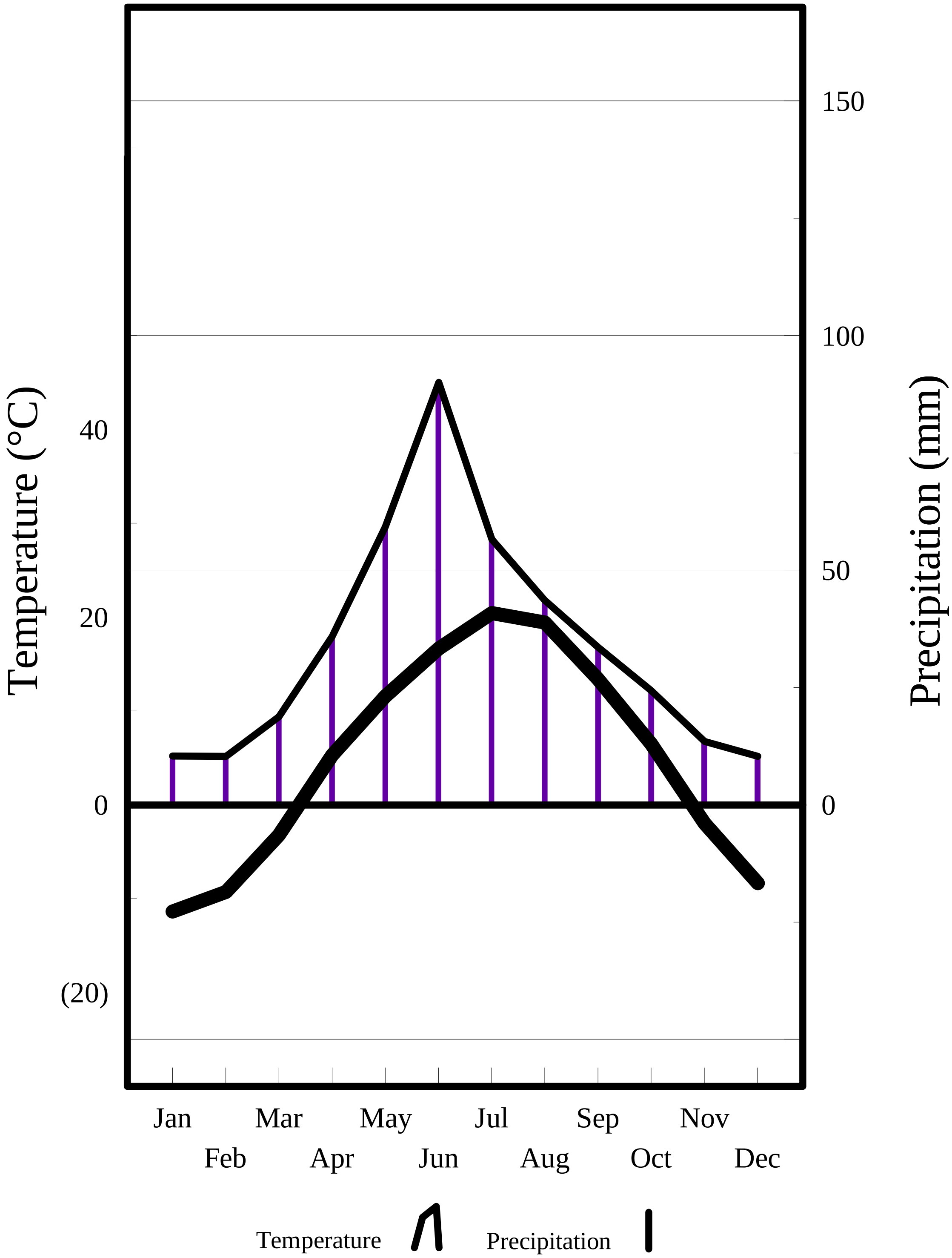

Fig. 2. Ombrothermic diagram of long-term (1892-2009) mean monthly temperature and monthly precipitation at Dickinson, North Dakota.

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Annual Flower Varieties for Western North Dakota

Dickinson Research Extension Station, 2009

by Tom Kalb[1], Extension Horticulturist; Jerry Larson, Twyla Weinschrott, and Chad Weinschrott, Horticulturists; North Dakota State University

Introduction

Annual flowers add instant color to home landscapes. These one-year wonders provide vibrant colors from spring to frost.

A total of 103 annual flower varieties were evaluated at the Dickinson Research Extension Center during the growing season of 2009. Varieties selected for testing were available to consumers at leading garden centers in western North Dakota.

Climate

Planting was delayed due to cool weather throughout spring as well as a late snowfall on 6 June.

The growing season in Dickinson was approximately three degrees cooler than normal through the summer until September when temperatures averaged about eight degrees higher than normal (Figure 1).

Abundant snowfall in winter led to moist soil conditions in spring. Normal rainfall levels occurred in June, followed by a wet July and dry August (Figure 1).

Frosts came late in both spring and fall; thus the growing season itself was close to normal in length. The last killing frost (28 °F) in spring was on 6 June and the first killing frost occurred on October 9. Killing frosts normally occur on 12 May and 23 September.

Methods

Plants were obtained from commercial garden centers in Dickinson and Minot. Six plants were evaluated for each variety.

The plants were transplanted on 12 June. Weeds were controlled with trifluralin and manual weeding. Plants were irrigated as needed using overhead irrigation. Plants were fertilized on 12 June, 7 July, and 18 August with 0.72N–0.24P–0.48K ounces per 100 square feet each time. Plants were deadheaded approximately every 14 days.

Varieties were evaluated for appearance, uniformity, health, vigor, and bloom number on 16 August and 23 September. Varieties were given a final rating of 1–6, with 1 = poor and 6 = excellent. Plants were measured for height and spread on 23 September.

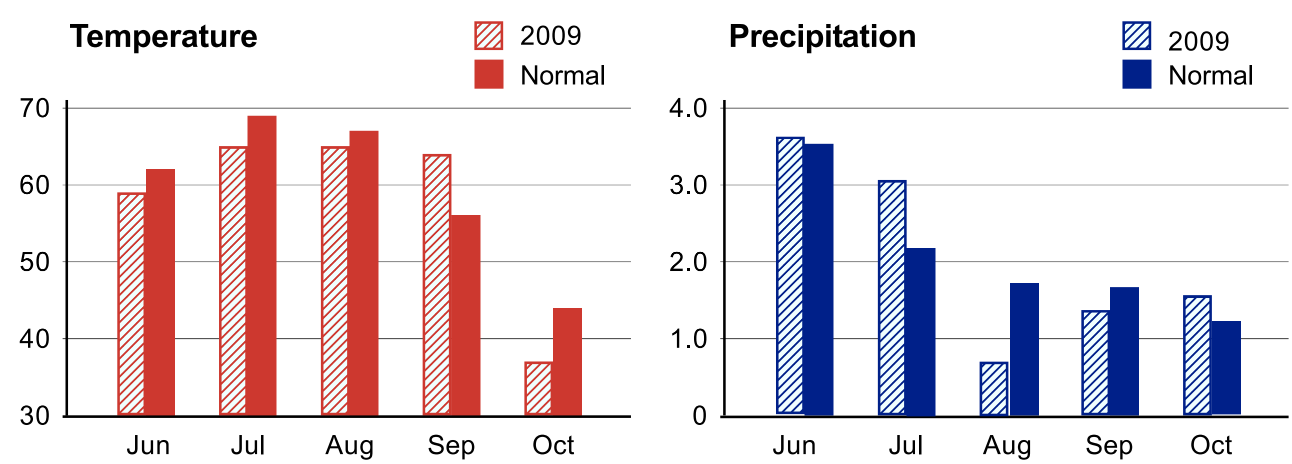

Figure 1. Monthly air temperature (°F) and precipitation levels (in.) for the growing season of 2009 and normal years (average of 1893–2008) in Dickinson. Source: North Dakota Agricultural Weather Network.

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Results

Plants were generally healthy but aster yellows disease affected some varieties of marigolds and petunias. The 'Wave' petunias were especially affected.

Table 1 shows the performance rating and comments for each variety in the trial. The following are general comments on major groups of annuals as well as miscellaneous varieties:

Marigold**.** Numerous varieties performed well in spite of our cool summer. Among the erect African types, 'Antigua Yellow' was especially impressive for its earliness. Its blooms were large and literally blanketed the dwarf 12-inch plants. 'First Lady' was most impressive for its uniformity, clear yellow blooms, and its attractive plant form. 'Inca II' and 'Jubilee' maintained their reputation as proven performers.

Among the dwarf French types, 'Bonanza Bolero' was most impressive. Its fiery blooms brightly adorned its plants; the plants themselves were healthy and uniform in appearance. The large blooms of the 'Durango' series were attractive. In contrast, the 'Little Hero' types were disappointing due to lack of vigor.

Petunia**.** Grandifloras 'Supercascade Rose', 'Prism Sunshine', as well as the 'Dreams' and 'Ultras' series did exceptionally well. Their flowers were bold and eye-catching. The 'Madness' floribundas were solid performers, and their free flowering habit was especially noteworthy after heavy rains. The 'Wave' petunias generally perform exceptionally well in our trials, but these varieties struggled with aster yellows disease in this particular trial.

Rudbeckia**.** The most impressive variety—perhaps among all varieties in the garden during midsummer—was 'Denver Daisy'. It grew vigorously and bloomed early. Its red and gold bicolor blooms were large and bold.

In the late season, the hybrid 'Tiger Eye Gold' was impressive for its abundance of blooms. The blooms of another new variety, 'Cherry Brandy' were a novelty red, but the blooms lacked brilliance and were sparse.

Growers would be advised to try 'Cappuccino'. Although it was not evaluated in Dickinson, it has done exceptionally well in other trials. The earthy, golden flowers of 'Cappuccino' are distinctively warm in appearance and abundant in number.

Zinnia**.** The 'Zahara' series, new in 2008, was most impressive in this and other trials conducted in the region. Its plants tolerated drought and produced an abundance of daisy-like blooms. It surpassed the already impressive 'Profusion' series for flower number and size. The blooms of 'Zahara Yellow' have a unique yellow-chartreuse color. We look forward to testing the 2010 All America Selections Winner 'Zahara Starlite' next year.

The prolific flowering habit of 'Zowie! Yellow Flame' was noteworthy. 'Uproar Rose' was especially impressive for the size of blooms and its long, sturdy stems.

Miscellaneous**.** The most talked about variety in the garden was 'Only the Lonely' nicotiana. The tall 60-inch plants produced stalks of pure white tubular flowers that were fragrant at night.

'Sparkler Mix' cleome was another tall plant that generated much interest. Cleome is vastly underutilized since it is not showy when gardeners purchase their bedding plants at garden centers. The unique flower heads provide for a wonderful background to a flower garden. Cleome is susceptible to flea beetles, especially after the canola crop is harvested, so gardeners need to be prepared for that. This particular trial in Dickinson did not suffer from flea beetles.

In contrast to these garden giants, the most impressive diminutive plant was 'Chilly Chili' ornamental pepper. The tiny plants were blanketed with an unbelievable amount of bright yellow and red peppers. It would make a very interesting—not to mention edible—addition to a garden.

'Blue Angel' salvia drew much attention for the unique aquamarine blue color of its flowers.

Gazania is an underutilized flower. The red striped petals of 'Tiger Mix' were amazing and the silvery foliage of 'Kiss Frosty Mix' added special beauty to the garden.

Among dianthus, 'Amazon Neon Duo' generated most interest. This variety is an upright type with large flower heads for cutting. The brilliance of its fuchsia purple flowers was remarkable.

Dahlias did well in this year's trial. 'Phantom of the Opera' was most impressive as its dark purple foliage contrasted well with its showy flowers.

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Table 1. Performance of annual flower varieties in Dickinson, North Dakota during 2009.

Name	Height	Spread	Rating[2]	Comments
Ageratum houstonianum 'Blue Danube'	6"	6–10"	●○○○○○	Early; compact plants with mid-blue flowers; mounded habit; not especially vigorous or showy
Amaranthus caudatus 'Love Lies Bleeding'	16–18"	18–20"	●○○○○○	Plants cannot support heavy seed heads; not very attractive
Antirrhinum majus (Snapdragon) 'Freesong Mix'	16–20"	14–18"	●●●●○○	Well-branched; suitable for cutting
Antirrhinum majus (Snapdragon) 'La Bella Mix'	20–24"	16–20"	●●●●●○	Plants are healthy and well-branched; flowers are open and abundant
Antirrhinum majus (Snapdragon) 'Rocket Mix'	30–36"	18–22"	●●○○○○	This popular tall variety struggled this year due to wind; plants fell over and some died back
Brassica oleracea (Flowering Kale) 'Emperor White'	12–16"	16–20"	●●○○○○	Fairly attractive, white edges appear in fall; not attractive in summer; heads slightly jut out from bottom of plants
Browallia speciosa 'Blue Bells'	10–12"	12–14"	●●○○○○	Compact plants; pale leaves
Calendula officinalis 'Bon Bon Mix'	10–12"	12–16"	●●●○○○	Bright flower colors; nice blend
Callistephus chinensis (Aster) 'Dwarf Queen Mix'	12–14"	10–12"	●○○○○○	Lots of double flowers in summer; prolific blooming stunted overall plant growth
Capsicum annuum 'Black Pearl'	18–22"	8–10"	●●●●○○	Plants with deep purple foliage; open plant form; jet black marbles for fruits
Capsicum annuum 'Chilly Chili'	8–10"	16–20"	●●●●●●	Very compact plants; absolutely covered with bright yellow and red fruits; fruits point upwards
Catharanthus roseus (Upright Vinca) 'Titan Rose'	10–14"	10–14"	●●●○○○	Bright rose-colored flowers; free flowering; foliage is not as glossy as expected; not as vigorous as expected
Celosia plumosa 'Fresh Look Mix'	12–14"	12–16"	●●●○○○	Early; non-fading colors; lots of blooms; plants lack uniformity
Centaurea cyanus 'Florence Blue'	32"	28"	●●○○○○	Healthy plants full of bright blue blooms until frost; plants eventually flopped over
Centaurea cyanus 'Florence Mix'	32"	28"	●●○○○○	Healthy plants with pink, white, and red blooms until frost; plants eventually flopped over
Cleome hasslerana (Spider Flower) 'Sparkler Mix'	36"	28–30"	●●●●●○	Colorful; healthy; upright plants with blooms in shades of pink, rose and white; good border plant; escaped from flea beetles this year

Cleome hasslerana (Spider Flower) ‘Sparkler Rose’	36”	28–30”	●●●●●○	Colorful; healthy; upright plants with rose-colored blooms; good border plant; escaped from flea beetles this year
Cosmos bipinnatus ‘Cutesy Mix’	24-28”	24–28”	●●○○○○	Plant growth lacks uniformity; yellowing leaves; large blooms in shades of pink, white, and purple
Cosmos bipinnatus ‘Sonata Mix’	24”	16–18”	●●●●○○	Loads of single flowers in shades of pink, white, and carmine
Dahlia pinnata ‘Decorative’	18–20”	16–18”	●●●●○○	Healthy plants with blooms in a bright blend of colors including purple, red and yellow; free flowering
Dahlia pinnata ‘Figaro Mix’	14–18”	12–14”	●●●○○○	Free flowering; bright, double to semidouble blooms
Dahlia pinnata ‘Phantom of the Opera’	24–28”	18–22”	●●●●○○	Dark purple foliage; taller flower stems than comparable types; flowers lack brilliance
Dianthus barbatus ‘Amazon Neon Purple’	20–22”	12–16”	●●●●○○	Late blooming; flower heads are full and globular, extremely vibrant, fuchsia-purple; upright habit; long stems for cutting; wind-damaged plants
Dianthus barbatus ‘Bouquet Purple’	16–20”	12–14”	●●○○○○	More upright habit than ‘Amazon Neon Duo’, but flower heads are thinner and lack brilliance
Dianthus caryophyllus (Carnation) ‘Lillipot Mix’	10”	10”	●●●○○○	Pleasant and clear colors; nice flower form; small stems, dwarf plants
Dianthus chinensis ‘Panda Mix’	8–10”	10–12”	●●●○○○	Less uniform but slightly larger plants; blooms are large and highly serrated; early
Dianthus chinensis ‘Super Parfait Strawberry’	8–10”	8–10”	●●●○○○	Dense mounds; large, scarlet-pink blooms with dark eyes; relatively few blooms
Dianthus chinensis ‘Telstar Mix’	10–12”	10–12’	●●●●●●	Healthy, uniform plants are loaded with blooms; early; blooms are bright with lacy edges; some flowers solid while others have contrasting colors
Dianthus chinensis × *barbatus* ‘Ideal Select Mix’	8–10”	8–10”	●●●●○○	Short mounds with lots of blooms; petals have bright contrasting colors; early
Dyssodia tenuiloba (Dahlberg Daisy) ‘Golden Fleece’	8”	14–18”	●●●○○○	Sprawling plants with mounds of golden daisy heads; some dieback
Gazania splendens ‘Kiss Frosty Mix’	8–10”	12–16”	●●●●●●	Very attractive, silver-leaved plants bear lots of flowers
Gazania splendens ‘Tiger Mix’	8–10”	10–12”	●●●●○○	Petals have reddish inner stripes making for a striking contrast; eye-catching
Gomphrena globosa ‘Fireworks’	24”	24”	●●●●○○	Medium purple globes adorn tall, wiry stems; more useful for cut flower bouquets than outdoor garden beds

Leucanthemum paludosum 'White Buttons'	16–20"	24–28"	●●●○○○	Still blooming strong; tiny white daisies; plants not as uniform as seen at other sites
Limonium sinuate 'Excellent Mix'	24–26"	20–24"	●●○○○○	Bloomed late; plants were healthy but subject to wind damage; good flowers for cutting
Lobelia species 'Regalia Sky Blue'	8"	10–12"	●●○○○○	Weak plants; few blooms
Marabilis jalapa (Four O'Clock)	28–32"	24–28"	●●●○○○	Unique, open form; small, trumpet-shaped flowers are flecked in shades of red, gold and white;
Nicotiana alata (Flowering tobacco) 'Hummingbird II Apple Blossom'	10–12"	10–12"	●○○○○○	Plants lacked vigor; not many flowers
Nicotiana alata (Flowering tobacco) 'Hummingbird II Red'	10–12"	28–30"	●○○○○○	Plants were unhealthy and lacked vigor; not many flowers
Nicotiana sylvestris (Flowering tobacco) 'Only the Lonely'	56–64"	14–16"	●●●●●○	Stately plants; most eye-catching variety in trial; fragrant at night; plants flopped over in late fall
Nierembergia caerulea 'Purple Robe'	8–10"	14–16"	●●●●○○	Compact, lacy plants covered with light purple, delicate blooms
Nierembergia caerulea 'White Robe'	8–10"	16–20"	●●○○○○	Compact, lacy plants with pure white, delicate blooms
Petunia × *hybrida* (Floribunda) 'Madness Double Rose and White'	12–14"	18–22"	●●●○○○	Rugged plants; masses of double, bicolor flowers
Petunia × *hybrida* (Floribunda) 'Madness Lavender Glow'	12–14"	18–22"	●●○○○○	Struggled this year; susceptible to aster yellows; brilliant lavender-rose blooms with glowing yellow throats
Petunia × *hybrida* (Floribunda) 'Madness Midnight'	12–14"	20–24"	●●●●●○	Velvety, dark blue blooms; tight branching habit; free flowering
Petunia × *hybrida* (Floribunda) 'Madness Orchid'	12–14"	20–22"	●●●●●○	Lavender blue petals with dark veins; plants were full and vigorous; flowers were small but abundant
Petunia × *hybrida* (Floribunda) 'Madness Red'	12–14"	16–20"	●○○○○○	Plants were a bit chlorotic; red color of blooms was a bit inconsistent and not as brilliant as preferred
Petunia × *hybrida* (Grandiflora) 'Celebrity Burgundy'	10–12"	24–28"	●●●●○○	Rich burgundy flowers; healthy plants with dense branching
Petunia × *hybrida* (Grandiflora) 'Daddy Blue'	12–16"	20–24"	●●●●○○	Healthy and vigorous; blooms early; deep purple veins
Petunia × *hybrida* (Grandiflora) 'Daddy Sugar'	12–16"	20–24"	●●●●○○	Plants became a bit chlorotic; orchid-colored petals with deep purple veins
Petunia × *hybrida* (Grandiflora) 'Dreams Appleblossom'	10–14"	16–20"	●●●●●○	Lots of soft pink flowers; vigorous plants with tight branching

Petunia × *hybrida* (Grandiflora) ‘Dreams Fuchsia’	10–14”	12–16”	●●●●○○	Beautiful fuchsia flowers with glowing throats; maintained dense branching habit; healthy
Petunia × *hybrida* (Grandiflora) ‘Frost Cherry’	12–14”	20–22”	●●●●○○	Cherry red blooms with pure white edges; lots of large blooms; rugged plants
Petunia × *hybrida* (Grandiflora) ‘Prism Sunshine’	10–14”	24–28”	●●●●●○	The best yellow petunia; plants were slow to get started this year
Petunia × *hybrida* (Grandiflora) ‘Sonata’	12–16”	20–24”	●●●●○○	Lots of big, double, pure white blooms
Petunia × *hybrida* (Grandiflora) ‘Supercascade Rose’	14–16”	28–32”	●●●●●●	Most impressive petunia this year; very large, bright rose-colored flowers; healthy plants
Petunia × *hybrida* (Grandiflora) ‘Ultra Blue Star’	14–18”	28–32”	●●●○○○	Large, navy blue blooms with white stars; very vigorous and slightly leggy
Petunia × *hybrida* (Grandiflora) ‘Ultra Burgundy’	12–14”	28–32”	●●●●●○	Rich, burgundy blooms; plants were healthy but starting to get leggy
Petunia × *hybrida* (Grandiflora) ‘Ultra White’	12–14”	36–42”	●●●●●○	Very full, very vigorous plants with lots of large, pure white blooms
Petunia × *hybrida* (Milliflora) ‘Fantasy Blue’	8–10”	20–24”	●●●●○○	Velvet blue, small blooms; low-growing plants do not sprawl to the extent that ‘Wave’ petunias do
Petunia × *hybrida* (Spreading) ‘Shock Wave Rose’	6–10”	28–30”	●●●○○○	Early blooming; rose blooms with white throats; flowers were not as abundant or large as preferred; aster yellows problem
Petunia × *hybrida* (Spreading) ‘Wave Blue’	6–8”	36–42”	●●●○○○	Rich blue flowers; proven performer but struggled with aster yellows this year
Petunia × *hybrida* (Spreading) ‘Wave Purple’	6–8”	28–32”	●●●○○○	Lustrous purple flowers; all-time favorite but struggled with aster yellows this year
Portulaca grandiflora (Moss Rose) ‘Margarita Mix’	4–8”	8–10”	●○○○○○	Compact plants struggled in cool weather; only a few blooms
Portulaca grandiflora (Moss Rose) ‘Sundial Orange’	6–8”	10–14”	●○○○○○	More vigorous and free flowering than ‘Margarita’, but still a weak performance this cool summer
Rudbeckia hirta ‘Becky Mix’	8–10”	8–12”	●○○○○○	Weak plants
Rudbeckia hirta ‘Cherry Brandy’	16–20”	16–18”	●●●○○○	Blooms were small; earthy, red blooms were unique but not especially showy; moderate vigor
Rudbeckia hirta ‘Denver Daisy’	22–26”	20–24”	●●●●●●	First rudbeckia to bloom; vigorous plants; gorgeous, giant blooms; petals are gold with maroon centers; very showy

Rudbeckia hirta ‘Indian Summer’	28–32”	24–28”	●●●●●○	Very large blooms; well-branched; bloomed late; looked wonderful in fall; free flowering; healthy plants
Rudbeckia hirta ‘Irish Spring’	24–28”	14–18”	●●●○○○	Plants were healthy and uniform; moderate in vigor; golden petals with shiny green eyes
Rudbeckia hirta ‘Prairie Sun’	20–24”	14–18”	●●●○○○	Very large blooms; attractive primrose tips on golden petals; green eyes
Rudbeckia hirta ‘Tiger Eye Gold’	16–18”	18–20”	●●●●●○	Compact, well-branched plants are loaded with blooms; slow to get started but looks great in fall; fabulous border
Salvia farinacea ‘Victoria’	24–28”	22–24”	●●●●●●	Healthy plants; lots of dense spikes of blue flowers; and old favorite; good for cut flowers
Salvia patens ‘Blue Angel’	28–32”	20–24”	●●●●○○	Crystal blue, tubular flowers are eye-catching although not prolific; foliage is healthy and lemon-scented; plants starting to flop over in fall
Salvia splendens ‘Salsa Mix’	12–16”	12–16”	●●●●●○	Healthy plants are full of densely flowered spikes in somewhat muted shades of purple, red, and white
Senecio cineraria (Dusty Miller) ‘Silverdust’	12–14”	20–24”	●●●●●○	Healthy and vigorous; suitable border plant; silvery, finely cut foliage with velvety texture
Tagetes erecta (African marigold) ‘Antigua Yellow’	12–14”	12–16”	●●●●●○	Dwarf plants are loaded with large yellow blooms; healthy plants; eye-catching; very early
Tagetes erecta (African marigold) ‘First Lady’	22–24”	20–24”	●●●●●●	Plants are healthy, upright, and extremely uniform; clear yellow blooms are brilliant
Tagetes erecta (African marigold) ‘Inca II Mix’	12–16”	14–18”	●●●○○○	Compact plants are loaded with blooms; strong stems; early; subject to aster yellows
Tagetes erecta (African marigold) ‘Jubilee Mix’	20–24”	18–22”	●●●●○○	Plants are healthy, sturdy, and upright; lots of flowers, large blooms
Tagetes erecta (African marigold) ‘Sweet Cream’	22–24”	20–24”	●●●●○○	Creamy white flowers; healthy plants, free flowering in fall
Tagetes patula (French marigold) ‘Bonanza Bolero’	10–12”	14–16”	●●●●●●	Dwarf plants are full of fiery blooms; healthy plants; uniform; overall very attractive
Tagetes patula (French marigold) ‘Disco Mix’	10–12”	12–14”	●●●○○○	Single-petal flowers; plants lack uniformity
Tagetes patula (French marigold) ‘Durango Outback Mix’	12–16”	14–18”	●●●○○○	Attractive mix; uniform plants
Tagetes patula (French marigold) ‘Durango Tangerine’	12–16”	14–18”	●●●●○○	Rich, tangerine-color blooms cover healthy plants; large blooms; uniform
Tagetes patula (French marigold) ‘Gem Golden’	16–20”	20–24”	●●●○○○	Tiny flowers cover basal branched plants; weak stems

Tagetes patula (French marigold) 'Janie Mix'	8–10"	8–10"	●●○○○○	Weak plants; crested flowers; not many blooms
Tagetes patula (French marigold) 'Little Hero Fire'	8–10"	10"	●●○○○○	Early; weak plants; damaged by aster yellows; golden yellow-red blooms
Tagetes patula (French marigold) 'Little Hero Flame'	8–10"	10"	●●○○○○	Early; weak plants; damaged by aster yellows; orange-red blooms
Tagetes patula (French marigold) 'Little Hero Yellow'	8–10"	8–10"	●●○○○○	Early; weak plants; damaged by aster yellows; bright yellow blooms
Tagetes patula (French marigold) 'Safari Red'	10–12"	12–16"	●●●●○○	Large, golden red blooms; damaged by aster yellows; free flowering and uniform
Tagetes patula (French marigold) 'Sunburst Yellow Splash'	16–20"	18–22"	●●●●○○	Free flowering; bright golden yellow blooms; taller, more upright, and less mounded than other French varieties
Verbena × *hybrida* 'Quartz Mix'	8–10"	10–14"	●●○○○○	Low-growing plants; uniform; green leaves with flowers along edges
Zinnia angustifolia 'Crystal Orange'	10"	10–12"	●●○○○○	Plants lack vigor; bloom early; small, daisy-like blooms
Zinnia elegans 'Distance Mix'	16–18"	12–16"	●●●●●○	Uniform and healthy; nice mix of colors; semi-double and double blooms; strong basal branches
Zinnia elegans 'Magellan Mix'	14–16"	14–16"	●●●●○○	Vigorous and healthy plants adorned with large, double blooms; bright colors
Zinnia elegans 'Oklahoma Mix'	30–36"	24–26"	●●●○○○	Healthy plants; lots of flowers for cutting; blooms are globular and only 2" across; bright colors
Zinnia elegans 'Short Stuff'	12–14"	12–14"	●●●○○○	Double blooms; plants lack uniformity
Zinnia elegans 'Uproar Rose'	30–32"	22–24"	●●●●●○	Glorious, giant, rose-colored blooms; very long and strong stems for cutting; healthy plants
Zinnia elegans 'Zinnita Formula Mix'	8–12"	10"	●●○○○○	Very dwarf, mounded plants with double flowers; lacks uniformity and vigor
Zinnia elegans 'Zowie! Yellow Flame'	24–28"	20–24"	●●●●●●	Plants are loaded with blooms; semi-double flowers with yellow tips and magenta centers; long stems for cutting
Zinnia hybrida 'Profusion White'	12–14"	12–14"	●●●●○○	White daisy-like flowers; less vigorous than 'Zahara'
Zinnia marylandica 'Zahara Yellow'	16–18"	18–22"	●●●●●●	Very uniform; free flowering; yellow blooms with a tinge of chartreuse; single, daisy-like flowers; vigorous

[2] Varieties were evaluated for appearance, uniformity, health, vigor, and bloom number on 16 August and 23 September. Varieties were given a final rating of 1–6, with 1 = poor and 6 = excellent. Plants were measured for height and spread on 23 September.

Noteworthy Flower Varieties for 2009

Annual flower trial bed

Annual flower trial bed ('Indian Summer' rudbeckia in foreground)

Antirrhinum majus (Snapdragon) 'La Bella Mix'

Capsicum annuum 'Chilly Chili'

Cleome hasslerana (Spider Flower) 'Sparkler Mix'

Cosmos bipinnatus 'Sonata Mix'

Noteworthy Flower Varieties for 2009

Dahlia pinnata 'Phantom of the Opera'

Dianthus barbatus 'Amazon Neon Purple'

Dianthus chinensis 'Telstar Mix'

Gazania splendens 'Kiss Frosty Mix'

Nicotiana sylvestris (Flowering tobacco)
'Only the Lonely'

Petunia × *hybrida* (Grandiflora)
'Dreams Appleblossom'

Noteworthy Flower Varieties for 2009

Petunia × *hybrida* (Grandiflora) 'Prism Sunshine'

Petunia × *hybrida* (Grandiflora) 'Supercascade Rose'

Rudbeckia hirta 'Denver Daisy'

Rudbeckia hirta 'Tiger Eye Gold'

Salvia farinacea 'Victoria'

Salvia patens 'Blue Angel'

Noteworthy Flower Varieties for 2009

Senecio cineraria (Dusty Miller) 'Silverdust'

Tagetes erecta (African marigold) 'Antigua Yellow'

Tagetes erecta (African marigold) 'First Lady'

Tagetes patula (French marigold) 'Bonanza Bolero'

Zinnia elegans 'Zowie! Yellow Flame'

Zinnia marylandica 'Zahara Yellow'

Characterization of *Salmonella spp*. from Post-weaning to Slaughter

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Abstract
The occurrence of *Salmonella* in cattle has been well documented but little is known of tracking its prevalence and antimicrobial resistance (AMR) from post-weaning to slaughter. This study follows a longitudinal approach, allowing for the best analysis of *Salmonella* prevalence and AMR in cattle. It was carried out to monitor variation in *Salmonella* prevalence and antimicrobial resistance (AMR) patterns in beef cattle from range (calves post weaning in North Dakota (ND)) to feedlot cattle up to slaughter (Nebraska). Two separate groups were analyzed, cattle which remained at the Dickinson Research Extension Center (DREC) throughout the course of the study and calves which initially were housed at the DREC, then transferred to a University of Nebraska Feedlot, where they remained until slaughter. Fecal samples were taken four times over a sampling period of eleven months, September 2008 – July 2009; a mid-line sponge sample was taken of the steers before slaughter. Laboratory culture of fecal and sponge samples for *Salmonella* followed a standard published procedure. Presumptive *Salmonella* positive isolates were further analyzed using API20E strips. National Antimicrobial Resistance Monitoring System (NARMS) panels were used for antimicrobial resistance (AMR) testing of *Salmonella* isolates. Additionally, PCR was performed to determine the prevalence of Integrase 1 gene in the *Salmonella* isolates and presumptive integrase positive isolates were further analyzed for the presence of a conserved sequence. Overall, the prevalence of *Salmonella* ranged from 7.9% to 92.1% in adult cattle throughout the study. The prevalence of *Salmonella* in calves at post weaning ranged from 27.7% to 54.4%, with one month, December 2008, displaying 100% prevalence. At the final sampling of calves which included a midline sponge sample along with a fecal grab, prevalence of *Salmonella* was 45.8% and 46.8%, respectively. *Salmonella* isolates displayed the most AMR towards chloramphenicol (57.3%), streptomycin (54.7%) and tetracycline (54.7%) in both groups. Overall, the integrase 1 gene was isolated from 100 (50.0%) isolates, with 88 (44.0%) isolates harboring a conserved sequence. In conclusion, this study provided data on AMR patterns of *Salmonella* shed by beef cattle at the different stages of production. Also, an association between AMR towards the various antimicrobials tested and presence of integron 1, on the *Salmonella* isolates recovered was investigated providing some information on the mechanisms of resistance to these antimicrobials. Most importantly, this research contributes information to the scientific literature on *Salmonella* prevalence and ARM risk assessment in the beef cattle food chain that can allow for development of appropriate control measures.

Introduction

Foodborne illnesses in the United States (US) are caused by a wide variety of microorganisms and are estimated to cause 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths annually (Mead et al., 1999).

Of all food borne pathogens that affect humans, *Salmonella* is widely considered to be one of the most important. A foodNet report estimated *Salmonella* related infections in the US to be 1.4 million illnesses, 15,000 hospitalizations and 400 deaths annually (Voetsch et al., 2004).

Among the many *Salmonella* serotypes, the most common associated with infection in humans are S. typhimurium and S. enteritidis. *Salmonella* can live in the intestinal tracts of humans, other animals, and birds. Foods of animal origin may be contaminated with *Salmonella*; therefore, eating raw or undercooked eggs, poultry, or meat can cause infection. Foods prepared with raw eggs can be an unrecognizable origin of contamination. Meat from poultry and ground beef are sources of contamination that should be well cooked before consumption.

The ability of Salmonella to become resistant to antimicrobials has hampered efforts in treating illnesses caused by this pathogen and has made the production and tracking of food products, especially those from cattle, more important. Antimicrobial resistance is the ability of microorganisms to evade the effects of antimicrobials through newly developed biological mechanisms (CDC, 2008). The ability of microorganisms to evade or to become resistant to antimicrobials can be acquired through integrons, which are genes that consist of a central variable region that often harbors antibiotic-resistance gene cassettes (Amita et al., 2004).

Procedure

Using cow-calf pairs located at the Dickinson Research Extension Center, the purpose of this pathogen survey project is to track the prevalence of pathogenic *E. coli* and *Salmonella* serotypes through the production continuum beginning on fall native range and ending at final harvest (steer calves). *Objectives*: (1) Determine seasonal prevalence change for pathogenic *E. coli* that carry shiga toxin genes and *Salmonella* spp., (2) Determine the level of antimicrobial resistance (AMR) and multidrug resistance in Salmonella strains isolated from beef cattle at different stages of production, and (3) Determine the association between the presence of Integron-1and AMR to 15 different antimicrobials (amikacin, amoxicillin/ clavulanic acid, ampicillin, ceftiofur, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfizoxazole, and trimethprim-sulfamethoxazole) in isolated *Salmonella* strains.

Fecal grab samples and rectoanal swab samples are being collected beginning before weaning on fall pasture and continuing through weaning, mid-winter (Feb), at spring pasture turnout on improved crested wheat, and on pasture mid-summer. The calves will be sampled on fall pasture, at weaning, at the end of unharvested corn grazing, midway through the finishing period (Feb), and just prior to final harvest. Laboratory isolation and definitive PCR serotype determinations were conducted under the direction of Dr. Margaret Khaitsa, Veterinary Epidemiologist, NDSU Veterinary and Microbiological Sciences Department.

Expected outcomes include: (1) Establishment of seasonal shedding patterns for shiga toxin producing *E. coli* serotypes and *Salmonella* spp., (2) Establishment of antimicrobial resistance patterns of Salmonella isolated from beef cattle throughout the production continuum, (3) Establish the connection between Integron-1 presence and resistance patterns to the antimicrobials tested.

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USDA/NRCS Conservation Innovation Grant
Forage-Based Beef Production Strategies for Western North Dakota

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This project was funded in part with a USDA/NRCS Conservation Innovation Grant number 68-6633-7-16.

Final Report Summary of Work Performed:

The objective of this project is to demonstrate an alternative beef management system that incorporates early weaning and a standing annual forage feed supply for weaned calves and cows that will produce heavy backgrounded calves and wintered cows without concentrating manure and negatively impacting the environment. Total beef systems that capitalize on extended grazing for both spring-born early weaned calves and cows as a divergence from conventional fall weaning into drylot and reduced hay wintering is uncommon in southwestern North Dakota. Project innovation uses a "leader-follower" protocol in which early weaned calves are backgrounded without long periods of feedlot confinement grazing unharvested corn and cows are wintered grazing lower quality corn residue after calves have gleaned the more succulent plant parts.

Profit volatility is common in the cattle business, and drought limits precipitation during the critical spring growing period in the northern Great Plains. Information generated by this demonstration can be used to address vital land and livestock resource issues, i.e. maintaining ranching business vitality and profitability while protecting the environment and water resources.

Results from the demonstration have been summarized in the itemized "Integrated Crop and Livestock Management Fact Sheet" shown in Appendix I for use by NRCS personnel engaged in non-confinement grazing and livestock management education.

Project Objectives:

1. Demonstrate native range forage sparing potential through early weaning and the subsequent effect on cow BCS in a beef management system.

2. Demonstrate the extensive, non-confinement potential of unharvested corn as an extensive feed base for calf growth and backgrounding followed by cow grazing of corn residue remaining after calves glean the most succulent aerial plant parts.

3. Demonstrate the prevalence of *E. coli* O157:H7 and Salmonella in manure and document soil nutrient and organic matter following late summer and early winter grazing of unharvested corn; and also document nutrient load in runoff water.

The calving period during the demonstration was from March 20 of each year to the first week of May. Over 80% of the cows calved during the first 40 days of the calving season. Forty-eight cow-calf pairs (steer calves only) were used each year of the investigation and were assigned to either early- or normal-weaning groups based on calving date. Subsequently, the August early weaning occurred during the second week of August when the early weaned calves were weaned from their mothers. One-half of the calves in each weaning date group were sent directly to the University of Nebraska Panhandle Research and Extension Center Feedlot, Scottsbluff, NE and the remaining one-half were placed in replicated feedlot pens and fed hay for 9-14 days for weaning stress recovery. At the end of the weaning recovery period, the steer calves were vaccinated for bacterial and viral calfhood diseases and put into replicated 4.5 acre unharvested green growing corn fields. When the calves completed harvesting the higher quality corn plant material, they were removed from the corn fields, weighed and delivered to the UNL Panhandle Feedlot for finishing also. After the calves were removed from the corn fields, the calves' mothers were put into the corn fields and grazed the corn stalk residue.

Pathogen prevalence was monitored among cows and their calves during grazing and feedlot conditions. Fecal grab samples and rectal swab samples taken at the rectal-anal junction were analyzed under the supervision of Margaret Khaitsa at North Dakota State University. Soil samples were taken each spring and analyzed for N, P, K, Su, Zn, Cu, and organic matter. Waste runoff water from fields grazed by cattle was analyzed for phosphate-phosphorus, potassium, total dissolved solids, and nitrate-nitrogen. During the 2-year study, western North Dakota was drier than normal which resulted in a single snowmelt event the last year of the demonstration.

Considering the extreme drought experienced during the second year of the investigation, the data and analysis were not combined. The summary tables and discussion provided are summarized in a Normal Precipitation Report and in a Drought Report for the second year of the study.

Project Deliverables

A. Workshops during the grant period (Appendix II):

1. Forage-Based Beef Production Strategies Field Day, September 26, 2007
2. 1st Annual Forage Beef & Cover Crop Workshop, September 24, 2008
3. 2nd Annual Forage Beef & Cover Crop Workshop, September 16, 2009

B. Tours:

1. Logan County, Kentucky Soil Conservation District tour of the CIG Forage-Based Beef Production Strategies project, September 17, 2008

C. Educational Electronic Media

The initial CIG proposal stated that an educational DVD would be prepared; however, it has been replaced with a Forage-Beef and Cover Crop website with live streaming video of field day presentations, educational PowerPoint presentations, and links to related sites. The website was selected, in lieu of the DVD, because it provides contact with a worldwide audience and can be updated with new information and links.

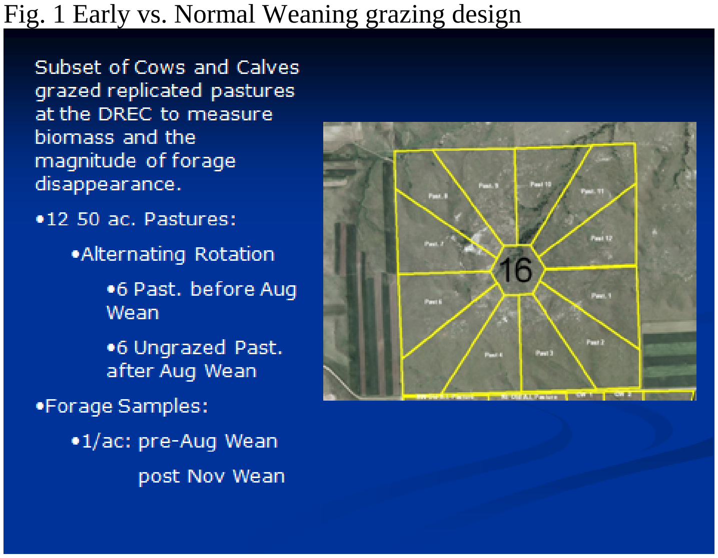
Website URL: http://www.ag.ndsu.nodak.edu/dickinso/cig/index.htm

Description of Significant Results, Accomplishments, and Lessons Learned:

1. Demonstrate native range forage sparing potential through early weaning and the subsequent effect on cow BCS in a beef management system.

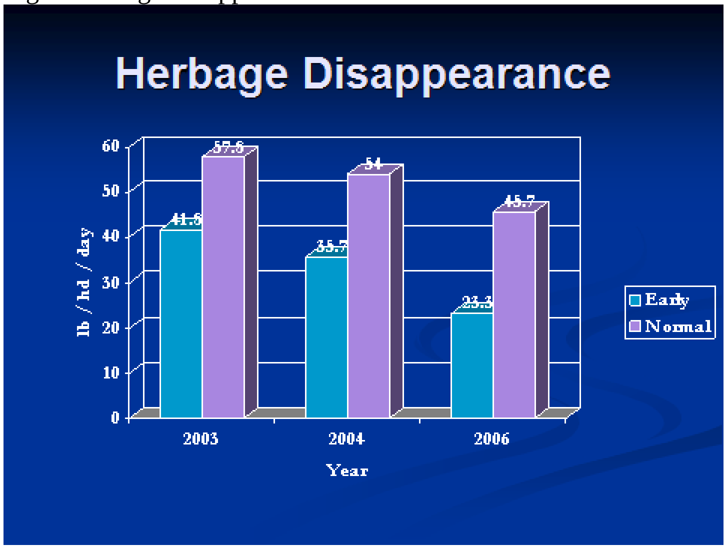
The key to successful early weaning management in a beef system is energy allocation. The energy requirement for the lactating cow is approximately 30% greater than that of the non-lactating cow. Thus, when calves are weaned early, the cow's requirement for lactation stops and range forage energy and nutrients are only needed for the cow's maintenance and growth. Research has shown that cows in body condition score of 5 to 6 (1-9 System) require less winter feed to maintain condition and have improved reproductive performance the next breeding season. Forage production and disappearance data was obtained over a three year period on a section of native range (146-96, Sec. 16) located in Dunn County, North Dakota. The early and normal weaning grazing design and forage sampling procedure is shown in Fig. 1.

Fig. 1 Early vs. Normal Weaning grazing design



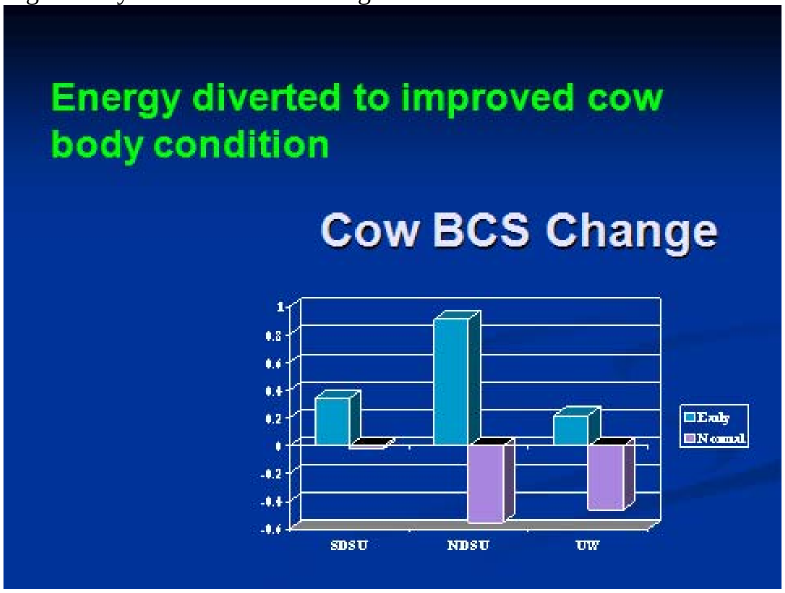
Forage or herbage disappearance expressed in pounds/head (cow)/day is shown in Fig. 2. The differential between cows that nursed calves varied between the years measured, but was actually very consistent at an average 18.9 pounds/cow/day less for cows that had their calves weaned early.

Fig. 2 Herbage Disappearance in Pounds/Cow/Acre



With the cessation of lactation facilitated by early weaning, energy allocation is naturally diverted from milk production to increased body condition. In Fig. 3 the effect of early weaning is depicted among three participating cow herds located at the Dickinson Research Extension Center, SDSU Antelope Station, Buffalo, SD, and the University of Wyoming. Early weaning consistently improved body condition score and ranged from 0.2 to 0.8 BCS points.

Fig. 3 Body condition score change



We have been able to demonstrate that early weaning will result in spared native forage. The next question in a beef system is to identify how to allocate the stored forage energy that was spared through early weaning. These data do not suggest a replacement for best management practices that incorporate rotational grazing, but reallocates how the spared forage may be utilized. Early weaning and the resultant spared forage can be used initially to improve plant vigor and provide for stocking flexibility, i.e. increase winter grazing capabilities, extensive heifer development at lower cost, and/or increase cow herd size.

2. Demonstrate the extensive, non-confinement potential of annual forage as an extensive feed base for calf growth and backgrounding followed by cow

grazing of corn residue remaining after calves glean the most succulent aerial plant parts.

Summary of Integrated Livestock and Annual Forage Grazing Results:

In the first objective we have demonstrated that early weaning consistently spares native forage and improves cow body condition. Cows that go into the winter with improved body condition require less winter feed to maintain condition and cows with body condition scores of 5 or better have shorter postpartum intervals, more prebreeding estrous cycles, and a potential for higher first service pregnancy rate.

While early weaning is very beneficial for the cow and native forage sparing, calf management is equally important, and to become a readily adopted practice, growth performance must exceed that which is obtainable grazing native pasture, and the practice must be economical. Without a management plan for the calves, early weaning would be impossible. Even with a plan, the practice requires extra management.

Results from the 1st year of the demonstration (Normal Precipitation)

Standing peak dryland corn forage nutrient quality was determined mid-September and tracked through to mid-January. Corn forage CP declined from Sep to Nov (9.16 to 8.66) and IVDMD declined from 75.2% to 57.0% (Table 1).

Peak DM corn production for the EW steers averaged 2.20 Ton/acre (Table 2) and peak DM corn production for the NW group was 1.93 Ton/acre (Table 3). Early weaned steers utilized an average 1.46 Ton/acre over the 70 day grazing period and NW steers utilized 0.41 Ton/acre. Field loss in stockpiled corn set aside for grazing after normal weaning was excessive averaging 0.90 Ton/acre. Compared to the EW treatment, the large field loss reduced available days of grazing by 70%.

Comparative systems backgrounding performance is shown in Table 4. Steer weight at EW did not differ (P=0.44), but gain among the NW-CN steers was reduced significantly (P=0.043) due to field crop shrink. Average daily gain for EW and NW steers was similar and greater (p=0.004) than the control steers despite significant crop shrinkage. System backgrounding economics are shown in Table 5 where gain value, input costs, net returns, and cost/lb of gain are summarized. The backgrounding cost/lb. of gain was $0.5933, $1.71, $0.5097, and $0.6564 for the NW-FLT, NW-CN, EW-CN, and EW-FLT, respectively. Net return/steer among the steers in EW-CN system was 33.5% greater than the EW-FLT system and 16.3% greater than the NW-FLT system. Stockpiling corn for grazing after normal weaning was not successful resulting in a net loss/steer of -$33.38. The stocking rate for early weaned calves that grazed unharvested dryland corn was calculated to be 0.25acres/calf/month and the stocking rate for stockpiled corn reserved for unharvested corn gazing after normal weaning was determined to be 0.82 acres/calf/month (Table 6). Following grazing by calves, cows grazed stalk residue. Stalking rate for cows expressed in acres/cow/month is shown in Table 6 for 1,000, 1,200, and 1,400 pound cows. The stocking rate for 1,200 pound cows grazing corn stalk residue previously grazed by EW and NW calves was 0.70 and 0.87 acres/cow/month, respectively.

For the purpose of comparing beef production from corn grazing during backgrounding with grain production, steer net return value per acre after expenses was converted to a corn grain equivalent yield per acre. Comparative values are shown in Table 7 over a range of corn prices per bushel from $3.00 to $5.00/bu. At $4.00/bu, the corn equivalent value of beef produced among the EW steers was equivalent to 87.5 bushels of corn/ac. The corn equivalent value of beef produced among the NW steers was equivalent to 26.2 bushels of corn/ac.

The effect of alternative weaning date and corn grazing on finishing performance is shown in Table 8. Early weaning and corn grazing backgrounding resulted in variable feedlot starting weights (P = 0001), and a large variation in the number of days on feed (P = 0.0001); however, harvest age (P = 0.27) and 4% shrunk harvest weight (P = .409) did not differ. For gain and FE, EW-FLT steers gained at the slowest rate (P = 0.001), were more efficient (P = 0.008), and feed and yardage cost/lb. of gain were lower (P = 0.0002). By contrast, EW-CN steers that were the most profitable at the end of corn grazing backgrounding were less efficient (P = 0.008) and feed and yardage cost/lb. of gain was higher (P = 0.0002) during retained ownership finishing. The NW-CN steers that grazed stockpiled dryland corn were the least efficient (P = 0.008) and had the highest feed and yardage cost/lb. of gain (P = 0.0002).

The primary health issue was bovine respiratory disease, which has been summarized in Table 9. The incidence of BRD among EW steers sent directly to the feedlot after weaning mid-August was markedly greater than for any of the later arriving treatment groups and treatment cost was 3.5 times greater than either the control or treatment groups that grazed corn during backgrounding.

The effect of alternative weaning date and corn grazing on carcass closeout measurements is shown in Table 10. Carcass closeout values for HCW (P = 0.78), dressing percent (P = 0.51), fat depth (P = 0.243), and yield grade (P = 0.23) did not differ. Corn grazing steers had significantly larger ribeye area (p = 0.053). Days on feed, which varied due to management system, directly affected marbling score (P = <0.0001) and the number of carcasses that grading USDA Choice or better (P = 0.10). The number of days on feed and the percent USDA Choice were 141.5/66.7%, 165.7/79.2%, 192.0/81.1%, and 280.8/94.4% for the NW-CN, EW-CN, NW-FLT, and EW-FLT, respectively.

The combined effect of calf placement cost, ingredient cost, treatment cost, freight, and interest cost affected finishing net return and are shown in Table 11. Calf placement cost had the most influence on net return. Closeout net returns were $3.11, -$84.06, $0.16, and $39.62/head for the NW-FLT, NW-CN, EW-CN, and EW-FLT, respectively.

Table 1.Corn Nutrient Change (Sept. – Jan.)

	C- Prot	***NDF***	***ADF***	***IVDMD%***	***IVOMD***	***Ca***	***P***
	%	%	%	%	%	%	%
Whole Plant/Stalks:							
Sept. 25, 2007	9.16	61.0	30.0	75.2	74.8	0.20	0.16
Nov. 15, 2007	8.66	70.2	40.5	59.0	57.0	0.23	0.12
Jan. 12, 2008(Residue)	4.36	79.8	50.3	43.5	40.9	0.32	0.05
Corn Grain:							
Sept. 25, 2007	14.1	12.2	3.10	90.8	90.4	0.03	0.37
Cobs:							
Sept. 25, 2007	4.33	81.5	39.2	64.1	63.1	0.01	0.12
Litter (trash on ground):							
Jan. 12, 2008	9.57	72.1	36.7	64.7	64.8	0.31	0.11

Table 2. Early Wean Corn Utilization

	Peak	***Calf***	***Cows***
	Production T/Ac	Utilization T/Ac	Residual Stalks T/Ac
Fields:			
4	2.05	1.11	0.94
6	1.92	1.24	0.68
8	2.64	2.02	0.62
Total Tons	6.61	4.37	2.24
Avg DM, T/Ac	2.20	1.46	0.75

Table 3. Normal Wean Corn Utilization

	Peak Production Sept	*Start Graze Nov*	*Field Loss*	*Calf Utilization*	*Cows Residual Stalks*
	T/Ac	T/Ac	T/Ac	T/Ac	T/Ac
Field					
5	2.11	1.18	0.93	0.54	0.64
7	1.6	0.89	0.71	0.27	0.62
9	2.08	1.02	1.06	0.41	0.61
Total Tons	5.79	3.09	2.70	1.22	1.87
Avg DM, T/Ac	1.93	1.03	0.90	0.41	0.62

Table 4. Alternative Beef System Backgrounding Performance

	NW-Control Pasture	*NW – Corn Grazing*	*EW – Corn Grazing*	*EW – Feedlot*	*SE*	*P-Value*
Weaning Date	Nov 7	Nov 7	Aug 15	Aug 15		
No. Steers	54	24	24	57		
Pre-Unhvsted Corn Grazing (Drylot):						
Days in Drylot[a]	----	13	13	----		
Drylot St. Wt.(Aug 15, Nov 7), lb	----	627	468	----		
Drylot End Wt., lb	----	639	481	----		
Drylot Gain, lb	----	12.0	13.0	----	2.91	0.52
Drylot ADG (Drylot), lb	----	0.923	1.00	----	0.22	0.53
System Days	84	21	70	86		
System Wt at Ely Wean (Aug 15) lb	436	457	468	405	22.1	0.44
System End Wt., lb	600	693	662	611	33.19	0.15
Gain, lb	164[ab]	54[b]	181[a]	206[a]		0.043
ADG, lb	1.95[b]	2.57[a]	2.59[a]	2.40[a]	0.126	0.004

[a]Weaned steers were held in drylot for 13 days before placement in the corn fields to get over weaning.

Table 5. Alternative Beef System Unharvested Corn, Pasture, and Feedlot Economics

	NW- Ctrl Pasture/ Feedlot	*NW – Corn Grazing*	*EW – Corn Grazing*	*EW – Feedlot*	*SE*	*P-Value*
No. Steers	54	24	24	57		
Gain Value [a,b,c,d]	$9,979	$1,413	$4,724	$10,980		
Input Cost:						
Pasture (Rent @$14.00/ac)[e]	$5,254					
Corn ($164/ac)		$2,214	$2,214			
Feedlot				$7,302		
Backgrounding Net Return	$4,725	-$801	$2,510	$3,678		
Backgrounding Net Return/Head	$87.50	-$33.38	$104.58	$69.56		
Cost/Lb. Gain	$0.5933	$1.71	$0.5097	$0.6564		

[a]NW Control Gain Value (8,910lb@$112/cwt)
[b]NW Corn Grazing Gain Value (4,334lb@$109/cwt)
[c]EW Gain Value (1,296lb@$109/cwt)
[d]Gain Value (9,804lb@$112/cwt)
Pasture Rent Calculation: 2.78 months, 2.5 AUM; = 6.95 Ac/AUM @ $14/Ac; = $97.30 x54 = $5,254.20

Table 6. Steer and Cow Stalking Rate for Unharvested Corn and Stalk Residue Grazing

	Normal Weaned Cows	***Normal Weaned Steers***	***Early Weaned Cows***	***Early Weaned Steers***
Steer Unharvested Corn, Ac/Steer/Month		0.82		0.25
Corn Residue, T/Ac	0.624		0.748	
Stalk Residue Requirement, Ac/Cow/Month				
1,000 Lb Cow	0.73		0.59	
1,200 Lb Cow	0.87		0.70	
1,400 Lb Cow	1.02		0.82	
Residue Value @$40/Ton Hay Equivalent	$337.00		$420.00	

Table 7. Corn Grazing Grain Equivalent, Bu/Acre

	Corn Bushel Price	***Early Wean – Grain Yield Equivalent***	***Normal Wean – Grain Yield Equivalent***
Steer Grazing Gain Value	$3.00	116.6	34.9
	$4.00	87.5	26.2
	$5.00	70.0	20.9
Corn Stalk Residue Grazing (Cows)	$3.00	10.4	8.3
Based on $40/Ton Hay	$4.00	7.8	6.2
	$5.00	6.2	5.0
Combined Steer Gain and Cow	$3.00	127.0	43.2
Stalk Grazing Value	$4.00	95.3	32.4
	$5.00	76.2	25.9

Table 8. Effect of Alternative Weaning Date and Corn Grazing on Steer Finishing Performance

	NW- Control Pasture/F-lot	***NW – Corn Grazing***	***EW – Corn Grazing***	***EW – Feedlot***	***SE***	***P-Value***
Start Wt., lb	600.0[c]	747.7[b]	690.3[d]	404.8[a]	0.00	<0.0001
Shrunk Finished End Wt., lb[a]	1186.9	1224.0	1249.9	1203.1	23.01	0.409
Days on Feed	192[d]	141.5[b]	165.7[c]	280.8[a]	3.44	<0.0001
Kill Age, Days	408.1	415.1	404.6	412.1	3.17	0.270
Gain, lb	586.9[c]	476.3[b]	559.6[d]	798.3[a]	9.46	0.0001
ADG, lb	3.06[b]	3.37[c]	3.38[c]	2.85[a]	0.056	0.0011
Fd/Head/Day (As Fed), lb	29.7[b]	36.0[d]	33.0[c]	27.0[a]	0.749	<0.0001
Fd/Head/Day (Dry Matter), lb	20.2[b]	24.5[d]	22.4[c]	17.8[a]	0.506	<0.0001
DM Feed:Gain, lb	6.60[b]	7.27[c]	6.62[b]	6.27[a]	0.157	0.008
Fd & Yard Cost/Day, $	$2.096[b]	$2.723[d]	$2.383[c]	$1.715[a]	0.053	<0.0001
Fd & Yard Cost/Lb of Gain, $	$0.6850b	$0.8080c	$0.7050b	$0.6017a	0.016	0.0002

[a] 4% Shrink

Table 9. Alternative Production Effect on Health Pulls and Treatment Costs

	NW- Control Pasture/Feedlot	*NW – Corn Grazing*	*EW – Corn Grazing*	*EW – Feedlot*
Pulls: 1	3.7%	3.75%	0.0%	17.5%
2				8.77%
3				3.51%
Avg. Treatment Cost/Head	$1.72	$3.87	$0.0	$9.92

Table 10. Effect of Alternative Weaning Date and Corn Grazing on Carcass Measurements

	NW – Control Pasture/F-Lot	*NW – Corn Grazing*	*EW – Corn Grazing*	*EW – Feedlot*	*SE*	*P-Value*
Hot Carcass Wt., lb	737.8	745.3	762.9	745.5	14.77	0.78
Carc. Dressing Percent, %	62.0	60.6	61.1	60.6	0.72	0.51
Ribeye Area, sq. in.	11.51[b]	12.3[a]	12.3[a]	11.7[b]	0.17	0.053
Fat Depth, in.	0.586	0.547	0.581	0.638	.0304	0.243
Yield Grade[a]	3.46	3.35	3.45	3.59	0.075	0.229
Marbling Score	442[b]	438[b]	453[b]	539[a]	12.75	0.0005
% Choice Carcasses	81.1	66.7	79.2	94.4	6.32	0.109

[a]Yield Grade correlation to percentage of boneless, closely trimmed retail cuts: 1 = 54.6%, 2 = 52.3%, 3 = 5.0%, 4 = 47.7%, and 5 = 45.4%

Table 11. Effect of Alternative Weaning Date and Corn Grazing on Finishing Economics

	NW – Control Pasture/ F-lot	*NW – Corn Grazing*	*EW – Corn Grazing*	*EW – Feedlot*
Expenses:				
Calf Value	$666.00	$783.22	$724.50	$566.72
Feed and Yardage	$402.06	$384.85	$394.52	$480.34
Treatment Cost	$1.72	$3.87	$0.0	$9.92
Freight ($4.5/mile; 425 miles)	$23.90	$29.88	$27.71	$16.20
Interest @ 6.0%	$34.18	$27.55	$30.90	$49.00
Total Expense	$1,127.86	$1,229.37	$1,177.63	$1,122.18
Carcass Value	$1,130.97	$1,145.31	$1,177.79	$1,161.80
Profit (Loss)	$3.11	-$84.06	$0.16	$39.62

Results from the 2nd year of the demonstration (Drought)

The second year of the demonstration was plagued with a severe drought. Although critical growing season precipitation was very short, the alternate pasture grazing system employed for these weaning date investigations provided sufficient grazable forage for the normal weaning date group (Nov. 1).

Annual corn forage seeded for grazing did not develop ears and overall tonnage was reduced significantly. The small crop limited the number of days for grazing to less than one-half of the previous year and the EW treatment lost money. Basically, the poor corn crop was salvaged, but at a loss. Corn nutrient analysis, production, and utilization are summarized in Tables 1, 2, and 3.

Steer performance comparing the NW group that continued to graze native range with the EW group indicated that ADG was comparable while the corn crop lasted. These comparative results are shown in Table 4.

The EW and NW corn grazing treatment group comparisons are shown in Table 5. The NW group grazed corn after weaning in November when the corn crop is mature and dried down. With no ears in the drought stressed crop, the pounds of gain among the NW steers was 58.6% less than the EW steers.

In the system economic analysis, net crop insurance payments were figured into the analysis. The analysis, shown in Table 6, resulted in net returns/steer of $69.25 for the NW pasture group, -$37.74 for the NW group that grazed corn, and $14.92 for the EW group that grazed green corn.

The steers from each weaning date treatment were followed from the end of backgrounding grazing unharvested standing corn to final harvest. As in the first year of the demonstration, the steers were fed at the University of Nebraska Panhandle RE Center Feedlot, Scottsbluff, NE and final harvest was at the Cargill Meat Solutions plant located in Fort Morgan, CO.

Not only did these steers go through one of the driest summers on record in ND, but the price of corn fed in the feedlot was historically high. The number of days on feed (DOF) for the EW steers was 41 days longer than for the NW steers. The EW steers gained 164 pounds more during the finishing period, but ADG was similar (NW - 3.26 vs EW - 3.39).

Finishing economic analysis has been summarized in Table 8. And due to the high corn grain cost, both the EW and NW groups in the demonstration lost money. However, because the NW steers were on feed for fewer days (41) they lost less money (EW -$266.98 vs NW - $144.54). Carcass quality was better among the EW steers that were on feed longer. The EW steer carcasses were numerically heavier, had larger ribeye area (P = 0.07), greater fat depth (P = 0.06), similar yield grade (P = 0.37), higher marbling score (P = 0.004), and numerically higher quality grade (Percent Choice Carcasses) (NW – 78.0 vs. 86.3).

Table 1. Corn Nutrient Analysis (Drought Stressed – Ears Did Not Develop)

	C- Prot	***NDF***	***ADF***	***IVDMD***	***IVOMD***	***Ca***	***P***
Whole Plant, %	10.71	59.10	31.50	66.65	66.11	0.35	0.13

Table 2. Early Wean Corn Utilization (Dry Matter)

	Peak Production, T/Ac	*Calf Utilization, T/Ac*	*Cows Residual Stalks, T/Ac*
Fields:			
4	0.88	0.35	0.53
6	0.93	0.47	0.46
8	1.70	1.53	0.17
Total DM, T/Ac	3.51	2.35	1.16
Avg. DM, T/Ac	1.17	0.78	0.38

Table 3. Normal Wean Corn Utilization (Dry Matter)

	Peak Production Sept, T/Ac	*Start Graze Nov, T/Ac*	*Field Loss, T/Ac*	*Calf Utilization, T/Ac*	*Cows Residual Stalks, /Ac*
Fields:					
5	0.50	0.64	0.14	0.50	0.14
7	1.52	0.66	-0.86	0.52	0.14
9	1.27	0.46	-0.81	0.27	0.19
Total DM, T/Ac	3.29	1.76	-1.53	1.29	0.47
Avg. DM, T/Ac	1.10	0.59	-0.51	0.43	0.16

Table 4. Normal vs Early Weaning: 2008 Steer Calf Performance

	Normal Wean Native Pasture	*Early Wean Corn Grazing*	*SE*	*P-Value*
No. Steers	24	24		
Weaning Date	11-3-2008	8-13-2008		
Days Grazing EW to NW	82 (2.69 Mths)			
Days of Drought Corn Grazing		44		
Weight at EW	482	482	17.64	0.99
Weight at Normal Weaning, lb	658			
Weight at End of Corn Grazing, lb		574	16.79	0.024
Gain	176	91	6.51	0.0008
ADG	2.14	2.07	0.13	0.76

Table 5. Standing Unharvested Corn Grazing: Early vs Normal Weaned Steers

	Normal Wean Native Pasture	*Early Wean Corn Grazing*	*SE*	*P-Value*
No. Steers	24	24		
No. Days Grazed	30	30		
Start Corn Grazing Wt., lb	657	499	23.33	0.008
End Corn Grazing Wt., lb	691	574	30.96	<0.0001
Gain, lb	34	75	3.10	0.0012
ADG, lb	1.13	2.50	0.093	0.0007

Table 6. Pasture vs Early and Normal Wean Grazing Economics

	Normal Wean Native Pasture	*Normal Wean Corn Grazing*	*Early Wean Corn Grazing*	*SE*	*P-Value*
No. Steers	24	24	24		
Days of Grazing	82	30	30		
Total Gain Value, $	1306.79	250.91	672.25	35.01	<0.0001
Gain Value/Ac, $	26.04[a]	55.76[b]	149.39[c]	5.13	<0.0001
Gain Value/Hd, $	163.35[a]	31.36[b]	84.03[c]	4.37	<0.0001
Net Crop Ins. Pymt./Hd., $	---	23.00	23.000		
Gain Value + Ins./Hd, $	163.35[a]	54.51[b]	107.17[c]	4.36	<0.0001
Pasture or Corn Prod/H, $	94.10	92.25	92.25		
Net Return/H, $	69.25	-37.74	14.92	4.37	<0.0001

Table 7. Early vs Normal Weaning: Effect on Finishing Performance

	Normal Wean Corn Grazing	*Early Wean Corn Grazing*	*SE*	*P-Value*
No. Steers	24	24		
Days on Feed	198	239	4.51	0.003
Kill Age, Days	459	438	3.39	0.020
Start Wt., lb	697	602	20.81	0.033
End Wt. (4% Shrink), lb	1343	1412	35.65	0.042
Gain, lb.	646	810	14.53	0.001
ADG, lb	3.26	3.39	0.038	0.094

Table 8. Early vs Normal Weaning: Effect on Finishing Economics

	Normal Wean Corn Grazing	*Early Wean Corn Grazing*	*SE*	*P-Value*
Feed/Head/Day (DM), lb	20.7	19.92	1.45	0.711
Feed/Lb of Gain (DM), lb	6.34	5.89	0.38	0.447
Feed Cost/Lb of Gain, $	1.06	1.03		
Feed Cost/Head, $	684.79	828.19	17.14	0.010
Yardage/Head, $	68.86	83.39	4.30	.075
Freight/Head, $	23.00	21.00		
Total Direct Expense, $	776.65	932.58	17.30	0.016
Purchased Calf:				
Direct Feedlot Expense, $	776.65	932.58		
Steer Cost/Head, $	640.10	586.74	12.42	.034
Total Expense, $	1416.75	1516.78	18.36	0.018
Carcass Value, $	1089.11	1122.60	13.24	0.17
Net Return, $	-327.64	-394.18	16.90	0.059
Retained Ownership:				
Direct Feedlot Expense, $	776.65	932.58		
Cow Cost, $	457.00	457.00		
Total Expense, $	1233.65	1389.58	17.30	0.015
Carcass Value, $	1089.11	1122.60		
Net Return, $	-144.54	-266.98	23.28	0.007

Table 9. Early vs Normal Weaning: Effect on Carcass Closeout Measurements

	Normal Wean Corn Grazing	*Early Wean Corn Grazing*	*SE*	*P-Value*
Hot Carcass Wt., lb	805.67	820.33	11.27	0.35
Fat Depth, in	0.456	0.513	0.0105	0.060
Rib Eye Area, sq. in.	12.26	12.78	0.133	0.072
Yield Grade	3.17	3.21	0.028	0.37
Marbling Score	543	619	15.73	0.0042
Quality Grade (Pct. Choice or better)	77.97	86.3	6.79	0.18

3. Demonstrate the prevalence of *E. coli* O157:H7 and Salmonella in manure and document soil nutrient and organic matter following late summer and early winter grazing of unharvested corn; and also document nutrient load in runoff water.

Soil nutrient analysis results are shown in Table 1. Soil samples were taken in the fall for the corn fields that were grazed by the EW steers and the fields where the NW steers grazed after the ground was frozen were taken in the spring. The soil sample results differ numerically, but statistically, there is no difference except for the number of pounds of nitrogen/Ac. The spring sample was significantly higher, which would be expected. It also should be noted that soil organic matter was similar between grazing treatment groups and ranged from 3.73% in the EW fields to 4.13% in the fields grazed by NW steers.

Waste water analysis was compromised by drought that limited spring snowmelt runoff to the last year of the study. Waste water collected was compared to Southwest Rural Water collected from the cattle water tanks. The analysis results are shown in Table 2. Compared to the water tanks, phosphate-phosphorus in runoff water was 5.4 times higher, and the potassium content was 11.9 times higher. The total dissolved solids and nitrate-N did not differ.

Surveys for both *E. coli* and *Salmonella* were conducted during the demonstration. Results of the survey are shown in Figures 1 and 2 below. The prevalence of *E. coli* in cows was highest in September and declined rapidly to zero when sampled in November and December. Prevalence in calves was significantly lower than in cows and by the December sampling period had dropped to between 5-10% of the calves sampled.

Salmonella prevalence in cows declined from the September sample to February and then increases seasonally in April. For calves, *Salmonella* remained relatively stable between 45-50% of the steers sampled except for the December sample when 100% of the steers tested positive for *Salmonella*.

Table 1. Soil Nutrient Analysis and Organic Matter Content following Early and Late Weaning

	N	*P_2O_5*	*K_2O*	*Sulfur*	*Zinc*	*Copper*	*OM*
Units	Lbs/Ac	ppm	ppm	Lbs/Ac	ppm	ppm	Pct
Early Wean Fields	189	19.3	365.3	79.3	1.03	1.64	3.73
Late Wean Fields	298	24.7	493.3	76.0	1.29	1.67	4.13
Std Error	21.72	1.81	51.7	9.39	0.159	0.428	0.481
P-Value	0.024	0.106	0.155	0.814	0.308	0.971	0.588

Table 2. Waste Runoff Water Nutrient Analysis

	PO_4-P (mg/l)	*Potassium (mg/l)*	*TDS (mg/l)*	*Nitrate – N (mg/l)*
Field Runoff Water	2.375	50.1	338.3	0.02
Southwest Rural Water	0.443	4.21	356.3	0.0
Std Error	0.437	7.18	27.24	0.0
P-Value	0.011	0.001	0.650	0.100

Fig. 1 *E. coli* Prevalence Survey Results

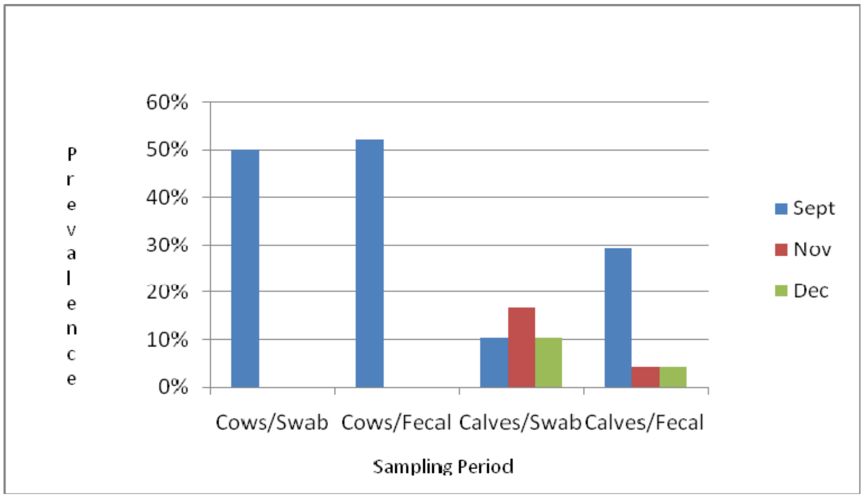
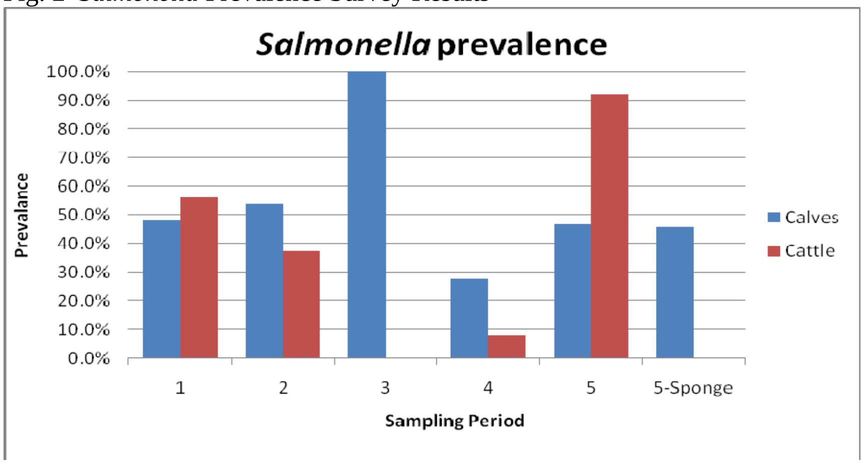


Fig. 2 *Salmonella* Prevalence Survey Results



Appendix I

Integrated Crop and Livestock Management Fact Sheet

General Statement:

Integrating crop and beef cattle production using an early weaning technique in which calves are removed from their mothers as much as 91 days sooner than calves are often conventionally weaned positively impacts productions economics resulting in greater net returns to the cow-calf enterprise while improving the range resource.

Impact on Cows and Native Range:

1. Cows that have their calves weaned as much as 91 days early react to the termination of lactation by increasing in body weight and body condition. Depending on cow frame size, the increase in weight and condition can be used to reduce winter feed cost.

2. Calf removal has the potential to reduce native range herbage disappearance by up to 36.9%.

2. Winter feed costs required to maintain brood cows during the winter represents the highest single cost in beef cattle production. Cows grazing corn stalks following EW calves can have their grazing season extended at very low cost because the cost of corn production has been expensed to cash crop calf production. The added weight gain cows experience after EW will provide reserves for corn stalk grazing without additional supplementation. However, when cows are expected to graze stalks more than 45 days,

1 to 2 pounds of a protein supplement needs to be provided. Cows weighing from 1,200 to 1,400 pounds will need approximately 0.75 acre of stalks/cow/month.

Impact on Early Weaned Calves:

1. Early weaned calves weighing from 300 to 400 pounds can be successfully weaned and backgrounded grazing standing unharvested corn. EW calves will gain from 2.0 to 2.6 lb/day at a cost of $0.51/lb of gain. The cost of gain for conventionally weaned calves is somewhat higher costing $0.59/lb of gain; however, *conventional weaning does not improve the range resource or cow condition*.

2. Once the annual forage corn crop has been seeded and weeds controlled, the work is nearly done. Calves grazing standing corn are supplied with a nutrient dense, whole-plant, diet that does not need additional supplementation. In this demonstration, protein supplementation was not provided after frost killed the plant and the corn dried down. Corn grain in the plant was expected to supply an adequate amount of protein to the rumen micro flora. Feed cost is reduced by grazing because there are no fuel, equipment, labor, or depreciation expenses incurred when the cattle do the work. EW calves have the potential for higher net return than NW calves.

3. Beef gain value is competitive with conventional corn production. The EW steer gain expressed in corn grain equivalents has been calculated to be as follows: The value of beef gain, when corn is priced at $3.00/bu is equivalent to 117 bu/ac. and beef gain, when corn is priced at $4.00/bu is equivalent to 88 bu/ac. These beef to corn grain equivalents are very competitive in SW North Dakota.

4. Compared to steers put directly into the feedlot that often experience respiratory illness, EW steers that grazed unharvested standing corn did not experience health problems such as pneumonia, foot rot, laminitis, pinkeye, or bloat. Treatment costs for chronic diseases were zero.

5. When finished, EW and NW steers return approximately the same net return. EW steers have lower placement cost, whereas NW steers are on feed less days. Due to the greater number of days on feed, EW steers have higher quality carcasses as evidenced by higher marbling score and a greater number of carcasses grading USDA Choice or better.

6. Nutrient load in waste water was higher in phosphate-phosphorus and potassium, but TDS and nitrate-N were similar to SW Rural water from stock tanks.

7. Fecal pathogens surveyed followed seasonal patterns.

Hay Substitution Using a Controlled Release Distiller's Dried Grain Supplement

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Summary:

Cows supplemented with a 24% CP controlled release distillers dried grain (DDG) supplement either pre- or post-calving consumed less hay. Cows that began receiving supplement 45 days before calving consumed the least amount of hay and the least amount of supplement on a per head per day basis. Overall cow weight change and body condition score did not differ between treatments. Cow rebreeding performance for first, second, third, and overall pregnancy rate did not differ. And calf birth weight, calf weaning weight, and calf age at weaning did not differ between treatments. Economic analysis, using hay priced at $60/ton and controlled release DDG supplement at $530/ton, did not result in an economic advantage for supplementation.

Introduction:

Drought in the northern Great Plains region is common and often impacts hay production. Short hay supplies are often addressed by selling cattle or replacing hay that didn't grow with purchased hay, CRP hay, annual forages, and co-products. Co-products have become important sources for nutrient replacement when hay supplies are short.

Nutrients found in corn DDGS are similar to the original grain except the nutrients become concentrated after starch removal during the fermentation process and heating during the drying process changes rumen degradability characteristics. After drying, the protein fraction degraded in the rumen is estimated to be 27.2% and the fraction escaping rumen degradation is estimated to be 72.8%. On average, corn DDGS contain 29.5% CP, 46.0% NDF, 88.0% TDN, 10.3% fat, 0.32% calcium, 0.83% phosphorus, 1.07% potassium, and 10.56 mg/kg copper, and 0.40% sulfur (NRC 1996).

Corn distiller's grains are often considered as a protein supplement; however, due to the co-products highly digestible fiber fraction and fat content, distiller's grains are also considered for their energy content. Unlike high starch feed grains, which can interfere with fiber digestion, DDGS are practically devoid of starch and do not interfere with forage digestion. The fat content of distiller's grains is expected to provide energy for lactation and may also be beneficial with respect to reproductive performance that is independent of caloric content. Wintering costs represent one of the largest expenses in the cow-calf enterprise; however, due to the unique concentration of nutrients in distiller's grains, the cost: benefit ratio when feeding distillers grains may be favorable.

This field study will evaluated a controlled release DDG supplement to determine intake and substitution for hay value, and contrast cow and calf performance with the cost of supplementation; identifying the overall substitution value of a controlled release DDG product.

Project Objectives:

1. Compared to all hay gestation (precalving) and lactation (postcalving) diets, evaluate the effect of substituting a portion of daily hay dry matter with DDGs from a controlled release DDG block on cow body condition, calf survival, reproductive performance, and weaning weight.

2. Conduct partial economic analysis and determine treatment net return.

Procedures:

Treatments:
1. All hay control diet (no substitution).
2. Pre-calving hay substitution with DDGs from a controlled release 24% CP DDG supplement beginning 45 days before calving begins.
3. Post-calving hay substitution with DDGs from a controlled release 24% CP DDG supplement beginning after calving.

Mixed age range beef cows (3 – 10 yrs) located at the Dickinson Research Extension Center (n = 108) were divided into three treatment groups of 36 cows each and 4 pen replicates with 9 cows in each replicate. One treatment group served as an unsupplemented control; a second group began receiving the controlled release DDG supplement substitution for hay 45 days before the scheduled start of the calving season, and the third group began receiving the same controlled release DDG supplement at the start of the calving season. The controlled release DDG supplement was offered continuously from initiation until the cows and their calves were turned out on improved pasture the first week of May.

Measurements and Observations:

1. Animal Weights -
   Cows were weighed initially, cows and calves were weighed weekly until calving was completed, at the end of the wintering and calving period when the cows are turned out on Crestedwheat grass pasture, and finally at weaning. Calf birth weight, May turnout weight, and weaning weight were recorded.

2. Cow Condition Evaluation –
   At each weigh period, all cows were body condition scored using the 0 - 9 scoring system and ultrasound fat depth measurements were taken at the same time at a location between 12th and 13th ribs as described by the Ultrasound Guidelines Council.

3. Pregnancy Rate -
   Cows in the study were bull bred and breeding cycle pregnancy rate and overall treatment pregnancy rates were based on fetal age determined using regression analysis of ultrasound cranial width measurement.

4. Forage and Supplement Analysis -
   The forage used in the study was alfalfa-grass mixed hay that was sampled and composited before analysis for moisture, DM, crude protein, NDF, ADF, calcium, and phosphorus. Controlled release supplement were core sampled and analyzed for ash, crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), invitro dry matter disappearance (IVDMD), invitro organic matter disappearance (IVOMD), calcium, and phosphorus.

5. Economic Analysis –
   A partial economic analysis was used to determine the value of supplementation.

Statistical Analysis:

Data were analyzed as a complete-block design using MIXED non-repeated measures procedure of SAS (1996).

Results:

This project was conducted during one of the most severe winters in North Dakota history. Multiple blizzards during the March – April calving period resulted in statewide calf death losses of approximately 85,000 head as reported through the North Dakota Extension Service. Calf death loss across all treatments in this experiment was 5.5%.

Nutrient analysis for the alfalfa-grass mixed hay fed and the controlled release protein supplement are shown in Tables 1 and 2.

Results for this cow wintering study to evaluate the substitution value of a controlled release 24% CP distiller's dried grain supplement for hay and to evaluate the subsequent effect on cow performance, rebreeding performance, weaning weight, and partial economic analysis are summarized in Tables 3-7.

Hay and supplement intake are shown in Table 3. By design, supplemented cows consumed less hay than the unsupplemented control cows, and those cows fed supplement pre-calving consumed the least amount of hay ($P = 0.0001$) and a greater amount of supplement ($P = 0.0614$) due to the 56 day longer pre-calving feeding period. The post-calving supplementation group received supplement for 33.5 days after calving and consumed less total supplement per cow ($P = 0.0614$), but average daily consumption was higher after lactation began (0.6025 vs. 0.855 Lb/cow/day) in the post-calving group ($P = 0.055$).

Cow starting, ending, and overall weight change (Table 4) did not differ between treatments; however, cow body weight decline was numerically smaller among the supplemented groups. Although not significant, weight loss among the unsupplemented control group was 2.8% greater.

Initial, calving, and ending cow body condition score (BCS) did not differ (Table 4). Although visual BCS evaluation was not sensitive enough to detect a difference between treatments, body condition evaluation based on external fat thickness over the rib using ultrasound technology identified a significant ending fat depth difference between control and supplemented cows (Table 4). On average, the fat depth decline for the supplemented cows was 23.4% less than the unsupplemented control cow groups.

Calf performance has been summarized in Table 5. Hay and controlled release supplement feeding was terminated the first week of May when the cows and their calves were moved to Crestedwheat grass pasture and subsequently to native range pastures the third week of June. Calf birth weight ($P = 0.507$), May turnout calf weight (P

= 0.872), final weaning weight (P = 0.971) and calf age at weaning (P = 0.381) did not differ.

Cow rebreeding performance is summarized in Table 6. First (P = 0.564), second (P = 0.172), and third (P = 0.765) breeding cycle pregnancy rates did not differ. While breeding cycle pregnancy rates did not differ significantly, on average there were approximately 15% fewer cows pregnant in the first breeding cycle among the cows that were supplemented pre-calving. Although the number of open cows did not differ, there were a numerically greater number of open cows among the post-calving supplementation group. The overall pregnancy rate following both pre- and post-calving supplementation did not differ between treatments.

Partial pre-tax economic analysis is shown in Table 7. At the onset, cows involved in the study were randomly assigned to treatments based on cow weight and lifetime most probable producing ability (MPPA). The MPPA value did not differ across treatments (P = 0.87). In the analysis, hay was priced at $60/ton and the controlled release supplement price was $530/Ton. Due to the small difference in weaning weight across treatments, calves were priced at $94.50/cwt with no price slide. Compared to the non-supplemented all hay control group, pre- and post-calving supplementation cost an additional $9.95 and $8.97/cow more, respectively.

Acknowledgement:

Partial funding was provided by the ND State Board of Agricultural Research and Education under agreement #8-25.

Table 1. Alfalfa-Grass Mixed Hay Nutrient Analysis

Moisture, %	9.1
Crude Protein, % DM	13.3
TDN, %DM	51.6
NDF, % DM	58.5
ADF, % DM	39.7
Calcium, % DM	0.95
Phosphorus, % DM	0.28

Table 2. Controlled Release 24% CP Supplement Nutrient Analysis

Ash, % DM	55.20
Crude Protein, % DM	27.78
NDF, % DM	12.85
ADF, % DM	2.54
IVDMD, % DM	85.75
IVOMD, % DM	63.39
Calcium, % DM	9.62
Phosphorus, % DM	1.52

Table 3. Hay Consumption and Controlled Release 24% CP Supplement Intake

	Control	*Ctrl-Rel DDG Pre-Calving*	*Ctrl-Rel DDG Post-Calving*	*SE*	*P-Value*
Hay Intake:					
Hay, Lbs/Cow	3561[a]	3391[b]	3469[c]	76.2	<.0001
Hay, Lbs/Head/Day	40.93[a]	38.97[b]	39.88[c]	0.88	0.0001
Controlled Release Supplement Intake:					
Days Supplement Fed	-	89.75	33.5		
Lbs/Cow	-	53.94[a]	28.58[b]	9.965	0.0614
Lbs/Cow/Day	-	0.6025[a]	0.8550[b]	0.1591	0.055

Table 4. Cow Performance Following Hay Replacement with a Controlled Release 24% CP Supplement

	Control	*Ctrl-Rel DDG Pre-Calving*	*Ctrl-Rel DDG Post-Calving*	*SE*	*P-Value*
Trial Length, Days	89.25	89.75	89.5	0.263	0.244
Cow Body Weight Change:					
Cow Start Wt., lb.	1518.7	1510.4	1497.5	57.81	0.217
Cow End Wt., lb.	1389.5	1410.0	1412.0	56.09	0.433
Cow Wt. Gain (Loss), lb.	(129.2)	(100.4)	(85.5)	16.39	0.217
Cow Wt. Gain (Loss)/Head/Day, lb	(1.44)	(1.12)	(0.96)	0.184	0.213
% Weight Decline	8.50	6.60	5.71		
Cow Body Condition Score Change:					
Start BCS	6.39	6.42	6.39	0.233	0.938
Calving BCS	6.39	6.47	6.47	0.223	0.854
End BCS	5.75	6.06	5.83	0.317	0.469
BCS Increase or (Loss)	(0.64)	(0.36)	(0.56)	0.133	0.358
% BCS Decline	10.0	5.61	8.76		
Cow Ultrasound Fat Depth Change:					
Start Rib Fat Depth, mm	5.86	5.91	6.03	0.702	0.955
End Rib Fat Depth, mm	3.58[a]	5.09[b]	5.00[b]	0.867	0.092
Rib Fat Depth Inc. (Decline), mm	(2.28)	(0.82)	(1.03)	0.548	0.185
% Rib Fat Depth Decline	38.9	13.9	17.1		

Table 5. Calf Performance Following Pre- and Post-Calving Hay Replacement with a Controlled Release 24% CP Supplement

	Control	*Ctrl-Rel DDG Pre-Calving*	*Ctrl-Rel DDG Post-Calving*	*SE*	*P-Value*
Cow Weight Change:					
Cow Weight at Calving, lb	1472.3	1503.6	1507.1	68.34	0.460
Cow Weight at Weaning, lb	1547.0	1464.4	1492.4	39.52	0.185
Cow Weight Gain (Loss)	74.7	(39.2)	(14.7)		
Weaning Cow BCS	6.22	6.02	6.03	0.248	0.825
Calf Performance:					
Calf Birth Weight, lb	98.3	95.0	94.7	2.34	0.507
Calf May Turnout Weight, lb	170.2	175.0	175.0	6.98	0.872
Calf Age at Weaning, Days	187.8	190.6	193.2	2.44	0.381
Calf Weaning Weight, lb	644.5	643.7	640.1	13.67	0.971
Calf Wt Gain/Day of Age, lb	2.91	2.87	2.82	0.051	0.484

Table 6. Rebreeding Performance Following Pre- and Post-Calving Hay Replacement with a 24% CP Controlled Release Supplement

	Control	*Ctrl-Rel DDG Pre-Calving*	*Ctrl-Rel DDG Post-Calving*	*SE*	*P-Value*
Breeding Cycle Pregnancy Rate:					
1st Breeding Cycle, %	52.8	38.9	55.1	11.14	0.564
2nd Breeding Cycle, %	23.4	38.9	24.9	5.83	0.172
3rd Breeding Cycle, %	21.3	19.4	13.4	7.85	0.765
Open, %	2.8	2.8	6.7	3.19	0.620
Overall Pregnancy, %	97.2	97.2	93.6	3.13	0.660

Table 7. Partial Economic Analysis

	Control	*Ctrl-Rel DDG Pre-Calving*	*Ctrl-Rel DDG Post-Calving*	*SE*	*P-Value*
Cow MPPA Value[a]	101.7	102.3	101.9	0.962	0.870
Feed Intake/Cow:					
Hay Lbs/Cow	3561[a]	3391[b]	3469[c]	76.2	<.0001
Controlled Release Suppl. Lbs/Cow	-	53.94[a]	28.58[b]	9.965	0.0614
Feed Cost/Cow:					
Hay @ $60/T	106.83	101.73	104.07		
Controlled Release Suppl. @ $530/T	-	14.29	7.57		
Total Wintering Cost	106.83	116.02	111.64		
Calf Performance:					
Weaning Weight, lb	644.5	643.7	640.1	13.67	0.971
Economic Analysis:					
Income/Cow -					
Calf Price Received/Cwt, $	$94.50	$94.50	$94.50		
Total Calf Value Received, $	$609.05	$608.29	$604.89		
Expenses -					
Hay & Controlled Release Suppl Cost, $	$106.83	$116.02	$111.64		
Net Return, $	$502.22	$492.27	$493.25		
Difference vs. Control, $	-	-9.95	-8.97		

[a] MPPA Value: Index of a cow's Most Probable Producing Ability. This value is generated from Dickinson Research Extension Center cows enrolled in the NDSU/ND Beef Cattle Improvement Association's Cow Herd Appraisal Performance Software program. The index ranks cows based on their lifetime production ability.

BeefTalk 436: Buying the Right Bull Means Checking His Grades

In the beef business, producers need to accept the fact that bulls need to be evaluated.

The common-sense process of buying bulls has not changed much. The requirements are simple. The bull needs four decent legs, a bit of appropriate muscle indicative of the product and a functioning reproductive system.

Cost usually determines which bull one brings home. The opportunity to buy a bull that offers a greater probability of producing profit-generating progeny is available and the evaluation process is simple.

Producer evaluation needs to focus on phenotype (what a bull looks like) and genotype (the genes a bull will pass to his progeny). What one sees is not what one always gets.

The process involves the identification of measurable traits relevant to beef production, which are traits that are indicative of profitable beef production. The secret is hidden in the traits.

In school, student learning is measured by appropriate evaluations (tests). The same is true of measuring production traits.

There are different thoughts on how to evaluate students. Yet, students are evaluated and their future careers guided by their individual interests, desires and abilities.

In the beef business, producers need to accept the fact that bulls need to be evaluated. The test results will help understand the future role of the bull.

Perhaps it is not fair to compare bull evaluations with student evaluations, but it does make for an easy comparison. As most of us have participated in parent-teacher conferences, through time we come to understand that certain grades are indicative of a better understanding of the subject than others are.

If our student is getting 90 percent of the questions right, the student could receive a high B or A for the course. If we visit during the conference and the student is getting only 40 percent of the answers right, the student may receive a D or F.

We understand that more effort or guidance may need to be involved with the growth and development of the student. We do not always like what we hear, but we move on, make decisions, and continue to guide and direct.

Now let us take that concept and apply it to what we have available to utilize in the evaluation of bulls. Breed associations publish the evaluations of all purebred bulls for appropriate traits that are indicative of performance and associated with the genes that will be passed on by the bull to his offspring.

These publications are called sire summaries and contain a tremendous amount of data. Actually, the publications probably contain more data than many producers want to see, but the data is there.

Very Valuable Sire Summary Tool

Check your bull's 'Percentile' ranking

With a quick fip of the page, breed associations print the ranking of all EPD evaluations.

Top 1% = a trait value x

Top 10% = y

Top 50% = z

Etc. -

Where do your bulls rank? Are they in the upper half or lower half of the breed?

It does not hurt to check!

Not unlike grading scales that are used in our own educational processes, a producer actually can go and look up how a bull did on his evaluation. Is the bull in the top 1 percent of the class or the top 50 percent?

Does the data in the sire summary show the bull is in the bottom half percentile? The point is, if one opens up the evaluations and finds the charts that generally are labeled "percentiles" or "percentile breakdowns" or something to that effect, the bull's score or EPD (expected progeny difference) can be compared with other bulls within the breed.

Use of this data will help producers make an informed decision. Is the bull the one you want and are the evaluations of the bull's traits where they should be?

Numbers work and the producer should compare managerial and production expectations with the evaluations of the bull's performance. If one needs high growth, why not look for bulls that rank high in their weaning weight EPD or yearling weight EPD.

Select the percentile ranking one wants to deal with and then go find the bulls with the right EPDs. There are many bulls, but, as a producer, one does not need to be poorly informed.

Check those evaluations. More later.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

BeefTalk 437: Who Is In The Bull Pen?

When buying bulls, we are really buying packets of DNA.

The coffee chat is filled with many opinions about how to buy bulls. The art of buying a bull requires an open mind, homework and a vision for the future of a producer's cowherd.

For example, we turn to the nutritionists if we want to get a better understanding on how cattle can utilize peas in rations. Ironically, peas influenced cattle decades before producers started to feed peas by way of Mendel, an Austrian monk.

He discovered the tip of the iceberg and used peas to teach us how genetics work. We actually can select for and change not only peas, but cattle as well.

When buying bulls, we are really buying packets of DNA, the genetic material that is contained in the germ cells of reproducing organisms. Since Mendel taught us the process, we have added to the core of genetic knowledge every year.

While Mendel was reviewing the difference between wrinkled and smooth peas, he also was carefully selecting the parents for the next generation. So who are the parents of the next generation of cattle?

The review begins with an inventory of the bull pen. While we have many breeds at the Dickinson Research Extension Center, this discussion will focus on Red Angus bulls.

Red Angus bulls P329, S13, S48, S49, S59, S6032, S6042, S6054, S6153 and S6158 are in the pen. All are registered with the American Red Angus Association.

It is important to maintain the registration even if the bulls will not be used in commercial production. Buyers should have papers transferred and obtain a membership in the appropriate breed association because the registration number is the tie to the data available on the purchased bulls.

Let me use bull S48 as an example. On the Red Angus Web site, we can type in his registration number (1114780) and the bull's current expected progeny difference (EPD) values can be retrieved.

While the accuracy may not be high for bulls that are not utilized throughout the industry, the predicted EPD values are the best estimate of performance available. His calving ease direct EPD value is minus 2 and his birth weight EPD is 3.

If one reviews the percentile rankings, also available on the Red Angus Web site, S48 currently ranks in the upper 95 percentile for calving ease direct and in the upper 85 percentile for birth weight. Simply put, this bull would be a bull the center would want to turn out to mature cows.

Moving along to the growth traits, S48 has a weaning weight EPD of 44 and yearling weight EPD of 71. These EPD numbers rank him in the upper 15 percentile for weaning weight and in the upper 25 percentile for yearling weight. This bull is expected to sire calves that grow.

As to the heifers, if the center were to keep them for replacements, S48's EPD values for milk and total maternal are 18 and 40, respectively. These values rank S48 in the upper 45 percentile for milk and in the upper 25 percentile for total maternal or expected weaning weight from the daughters of S48 once they get into production.

Report Card

Red Angus Bull S48 (1114780)

Trait	EPD Value	Breed Percentile
CED	-2	95
BW	3.0	85
WW	44	15
YW	71	25
Milk	18	45
TM	40	25
MARB	0.05	55
REA	0.33	10
FAT	-0.01	20

In a nutshell, the bull is sound, looks good and is performing well. S48 certainly deserves to be left in the bull battery as a bull for mature cows.

As far as his progeny goes, his EPD values for marbling, ribeye area and back fat are 0.05, 0.33 and minus 0.01, respectively. The percentile rankings for these EPD traits are in the upper 55 percentile for marbling, upper 10 percentile for ribeye area and upper 20 percentile for back fat.

Again, the progeny of this bull predicts that he will produce very acceptable carcasses on the rail and given the growth data, a very acceptable feedlot performance. He is a keeper.

The next step is to review the other nine Red Angus bulls, plus the other bulls in the bull pen. However, for now, I'm out of space and time.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

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BeefTalk 438: Making Sense of the Bull Pen

When the bulls are penned is a good time for a close evaluation.

Last week, the report card on bull S48 was to keep him for the 2009 breeding season. This periodic review is used on all bulls at the time of purchase and periodically throughout a bull's life.

The first evaluation of older bulls is for soundness because putting resources into a bull that has limited breeding capacity is impractical. When the bulls are penned is a good time for a close evaluation.

Small problems tend to become big problems. Minor structural problems often will develop into movement problems during the breeding season.

The breeding soundness exam should be scheduled prior to turn out. With all the cold weather lately, now is a good time to monitor for frozen scrotums, especially if the bulls were not bedded or protected from the severe cold.

For this discussion, I will concentrate on the 10 Red Angus bulls at the Dickinson Research Extension Center. The 10 are P329, S13, S48, S49, S59, S6032, S6042, S6054, S6153 and S6158. These bulls are registered with the American Red Angus Association and the registrations and data are current.

To begin the evaluation, I gathered the weights and body condition scores of all the sound bulls. The oldest bull was born in 2004 and weighed 2,445 pounds with a body condition score of 7.

The other nine bulls were born in 2006 and ranged from 1,735 to 2,020 pounds and had body condition scores of 5 to 8. None of these bulls are overly thin and only one bull is starting to carry some excess.

All the bulls were rated for some of the expected progeny differences (EPDs) available from the Red Angus Association. The challenge with data collection is information overload.

There are various reasons why a bull remains in the bull pen, but he is there for a reason. The information available on sale day was impressive enough to buy the bull or he was simply affordable.

In the end, a simple question remains. "Are they still good enough to stay or are there better bulls?" In an attempt to answer this question, I developed a scoring system.

The bulls that weighed more than 2,000 pounds received an A. Those that weighed between 1,800 and 1,999 pounds were given a B and those bulls that weighed less than 1,800 pounds were given a C grade.

For body condition, those scoring a 6 or higher received an A, those scoring a condition score of 5 received a B and those scoring a condition score of 4 or lower got a C. There were no bulls with a condition score of less than 5.

Report Card for 10 Red Angus Bulls

Dickinson Research Extension Center

	P329	S13	S48	S49	S59	S6032	S6042	S6054	S6153	S6158
Body Weight	A	A	B	B	A	C	A	C	C	B
Body Condition	A	A	A	B	A	A	A	B	A	A
EPD CED	C	C	C	C	C	B	C	C	C	B
EPD BW	C	B	C	C	C	A	C	C	C	C
EPD WW	B	B	A	B	B	C	C	C	B	A
EPD YW	C	B	A	B	B	C	B	C	C	B
EPD Milk	B	B	B	C	B	B	C	C	C	B
EPD TM	B	B	A	C	B	C	C	C	C	B
EPD Marb	B	A	C	B	C	C	C	A	C	C
EPD REA	B	B	A	B	B	A	C	B	B	B
EPD FAT	A	B	A	B	A	A	B	A	A	B
Average Grade	B(33)	B(35)	B(36)	C(29)	B(33)	C(32)	C(28)	C(28)	C(28)	B(33)

For EPD values, A = upper 25% of breed percentiles; B = upper 50% of breed percentiles; C = less than 50% of breed percentiles.

For body weight, A = more than 2000 pounds, B = 1,800 to 1,999 pounds, C = less than 1,799 pounds.

For body condition, A = score more than 6, B = score 5, C = score less than 5.

In addition, if a bull ranked in the upper 25 percentile within the breed for a specific EPD trait, the bull received an A. The bull received a B if the EPD value was in the upper 50 percentile but less than the 25 percentile. Bulls with an EPD value in the lower 50 percentile received a C.

Report Card for 10 Red Angus Bulls

Dickinson Research Extension Center

Bull	Body Weight	Body Condition	EPD Grade
P329	A	A	C
S13	A	A	B
S48	B	A	B
S49	B	B	C
S59	A	A	C
S6032	C	A	C
S6042	A	A	C
S6054	C	B	C
S6153	C	A	C
S6158	B	A	B

For EPD values, A = upper 25% of breed percentiles; B = upper 50% of breed percentiles; C = less than 50% of breed percentiles.

For body weight, A = more than 2000 pounds, B = 1,800 to 1,999 pounds, C = less than 1,799 pounds.

For body condition, A = score more than 6, B = score 5, C = score less than 5.

The report card on the Red Angus bulls (or should we say their grade point average?) was P329 (B), S13 (B), S48 (B), S49 (C), S59 (B), S6032 (C), S6042 (C), S6054 (C), S6153 (C) and S6158 (B).

In summation, the bull pen has five good Red Angus bulls and five that are average. With the buying season opening up, the center can better evaluate how many bulls are needed and develop a budget to work with.

The process may seem cumbersome, but the point is that we gather some data and rank the bulls. Does the data support keeping them or are better bulls on the market that might meet our production goals?

As a producer, you need to become comfortable working the numbers and incorporating data into your decisions to meet your goals. Happy bull buying!

May you find all your ear tags.

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BeefTalk 439: Easier to Haul Home a New Bull Than a New Cow Herd

As a producer, you really do not know if the individual animal performance is more a function of selected genes or unique management.

A fundamental question was asked the other day. Why not pay more attention to the offspring of the bull when a producer is re-evaluating the bull pen rather than the current predicted performance of the bull?

This question is a very good and relevant question in the context of overall beef production. The reality of managing a beef cattle operation has many daily demands in terms of inputs and outputs.

There is no simple process to place a calf up for sale, so, for at least today, let's continue to focus on genetics because the bull buying season is upon us. The evaluation of a bull's progeny would be and is another component of understanding if a bull is the right one.

Unfortunately, the question is a lot easier to ask than answer. These concerns should lead a producer to a fork in the road. One fork points to breed associations and utilizes their expertise in sorting and reporting correct genetic feedback.

The other fork points to cow management and calf evaluations. These are two unique and different data functions and clearly have different outcomes.

Bull buying focuses on the first fork, so the information only is as good as the ability of the breed associations to analyze the data and report results. Once calculated and expressed as an expected progeny difference (EPD), the ability to predict the genetic potential of a particular bull is excellent.

The second fork is in the herd process. As genes are placed in the cow herd, the performance of those genes is dependent on cow herd management. The associated records collected within a cow herd are more related to managerial questions, not genetic questions. Therefore, most records have the management of the herd and the genetics of the herd confounded.

In other words, as a producer, you really do not know if the individual animal performance is more a function of selected genes or unique management. Both are important.

The obvious response would be that what a producer sees is what a producer gets. The overwhelming comfort level tends to accept what is seen over what the EPDs predicted.

Normally, they do agree, but not always. However, it is better to accept the breed association’s predictions when evaluating the progeny of a bull. Yes, that causes consternation, but, amazingly, large data sets do predict with great accuracy the answer to the question.

Use EPDs generated by breed associations to buy bulls. Use herd management records to manage cows. In a pure world, all the bulls would be individually mated to a known group of cows. The calves would all be tagged and documented and the data collected. However, most cattle are group mated. In other words, more than one bull is turned out to a group of cows or the bulls are rotated. This provides some level of assurance that the cows will be exposed to a fertile bull.

In these cases, the individual sire of the calves is not known and most cattle are not randomly mated within a herd. In other words, when comparing calves, the parents of those calves were selected through specific mating plans and the evaluation of the calf is an affirmation of the plan.

If the calf does not meet expectations, it is the plan that needs to be revised, not the data going into the plan. Both the cow and bull contribute to the plan, but the known accuracy of a genetic prediction generally is greater for the sire than the dam.

In addition, a yearling bull that conceives a calf will be 2 years old when the calf is born. He will be 3 years old when the calf is more than likely harvested and he already will have conceived his third set of calves before the harvest data is analyzed from the first set of calves the bull sired.

No wonder the data needs to be right at the time of purchase. Finally, although predicted performance is utilized to buy bulls and to re-evaluate bulls, cow performance is important.

However, in the big picture, a cow herd is the product of bull genetics and it is a lot easier to haul home a new bull than a new cow herd.

May you find all your ear tags.

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BeefTalk 440: Know Your Environment Because Cows Depend On It

The challenges this winter have been many.

While morning coffee discussions are starting to focus on spring planting, the strain of the cold and snow remains. The challenges this winter have been many. Cows have had to be moved, the feeding season is long and the cost of feed is high.

This past year's experiences tend to drive producers out of the business. At the Dickinson Research Extension Center, cull cows, excess bulls and calves were sold early.

We started feeding hay to cows, bulls and heifers in October. The feed inventory is adequate, but also created a $100,000-plus invoice, which was paid.

The positive is that the snow should provide some opportunity for much-needed moisture in the area. The beef business cannot survive without moisture.

The center has used no-till crop production and incorporated cover crops into the cropping system. No-till will conserve moisture, keep desirable living plants present and improve the overall health of the soil.

Simply put, the soil is alive. However, just like cattle, plants need to fit the environment.

Developing cropping and livestock systems and then integrating the two systems is not easy. This is especially more difficult when moisture is limited.

From east to west across the northern Plains, not all locations are treated equally. A drive along Interstate 94 from eastern North Dakota into central Montana vividly makes that point.

Even taking two sites near each other, such as Bismarck as the east and Dickinson as the west (approximately 100 miles apart), there is a noticeable difference. Lee Manske, DREC range scientist, reviewed the average weather data for the two sites during a 30-year period (1971-2000).

The two sites appear very similar in precipitation. For Bismarck, the 30-year average was 13.89 inches for the growing season and 16.84 inches annually. For Dickinson, the 30-year average was 14.22 inches for the growing season and 16.61 inches annually. However, upon closer evaluation, there is a difference.

The early growing season (April, May and June) precipitation was 6.27 inches for Bismarck and 7.44 inches for Dickinson. The midseason (July and August) precipitation was 4.73 inches for Bismarck and 3.85 inches for Dickinson. The late-season (September and October) precipitation numbers were very similar for both sites, 2.89 inches in Bismarck and 2.93 inches in Dickinson.

Now let's look at temperatures during the same period. The early growing season temperature for Bismarck was 54.5 degrees, midseason 69.6 degrees and late-season was 51.3 degrees. For

Dickinson, the early growing season late-season 49.4 degrees.

In summary, Dickinson has a cooler average temperature than Bismarck and receives almost 19 percent more rain during the early growing season, but receives almost 19 percent less rain during the middle of the growing season.

Does such difference in long-term weather change an environment? Well, look out your window. What does that mean in dry years?

Growing Season Precipitation

	Bismarck	Dickinson
April	1.46	1.63
May	2.22	2.29
June	2.59	3.52
July	2.58	2.20
August	2.15	1.65
September	1.61	1.62
October	1.28	1.31
Average growing season	13.89	14.22
Annual average	16.84	16.61

In 2008, Bismarck received 94 percent of its normal, long-term average precipitation during the early growing season and 84 percent during the middle of the growing season. Dickinson received 60 percent of its normal, long-term average precipitation in the early growing season and 71 percent during the middle of the growing season.

Overall, Bismarck received 101 percent of its long-term average precipitation for the growing season. Dickinson received 66 percent of its long-term average precipitation for the growing season.

There is something about going west. The west is slightly cooler and has good spring rains, but there is a good chance that moisture will be lacking by midseason. A midseason with a shortage of moisture is a tough time to plant alternative forage, but it is even worse in dry years.

As beef producers, plan early. Like most years, if those early season rains don't add up, especially two years in a row, late-season alternatives are scarce, at least in southwestern North Dakota.

Know your environment and then plan and plant accordingly. Your cows depend on it.

May you find all your ear tags.

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BeefTalk 441: Responsibility From Beginning To End

Now is the time to re-evaluate feed intake!

A troubling event occurred this past week at an auction barn. There was a feeling of "not wanting," but also a feeling of "that is the way it is."

The auction barn is known as a social center and a place to sell cattle. People share stories and experiences that go along with an industry that is speckled with considerable individualism.

This past week at the auction barn, the business of selling cattle was taking place. One could observe a number of things that really involved livestock, people, perception and reality.

The effects of a long and cold winter were evident. The cattle were thin, particularly the older cattle, and it was obvious the tough winter was gaining the upper hand.

This reality pointed to the fact that now is the time to re-evaluate feed intake! Cattle need energy and a balanced ration to survive the demands of winter and pregnancy.

Thin cattle are simply underfed. These thin cows will have problems at calving and rebreeding. They will have little milk, poor colostrum and weak, emaciated calves. It is time for a simple decision to be made. Visit your cattle nutritionist today or your veterinarian tomorrow.

Back to the sale barn. The cattle were handled well and the sale was prompt and efficient.

However, one cow did stand out. The cow was the cause of my troubled feeling. It was a feeling of concern.

The cow was licking off her newborn calf that was born at the auction barn. While the pair was properly cared for, an auction barn is not the place for birthing a calf.

A cow that is nine months pregnant and due to calf should be at home, but I had the feeling "that is the way it is."

A few more pens down the line, a pregnant mare was awaiting sale. The mare looked like many mares because she was preparing for foaling when the weather warms up and spring settles in.

Mother Nature has equipped horses with a very timely reproductive system that times foaling with spring, thus limiting the number of concerns about foaling during winter storms. This is true for all wild mammals, each with its own reproductive system, well tuned to its respective environments.

However, this mare was out of place, so the feeling of "that is the way it is" came back.

However, that really is not true. Producers need to perform a self-evaluation of situations like this.

Cows or mares are the reproductive unit that forms the foundation of the herd. Management is the key to the success of any operation. The management of herds includes the evaluation and re-evaluation of production practices.

Even without records, a cow that is due to calf is noticeable. In reality, if one stays up and waits for her to calf, you may wait a couple of weeks, but sloughing her off in the market chain is inappropriate.

Likewise, why is a bred mare being sold at this time? Perhaps the stud should not have been put out.

Now, before the e-mails start flying, I do understand that plans can change and “that is the way it is.” However, breeding livestock requires planning. When those plans slip, the cow calves in the auction barn.

That is reality. However, the perception is one that casts a shadow not just on one producer, but all producers. Cattle that enter the market chain enter as market beef and it is up to us as producers to evaluate ourselves to make sure we only send market beef to auction.

We should manage around cull cows. At the same time, we are responsible for the animals we breed and we must remain responsible to the end.

May you find all your ear tags.

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BeefTalk 442: Feed the Cows and Feed Them Right

If more time was spent discussing the nutrient requirements of beef instead of the merits of different management systems, all the cows would be better off.

Winter continues to pummel us with extreme cold, wind and snow. A normal winter, if there is such a thing, occasionally gives us a breather, but not this year.

Winters like this year create discussion about what type of cattle operation is best. Despite the discussion, the fact remains that the cows need to be fed.

Calving-time discussions are relevant, as are discussions on high versus low input and big versus small cows. The bottom line is that producers must select a cattle management system they are comfortable with. What is even more important is that, in every system, producers still must feed the cows.

If more time was spent discussing the nutrient requirements of beef instead of the merits of different systems, all the cows would be better off.

The discussion with a nutritionist involves four basic needs. How much do the cows weigh and milk? How is the environment affecting the feeding requirements of the cattle? What stage of production are the cattle in? Lastly, what type of feed do you have available?

The answers to these four questions have nothing to do with the management system the producer has developed. The important part is that the producer can answer the questions factually so the nutritionist can correctly calculate a feeding plan.

The nutritionist will take into consideration the cows, environment, stage of production, feeds available and the nutritional analysis of those feeds when the ration is formulated. Getting the correct answers are critical.

Let’s take the very first question about how big the cows are. Greg Lardy, North Dakota State University beef cattle specialist and nutritionist, shared some calculations that help show the amount of feed that a cow would need in a given environment (5 degree F temperature and no mud), a given milk production (17.6 pounds peak milk production during lactation) a given stage of production (a cow in the last two-thirds of pregnancy) and a given feed resource (55 percent total digestible nutrient forage).

Lardy calculated the dry matter intake for every 100 pounds of cows weighing from 1,000 to 2,000 pounds. The 1,000-pound cow requires 26.5 pounds of dry matter per day, while the 2,000-pound cow requires 42.2 pounds of dry matter per day.

The larger cow needs a lot more than a fork or two more of hay. It actually needs 15.7 pounds more of dry matter. It’s simply a biological need, which is not good or bad.

Likewise, the smaller cow will waste feed that is provided over what she actually needs, so know your cows and how much they need to eat.

If we accept Lardy's assumptions, the 1,000-pound cow needs 26.5 pounds of dry matter forage. Here are the daily dry matter needs for different weight cows:

1,100-pound cow needs 28.2 pounds of dry matter
1,200-pound cow needs 29.9 pounds of dry matter
1,300-pound cow needs 31.5 pounds of dry matter
1,400-pound cow needs 33.1 pounds of dry matter
1,500-pound cow needs 34.7 pounds of dry matter
1,600-pound cow needs 36.2 pounds of dry matter
1,700-pound cow needs 37.8 pounds of dry matter
1,800-pound cow needs 39.3 pounds of dry matter
1,900-pound cow needs 40.7 pounds of dry matter
2,000-pound cow needs 42.2 pounds of dry matter

Beef Cattle Nutrient Requirements

Cow Weight	Estimated Dry Matter Intake (Pounds per Day)
1000	26.5
1100	28.2
1200	29.9
1300	31.5
1400	33.1
1500	34.7
1600	36.2
1700	37.8
1800	39.3
1900	40.7
2000	42.2

Source and Assumptions -

Dr. Greg Lardy, North Dakota State University Beef Cattle Specialist and Nutritionist, Based on the 1996 NRC Beef Cattle Nutrient Requirements Table Generator.

Dry Matter feed required at 5 degree temps, no mud, 17.6 lbs peak milk during lactation, last 2/3rds of pregnancy and 55% TDN forage.

This illustrates how the amount of feed a cow needs varies considerably by body weight. Other factors also influence the amount of dry matter forage a cow needs to consume.

Now is not the time to misjudge cow nutrition. When you get to visit with the nutritionist, make sure you adjust the cow feeding for your environment, cow size, expected milk production and cows at calving time.

Have a good feed analysis in hand and be able to describe your feeding system so appropriate feed wastage also can be factored in. Now is not the time to debate cattle management systems. Instead, feed your cows enough and feed them right.

May you find all your ear tags.

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BeefTalk 443: Three Numbers to Think About

Today's successful beef operators evaluate their records against benchmarks.

Calving time is imminent. This is easy to see as the cows settle into the final weeks of gestation.

Cows are a bit slower to get up. Their movement is not as decisive and the placement of feet is more careful.

There is a noticeable decrease in the willingness to jockey for the pecking order. A certain contentment descends upon the herd prior to calving.

The cows are not stomping at the gate or pushing on the fences. The cows just lie around, chew their cuds and watch the sun rise and set - except those cows that still seem headed to the gym.

These "gym" cows are moving up the pecking order, grabbing the choice morsel of hay or protein cube. These cows show no evidence of a bulky middle and all their joints are well-intact and secure. These are the nonpregnant, freeloading critters.

These open cows are one of three major data points that make the difference for successful beef cattle operators. Aborted cows and dead calves are the other profit thieves.

Successful managers extrapolate information into meaningful data. Today's successful beef operators evaluate their records against benchmarks.

In the North Dakota Beef Cattle Improvement Association's CHAPS program, benchmarks are the barometers. Let's begin by reviewing the percentage of cows exposed to the bulls that actually wean a calf.

Within CHAPS, 90.8 percent of the cows wean a calf, leaving a freeloader rate of less than 10 percent. The data shows that 6.5 percent of the exposed cows were diagnosed as open or failed to calf in the spring, 0.73 percent of the cows were pregnancy checked and failed to calf (estimated abortion rate) and 3.03 percent gave birth to a calf that died sometime between birth and weaning.

These numbers affect the profit center immensely. If the typical weaning weight is 560 pounds, a producer with 100 cows fails to haul out 5,600 pounds of calf in the fall. This is assuming a 90 percent weaned calf rate (rounding 90.8 percent down to whole calves).

The calves simply are not present. Regardless of how one values the calves, the potential income from 5,600 pounds is no small change.

In business, the loss (dollars) needs to be made up. All those cows that do not raise a calf still generate bills that need to be paid.

There is another thought. If the typical 100-cow herd is weaning 500 pounds of calf per cow exposed, 50,000 pounds of calf is weaned.

Ideally, every cow exposed would wean a calf. If every cow weaned a calf and those calves averaged the typical 560 pounds, then the potential total pounds weaned would be 56,000 pounds.

Of the missing 6,000 pounds of calf, more than 93 percent of the missing weight is due to open or aborted cows and dead calves. Improving these numbers should be the goal of every beef operator.

3 Three Numbers to Think About

Cows open	6.50 %
Cows aborting	0.73 %
Calves dying	3.03 %

Several things cause open cows. There is enough research to suggest that nutritional failings would be high on the list. Right now, cattle that are underfed or fed improperly are busy subtracting from the bottom line or profit within a beef operation.

Likewise, those cattle that are not vaccinated for common diseases also are busy subtracting from the bottom line or profit. Prevention of future income losses start today.

Total herd performance is planned and executed months in advance. Those weak, poorly nourished calves with weak immune systems and cows that are slow to cycle are produced and do not occur by accident.

Proper management means precalving preparation. Precalving preparation actually starts prior to breeding by using effective vaccination programs and good nutrition.

So, look those cows over well. Start thinking about calving, as well as next year's breeding program.

May you find all your ear tags.

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BeefTalk 444: Alfalfa Is a Great Supplement

Grandpa always said sheep get the hay first, cows second and the horses third.

There was a pleasant view as I went to the auction barn the other day. The semi-trailer truck was sitting in the parking lot with a load of alfalfa hay. Under many situations, no one would really notice, but the long, drawn-out winter has many producers checking their hay inventory as frequently as the weather forecast.

Sometime ago, the late Joe Whiteman from Oklahoma State University mentioned that livestock husbandry should be simple. He said that we tend to complicate the ins and outs and sometimes even get confused as to whether we are “in” or “out.” So, Whiteman believed in alfalfa. He fed sheep alfalfa for years with very few problems.

“It was the alfalfa,” he always would say. Having a rather strong sheep background and having taught many producers how to raise sheep, I adopted the same principle. If in doubt, give the ewe a cake of alfalfa hay. That cake, in terms of a herd, would be a pound per head prior to lambing.

The old saying, “A sick sheep is a dead sheep,” never held true when the ration was right and that cake of alfalfa hay was available. You might be asking why in the world beef producers need to know about feeding sheep. Well, grandpa always said sheep get the hay first, cows second and the horses third. In fact, the truth be told, we generally couldn’t find the horses. They were camped somewhere enjoying winter because ample roughage was available and they had good pickings.

Back to the cattle pens. Those cows need feed and, in winters like this, if production is to be maintained, Whiteman’s sheep philosophy raises a point. In a round-about way, the well-being of ruminates (cows, sheep and the many other four-stomached, four-legged, four-hoofed animals) comes down to having a mix of roughages available.

Usually, summer brings abundant green grass. The winter is quite dependent on some of that green grass being preserved. The key to having good nutrition is the word “green.” As cattle are confined and the availability of forage becomes physically restrictive or cost prohibitive, the green tends to disappear from the ration. More and more feed is delivered, but it is brownish, which is the color of mature, older forage. The other feed is gold, which is the color of straw and many of the grain products that are cattle supplements.

All rations need balance. The correct supplements must be added under the advice of a good nutritionist. These rations will work, but, if push comes to shove and you have more low-quality feed, there is a very real possibility there will be detrimental effects to the late-pregnancy or early-lactating cows. Therefore, that semi-trailer load of alfalfa certainly reminded me of what Whiteman would say, “Feed some alfalfa.”

Often, the price seems high, but one is not going to feed alfalfa to beef cows at an all-you-can-eat rate. Just like the ewe, a pound of alfalfa a day really helps and a cow is no different. To start calculating a ration, 5 to 7 pounds of alfalfa a day would be a great starting point for any nutritionist. Unfortunately, the alfalfa is not always available, but the feed dealer may have some alfalfa-based supplements or cubes that certainly would help a cow.

> **Feed Some Alfalfa**
>
> Supplement 5 to 7 pounds of alfalfa hay a day for good nutrition.
>
> Five, 60 pound, square bales is all it would take to supplement 50 cows a day.

The point is relatively simple. The world is better off with a mix of things and so are cows. Having some variety helps cover up things one type of feed may be lacking.

In the cow business, we tend to start feeding a stack of hay, which is unlike the feedlot calf that gets a balanced ration every day. The cow may be stuck eating out of one haystack. If that stack is brown or golden, with no evidence of wellpreserved green plants, look for a supplement.

The next time you see a load of alfalfa hay, don't be so quick to dismiss the hay as dairy feed. Maybe, think twice about it and have some alfalfa delivered to your place.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

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BeefTalk 445: There is No Profit from Calves that Cost $2.80 Per Pound

Is the return for the added performance of the calves worthwhile?

"The pass is open" is an expression that is used by residents and travelers in mountainous areas. This year, the saying, "the interstate is open" would ring a bell, especially given all the changes in travel agendas in the past three to four months.

A more relevant outburst, "the yard is open," can be heard muffled in the sound of water starting to flow. That call means some of the outbuildings can be accessed and the start of a more normal routine is evident.

A normalcy is needed because calving is or soon will be the routine of choice. Cattle producers know the demands of calving and the need for good, clean space.

The Dickinson Research Extension Center started calving with mixed results. The weather has not been horrendous and the first-calf heifers are up close.

The first calf born, however, was dead. The feeling of seeing the desire and efforts of a cow that wants to be a mother and is licking and nudging her dead calf is not good.

We simply don't know what went wrong. One cannot be present for every birth.

The second heifer was calving and having difficulty, so life moves on. The birth was assisted, but she ended up with a 96-pound calf. However, the heifer was belligerent and ornery.

Her intent on inflicting damage to us or the calf was obvious, so out of the pen she went. She will spend her remaining days with us in the feedlot, but with us out of her reach.

Fortunately, heifer 7037 was still looking for a calf and adopted the calf with no questions asked. Sometimes things actually do work out.

The center has tried to keep birth weights low and calving ease high when selecting bulls for heifers. This year's sire of the calves was listed in the top 15 percent of the breed for calving ease and the top 45 percent of the breed for birth weight (the smaller birth weight expected progeny differences (EPD), the better).

The bull was a high-growth bull that is in the upper 15 percent of the breed for weaning weight, upper 10 percent for yearling weight and has very good carcass EPD values. The bull is a good bull, but is he a heifer bull?

One can listen to the usual hemming and hawing, but for us, the bottom line is this bull is not a heifer bull. One is always a little on edge with high-growth bulls bred to heifers.

In this case, the four calves that had difficult pulls or cesarean sections have averaged 84.5 pounds. Out of 26 heifers, we have lost three calves and assisted five births (one light assist).

Of the dead calves, two were born dead and the third was a cesarean section. Of the four difficult assisted births (other than the cesarean section), they are doing fine, but had big calves.

The four calves that needed assistance averaged 98 pounds and ranged from 92 to118 pounds. Of the 21 heifers that had no birthing problems, their calves averaged 82 pounds at birth and are doing fine.

Although hard to document, when a set of calving heifers are slow to recoup after calving and the calves are cumbersome at best, you should know you are pushing the envelope. We pushed the limits and created a manageable, but difficult situation.

PROFIT?

"There is no profit in a calf that costs $2.80 per pound to deliver by caesarean section and has no heartbeat."

Is the return for the added performance of the calves worthwhile? We will wait and see, but I can tell you it costs $2.80 a pound to produce a calf through caesarean section.

There is no profit from calves that cost $2.80 per pound and have no heartbeat.

With that, it is time to ponder next year's breeding bulls and wait for the pheasant wattles to turn red. Spring is coming and, yes, "the yard is open!"

May you find all your ear tags.

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BeefTalk 446: Unwanted Calf Average Daily Gain

The influence of gestation length provides measurable data.

Whew, only one left.

The Dickinson Research Extension Center is busy calving heifers. Thank goodness, the center only has one heifer left that is bred to a bull that will be called a noncalving ease sire.

The heifers were bred May 22. The calving season started five days early on Feb. 24, with one calf born dead.

That was followed with one calf on the 25th that was assisted, two calves on the 26th with no assists, three calves on the 27th with no assists, six calves on the 28th with one assist, eight calves on March 1 with one assist, three calves on the 2nd with one assist, three calves on the 3rd with one assist, three calves on the 4th with no assists, nine calves on the 5th with four assists, two calves on the 6th that were both assisted, one calf on the 7th that was assisted, and one heifer on the 8th with no assistance.

The fact that eight heifers calved on their due date is noteworthy. Now that the calves are on the ground and we have worked through the difficulties and extra management and labor, the influence of gestation length provides measureable data.

Of the 21 heifers that calved on or before the actual calving date, the average birth weight was 83.4 pounds and only three of the heifers (14 percent) required assistance. Of the 22 heifers that calved after the due date, the average birth weight was 88.7 pounds and nine of the heifers (41 percent) required assistance.

The average gestation length for those heifers that calved on or before their due date was 281.7 days and the average gestation length for those heifers that calved after their gestational due date was 286.5 days. The difference of 4.8 days in gestation length was 5.3 pounds in birth weight, which is 1.1 pounds per day of fetal growth in these heifers. This is not a good thing and only can be controlled by selecting the right bull.

The bottom line, in an effort to lower calving difficulty, the average birth weight of the calf needs to be sufficiently lowered to account for a lower birth weight and for calves that may not be born on time.

Keith Vandervelde, University of Wisconsin Cooperative Extension Service educator, responded and noted, "… your experience with a difficult calving-ease bull points out the need to be more aware of the top calving-ease and low birth weight expected progeny difference (EPD) bull. The bull described was almost breed average for birth weight EPD and instead of being in the top 45 percent group; you need one in the top 10 percent of the breed. Give up some growth for a live calf because dead calves do not weigh up well in the fall."

He went on to say, "I do not know the breed you are working with, but if it is Angus, go for a calving ease (CE) value of 13 or better and minus 1 or less for a birth weight EPD. If it is a Red Angus, then insist on a minus 3.5 or less for a birth weight EPD to compare with the Black Angus values. Don't forget the heifers own genetic values contribute 50 percent and maybe you need to tone down the growth on the bulls you are using for sires of the replacement heifers."

Influence of Gestation Length on Calving Difficulty

	21 Heifers	22 Heifers
Average gestation length	281.7 days	286.5 days
Average birth weight	83.4 lbs.	88.7 lbs.
Percentage assisted	14%	41%

Dickinson Research Extension Center

Keith offers some very good suggestions and gives a practical solution based on numbers within the Angus or Red Angus breeds. The same process could be utilized for any of the breeds. The reason the breed or source of the bull was never stated was to encourage producers to look for solutions rather than simply put blame on a certain bull.

The bull is good, but not utilized correctly. The bottom line, the numbers don't lie. Although four-leaf clovers may bring people good luck, cows just eat them.

May you find all your ear tags.

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BeefTalk 447: Why Is It We Always Talk About the Bull Last?

The 2009 calf crop is not arriving as quickly as expected. This has not been all bad because the cold weather was not conducive for calving.

Yet, if one wants to start calving March 1, then one needs to start on March or April 1 or whenever the desired date is. Typically, almost two-thirds of the calf crop should be born within three weeks of the starting date.

This is a benchmark value for members of the North Dakota Beef Cattle Improvement Association. Members accomplish their goal and will be about 90 percent done with calving within six weeks of the start.

In reality, a productive herd will have several cows calving before the due date and calving should quickly build for three weeks and then quickly but gradually let up. Creating such a herd is not an easy task and some understanding of basic cattle reproduction is helpful.

Typically, a cow's estrous cycle runs every 21 days, so one can expect about 5 percent of the cows to be in estrus during the breeding season on any given day. Likewise, one also can anticipate 5 percent of the cows to calve on any given day during the calving season.

The typical gestation length for beef cows is 281 to 285 days or something close to that, but it depends on the breed. That only leaves 80 to 85 days (give or take) from the day a cow calves for the cow to conceive a calf for next year. Not unlike the kangaroo, where it is often heard "there is always one in the pouch," the same is true for the cow nine months of the year.

Observe those cows after calving and start making notes. Those cows that have calved should have an estrous cycle within 60 days of calving.

This is important because when the bull is turned out, the cows should be on their second estrous cycle post-calving and be ready to breed. Feed and treat them right and it will work.

Remember the bull. He needs to pass a breeding soundness exam and be fertile prior to being turned out to the cows. The comment "the cows did not seem to be calving as soon as they should be" is a problem from last year.

In a bull, one sperm cell and only one will meet up with the released egg and conceive new life. That one sperm cell was simply a cell until the male system indicated to it that it was to become a sperm cell and have an opportunity to compete with several of its roommates to become a sire.

This doesn't happen overnight. It takes more than 54 days from the time a cell is tapped to become a sperm cell for the cell to run its course and become a mature, healthy sperm cell capable of swimming the distance to fertilize an egg.

The moral of the story is to get those bulls in shape at least two months prior to the breeding season. Feed, pamper and prepare them for the only destiny they have - to breed and impregnate cows.

Failure to perform these two tasks is terminal and far too costly for the owner.

Two Rules of Thumb

Cows should express estrus within 60 days of calving!

60 DAYS

Bull fertility improvement programs must be accomplished 60 days prior to bull turnout!

While the current focus is calving, the time is now for one to pay attention and develop some expectations of the upcoming breeding season. It takes two, the cow and the bull. If either fails, so does the operation, particularly the bull.

When one turns a bull out to 30 cows, the expected outcome is 30 calves and only fertile, physically fit bulls can meet the goal. Do not wait; go immediately to the bullpen and evaluate potential sires

Remember, what you do today will reward you with bulls that are in peak fertility 80 days from the start of the calving season.

May you find all your ear tags.

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BeefTalk 448: Horses and Beef, They Still Go Together

The cost of raising beef cattle continues to go up, as does the cost of maintaining a working ranch horse, which affects the bottom line of the beef business.

The other day was difficult. The discussion centered on the horse industry as the Dickinson Research Extension Center was reviewing program costs. As the horse program was discussed, the updated costs were noted.

Based on a five-year average, the annual cost (direct and overhead expenses) for maintaining a producing mare and nursing foal was $764.68 per year, with $570.16 attributed to direct costs (feed, breeding fees, veterinary, livestock supplies, marketing, equipment repairs and fuel, etc.). The remaining $194.52 was overhead costs that are calculated and allocated based on a typical percentage of use for each enterprise within the ranch.

The same five-year average was used to calculate raising a young horse. The annual cost averaged $893.75 per horse. The annual direct costs for the growing young horse averaged $745.92 and the overhead costs were $147.83.

These horses are weaned colts all the way up to those in the early training phase. For the horses that remain in service to the ranch (working ranch horse), the annual costs have averaged $829.43, with the direct expenses averaging $681.42 per year and the overhead expenses averaging $148.01 per year.

So what was difficult about the discussion? In a nutshell, the costs are very typical and certainly could be noted as a function of the times. Inputs are expensive, but most people understand that. The difficulty rests in the value of the horse compared with the maintenance cost.

Ranch costs do keep going up. The cost of raising beef cattle continues to go up, as does the cost of maintaining a working ranch horse, which affects the bottom line of the beef business. That simply means producers need beef prices to keep pace with increased costs.

Keep the working horses and look for better beef markets. The question about brood mares is much more difficult because these costs need to be covered by the value of their offspring. The value of a young colt not only carries with it the cost of production for the mare, but also for the production costs of the young horse until the time of sale.

Right now, the market is not supporting those costs. For the Dickinson Research Extension Center, that means fewer horses, particularly the stud. However, the real answer is in finding and maintaining better markets, more opportunities and competition for each year's foal crop. Unfortunately, not unlike the center, many producers also are faced with short-term decisions that affect cash flow.

Many producers have indicated they have and will breed fewer mares and that the increasing costs and low values of the foals was the deciding factor. Ultimately, supply and demand will catch up. However, as one producer said, "What may happen as a result of this current market is the number of foals/horses hitting the sales market. Sales should be down as many informed people will breed fewer mares. However, there doesn't seem to be any decrease in the number of beginner and novice breeders! They see all of these cheap horses, such as bred mares and studs, that they can pick up and add to their herds. Many of these herds are ‘grade horses’ (meaning cute or had neat color) and may be crossbred to create more grade horses.”

Annual Horse Production Costs

	Direct	Overhead	Total
Brood mares and nursing foals	570.16	194.52	764.68
Growing horses	745.92	147.83	893.75
Working ranch horses	681.42	148.01	829.43

Example direct expenses - feed, breeding fees, veterinary, livestock supplies, marketing, equipment repairs and fuel, etc.

Example Overhead expenses - machinery leases, utilities, professional fees, machinery and building depreciation and other miscellaneous

Dickinson Research Extension Center fve year averages.

That certainly is a challenge given the current limitations on marketing horses for slaughter. There are limited outlets to allow the industry to control excess inventory effectively and allow demand and supply to match up.

More and stronger markets are needed. In the meantime, as many producers noted, breeding horses should be for those who have a history and desire to execute a well-written business plan that justifies breeding a mare

May you find all your ear tags.

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BeefTalk 449: Bedding Beef Cows Is Essential

Challenges abound this year as North Dakota and many surrounding areas are living through a tough spring.

This spring is certainly one to remember. At the Dickinson Research Extension Center, calf death loss is just more than 11 percent, almost quadruple the typical loss of 3 percent for North Dakota Beef Cattle Improvement Association members.

This does not make anyone very happy. In fact, it stings harshly. However, challenges abound this year as North Dakota and many surrounding areas are living through a tough spring.

One of the key areas to mitigating calving losses is providing appropriate calving locations to fight severe weather stress. This is critical to calf survival.

Charlie Stoltenow, NDSU Extension Service veterinarian, says, "Prevention consists of keeping the animals, especially newborns, warm and dry. Windbreaks must be provided to counteract the effects of the wind chill."

He goes on to say, "Bedding also is essential. It has two functions. It insulates the animal from the snow and ice underneath the body, which prevents hypothermia and frostbite, and lowers the animal's nutritional requirements. Bedding allows the animal to 'snuggle' into it and lowers the body surface area exposed to the wind."

The bedding process is a chore that is low on the list. The cattle are feed, watered and evaluated on a daily basis. Cattle needing attention are sorted and cared for. As the day draws to a close, the bedding process starts.

It is important to provide an acceptable place of rest for cattle. Calf survival depends on adequate protection and bedding is essential to the total beef operation throughout the production cycle.

Research shows that cattle prefer being bedded and their overall performance and net return improve with bedding. Vern Anderson, Carrington Research Extension Center animal scientist, says, "Livestock perform better when not subjected to environmental stress. Feeding cattle in the winter, with snow, cold winds and subsequent spring mud creates a challenge."

In a two-year study of steers at the Carrington REC, performance and net return was much improved. The steers received little to no bedding, modest bedding (an average of approximately 20 pounds per head per week) or generous bedding (an average of approximately 35 pounds of bedding per week per head).

Anderson evaluated wheat straw, corn stover and soybean residue as bedding materials and observed that the steer performance was better for wheat straw.

Teresa Dvorak conducted a similar study with heifers at the Dickinson Research Extension Center. She evaluated barley, oat and wheat straw, and corn stover.

The heifers were bedded at approximately 20 pounds per head per week. All the bedding materials were found very similar as to animal performance, but keep in mind the warmer weather in Dickinson.

While the discussion of bedding seems trivial, it really isn't. In years like this, many producers are looking for more bedding, but it is not easy to find.

Calf Survival

"Prevention consists of keeping the animals, especially newborns, warm and dry. Windbreaks must be provided to counteract the effects of the wind chill. Bedding also is essential. It has two functions: It insulates the animal from the snow and ice underneath the body, which prevents hypothermia and frostbite, and lowers the animal's nutritional requirements. Bedding allows the animal to 'snuggle' into it and lowers the body surface area exposed to the wind."

Charlie Stoltenow, NDSU Extension Service Veterinarian

Dvorak notes an adequate bedding pack takes time to develop within the livestock facility to bed cattle more effectively.

"Sufficient bedding needs to be added to each pen to create a pack," she says. "Once the pack is established, bedding can be added as needed."

There are two positive points with spring moisture. First, grass and grain will grow. With grass comes beef production and with grain comes good straw. Both are needed.

The second point is that excessive moisture certainly highlights the high ground. Start taking notes now to prepare for the next wet year.

Now is the time to start a good pack in lower areas and to start looking for next year's straw supplier.

Bedding at a rate of 20 to 40 pounds of straw per head per week, 80 to 160 pounds of straw per head per month or 480 to 960 pounds of straw per month per head for a good, long six-month winter means up to 150 tons of straw per 100 cows.

The bottom line is that bedding is essential and in years like this, it means survival.

May you find all your ear tags.

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BeefTalk 450: The Stress and Strength of the Prairie

Beef production on the prairie takes place within an environment that is not always kind. In fact, the prairie environment might aptly be described as harsh.

Producer expectations do not always hold up, stressing us to the point that our joy of life may be compromised in our misery. In the end, we need to survive the stress to get to our strengths.

Maturation is a process of preparing ourselves for the difficulties of life. A failed test, the late night and subsequent tardiness, the missed basket or catch or the forgotten line are experiences that prepare us for the challenges of falling.

The bottom line relative to beef cattle management and personal growth for that matter is our true growth is achieved by overcoming the failure to accomplish what it was we each set out to achieve. How we handle the failures and ensuing stress really charts our ability to survive.

As we incorporate our experiences into our adult lives, we will learn and grow into our lives. Even then, our environment and the many events around us do not always take us where we thought we were going.

This spring, the northern prairies have presented us many challenges. When challenged, at times we prevail, but when we see all we have worked for literally disappear, the stress mounts.

Finding words to express the stress of the moment are difficult. There always will be that moment in all our lives when we really don't know if life is really worth the effort.

We weigh the fear of losing all that we have, losing someone close to us or what tomorrow may bring. We hope the scale always will tip to tomorrow to bring us a new day filled with renewed hope.

Hope, faith and love are the pillars that shore up our lives and bring meaning to another day. What tomorrow brings never really is known until we are there.

What we want or even the very things we need may not be there, however, hope, faith and love will be.

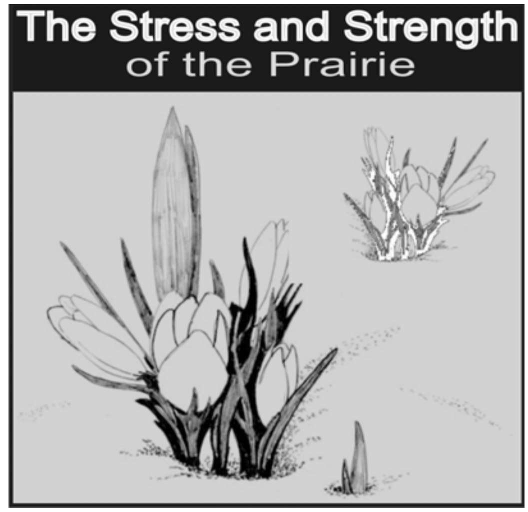
If we cannot determine our needs and our wants, then there is no hope, faith or love. There is only abandoned space that is unwillingly left empty.

With emptiness, fear, despair and pain exist. Life is not easy. Life never will be easy.

We can, if we are not careful, become weary of life and lose the joy that hope, faith and love brings us. We must remember weariness is not something that we can lay sole claim to.

The pioneer prairie settlers grew weary as well. In beef production, the challenges and tribulations of bringing one day to a close and preparing for tomorrow always has been with us.

Our predecessors hurt and cried. We hurt and cry.



Somewhere in the midst of the fear, despair and pain, we need to look through those tears. We need to look beyond the pain so we may endure what we face in anticipation of what is to come.

This year, spring is having a particularly difficult birth. Struggling would be a mild term. Needless to say, spring will arrive.

Let us pray for endurance to look forward with a willing spirit that will sustain us within our own suffering and those around us. May we persevere through God's love during difficult times and find the joy that tomorrow will bring with renewed hope, faith and love.

Life is always worth living, even when our current situation seems bleak. When we lose control, we struggle with the stress.

Tomorrow will arrive. For those born tomorrow, this was not a bad spring. However, it is up to us to carry on and prepare them for what they, too, will someday experience.

Talk, pray and listen.

May you find all your ear tags.

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BeefTalk 451: The Tag Takes a Team

It takes a team and everyone on that team must be on the same page.

News of an animal identification system seems to be slowly, but methodically, percolating through the news again. News is ongoing and quite competitive in a strange way, so getting some space is always significant.

In fact, Steve Holcomb of Pardalis Inc. recently noted, "Food safety is front and center on the public's agenda. The chatter is back in the beef industry that mandatory animal ID 'is coming' …. The whole atmosphere has significantly changed from two years ago."

Some strong thoughts and, I am sure, some strong reactions will be coming. However, as cattle producers, we cannot argue with change. We can only do our best to steer change. So what do we do? A good question and challenge for a time that already is overcome by challenges.

The other day, the Dickinson Research Extension Center purchased some replacement heifers. Interestingly, the search for age and sourced heifers is not easy. Finding a set of heifers that meet all the requirements takes time because the vast majority of the heifer lots are presorted, commingled heifers.

The heifers are good and the management is good, but there is no age and source verification. The data simply is missing, but, as producers, we know the packages are great. Perhaps that is the crux of the discussion.

As Holcomb has pointed out in previous discussions, as an industry we have and continue to fail to connect the value of data with the value of the product. The tag is the connection, so without the connection, the tag obviously has no value and the opportunity for enhancement through "connective marketing" is zero. It comes down to value, enhanced value and some sharing of that value among the players.

The center finally did locate and purchase some replacement heifers. During the sale, the steers from the same operation sold prior to the heifers in age and sourced lots. The sale went along quite well.

Paraphrasing the local livestock exchange, "In this sale, we were finally able to get a true test of the value of source and age verification. The load lots of eight and nine weight steers were age and sourced verified and electronic identification tagged. They sold extremely well and age and source verification had a lot to do with it."

The exchange went on to say, "For those who are contemplating age and source verification, you need to understand that signing calves up and tagging them does not make this happen by itself. The cattle need to be top-quality, uniform and in good condition (clean and green). If you age and source verify, but don't have things in order, you will be sorely disappointed."\

These comments from the local livestock exchange are a very true assessment and a very progressive statement summarizing the sale. Did those who purchased the age and sourced lots pay more and did the producers who sold the heifers take home more cash? Well, two truckload lots of very nice black steers weighing in at 840 pounds topped at $96. A very nice sister set of black heifers at 784 pounds hit $97. These lots and the other aged and source verified lots were not that difficult to pick out of the sale summaries. They brought more dollars. Enough said.

Sale Summaries

Age and source verifed lots were not that diffcult to pick out of the sale summaries. **They brought more dollars.**

The results were there, but as I stated at the start of this article, times of change are again knocking at our door. We can build barricades or we can adapt, but both take work and dollars. Neither is simple.

Mistakes will be made, dollars lost and dollars earned. We will backtrack and move ahead since we must move ahead if, as an industry, we are to stay ahead of those who think they know more than we do. Is mandatory identification the answer? No. Is doing what we want to do the answer? No. It takes a team and everyone on that team must be on the same page. It must be flexible enough to respond to change and responsive enough to keep this industry what it is.

In closing, the tag gives us the most headaches because the tag is the source of all the data. The data is our best friend and our worst enemy. However, as was reported at the recent cattle sale, if you don’t have these things in order first, you will be sorely disappointed.

May you find all your ear tags.

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BeefTalk 452: What Is EDI?

EDI simply is the processes that allow different data sets to be transferred or shared among individuals or others to meet a need.

The beef industry is struggling with data and data tracking. This statement, while met with a wide range of pro and con reaction, does point to the fact that there is slippage occurring.

There is a lot of very good data collected, processed and utilized within the beef industry. When it comes to agricultural economic and marketing data, most individuals and agencies take a back seat to the U.S. Department of Agriculture and associated businesses.

Many other excellent data systems are implemented and utilized within the beef business. The industry has the ability to handle the data, but the issue appears to be the desire to apply the data for the betterment of the industry.

At a recent data discussion, the acronym EDI came up. The focus of the discussion was based on the need of sharing data and how data can move seamlessly and effectively through a system.

EDI stands for Electronic Data Interchange. EDI simply is the processes that allow different data sets to be transferred or shared among individuals or others to meet a need.

Understanding the role EDI can play in the beef industry is critical. EDI is a key component for effective business relationships among ranches, companies and governments from the area, region, state, country and world. EDI can provide a worldwide interface for potential markets.

Now let's step back a little bit and look at the beef industry. On a personal note, I can remember during my college days that the Animal Science Department was having a problem. There was this course called statistics that was causing considerable consternation among those of us trying to graduate.

A requirement of graduation, the course had a dismal track record of success within the Animal Science Department. The department chair was considering teaching the course in the department rather than exposing the students to the math or statistics department because data and these young cattle prodigies were not getting along.

Those who understand statistics realize that statistics require data and data requires management. None of these mentioned activities registered with a bunch of students who simply wanted to learn how to raise cattle.

Things have not really changed. If one were to ask a group of animal science students today, the relevance of a statistics course would seem distant. Not distant to all students, but to quite a few.

The early university prerequisites of math are properly executed, but the connection to the students' eventual career still seems very soft. The implication and adoption of what is being taught is not being accomplished.

This has nothing to do with intelligence, ability to perform or one's capacity to learn. However, it does have everything to do with how one perceives his or her world and what to accept as reality or dismiss as incidental.

Beef producers actually own two things, which are cattle and data. Both have value and both need to be understood.

CalfAid Tracking for 2008 Calves
Dickinson Research Extension Center

	Total	Percentage
Production	5,220	
Replacement	2,247	43.0
Background	102	2.0
Feedlot	2,810	53.8
Slaughter	0	0.0
Lost	61	1.2

The Dickinson Research Extension Center continues to track age- and source-verified cattle. We track cattle and we manage data.

After several years, tag and data processing acceptance is improving. The center is tracking 5,220 calves from 2008. Of these calves, 98.8 percent are still in the system.

Comments, such as "I am short paper work" or "Waiting for the right premium," are more prominent than "I cut those useless tags out." However, the industry is very soft on the data and certainly struggles with managing the data for optimum value.

In reality, it may be that the statistics class would not have been so bad. Like many parts of success, it needs to be learned. For now, move aside that collection of cattle feeding, genetic, health, reproduction, management and meat books to make room for a good data book and look up EDI.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

BeefTalk 453: I'm Getting Too Old for the Chicken Dance

Producers surveyed this spring anticipate delaying bull turnout this summer by nine days.

North Dakota Beef Cattle Improvement Association members have a recorded an average daily gain of 2.52 pounds for calves on summer pasture. This means the 70,000 calves measured through the NDBCIA's CHAPS program cumulatively gain on a daily basis 176,400 pounds, 1,764 hundredweight or roughly 88 tons.

These statistics are especially pertinent following the tough winter and spring we experienced. These challenging weather conditions translate into more work and, for many producers, higher than normal calf death loss.

The natural reaction is to pull back and delay bull turnout so calving will take place later. A look at data from the 2003 through 2007 CHAPS program shows the average bull turnout date was June 9, with a predicted beginning calving date of March 19 (based on a 283-day gestation). The actual average calving date for those herds was April 3.

Producers surveyed this spring anticipate delaying bull turnout this summer by nine days. Is that a good thing to do?

We already know the average daily gain for summer calves is 2.52 pounds. The net result is that for every day that bull turnout is delayed, producers will have one less day of calf growth.

The delay means 176,400 pounds of beef for these 70,000 calves will not be realized. CHAPS benchmarks show a producer with 100 cows usually weans 90 calves (6 percent open cows, 3 percent calf death loss and 1 percent abortions and other losses).

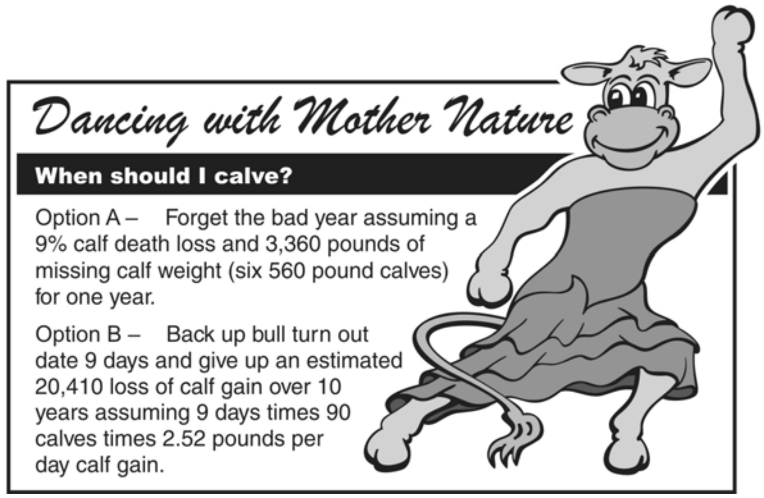
If the bulls are turned out nine days later, a producer gives up an estimated 2,041 pounds of calf in the fall (nine days times 90 calves times 2.52 pounds). Imagine a producer with a 9 percent calf death loss because of tough weather. A producer needs to sit down and think through the numbers.

The additional 6 percent loss, or approximately six calves for this 100-cow herd, is actually six times the average weaning weight for each calf. The benchmark value for the 70,000 calves in the CHAPS program is 560 pounds, which means producers would lose 3,360 pounds because of the six additional calves that were lost.

Producers need to evaluate if the risk of losing 3,360 pounds of calf reoccurring is greater than the planned management change of moving the bull turnout date back nine days. If we have a similar winter and spring next year, backing up the calving date to avoid difficult weather would be good.

However, if these events only happen once every 10 years, backing up the calving date would amount to an estimated 20,410 pounds of lost calf gain (10 years times 2,041 pounds), while the one bad year resulted in 3,360 pounds of lost calf gain for that particular year. In that case, the answer would appear to be to leave the calving date as is.

No simple answer exists. One could back up the calving date nine days and wean nine days later and actually wean the same amount of calf. This sounds good, but an early snowstorm on a bunch of bawling, freshly weaned calves is no good, either.



The bottom line is that ranching and farming is a dance with Mother Nature. We asked for the dance.

I would like to think the dance is a nice, refined waltz, but a fast two-step or maybe a wild polka is to be expected. Unfortunately, the “chicken dance” is thrown in every so often. Hold on to your hats because no one really knows just when and where the dance will end.

At the Dickinson Research Extension Center, we are settling on bulls going out the week of June 15 for the mature cows. The bulls will go out to the breeding heifers the last days of May. That puts next year’s mature cows on a schedule to start calving March 25, which is a few days later than we have been.

I guess I’m getting too old for the “chicken dance.”

May you find all your ear tags.

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BeefTalk 454: Calving Date Equals Latitude and Altitude

As cow-calf producers, we understand where we live, but when we seek advice, we often seek that advice from those who live elsewhere.

As with any major change within a beef operation, each change needs to be thought out and penciled through. Recently, the bull turnout and subsequent calving date have been the focus of considerable discussion.

For all practical purposes, the life of a ranch (or farm) literally centers on those periods that require intensive work. Calving certainly is one of those periods. The concept of calving date is critical. If a ranch does not have a live calf actively gaining weight, then the ranch only has expenses, but no income.

Perhaps the concept is not much different than a feed yard. If a feed yard is not feeding cattle, then the yard only has expenses. What is interesting, as most feeders know, feed yards must have cattle, but having cattle does not mean the cattle are making money.

Generally, if the yard is operated and managed astutely, the feed yard is operating on a positive margin. That is a fundamental every fall as feed yards compete for calves because they all know that no calves means no money.

Likewise, as cow-calf producers, ideally, each workday would generate income. However, we all know that is not the case because the calf growing season is limited to a certain time of year. That is a critical thought, as calf gain needs to be maximized during seasonal periods that offer the opportunity for calf growth. Understanding these periods is dependent on two general principals, latitude and altitude.

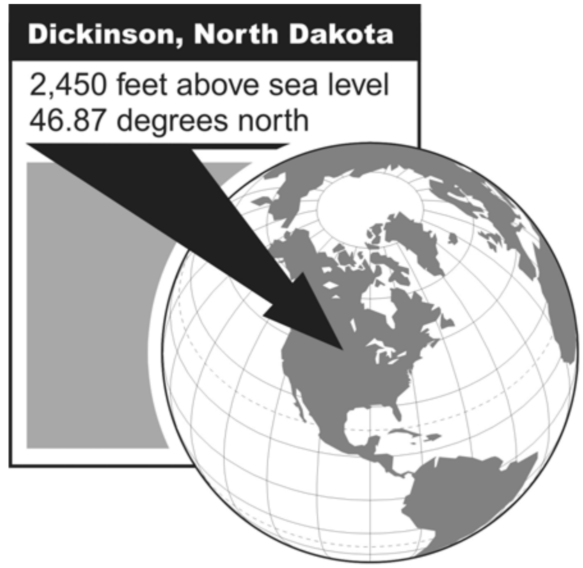
Latitude is a measurement that indicates how far north or south our operation is from the equator. Altitude is the distance our operation is above or below sea level. In simpler terms, each producer needs to understand where he or she is in respect to his or her environment.

Those who are closer to the equator have less snow issues than those who are farther away. However, those who are closer to the equator have more heat issues. Interestingly, heat may be more detrimental to growth than cold, particularly if the cattle are not acclimated to their environment.

On a personal note, an acquaintance once moved his cows from the merciless winters of the northern Great Plains to the perceived balmy southern Great Plains. He returned a couple of years later with cows in tow, pondering how anyone survives the south because it’s too hot.

As cow-calf producers, we understand where we live, but when we seek advice, we often seek that advice from those who live elsewhere. All advice must be filtered to match one’s own environment, but then a large dose of common sense needs to be added in. In reality, there is no perfect place or climate. Perhaps, before one gets too carried away making changes, one needs to seek the wisdom of those who have been there before us.

As we grow in life, we seldom appreciate what our parents tell us. We graciously acknowledge our grandparents as they recall the old days, but they lived it. Generally, parents and grandparents will be the first to say, “Are you sure you want to do that?” Typically, we seem to think we know better and move on. Maybe we do, maybe we don’t.



Keep in mind, as major operational changes are considered, one needs to filter the many meeting comments and written editorials with a good dose of local input.

Obviously, a change in calving date has a major impact on an operation. Skirting Mother Nature is not a simple task. Again, keep in mind that an operation is a combination of inputs and outputs. In simple terms, the output is calf gain. As has been noted previously, a good benchmark for calf gain is 2.52 pounds (the summer average daily gain for more than 70,000 calves involved in the CHAPS program).

Also, keep in mind that when a cow calves does not change the cow’s nutritional requirements. In other words, the cow needs to meet her daily nutritional requirement for her individual maintenance and growth as well as fetal growth and milk production regardless of when she calves.

The environment (latitude and altitude) impacts the cow. Temperature and precipitation also need to be accounted for.

So why is the question regarding calving date being asked today? Well, cattle operations are contemplating a change. However, let’s grab a pencil before that change is made.

I’ll have more next time. Until then, look up your latitude and altitude and write it down. For starters, the latitude of Dickinson, N.D. is 46.87 degrees north. The elevation is 2,450 feet above sea level.

May you find all your ear tags.

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BeefTalk 455: One Needs to know Costs

Calving at a later date gives producers an increased opportunity to place cows on grass while the cow is either very pregnant or milking.

Managerial changes require a review of both the positive and negative. Previous discussion on changing the calving date has resulted in two major points: reducing the cows' winter feeding costs and lower the death loss among newborn calves.

Both significantly affect the bottom line. How much is also important.

North Dakota Beef Cattle Improvement Association producers have a five-year average of 3.2 percent calf death loss. Those producers have a typical bull turnout date of June 9, with a predicted beginning calving date of March 19 (based on a 283-day gestation period).

The actual average calving date for those herds was April 3, so late March and April calving has not been very harsh on calves.

A storm will cause consternation and even devastation, but calving late enough to avoid winter weather probably is not practical. On May 13, we had snow and chilly (below freezing) temperatures, which were enough to chill a newborn calf.

While things have not been all that bad in the long run, inputs and outputs need to be assessed to evaluate a shift in production practices. The feed requirements of the cow and calf are set. If one knows the situation, the appropriate amount of feed can be calculated.

If the environment is not changing, the requirements will not change significantly. Calving at a later date gives producers an increased opportunity to place cows on grass while the cow is either very pregnant or milking, which are, generally, peak nutritional times.

Both periods require additional feed. If one is hauling feed manually or by the tractor scoop full, the additional feed is noticeable.

Turning cows on grass brings a sigh of relief because the cow actively can gather her own feed. Remember, a cow's requirements did not change, only the source and feeding process changed.

Input costs are critical to any management decisions. Assume a producer can rent land for $20 per acre on which to run cows.

In a very simplistic way, the producer needs a connection between the available forage and price per acre.

In general, a ranch manager could look at trying to feed a 1,300-pound cow with approximately 1,000 pounds of forage per month (essentially 30 pounds a day for 30 days, plus 10 percent waste). The other option the ranch manager has is opting to turn the cow onto grass.

For the cow standing in the pen, costs are calculated on the price of hay. At $60 per ton, hay costs the ranch $30 per month to feed the cow. At $120 per ton, hay costs the ranch $60 per month to feed the cow. The lower end barely works, but the upper end does not. The same is true for grass.

As producers compete with each other for grass, the assumed lower cost option (grazing) can disappear quickly with aggressive bidding. At $20 per acre and with production of 2,000 pounds of herbage (in western North Dakota), the producer is looking at $20 per ton of herbage available land costs.

Selected Five-year Average Managerial Decisions

North Dakota Beef Cattle Improvement Association Producers

Bull turnout date	June 9
Predicted start of calving	March 19
Actual average calving date	April 3
Production response	
Calf death loss	3.2%

However, for grazing, the question gets more difficult. If we stock converted hay land at two acres per head, we are assuming the cow will only graze approximately 1,000 pounds of forage.

Either way, $20 per acre rent becomes $40 per cow per month (two acres per cow). One can change the production scenario, but hauling hay to a cow or hauling a cow to grass is totally dependent on the cost of the resources.

One needs to know actual costs. Assumptions can get one into trouble.

Now we need to look at actual numbers for western North Dakota, but more on that subject next time.

May you find all your ear tags.

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BeefTalk 456: Opinions Count, But So Do Numbers

Opinions aside, the bottom line remains the knowledge gathered from numbers.

The beef business never has been short on opinions. Good opinions and the willingness to share those opinions are the core to any dynamic, independent business.

For beef producers, independence is manifested in the concept, “I need to get the work done.” There are few self-help books when the weather is bad, cows are calving and a day only has 24 hours.

Opinions aside, the bottom line remains the knowledge gathered from numbers. While there are several ways to review the numbers, the key point is to base management decisions on the numbers.

North Dakota Farm Business Management Education Program instructor Jerry Tuhy stressed that numbers help producers evaluate their operations. The evaluations help chart the future, so managerial change can be reflected in a positive net return.

Within the farm management program administered by Jerry, 119 units had a beef cow-calf enterprise. The average net return per cow was $12.11. Labor and management charges were not included.

Jerry separated the data into two groups: units with less than 70 percent of their gross income from beef cattle and units with greater than 70 percent of their gross income from beef cattle.

Figuring no labor or management charges, herds with less than 70 percent of their gross income from beef reported an average net return per cow of $12.43. Herds with more than 70 percent of their gross income from beef had an average net return of $9.17.

A closer look revealed the upper 20 percent had an average net return of $130.25 per cow. The lower 20 percent had an average net return of a negative $153.78 per cow.

Pause and look at the numbers. The spread from the top 20 percent to the low 20 percent was $284.03. Let me repeat that: The spread for the top 20 percent versus the low 20 percent was $284.03.

Those with a negative net return cannot expand. Those on the high end may feel more secure. However, expansion still is limited due to labor needs. Unlike crates and other shipping boxes, cattle cannot be parked until tomorrow.

Further review of the southwestern North Dakota herd data by Jerry revealed interesting peripheral differences. The lower-half net income herds had more feed expense and greater direct and overhead expenses, which increased the cost of production.

While both groups had similar average weaning weights, the most obvious conclusion is producers need to control costs. The beef cow has been and probably always will remain a low-cost enterprise.

More than likely that is why many producers are seeking to make changes within their operations. Some of the more recent avenues of change involve cow size and calving date because both of these two variables impact nutritional requirements and the environment.

The mentality of cost constraints is real. When one looks closer at the cost of production (now including labor and management) and sorts the beef data on costs, the data reveals an interesting note, according to Jerry.

Variability of Net Return in the Beef Business

Average Net Return - positive $12.11 per cow (no labor or management charge)

The upper 20% - positive $130.25 per cow

The lower 20% - negative $153.78 per cow

The spread for the top 20% versus the low 20% - **$284.03 per cow**

2008 State Report
North Dakota Farm Business Management Education

Still, the high-cost units had greater feed expenses and direct and overhead expenses. The low-cost operations had more weaning weight to their calves.

Those units or herds that were reflective of a greater net return also had a greater output in terms of calf weight sold. It is very important as one makes changes to the operation that all aspects of the operation are evaluated and considered.

Beef cattle evaluation needs to be more than just opinion. As was noted at the start of this BeefTalk, opinion is good, but if one is going to bet the ranch on it, some numbers are certainly much more comforting.

This still is the dilemma. Later calving and smaller cows, if done in haste, may constrict output.

Well, it is a nice spring day today and the grass is starting to grow, so the newborn calves will be happy. However, I need to stay inside and rework some numbers.

May you find all your ear tags.

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BeefTalk 457: The Right Bulls Produce the Right Calves

What is important is to look at the numbers and find a bull that will work within your herd.

The discussion when to breed cows has to end eventually. Spring and breeding time is here at the Dickinson Research Extension Center.

The heifers were synchronized for timed insemination through an initial injection of a gonadotropin-releasing hormone (often referred to as GnRH and available in several commercial formulations) followed by seven days of progesterone administered by a controlled internal drug-release device (often referred to as CIDR, a registered trademark of DEC International, NZ, Ltd.)

On day seven, the CIDR was removed and the heifers received an injection of prostaglandin. Fifty-four hours later (plus or minus two hours), the heifers were bred by artificial insemination (AI), given a second injection of GnRH and hauled to grass. Cleanup bulls were turned out once the heifers quit exhibiting estrus.

Two key dates loom ahead. The first will be late July when the heifers are ultra-sounded to determine the pregnancy percentage from AI. The second will be when the heifers calve.

We are hoping to avoid the trouble of this spring. Those who read BeefTalk recall we pulled more calves than expected and we even had one calf delivered cesarean.

This was unacceptable, particularly with the long, difficult winter. Many have asked who the bull was, but that is not important.

That same bull may very well work in someone else's herd. The particular breed or genetic makeup of the heifers or cows also can influence the outcome.

What is important is to look at the numbers and find a bull that will work within your herd. Last year, the center bull had a calving ease expected progeny difference (EPD) of 9, a birth weight (BW) EPD of 1.9, weaning weight (WW) EPD of 53 and yearling weight (YW) EPD of 100.

The bull ranked as an Angus trait leader for growth. He also had a rib eye area (REA) EPD of .78, which ranked the bull in the upper 1 percent of the breed. The other carcass traits also were very excellent, but enough numbers.

So what is happening as the weather warms up? This year’s surviving calves look great. “Trend setters” and “haven’t seen calves quite that good for a while” are some of the descriptions. Memories are short and those dead winter calves are buried and gone. The dry cows were converted to cash and life goes on.

What bulls did we use this year? I am not going to name them, but let's look at the data.

The center had a bull in the semen tank with a calving ease EPD of 14, BW EPD of minus 0.7, WW EPD of 42, YW EPD of 84 and REA EPD of .09.

Bull EPD Values

NDSU Dickinson Research Extension Center

	Last year's Angus bull	This year's Angus bulls	
Calving Ease	9	14	14
Birth Weight	1.9	-.07	-1.3
Weaning Weight	53	42	58
Yearling Weight	100	84	103
Rib Eye Area	.78	.09	.44

The bull is not the growth bull that we used last year, but is certainly acceptable. The bull will be used along with another bull who also has a calving ease EPD of 14, BW EPD of minus 1.3, WW EPD of 58, YW EPD of 103 and REA EPD of .44.

The second bull is an obvious trait leader for growth and carcass in the Angus breed. We will look forward anxiously to a good artificial insemination conception rate and a great calving season.

The center knows well what happened last year. We hope that good data and good planning with the bull selection will work out beginning March 7. That's the day the heifers are due to start calving.

We will be in the thick of calving as March arrives, but as usual, the heifers always are close to home, so we are thinking positively. On second thought, a little luck would not hurt.

Life does not always go our way and even numbers vary in accuracy. However, what else do we have? If we become fearful of muscle growth in the cattle business, we have created a very big hurdle.

May you find all your ear tags.

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BeefTalk 458: Small Cattle Need Muscle

Sometimes big surprises come in smaller packages.

Do you know your cows? Do you have medium-framed, medium-sized cows or smaller- framed, medium-sized cows or smaller-framed, small-sized cows?

The answers to these questions will impact management decisions. The Dickinson Research Extension Center has sorted the main brood cows into two distinct types of cows.

The first set of cows averaged just more than 1,400 pounds at spring turnout on crested wheatgrass. They are part of a study involving cropping rotations and range systems harvested by grazing cow-calf pairs and early weaned calves. The second set of cows averaged 1,060 pounds when turned on crested wheatgrass this spring. The cows are utilized in the center's native range systems. The calves traditionally are weaned in the fall, backgrounded and finished.

The hair pulling arrived when the bull pen was evaluated. The bulls in the pen were designed to breed at least medium-framed, medium-sized cows. In other words, they all looked good for 1,400-pound cows.

The Red Angus bulls had average expected progeny difference (EPD) for birth weight (BW) of 1.9, weaning weight (WW) of 35.8, yearling weight (YW) of 59.8 and .09 for rib eye area (REA). These numbers put the bulls in the upper 50 percent of the breed. The exception was birth weight, where the bulls ranked in the lower 25 percent of the breed.

These are not heifer bulls. They would work well on the larger cows, but not on the smaller-framed, lighter cows. There was too much birth weight and not a really good indicator of the calf's mature size.

If the only bulls utilized in the breeding program produce the medium-framed, medium- sized cows, the ability to maintain a smaller, mature-sized cow is compromised. However, there were some good bulls still available.

The center put together a group of bulls that had an average EPD of minus 3.1 for BW, 24 for WW, 48.7 for YW and 0.22 for REA. These bulls offered reduced birth weight, acceptable growth and very excellent rib eye area.

The point is that normally one would be a bit taken aback on the growth numbers because the bulls rank in the lower end of the Red Angus breed for weaning and yearling growth, but let's repeat the rib eye area EPD of .22. Note that these bulls are in the upper 20 percent of the Red Angus breed. The center does not want to breed smaller cattle that have no muscle.

These bulls should maintain a smaller weight cow and keep or improve rib eye area. The beef business must remain a beef business, not a small-cow business.

However, sometimes big surprises come in smaller packages. For instance, the Red Angus

Association publishes a newer EPD abbreviated as ME, which is an evaluation of the maintenance energy requirements for mature cows. This value predicts the differences in energy requirements among the mature daughters of individual Red Angus bulls.

Red Angus Bull Pen Stats
Dickinson Research Extension Center

	Big Boys	"Not So" Big Boys
Birth weight	1.9	-3.1
Weaning weight	35.8	24.0
Yearling weight	59.8	48.7
Rib eye area	.09	.22
Maintenance energy	8.2	0

In the case of these two groups of bulls, those bulls available for the larger cows had an average ME value of 8.2. The average ME value of the bulls selected for mating to the smaller cows was zero.

The lower the ME value, the better. In other words, the bulls selected for the smaller, mature-weight cows actually are not only predicted to sire calves that are lighter weight, the calves also will have more muscle and subsequent daughters will require less dry matter feed.

These are interesting concepts as the center prepares to maintain a herd of cattle that is closer to the 1,000- to 1,200- pound body weight than the 1,400- to 1,600-pound body. It is important to remember that even small cattle need muscle and the ability to put 550 pounds plus of quality beef on the rail.

The numbers do tell the story. We simply need to read the book.

May you find all your ear tags.

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BeefTalk 459: The Curves Are Getting Tight

Each operation needs to complete an inventory of principle resources available and review potential income sources.

Tight curves on any roadway require a driver to slow down. Even if one is familiar with the road, changing conditions create unpredictability.

This same is true in the business of agriculture, especially the life of a farmer or rancher. Producer families spend much of their lives on the edge. When the edge is soft, it is better to pull back, rethink and see what happens.

Sometimes we really need to rethink our decisions. Recently, I reviewed enterprise analysis numbers with local North Dakota Farm Business Management instructor Jerry Tuhy.

Traditionally, the North Dakota Farm Business Management data is averaged and the data sorted into three groups based on net return. The groups are the lower 20 percent, middle 60 percent and upper 20 percent. The unit of measurement is a cow.

This type of sorting maintains confidentiality and provides provoking questions for all producers to consider. The most obvious question is how lower net return producers can increase their net return.

That is a good question. However, the data reveals the total difference in net return through the years does not vary much and does not go away.

In the 2008 analysis, the spread for the average net return per cow was $284.03. The lower 20 percent group showed a loss of $153.78 per cow, while the upper 20 percent group showed a profit of $130.25 per cow. That means the lower 20 percent group averaged $284.03 lower than those producers in the upper 20 percent group.

Those in the lower 20 percent group should do considerable pondering.

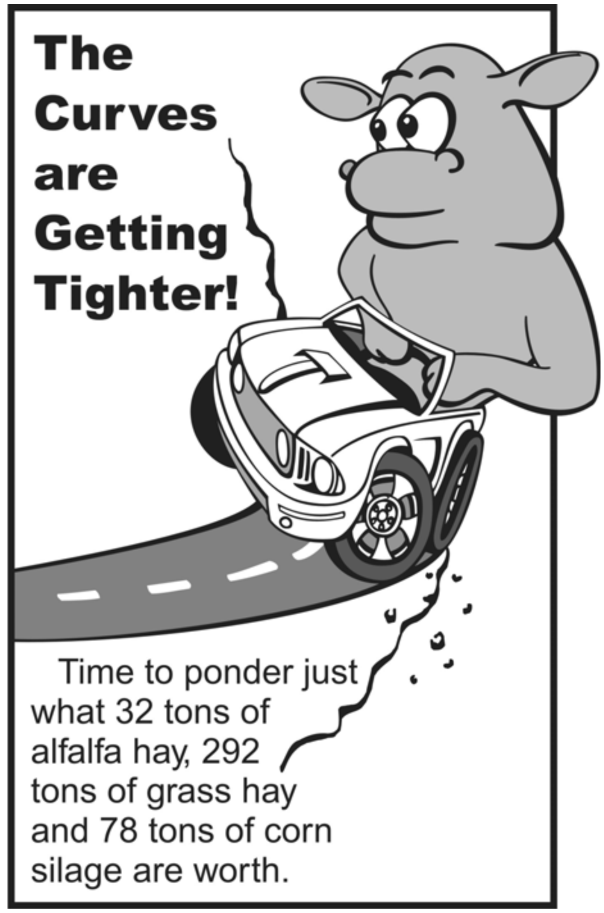
Should they remain in the beef business?

While that seems rather harsh, it is reality. Each operation needs to complete an inventory of principle resources available and review potential income sources.

Beef is the obvious resource and potential income source. However, in the case of those herds that averaged a negative net return, perhaps the answer should not be so quick.

For instance, these same producers fed their cows 77.2 pounds of protein, vitamin and mineral supplements valued at $16.25 per cow. These producers also gave the cows 36.1 pounds of creep or starter feed valued at $3.24 per cow, 54.1 pounds of a complete ration valued at $4.52 per cow, 1,556.8 pounds of corn silage valued at $16.08 per cow, 644.2 pounds of alfalfa hay valued at $20.71 per cow and 5,859.8 pounds of hay valued at $127.09 per cow.

If the cows were not on the place, the purchased feed supplements of $24.01 would not occur. The average herd size for these producers was 96.8 cows. For easy figuring, we set the herd size at 100 cows.



Without the cows, $2,401 would not be spent on supplements. In addition, approximately 78 tons of corn silage, more than 32 tons of alfalfa hay and more than 292 tons of hay would be available for sale.

Other direct expenses would not be relevant because the focus of net income would shift to the net return of producing corn, alfalfa and hay.

If the direct expenses involved in these operations also were negative, there is no enjoyable discussion left. However, if a profit margin does exist within these three enterprises, the appropriate managerial decision would be to sell the cows, retire the facilities and enter the plant world.

This is not a real enjoyable BeefTalk to write. Reality does tell us the curves are getting tighter and the options fewer.

If the beef enterprise in not generating positive cash for the operation, then the operation is subsidized by outside income or change is in the wind. It may be time to ponder and add up just what 32 tons of good alfalfa hay, 292 tons of grass hay and 78 tons of corn silage is worth.

Why feed it to the cows and lose $16,388 when one could sell it. In addition, the grassland is now available for rent.

The hope is that there are cattle producers around to rent the land. Every action has a reaction.

May you find all your ear tags.

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BeefTalk 460: The Plight of Being Average

With rising input costs and falling calf value, survival in the beef business is a very real question for many producers.

The cattle business is a profession that requires considerable education and experience. In other words, the managerial inputs need to be well thought out so that the ramifications or consequence of doing or not doing something has the desired outcome.

With rising input costs and falling calf value, survival in the beef business is a very real question for many producers. Unfortunately, our simple willingness to do what we have previously done is a major impediment to moving forward. At the end of the year, if the dollars and cents are added up and the bottom line is pathetic, what does it take to move from the status quo to a more proactive thought process?

It is not easy, but if a producer wishes to remain in the beef profession, reality needs to be addressed. If we were to review the numbers, a good source is the 2008 annual report for the North Dakota Farm and Ranch Business Management Education Program (http://www.ndfarmmanagement.com).

As has been noted before, if the 119 producers engaging in a cow-calf enterprise are sorted by net return per cow, assuming 100 cows in the herd, then the lower 20 percent lost $15,378. The middle or average producer made $1,521 and the top 20 percent of producers made $13,025.

These net returns do not include a charge for labor and management, so the average beef producer has $1,521 to pay himself or herself for his or her effort. There is another way to tap reality. If a typical summer job pays $10 per hour, the average producer could have worked four weeks off the farm or ranch and made more money than was made in the beef business. Just as those producers who are not making a profit, the average producer needs to look at the operation and ask just what is the primary product produced on the farm or ranch.

In the annual report, one can approximate that the average cow-calf producer fed 104 tons of corn silage valued at $21 per ton, 21 tons of alfalfa hay valued at $58 per ton and 259 tons of hay valued at $40 per ton.

If one was to assume these forages were produced on the ranch (the report does not indicate the source of forage), then those values were retrieved by marketing the forage through the cows. The function of ruminate animals is to convert forage into a marketable product.

If I was to sum up the plight of the average beef producer, the work is hard, the pay negligible, but the farm or ranch forage was marketed at reasonable prices, and the producer is certainly worthy of being in the forage business. Are the cows the right tool to add value to the forage from the operation is the obvious next question. It is a good question and worth asking of a professional cattle person. The answer is not simple and that is why average producers should not seek to remain average because there will come the day when it is easier to simply market the forage and let someone else feed it.

Average producers must dismiss the innate willingness to accept the current negatives based on an optimistic wish that next year will be better. Many producers, perhaps too many, have come to accept the concept that going backwards occasionally is an accepted principle in agriculture. Such thinking leads to the principle that the bank will carry us for another year and the upcoming good years will bail us out.

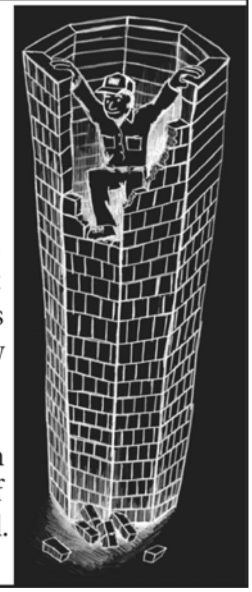
However, if, as beef producers, we simple choose to remain average, in reality, the good years only will bring us back to break even. We can and must do better. We must become professionals who truly use our education and experience to excel in the beef business.

Let’s do something.

Take a deep breath, look up and jump as high as you can. Keep jumping until you can see over all the walls one has built up through the years. Even though the vision may not be clear, make the commitment to grab the top of one those walls and tear it down. When you land and the wall is lying at your feet, look out and simply say I can do this.

A Thought for the Day

Let’s do something. Start tearing down the walls that have been built through the years that keep producers at average. Now is the time to move on to ideas that can make the beef industry excel.



Now step over the rubbish and let’s move on. More later.

May you find all your ear tags.

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BeefTalk 461: How Does One Stay in the Beef Business?

Change for the better means data or records to guide in and out value, direct expenses and overhead within a beef operation.

As a profession, the cattle business never has been easy. Many would sum up their experience as “a lot of hard work and little pay,” and adding a final quip, “but it is a good life.”

Will the next generation say the same? The part about the hard work and little pay seems well accepted, but the last quip will cause a slight gaze down the interstate.

As noted in the 2008 Annual Report for the North Dakota Farm and Ranch Business Management Education Program (http://www.ndfarmmanagement.com), there is a considerable spread in a producer’s concept of what “little pay” means. Previously, it was noted that by sorting the 119 cow-calf producers by net return per cow, the lower 20 percent lost $153.78 per cow, the middle or average producer made $15.21 per cow and the top 20 percent made $130.25 per cow.

This total spread of $284.30 in net return from the low to the high group does not include a charge for labor and management. In essence, the lowest net return group paid someone else while they worked hard raising grain, forage and cattle.

The middle group (the majority of producers) worked hard caring for their cattle. Essentially, they choose to market grain and forage through their cattle, with little value added. The higher net return producers managed to add considerable value to their grain and forage by producing beef.

Economic spreads exist within any profession. For the professional beef producer, knowing which category the beef enterprise fits in is important because three potential scenarios exist.

In the first scenario, a producer believes the beef cattle are making a profit, but they are not. No managerial or production changes are initiated. Unfortunately, a financial crisis eventually unravels and the producer has to make quick, uninformed, life-changing decisions.

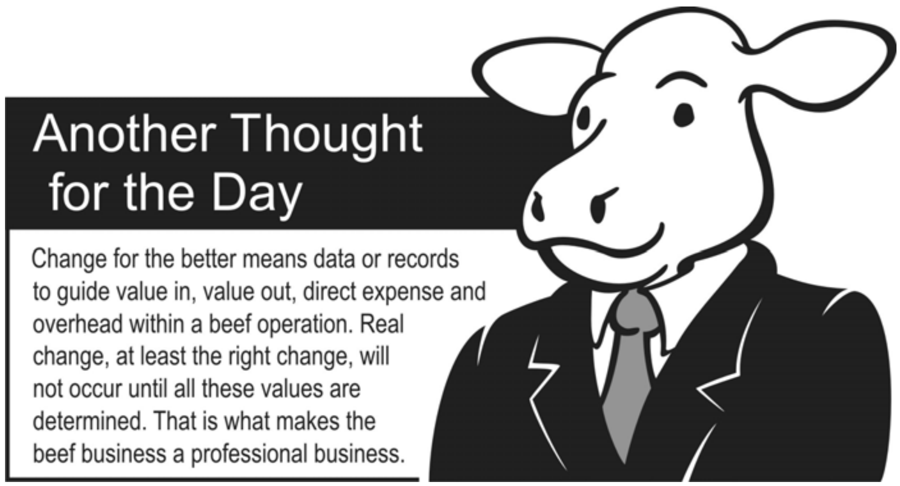
In the second scenario, a producer believes the beef cattle are not making a profit because the mass media says that times are tough. In this case, the producer initiates change when, in fact, the operation already was a profitable enterprise.

The third scenario includes the producers who know the ins and outs of the beef enterprise thoroughly. Their managerial decisions are based on adequate records.

The challenge is to know where, as a beef producer, the beef enterprise sits. Do not assume anything because profitable enterprises track income, direct expenses and overhead expenses.

Income within a beef cow enterprise often is noted as being calves. However, that is only one piece of the income equation. There is value in marketing heifers, cows, bulls and replacements.

The data shows a $160.61-per-cow spread in the dollars available to the enterprise between the low net return producer and the high net return producer when tracking purchasing, marketing and transferring the value of each type of cattle within or out of the enterprise.



This $160.61 value is the sum of focused marketing processes for all classes of cattle leaving or arriving on the operation. This adds value to an operation and accounts for 56.5 percent of the total difference in net return between the low and high producer groups.

Unfortunately, the in and out beef values for an operation are seldom calculated. Without these values, the discussion focuses on reducing costs when, in fact, increased value may be the real answer.

The direct cost spread is important and should not go unnoticed. In this case, the direct costs are $95.92 per cow and account for 33.8 percent of the net return spread followed by a spread of $27.49 per cow for overhead costs that accounts for only 9.7 percent of the spread in net return from the low to the high net return producers.

Change for the better means data or records to guide in and out value, direct expenses and overhead within a beef operation. Real change, at least the right change, will not occur until all these values are determined. That is what makes the beef business a professional business.

May you find all your ear tags.

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BeefTalk 462: What Is the Real Value In a Beef Herd?

To know our real opportunity to make a profit, we should know what the gross margin is when we sell calves, bulls and cows connected to the enterprise.

Usually, when businesses buy and sell inventory, one of three things happens.

Under option one, the item sells for more than it was purchased for and one has the opportunity to make money. The second is the break-even option. This is when an item sells for the same as the purchase price.

The last option is selling an item for less than the purchase price, which some refer to as depreciation. Option two and three are both losers because there is no opportunity to make money.

This change in value has a huge impact in business and often is referred to as "gross margin." If a producer wishes to spend some money to make money, then a profitable gross margin is the correct starting point and an increased value of the product is desired.

If a producer buys calves at $500 per head and projects selling the calves at $600 per head, then the producer has $100 to work with to attempt to make a profit. The $100 is not profit, but rather is the available budget one has to work with.

Within the process of buying short-term cattle, the concept of gross margin is more common than within the cow-calf segment of the industry. However, the principle still holds true.

Cow-calf producers invest in cows. To know our real opportunity to make a profit, we should know what the gross margin is when we sell calves, bulls and cows connected to the enterprise. This is money committed or invested in cattle versus cash out.

How does one calculate gross margins within the beef operation? Jerry Tuhy, instructor for the North Dakota Farm and Ranch Business Management Education Association, explained the process that is utilized to generate gross margin within the cow-calf enterprise.

Jerry noted the gross margin reported in the program's 2008 annual report includes deprecation as well. He says the calculation for the 119 beef enterprises (average herd size 163.4 cattle) showed a gross margin of $466.19 per cow.

These beef producers sold $151.44 worth of calves per cow and transferred out $372.21 of calf value (typically replacement heifer calves that will transfer back in following breeding and steers or extra heifers that are backgrounded). These herds averaged $523.65 worth of calf value generated per cow, as well as $111.25 in value for the cull bulls and cows.

Although minor, hedging, butchered beef and miscellaneous income provided an additional $7.67. The total value generated per cow for these operations was $642.57.

Jerry reminds us that not all that value is available to write checks against. In other words, the inventory needs to be maintained, and these herds spent, on the average, $81 per cow on replacement bulls or cows and transferred in their home-raised replacements valued at $67.73 per cow.

A total of $148.42 was spent to maintain the breeding herd. In addition, an inventory change of $28 per cow was a drop in asset value from the beginning of the year to the end of the year for the cows and bulls.

Essentially, for both cows and bulls, market value at the end of their productive life is considerably less than their value when they entered the herd.

Gross Margin Per Cow

North Dakota Cow-calf Enterprise	
Beef calves Sold	$151.44
Beef calves transferred out	$372.21
Market cows and bull value	$111.25
Miscellaneous value	$7.67
Total value generated	**$642.57**
Purchased replacement value	$80.69
Transferred replacement value	$67.73
Total value for inventory replacement	**-$148.42**
Inventory change (depreciation)	**-$27.96**
Calculated cow-calf gross margin	**$466.19**

"Add up all the pluses and minuses and you get gross margin," Jerry says.

As was stated earlier, the gross margin value for the average cowherd in this data set was $466.19. The bottom line, direct and overhead expenses and labor/management charges must come out of the gross margin value.

The cow-calf enterprise is not any different from any other buy-and-sell game. In the end, you need to have enough margin within the enterprise to accommodate all that you want to do, including making a living.

That is important. Just ask Jerry Tuhy.

May you find all your ear tags.

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BeefTalk 463: Capturing Value Is The Name Of The Beef Game

Given the costs involved in producing beef, producers must strive to maximize their gross margin.

Beef production is about value. There are many components and obviously many ways to raise beef, but the bottom line is value. The product has to have value.

In economics, value is a product of supply and demand. Many educational opportunities, such as the North Dakota Farm and Ranch Business Management Education Program (http://www.ndfarmmanagement.com), have and will continue to aid producers who are active in the beef industry by helping them understand better the concept of value.

But does this effort pay off? Well, as with many things, it is not always easy to know what is the exact driving force in the industry, but it is interesting to see the spread in value that producers managed to achieve in 2008.

Data from 119 herds in the North Dakota Farm and Ranch Business Management Education Program shows the average producer sold or transferred out of the beef cow enterprise 528 pounds of calf per cow within the cow-calf enterprise. This transfer generated an incoming dollar value per cow of $523.65 based on pounds of calf produced.

Further study showed the lower 20 percent sold or transferred out 485.2 pounds of calf per cow within the cow-calf enterprise. This generated an incoming value of $465.23 based on pounds of calf produced.

The upper 20 percent of these same herds sold or transferred out 557.8 pounds of calf per cow within the cow-calf enterprise. This generated an incoming value of $576.27 based on pounds of calf produced.

The spread of $111.04 is huge. The lower net return group of producers marketed less beef per cow in the operation and valued each pound of beef produced at 96 cents per pound. The upper net return group marketed 72.6 pounds more beef per cow in the operation and valued each pound of beef at $1.03 per pound.

The sale of cull cows averaged $111.25 per cow in the 119 enterprises. The lower 20 percent averaged $101.11 per cow, while the upper 20 percent averaged $117.06 per cow.

The bottom line needs to have positive value. There is no question that there is difference in how producers capture value.

What drives the beef industry? Value of product should rank first, at least in the minds of the majority of producers.

Very often, the value of beef is distanced from the beef producer. The reason is simple. The value of beef does not occur until the customer buys and consumes the product.

In the case of the many additional products derived from the beef carcass, the various products are sold within each respective market. While the value picture is fuzzy at the producer level, value must follow back through the system to the producer.

Value of Beef Calves

Calves Sold and Transferred out of 119 Cow/Calf producers involved within the North Dakota Farm and Ranch Business Management Education Program

Upper 20%	$576.27
Average	$523.65
Lower 20%	$465.23

Based on value of calf sold per cow within the cow calf enterprise

If there is a message today, producers, at least some producers, are capturing more value, which in turn positively impacts the producer's gross margin. Given the costs involved in producing beef, producers must strive to maximize their gross margin.

As much as the word causes some consternation in the beef business, the word “premium” has been lamented and still is lamented as something that really does not exist in the beef business. For those producers who wish to continue to mourn over the lack of obvious premiums, there is a lesson in these numbers.

The market place does not treat all cattle equally. The value of cattle certainly is discovered at the auction barn and is being, at least in the cattle involved in the North Dakota Farm and Ranch Business Management Education Program, achieved for those producers who have managed to be a high-net-return-per-cow enterprise.

Perhaps there is a need for less discussion and more pondering while enjoying that cup of coffee. Considerable thought should be put into why some cattle are more valuable than others.

How can I, as a producer, not only produce those cattle, but also develop a marketing plan that will maximize dollar value?

May you find all your ear tags.

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BeefTalk 464: Ranching is a Balance Among Land, Grass and Beef

How much grass is available and how many cows can the ranch run?

Management generally implies input followed by discussion, decision and implementation. The amount of input generally reflects the seriousness of the topic.

Recently, the Dickinson Research Extension Center discussed the allocation of cattle resources. Believe me, everyone sat up at the table. Why?

Well, essentially, dear to the heart of every rancher is cows. Any discussion that may impact cow numbers is dear to the heart.

At the same time, the amount of available grass is just as critical because anyone in the "cow business" really is in the "grass business." Both are intertwined and often swapped back and forth.

Two critical questions crop up. How much grass is available and how many cows can the ranch run?

These questions can start a long discussion with considerable seasoning, depending on the year. This year's mood, a year with ample precipitation and grass, is considerably different than last year, which was a year with little precipitation and grass.

One thing became clear early in the discussion. There is excellent scientific data that allows for the evaluation of a ranch and the carrying capacity in regard to cattle numbers.

Gone are the days of guessing. There are newer programs and tools available to determine a pasture's carrying capacity or that of the whole ranch.

The computer has changed the ability to make decisions and the speed at which decisions can be made. One can find an "ecosite" description of land parcels through a process that certainly is simplified.

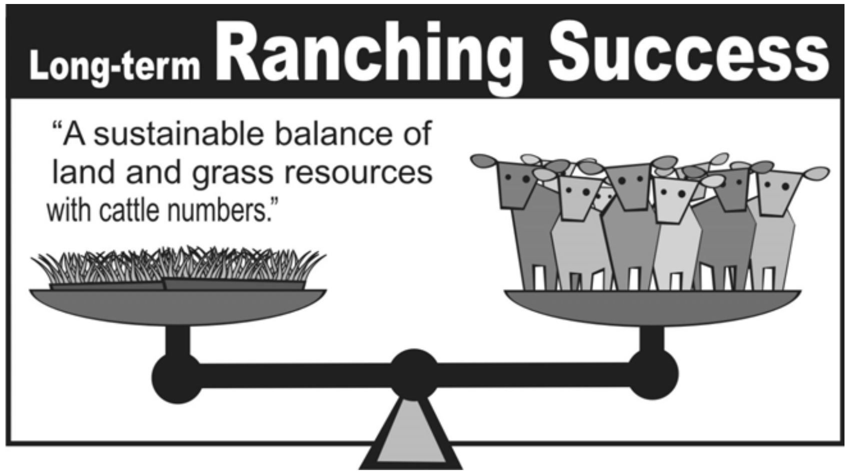
The center still has everyone sitting on the edge of his or her chair ready for input once the preliminary stocking rates are estimated. Sound science is the base of the estimates, but regardless of how sound the science is, when the output does not match the historical use, eyebrows are raised.

In the end, each ecosite, or one could say soil type, has only so much capacity to produce vegetation. The vegetation (which producers call forage) is produced only with timely precipitation.

Not all the production is available for consumption and, depending on past usage, not all the production has the same value. Having said that, the center, as with most producers, needs to evaluate and implement a base grazing system that places cattle on pasture for a desirable amount of time without having to move cattle excessively.

This is not a discussion of grazing systems but baseline carrying capacity so the appropriate cowherd size can be verified. The data reveals large variations within pastures.

Not all pastures are created equal. Each pasture is made up of productive and not so productive ecosites. The stocking rate for each individual site must be determined and then all the sites added to determine the number of acres per animal unit month (AUM) per pasture.



For instance, one section at the center has four pastures. The initial calculations for each of the four pastures are 46 AUM, 36 AUM, 43 AUM and 39 AUM. This is based on the initial evaluation of the ecosites per pasture for a total of 164 AUM for the section.

If the center is to utilize the section for 4.5 months, then the number of 1,200-pound cows and their calves that could run on the section would be 32 cow/calf pairs. Well, there go the eyebrows because the historical use of the section has been greater than that.

However, discussions will follow, additional input will be obtained and decisions will be made. In the end, getting a handle on cattle costs means getting a handle on a ranch's base unit, which is grass.

Everything except the grass is an add-on. Those add-ons carry with them additional expense.

The add-ons impact time, operations and the bottom line. They can mean more money spent and not more coming in.

Time will tell, but a sustainable balance of land and grass resources with cattle numbers is critical to the operation of a ranch. The discussion continues, so more later.

May you find all your ear tags.

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BeefTalk 465: 2009 Production Benchmarks Are In

In reality, the need is to grow profitable cattle that a producer can appreciate and still meet industry needs.

The new scores for beef cattle performance have just arrived. The scores are the annual North Dakota Beef Cattle Improvement Association (NDBCIA) benchmark values gathered from producers utilizing the CHAPS (Cow Herd Appraisal Performance System) program.

Since 1963, the NDBCIA has presented these annual evaluations as five-year rolling herd performance averages for several traits. The NDBCIA's purpose is the improvement of beef cattle by focusing on genetic improvement.

The association also is cognizant of the yearly management involved in beef cattle production. The benchmarks allow producers to compare their individual herd to the overall averages, allowing individual herd performance to be evaluated, discussed and, perhaps, methods of change proposed.

The comparison of numbers always needs to be done cautiously because we do not all walk in the same pair shoes. However, it is beneficial to know in which game we actually are playing. If we don't know what others are doing, we can stray.

Data trends also can be evaluated. In reviewing the yearly values for cow age, the cowherd is getting older. Calves are being weaned at an earlier age and at heavier weights.

Reproductive values are more positive. "Calf death loss" is down and "pounds weaned per cow exposed" still is holding above 500 pounds. That is good.

Growth and reproduction tend to be the mainstay of the beef business. Those involved in the NDBCIA CHAPS program excel. Growth, like in the feedlot business, is a major component of profit for the cow-calf producers.

The total pounds times the price contributes in a major way to the gross income. Cow-calf producers know good health programs are an integral part of reducing calf mortality and aiding in calf growth.

The bottom line dictates that cows make producers money by producing calves that have more value than expense. The value of the calf is determined principally by weight, but in contrast to the feedlot calf, the cow also must carry the burden of expense for cows that do not produce a calf.

While the open cow has a market value, the value will not cover the cost of replacing the cow. Therefore, each cow in the herd has to produce to cover her annual expenses and also the nonproducing cows.

The better the herd reproduction, the more likely the herd can cover expenses. As the NDBCIA evaluates traits to measure cow performance, "pounds weaned per cow exposed to the bull" is a trait that factors in both the management and genetics involved in a herd of cattle.

This is just an example of the many traits NDBCIA monitors through the use of the CHAPS program. Additional traits follow along with the current benchmark.

CHAPS 2009 Production Benchmarks	
Number exposed	218 cows
Average cow age	5.7 years
Pregnancy percentage	93.5%
Calving percentage	92.9%
Weaning percentage	90.9%
Calving 1st 21 days	63.9%
Calving 1st 42 days	88.9%
Calving 1st 63 days	95.6%
Average weaning age	189 days
Average weaning weight	565 lbs
Average frame score	5.8
Weight gain per day	3.01 lbs.
Pounds weaned per cow exposed	505 lbs.
Replacement percentage	15.7%
Culling percentage	14.6%

The average CHAPS producer exposed 218 cows to bulls. The cows had an average age of 5.7 years. Of the 218 cows exposed to the bull, 93.5 percent were pregnant in the fall, 92.9 percent calved in the spring and 90.9 percent weaned a calf in the fall.

During the calving season, 63.9 percent calved during the first 21 days, 88.9 percent during the first 42 days and 95.6 percent within the first 63 days of the calving season. On average, the calves were weaned at 189 days, weighed 565 pounds and had a frame score of 5.8.

These growth numbers translated into a 3.01-pound weight gain per day of age and a 639-pound adjusted 205-day weight. For every cow exposed, CHAPS producers weaned 505 pounds of calf.

Knowing these numbers allows for appropriate modification through management or genetics. There are no absolute answers to what a particular ranch should produce. The academic answer is optimization.

In reality, the need is to grow profitable cattle that a producer can appreciate and still meet industry needs. Each producer must answer the question, but the answer must be based on data that ultimately tells the producer if he or she is in the game.

May you find all your ear tags.

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BeefTalk 466: Four Points to Think About

Additional diligence in the current tracking systems certainly will cut down on the calves not accounted for.

Four things beef producers might want to think about are food safety, seamless regionalized calf-to-feedlot health connectivity, implementation of improved RFID (radio frequency identification) technology and value capture for the producer.

Realized or not, these four points have a significant impact on the beef industry. Producers want to maximize business options and maintain the flexibility to market their stock by utilizing methods that effectively capture value for the producer and enhance that value to all links in the beef industry.

For instance, as beef producers, food safety is our business. The industry needs to have adequate diagnostic capabilities and first responder teams that have the training, expertise and incident command structure. This includes daily integration of herd health and the application of animal health crisis intervention skills.

The ability to respond is critical to minimize the impact of a threat and requires essential networking by state and federal veterinarians, regional animal diagnostic laboratories and trained first responders with appropriate equipment, supplies and work force to detect, confirm, trace, fight and overcome the impact of harmful pathogens within the food chain.

One could put himself or herself in the cow's shoes. The cow looks and sees two cows drop next her, so she dials 911. Who is going to answer and respond?

A real challenge is the current mobility of beef cattle and the potential exposure. The dynamics of the beef industry today forces us to raise questions about herd health. Not only is maintaining acceptable herd health protocols critical, so is the implementation of programs that accommodate the flow of cattle from region to region while maintaining the national health of the herd.

The Dickinson Research Extension Center has implemented seamless regionalized calf-to-feedlot connectivity. Calves within a 200-mile radius of the center can be identified, health stamped with appropriate data tracking and value captured. Despite industry hesitation, this is the present, not the future. Industrywide acceptance to herd health must include value capture for the producer.

Improved methods that allow for the locating and finding of producer value are essential. New techniques, such as newer RFID technology, can help move the industry from the turtle to the hare. This technology needs to be explored to resolve much of the frustration that exists in the beef industry regarding animal identification and subsequent opportunity to return value to the producer.

This is not a mandatory versus voluntary discussion. Instead, it is a discussion that focuses much of the lost opportunity at capturing value for producers on relatively expensive processes that often times are difficult to verify. Such exercises have plagued the industry response, resulting in a relatively high degree of pessimism about future efforts.

Unfortunately, those in the industry who desire to capture value are stymied as well. The value discussion needs to focus on how producers can come to appreciate more the range in carcass value on the rail. The opportunity is evident in the value spread of carcasses or beef on the rail.

For instance, the current average on the last five lots of DREC cattle estimates the spread in carcass value at $165 from the low 20 percent to the upper 20 percent within each lot. That is a lot of money and will impact producers. Finding value is an internal question for producers.

However, the process of removing low-valued cattle in a commodity world that seeks cattle opportunity through “value added” still is troubling. Perhaps the discussion could center on capturing the upper end of value within the carcass. This opportunity pays the producer rather than adding value to low-valued carcasses, which is a value that is seldom returned to the producer.

The bottom line is we need real outcomes from thinking. Thinking creates thoughts that produce discussion. If our discussions reflect sensible means and judgment and sustainable actions that enhance our desire to be good stewards of our resources, we will find solutions that work. In the end, an outcome should be keeping a few more dedicated cow-calf producers on the land they so cherish.

May you find all your ear tags.

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BeefTalk 467: Why Are the Raspberries Still Here?

If we are going to feed the world, we at least need to engage the world.

In food production, things are never the same because many variables come into play on a daily basis.

The other day I noticed the raspberry bushes were full of raspberries. Most would say that they are supposed to be. However, the real answer is that the raspberries are not supposed to be there because the birds always eat them.

One could put bird netting on the raspberries to protect them and make a modest attempt to harvest them for eating. In the end, the wind seems to have a different opinion, so Mother Nature wins and the birds eat the raspberries.

The only thing gained by the netting effort is a dash of frustration not there before attempting to save the raspberries. As I stood eating the raspberries, I could not help but wonder just where the birds are.

There are a few more cats around. Last year's winter appeared to have killed off all the territorial tomcats. However, Mother Nature provided a new class of cats that are sleek and ready to hunt. In fact, one ran past the shop carrying a gopher the other day. The only remorse was that it was not a pocket gopher. Still, birds always seem to keep ahead of the cats.

The low temperature the other night was 39 degrees, so I had to take a quick glance at the calendar to remind myself it was still August.

Last year at this time, the cows were hungry and the main points of discussion were how to cull the herd before all the grass was gone. By year's end, the grass and many of the cows were gone. Probably the biggest regret was not selling more cows.

This year, it is still raining, the grass is plentiful and the hay is wet. The occasional dry day allows for rolling hay.

The next question will be: “How do I feed moldy hay?” The answer: “You don’t, at least not without a proper lab test to understand what living organisms inhabit your hay pile.”

Water does some interesting things. The greatest is the enhanced diversity of all living things. Life that seems to fade away in dry years remarkably reappears with the rain.

Anyway, I still don't know where the birds are, but anyone who actually knows how to put up hay will shine this year. In the big picture, food production takes a lot of experience.

Those neatly wrapped packages in the grocery store do not just appear. Food production takes a lot of experience.

It is the experience that we cherish and look for, but unfortunately it often is hard to find. How many times can a summer be different?

Very few summers are ever the same. The process of making a living out of each summer is complicated.

For the beef producer, the increasing challenge is to find time to mix and match all that Mother Nature throws our way, but still fulfill the expectation of the consumer who desires to pick up those neatly wrapped packages in the grocery store.

The expectation of the consumer is real. Just try working the counter of a quick-service restaurant and run out of a menu item. Mother Nature can be frustrating, but an irritated consumer can be downright mean.

Let's return to four things that as beef producers we should keep thinking about. The four are food safety, seamless regionalized calf-to-feedlot health connectivity, implementation of improved RFID (radio frequency identification) technology and value capture for the producer.

The world is changing. If we are going to feed the world, we at least need to engage the world. Perhaps that means giving a little, which also means we get a little.

Beef production makes sense. Eating beef makes sense.

We just need to make sense of a more complicated system that still does not know where the birds went. What really worries me is that too many of us did not even notice the birds were missing.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

BeefTalk 468: One Out of Five Is Not Good Enough

Additional diligence in the current tracking systems certainly will cut down on the calves not accounted for.

As fall approaches, producers are thinking about selling calves. This involves the associated management and health programs that go along with preparing calves for market.

The empty pens mean cows and calves are still on grass, but that will change soon. Speaking of change, things change a little each year a producer brings the calves to town.

This year is no different. Current topics center on animal identification, as well as other managerial and marketing thoughts.

As noted previously, four points emerge from these discussions. The four are food safety, seamless regionalized calf-to-feedlot health connectivity, implementation of improved RFID (radio frequency identification) technology and value capture for the producer.

One could ask if those thoughts are in order because they could be reversed, so returning value to the producer could be first. However, the order is quite dependent on who is in the room. Priorities for each segment of the beef industry are different, but the dollars are still competitive within the industry.

A few years ago, the Dickinson Research Extension Center began documenting the flow of cattle from one segment of the industry to the next in an effort to better understand the current state of the beef industry regarding electronic cattle identification and the ability to track cattle.

The research has yielded considerable data on tracing cattle. The center asked two questions. First, how effective is the current system to track cattle movement? Second, how effective will the electronic identification of individual calves be?

The center distributed 23,229 low-frequency tags. After the calves were tagged, individual producers conducted business as usual and the center's team initiated an extensive trace-back effort once the calves were sold.

Tracking involved extensive contact with producers, stockyards, brand offices, buyers, backgrounders and feeders. To date, the estimates of calf movement indicate that approximately 23 percent have been retained on the producer's place and are assumed to be herd replacements. (The center has not tracked cull heifers, cows or home harvest).

As these calves left the place of birth, the DREC research team estimated that more than 21 percent of the calves were traced all the way through to harvest so carcass data could be retrieved. More than 33 percent were traced to the feedlot, but the center was unable to trace the calves to the place of harvest. Just more than 8 percent only could be traced to the backgrounding facility. Just more than 14 percent were not traceable from the first point of sale.

The results have not changed much during the years of tracing. The principle point of loss was during the marketing process.

Accountability

23,229 calves recorded by the Dickinson Research Extension Center

Calves as replacements	23.1%
Calves with carcass data	21.3%
Calves traced only to feedlot	33.3%
Calves traced only to backgrounder	8.1%
Calves lost at frst point of sale	14.2%

Calves moved through or were commingled with larger groups of calves, so the ability to follow the calf to the next destination was not available or not recorded. The current systems for tracking cattle only are moderately effective. The systems are not 100 percent effective.

At what point additional tracking systems are required still is unknown. Additional diligence in the current tracking systems certainly will cut down on the calves not accounted for.

In the end, only one out of five calves returned carcass information to the producer. Although the reasons vary, the door remains open for producer frustration.

As has been noted before, the value discussion and subsequent return to the producer is real. The dollars just need to flow as is indicated with the range in carcass value at the rail. The opportunity is evident in the value spread at the farm or ranch gate and the rail.

We talk about value, but impact and opportunity never will be realized for the producer until, as a cattle industry, we measure what we want to improve, identify what we measured and market what we identified. One out of five is not good enough.

May you find all your ear tags.

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BeefTalk 469: Not All Land Is Created Equal

Land mapping process identifies potential forage production for all the individual ecosites to determine the number of acres needed to provide the nutritional requirement for a cow for a month.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Recent BeefTalk articles focused on bull buying simplicity. An estimate of the expected progeny difference (EPD) of a defined trait between two bulls of the same breed involves simple subtraction of the EPDs for the desired traits.

If a producer wants to compare bulls from a different breed, the EPDs need to be adjusted to a common breed. Then the same process will work. Add or subtract the EPDs from the desired bulls and then look at the EPDs for the bulls you have selected.

Imagine Bull One, with a yearling EPD of plus 113, and Bull Two, with a yearling weight EPD of plus 111. Mathematically, in a random mating, Bull One should sire calves 2 pounds heavier as yearlings, so the calves would be very similar in yearling weight.

Add Bull Three with a yearling EPD of plus 60. We still would expect that there would be an average difference in yearling weight of the progeny of 53 pounds in favor of Bull One.

The question is why this formula doesn't always work. Bull One's calves, as yearlings, probably will not be 2 pounds heavier than Bull Two. Bull Three's calves most likely will not weigh 53 pounds lighter than the yearlings of Bull One.

The simple reason, as noted above, is random mating, which implies no bias or conscious effort to select what cows get bred to each bull. In other words, the larger cows were not bred to Bull One and the smaller cows were not bred selectively to Bull Three.

Most people do not breed their cows randomly, which may be the primary reason the actual results of mating do not match the calculated EPD. The genes for the additional growth were distributed randomly across all the calves produced, but the calculations may not be able to substantiate the end result.

Another reason the calculated EPDs were not observed is the accuracy of the actual EPD value printed for the sire. For example, Bull One's printed EPD for yearling weight is plus 113, but in reality, although unknown, is plus 105.

This is the point where many producers hang up the sheet and go look at the bulls. These numbers are estimates based on the best set of actual data available.

The end result is the printing of a number that is used to predict the EPD. Selection by numbers also may mean that a producer has taken the time to at least attempt to understand the accuracy number that is printed alongside the actual EPD listed.

The accuracy number lists the probability that the EPD number is more likely to happen. Simply put, bulls that have accuracy values closer to one are more accurate than those bulls that have accuracy values closer to zero.

No estimated number is 100 percent accurate because the process intends to predict something that is not known. So, the more information (for example, the more number of offspring a bull has sired or the more ancestral information available) that is utilized in the process, the more accurate the end prediction is.

As end users of the numbers, we can be more comfortable in using bulls with accuracies closer to one because the number is more reliable. At this point, many will have quit reading this BeefTalk. The simple thought is that numbers are something the mind can play with for only so long.

That may or may not be true, but rest assured, even if one does not fully understand all the numbers that are printed in a sire evaluation, the basic principle is still true. Bull selection by the numbers is simple.

Understanding all of the numbers may create some head scratching. The important thing is to try to understand the numbers and don't let the overall lack of understanding get in the way of using EPDs. Good luck.Land mapping of "ecosites" in pastures is helping producers determine stocking rates. This mapping process identifies potential forage production for all the individual ecosites to determine the number of acres needed to provide the nutritional requirement for a cow for a month.

Did you know this process commonly is called acres per animal unit month (AUM) per pasture?

The process seems complicated, but times are changing. The concept of individual ecosites within a pasture and relative productivity is very real, so it is time to listen up and get with the program.

Life is a learning process. If one is not careful, one can spend much of life ducking these processes.

Regardless of how much each of us knows, there always is something else to learn. If our personal library is full, people who are more knowledgeable can be found because no one has a corner on all knowledge.

Those of us involved in beef cattle have more than likely fed beef cattle. We want to make sure we feed our cattle correctly. For those in charge of rations, the National Research Council (NRC) is referred to often.

The NRC publication contains the nutrient requirements of beef cattle through the many stages of development. The publication also is a guide to how those requirements might be met. Most nutritional sources go to great lengths to provide the best estimate of the expected value of the cattle feed.

For example, the NRC estimates the crude protein value of wheat straw at 3.6 percent and oat straw at 4.4 percent. Neither would meet the 7.7 percent daily protein requirement of a 1,300-pound mature cow during the last third of pregnancy. Astute cattle producers know a complete straw diet never will meet the nutritional needs of cows.

On the other hand, crested wheatgrass hay that is cut during full bloom has an estimated 9.8 percent crude protein value and would meet the nutritional requirements of the same 1,300-pound cow. In fact, crested wheat hay generally would meet the protein nutritional requirement for mature cows, except for the high-milking cows. In that case, more protein is needed.

One could go on regarding the nutritional needs of cattle. I prefer to return to the initial point that we can all keep learning.

Learn we shall. Just like the world of nutrition, modern technology has documented the many acres of land we ranch. Through the U.S. Department of Agriculture's Natural Resources Conservation Service (NRSC), considerable information is available on many parcels of land across the country.

A quick click on the Web at http://websoilsurvey.nrcs.usda.gov/app/ shows that "Web Soil Survey" provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA's NRCS and provides access to the largest natural resource information system in the world.

The Web site says, "NRCS has soil maps and data available online for more than 95 percent of the nation's counties and anticipates having 100 percent in the near future. The site is updated and maintained online as the single authoritative source of soil survey information."

What a great asset for those who make their living off the land. However, what is more important, by learning new techniques and processes, the land we farm and ranch becomes more like the straw and crested wheatgrass hay we talked about previously.

There are great differences on the productivity of the various ecosites within a farm or ranch. As the Dickinson Research Extension Center jumped on the learning curve, we discovered that native range pasture varies from 4.62 acres per AUM to 2.42 acres.

Keep in mind that one AUM assumes 30 pounds of dry-matter intake being consumed daily by a 1,000-pound cow for 30.5 days. However, just as cows cannot survive on an all-straw diet, they will not survive, nor will the land, on overstocked pasture.

Range Pasture Production Capacity

Dickinson Research Extension Center	
Pasture 1600	4.62 acres per AUM
Pasture 2805	2.42 acres per AUM

USDA Natural Resources Conservation Service

May you find all your ear tags.

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BeefTalk 470: Knowledge and Wisdom Should be the Goal

The heart of the issue is not the failings of systems that try their best to keep up with our expectations, but rather our demands in the first place.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

There are weeks where the pace of our lives overcomes the point of most discussions. We sometimes struggle finding what the point was. Some would say it's the pace at which we live, so get used to it.

While the pace is hectic, perhaps it is not very realistic. The other day, I had breakfast in Kansas City and traveled 600 miles to Denver for brunch. After that, it was another 600 miles to Dickinson for lunch and then 300 miles to Fargo for supper.

Some would say that is excessive, but the fact remains that such schedules are doable as those in business know.

At least for domestic travel, I am fully vaccinated, bunk broke, water trained and even have some age on me. However, I still ended up in the sick pen the next week.

Just like cattle, with a couple of days to recover, life goes on. Not only do we tend to move at a fast pace, the real challenge is that the expectations move into all that we do at the same (or faster) speed.

We expect our perception of the world to follow us, so that becomes the heart of our current dilemma. Recent news articles have been very pointed at a food industry that has tried and continues to try to meet the demands of a mobile, demanding client.

The heart of the issue is not the failings of systems that try their best to keep up with our expectations, but rather our demands in the first place.

When those around us simply don't understand during times like this, we really should ponder and realize that no matter what we do, there are only two outcomes. One outcome is based on reality and the other on perception.

In the case of beef, the matters are complicated by numerous systems of production that interact on a daily basis within a very horizontal industry. Many players do not need to, nor desire to, interconnect because their success is not determined by the success of the whole.

This is sad but true. It reminded me of the experimental methods in animal research class at Oklahoma State University. The late professor Joe Whiteman taught the class.

In a relatively loud voice, Whiteman instilled in us very quickly that the life we have is not something to be taken for granted. The many processes that we undertake to educate ourselves must be forthright, objective and well thought out.

In the end, do we challenge ourselves intellectually to seek better or do we simply except the status quo and survive? For mankind to benefit, knowledge must be obtained.

Knowledge is this vast amount of information that is preserved or stored within our culture that ultimately needs to be utilized for our benefit. The source of knowledge is science, a systematic process that records information.

The use of knowledge is called wisdom. In theory, with wisdom some good should come to us. Whiteman reminded us of two quotes.

The first quote was from Sir Francis Bacon and said, "Read not to contradict and confute, nor to believe and take for granted, but to weigh and consider."

The second quote was from Lord Byron and reads, "To be perfectly original, one should think much and read little, and this is impossible for one must have read before one has learned to think."

Well, the bottom line is one can quickly conclude there are many confused processes today that in reality, the proponents should have sat through professor Whiteman's class. However, he is not here to teach anymore, but that doesn't mean those who read cannot appreciate it.

In the end, we must be careful not to simply come to believe that how we live is how we should live. The reality is the fact that knowledge and gained wisdom would suggest differently.

May you find all your ear tags.

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Two Good Quotes to Ponder

Bacon - “Read not to contradict and confute, nor to believe and take for granted, but to weigh and consider.”

Byron - “To be perfectly original one should think much and read little, and this is impossible for one must have read before one has learned to think.”

From Beveridge, W.I.B. 1957. The Art of Scientic Investigation. Rev. Ed., W. W. Norton and Co. Inc., New York

BeefTalk 471: The Simpler the Better

If you want to know how much something weighs, weigh it.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

At one time, a tag and scale were all the tools needed to start a beef cattle production record system. The tag was placed at birth and the mother and birth date were recorded in the free notebook from the local livestock business.

Come fall, the calves were gathered up. The weights were written in the notebook and the calves were shipped.

Using this method, beef cattle record associations evolved. Many have become history, but others have gone on to advance the beef industry.

This simplicity is important to remember. Today's producers face a much more demanding world that is complicated by an array of acronyms or other assorted abbreviations and half-done directions.

Short, abbreviated words are good, but if the local vernacular (the spoken language) does not include the term, the abbreviated words become an obstacle to learning. However, it never hurts to learn, even if the process may seem somewhat frivolous.

In the world of beef, the newer DNA sciences are bringing us numerous terms that may be unfamiliar. It brings more frustration as one combines these terms with the many facets of age and source verification that interact with a multitude of different companies.

In the end, the phrase "the simpler the better" probably sums up the process best. There are so many new things popping like popcorn that it is difficult to keep things simple, but one should try.

In beef production, the principle trait is weight. The ability and/or time that it takes an animal to gain weight is an overriding factor in the business. The composition of that weight is important, too. However, the weight itself generally takes precedence, assuming that the cattle that are being weighed are typical, normal cattle.

The golden rule that continues to apply says, "If you want to know how much something weighs, weigh it." Weight is the foundation of any beef record system that is designed to improve production.

The early beef improvement groups formed the foundation and underpinning of data collection today. While the traits have expanded, the number of times a trait may be measured has increased and even a few new traits have arrived, but the calves still need an ear tag and scale to walk across.

The information is valuable, so the more documented records you have available for each cow, the better equipped you are to make bold, decisive decisions about culling, selection and mating systems. The managerial decisions you make today can have a huge impact on the future of your herd for many years to come.

As an aggressive cattle producer competing in today's complex beef market, you need to utilize all the tools available to reduce guesswork. This will add predictability to your herd performance. Various programs are available. For example, the North Dakota Beef Cattle Improvement Association developed CHAPS 2000 (Cow Herd Appraisal Performance Software) in the mid-1980s and still utilizes the program.

Commercial cattle producers are encouraged to keep the process simple. Those that have not been involved in a performance and managerial evaluation before need to make a giant leap and identify their cows and calves with an identification system of ear tags or freeze branding.

Once the cows and calves are identified, the minimum records for an effective program include cow and calf identification, cow age, calf birth date, calf gender and weaning weight and date.

While that seems simple, we all know that is not true. Cattle are difficult by nature, so trying to convince them to get on a scale and cooperate is another story.

However, now is the time to contact the North Dakota Beef Cattle Improvement Association or similar organization and send in all that good data that rests in the calving book.

If you did not keep a calving book, now is the time to make a resolution to get one for next year.

May you find all your ear tags.

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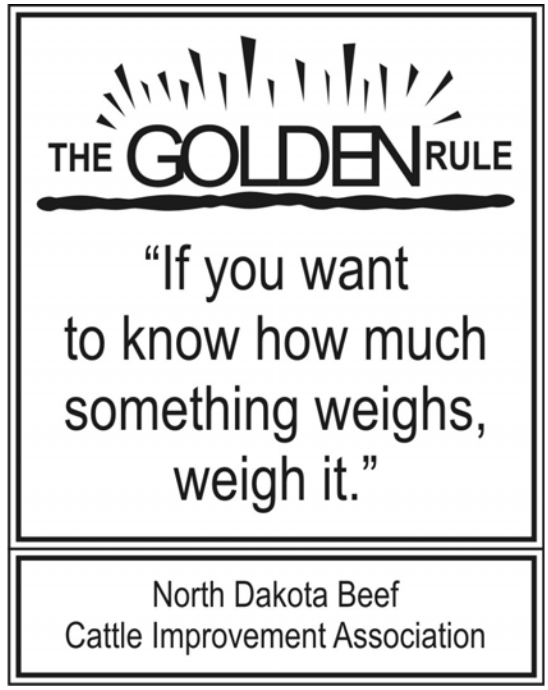

BeefTalk 472: Today's Market Preparation Begins with an Ear Tag

The process of preparing calves for market does not change the anticipation or remove the nervousness associated with marketing the annual calf crop.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Market and price are foremost in the minds of producers as they contemplate the fall roundup. The market watch can be nervy because market slippage can mean big dollars.

Producers cannot control the base market. Only the market's rise and fall are left for the producer. The market shifts can be muted with contracts and other selling options, but the anticipation, the good and bad, generally remains somewhat raw.

The focus on market product begins with getting calves ready to sell. Astute producers know market preparations began with breeding decisions because the type of calf for sale is a product of selected genetics.

Fall brings on the urgency of market preparation, which was initiated when an ear tag was placed in the calf at birth. Not everyone agrees, but market signals today point to opportunity for age- and source-verified calves.

The ear tag and calving book are today's starting point for marketing calves. Being able to present the calves as being age and source verified is a positive factor.

The calves also need to be preconditioned because preconditioned calves are the norm, not the exception.

At the Dickinson Research Extension Center, in response to the recommendation of our local veterinarian and in preparation for fall shipping, the standard protocol is to vaccinate the calves before spring turnout to pasture with a seven-way clostridial. This includes blackleg caused by clostridium chauvoei; malignant edema caused by clostridium septicum; black disease caused by clostridium novyi; gas gangrene caused by clostridium sordellii; enterotoxemia and enteritis caused by clostridium perfringens types B, C and D; and histophilus (haemophilus) somnus.

The calves also received a five-way viral product at turnout for infectious bovine rhinotracheitis, bovine viral diarrhea types I and II, bovine respiratory syncitial virus and bovine parainfluenza 3. Two to eight weeks prior to weaning, a booster vaccine is administered for clostridial/somnus and the five-way viral.

At the same time as the booster vaccination, calves receive their initial vaccination for Pasteurella Haemolytica-Multocida. These numerous vaccinations seem rather cumbersome and the names rather long and complicated, but with today's combined vaccines, the process is simple.

Many veterinarians and distributors can guide a producer to the appropriate health protocol that fits the local area. Once a proper vaccination protocol has been established for the calves, the desire to have bunk-broke calves that are quick to find water and feed on arrival are always in demand.

These calves adapt well and adjust to new feedlot conditions. Dumb, newly weaned calves have to learn what life means without mom. They do learn, but the learning curve is steeper and comes at a greater cost once the calves leave the home ranch.

The process of preparing calves for market does not change the anticipation or remove the nervousness associated with marketing the annual calf crop. Daily, weekly and monthly market swings make the annual sales event a crucial day in the life of a farm or ranch.

Perhaps the best advice is to group calves following proper preparation for the market and then market one set or group at a time. While the thrill of seeing all the calves trucked to the sale barn and sold is exciting, it might make better sense to partition selected groups of calves through a series of days and with specific markets in mind.

The bottom line remains. Calves will bring what the market needs, but no more or less.

Finding and presenting calves at their best won't hurt. Soliciting and letting a few extra buyers know the calves are coming can be helpful.

Also, there are some new players in the market. If your calves are appropriately age and source verified and packaged right, you are on the right side of the equation.

Remember, marketing calves starts with a calf book. If you don't have one, please call.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

Getting Calves Ready for Market?

– DON'T FORGET –

Market Preparation Starts When an Ear Tag is placed in the Calf at Birth

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

BeefTalk 473: Age and Source Verification

Age and source verification for meat and source verification for many more food products are management processes that seem to please consumers.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

In nature, fall brings a shift in focus. It is time to accumulate, evaluate and tabulate. For beef producers, gathering and marketing animals are front and center because the store is closing for the year, so come back next summer.

This is the time of year when life gets a little tougher. For many, the grocery stores remain stocked, which is the consumers' only view of food production.

In past generations, grandma stocked the root cellar, canned the summer's produce and added a few pullets to the hen house. Grandpa harvested the grain and started the calves, pigs or lambs on feed for winter meat.

Through the years, farms have increased in size and productivity, ultimately supplying our city cousins with a near endless supply of food. At the same time, people simply have forgotten where food comes from.

In the last decade, there has been a movement to reconnect the art of food production from the producer to the consumer. While the reasons may vary, this new dimension of agriculture is growing.

Age and source verification for meat and source verification for many more food products are management processes that seem to please consumers. While the connection back to the actual producer may be marginal, the knowledge about the food we eat brings some contentment to human well-being.

For beef producers, age- and source-verified cattle are earning premiums of $25 to $35 per carcass. The premiums vary depending on the program, but cash is being offered for ranch- or feedlot-verified cattle through to the packer.

Chip Poland, Dickinson Research Extension Center livestock specialist, and I start two days of each week teaching the cow-calf management class at Dickinson State University. The attitude of the 15 potential beef producers is reflective of the industry.

The struggle with the concept of premiums from age and source verification is real. The skepticism is not easily overcome because new programs require work and working cattle is never easy.

While additional money may be offered to the industry, there are many in the industry with their hands out. The cow-calf producer often is last in line.

The so-called premiums, if one wishes to call them that, seem to be thinner for those at the end of the line versus those at the beginning of the line. However, there is opportunity. With opportunity, the challenge of capturing more market share is real.

Unfortunately, business as usual must be set aside. For these 15 students and, we hope, other producers as well, a willingness to make the connection from producer to consumer needs to be approached. The process can be complicated or relatively simple.

The amount of the premium is dependent on the current demand that feedlots have to buy age- and source-verified cattle and the availability of properly age- and source-verified calves. Most markets will indicate a positive relationship between age- and source- verified calves and value, depending on the underlying worth of each producer's calves.

Calves doing poorly still are calves doing poorly, with or without age verification. Good calves always find their way to the top.

The only real way to grab the full premium is for the producer to retain ownership of the calves all the way to the packer. In that case, the packer will hand you the premium and all skepticism should end.

However, that means increased market risk. For many, $35 is not worth the retained ownership. However, for today, feedyards are looking, so why not age and source verify your calves and work diligently with your local sale barn to make sure all buyers are well aware of the quality of your calves and their eligibility for additional foreign markets?

It never hurts to brag a little while you sell your calves.

May you find all your ear tags.

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BeefTalk 474: Just Under the Floorboards

If one has ever dismantled an old home, lifting the floorboards can be quite interesting. Perhaps it is as simple as an old coin that rolled between the boards or a long-held stash of papers put there as a place to reside and eventually were boarded over.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

If one has ever dismantled an old home, lifting the floorboards can be quite interesting. Perhaps it is as simple as an old coin that rolled between the boards or a long-held stash of papers put there as a place to reside and eventually were boarded over.

The sad truth is that the value of the find, which was worthy of a special place when packed away, more than likely will be trashed.

Time is the trump card that determines value. If things under the floorboards are not retrieved at some appropriate time, the value may be missed.

For us in agriculture, there are days when it would seem easier to live under the floorboards and let the complications of our world pass us by. The business of the day could be observed by sound.

We could hear those engaged in the day-to-day business of feeding the world running overhead while we chose to live out of sight and out of mind under the floorboards. That may seem a bit eccentric, but in some cases it is true.

It is important to realize that if we choose to live under the floorboards, the rest of the world will speed by. The accessibility of the interaction with local markets, regional flavors and heritage foods are the cornerstone outlets for the products that may be served around the world.

Perhaps those who originally were involved do know the real flavor under the floorboards. However, remove one generation, seal the packet and add water upon opening and the generation once removed seems happy. We hope we can remember those special times and those special foods that didn't come from under the floorboards, but were that special meal that only home could serve.

Maybe the flavors were not flavors at all. The flavor came from the stories, the sights and smells of all that was around us, plus the right plates, cups and person at the table or in the chair. Oddly enough, the smell of turned soil as the potatoes were dug and the musty cellar as one retrieved canned beets actually embellished the pot roast, mashed potatoes, gravy and the side of pickled beets and cucumbers (commonly called pickles).

Likewise, bringing home a freshly hunted pheasant may seem like it takes a lot of prep work, at least until the meal is served topped with new memories. Maybe life under the floorboards is not all that bad.

Some may laugh and there are always those who have a new scheme, a new market and new need to travel somewhere. And that is all right.

But maybe, just maybe, many of our challenges are simply from the very speed at which we run. We comingle, mix, blend, stir and market.

We expand drive-through options, tighten the coffee lids, secure the cup holders and punch in driving directions. We charge the cell phone, expand data links and facilitate business and family operations as scheduled.

Maybe we simply ought to slow down. This is not a simple point and certainly not a point accommodated by the appointment desk. However, when it comes to agriculture, which translates into food, maybe flavor really does not exist. Instead, our food simply becomes what we are.

This is something to think about since pot roast and stew, one generation removed, is not pot roast and stew. However, I have to go because the trucks are coming and the calves are bawling. I need my flu shot (actually two of them), parent teacher conferences are scheduled and the world needs to be fed.

May you find all your ear tags.

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Our Food Becomes What We Are

Maybe the flavors were not flavors at all. The flavor came from stories, the sights and smells of all that was around us.

BeefTalk 475: Four Tons of Calf Is Not Easy to Give Up

Evaluate the cows, check the condition score and take steps to start improving the most likely problem, which is cow nutrition.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

The fall of the year is the time to make herd evaluations and managerial and nutritional improvements without fighting the weather. The key to understanding the overall performance of a herd is reproduction.

For example, the calving distribution of the herd is very important because delayed calving costs pounds. The calving distribution indicates how many cows calved within each 21-day period of the calving season.

The actual number of pounds lost due to later calving is critical. By viewing the average calf weight by 21-day calving periods, this lost income potential actually can be traced.

For example, let's compare two herds of cattle that calved in 2008 and restrict our discussion only to those cows that calved during the first, second or third 21-day period of the calving season. The first herd (herd A) has 186 calves during this 63-day period with 74.7 percent of the cows calving in the first 21 days. In other words, the cows bred well. The larger second herd (herd B) has 256 calves during this 63-day period, but only 42.5 percent of the cows calved during the first 21 days.

Is there a difference in these two herds? Obviously herd A is a tighter, more reproductively responsive herd. So what does this mean? One could evaluate actual weaning weight. However, even before overall improvement in calf weaning weight is discussed, a more serious problem is the pounds of weaning weight given up due to later calving.

In herd A, the more reproductively responsive herd, those calves born during the second 21 days of the calving season are 42 pounds lighter than those born during the first 21 days of the calving cycle. Those born during the third 21 days of the calving season are 86 pounds lighter than those born during the first 21 days.

In herd B, the herd with a more spread-out calving season, those calves born during the second 21 days of are 41 pounds lighter than those born during the first 21 days. Those born during the third 21 days of the calving cycle are 88 pounds lighter than those born during the first 21 days.

I realize that not all the calves can be born during the first 21 days of the cycle. However, the degree of effort put forth to keep cows calving early in your chosen calving season needs to be proportional to the amount of weight lost in the lighter calves. Regardless of herd A or B, both herds are giving up more than 40 pounds for every calf delayed into the second cycle and almost 90 pounds into the third cycle.

Adding this weight loss to the number of calves in each cycle, herd A gave up 1,680 pounds on 40 calves born during the second 21 days of the calving season, while herd B gave up a whooping 4,551 pounds on the 111 calves born during the second 21 days.

If one looks at calves born during the third 21 days of the calving season, herd A gave up 602 pounds on seven calves and herd B gave up an additional 3,168 pounds on 36 calves. Adding up the weight loss, herd A lost 2,282 pounds or 1,231 pounds per hundred calves, while herd B lost 7,719 pounds of calf or 3,045 pounds per hundred cows. Granted, the younger, lighter calves may bring more dollars per pound to help offset some of the losses, but they don't bring more dollars per head.

However, the overriding principle is one of pressure in a herd to keep the cows calving early with respect to the desired calving season. Each producer sets his or her calving date for the type of cows he or she wants to raise and then needs to review the herd's reproductive performance utilizing the calving distribution.

If you're not satisfied, evaluate the cows, check the condition score and take steps to start improving the most likely problem, which is cow nutrition. Doing it next spring after calving is too late. See your nutritionist because 4 tons of calf is not easy to give up.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

Delayed Calving Costs Pounds

Herd A — 186 calves	
Percentage of Cows Calving in the first 21 days of the calving season	74.7%
Pounds lost for calves born during the second 21 days of the calving season	42
Pounds lost for calves born during the third 21 days of the calving season	86
Total Pounds Lost	2,282
Herd B — 256 calves	
Percentage of Cows Calving in the first 21 days of the calving season	42.5%
Pounds lost for calves born during the second 21 days of the calving season	41
Pounds lost for calves born during the third 21 days of the calving season	88
Total Pounds Lost	7,719

BeefTalk 476: Starting From Scratch Should Bolster Confidence

Fairness and other market positioning often are expressed as frustration or confrontation rather than organized planning.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Recently, several individuals have pondered and shared their thoughts on how the beef industry might change. The reason for the change always varies depending on the particular perspective of those visiting.

However, there is a common thread that often perks through the conversation. That thread being the feeling or expressed thoughts that the rest of the world is pushing in one direction while individual producers are pushing in another.

Fairness and other market positioning often are expressed as frustration or confrontation rather than organized planning. The outcome of the conversations is varied. However, the general summation usually leaves things as they are, a little frustrated, but willing to go. That frustration is real as is the consequence of not being able to make the cash flow in the desired amount.

There is another underlying frustration that goes deeper than the fiscal outcome. That is a basic mistrust of those who partner with producers in the beef industry. The feeling is very evident in any discussion of marketing options that producers are asked to choose from and with whom they choose it.

There is no easy answer to any of these questions. I am reminded of a beef short course that was hosted by the Decatur County Feed Yard at Kansas State University a few years back. A principal reason for the short course was to allow producers to get a better understanding of this product we call “beef.”

As producers, if we undertake a journey to better understand our product, then perhaps some of those ingrained fears can be put to rest. Understanding our product is paramount. I, like all producers, periodically must renew and increase my knowledge about the carcass that is put on the rail, not the calf we sell.

Interestingly, I was able to track down a couple of Internet sites that are readily available and very informative. As I was paging through the short course notebook, a page was printed indicating U.S. Department of Agriculture market news. That page listed index values for beef carcasses, but more importantly, opened the door to another Web site (http://www.ams.usda.gov/mnreports/lm_xb459.txt) that noted national weekly boxed beef cutouts and cuts based on negotiated sales.

The page noted the value of the various beef cuts that were traded in the morning or afternoon. There also was a weekly summary and a weekly summary covering several years.

Lots of information was available, but lots of “Greek” notations as well. Thus, the need to learn, in particular, what were these IMPS numbers associated with the naming of the various parts of the beef carcass. Doing a search on the Web, IMPS stands for institutional meat purchase specifications. Through the USDA Agricultural Marketing Service, a description of all the IMPS numbers can be printed out or read on the Web site.

What is important is that the value of an individual carcass is contained in the knowledge of the various parts of the beef carcass and the associated value of each part. As I dusted off the old notebook, one of the steers that we studied was calf 67603. The calf was harvested with the fore quarter made into ribeye roll, short and back ribs, cap/wedge meat, chuck clod, boneless chuck roll, arm deep pectoralis, chuck tender, neck bones, outer and inner skirtsteak, boneless brisket, 50/50 trim, 90/10 trim, fat and bone. This gives us a total of 16 retail products.

From the hindquarter, 17 retail products were generated. They were: defatted tenderloin boneless short-cut strip loin, top sirloin butt, bottom sirloin butt/flap, bottom sirloin butt/ball tip, bottom sirloin butt/tri-tip, knuckle, top inside round, eye of round, bottom round flat, heel of round, flank steak, kidney, 50/50/ trim, 90/10 trim, fat and bone.

Maybe there is some reason for producers to be frustrated at the depth of the beef industry. However, when it comes to understanding the beef industry, comfort will come with knowing the pieces. If we can bolster our confidence in knowing that the value that moves its way through the beef world really is a summation of the values of the many individual products, perhaps formulating better relationships with industry partners will be easier.

$ $ Value of Beef! $ $

Great market news can be found on the USDA Web site. Go to:

http://marketnews.usda.gov/portal/lg

Click on National Daily Boxed Beef Cutout and Boxed Beef Cuts

Now back to the Web site to start gathering the value of box beef.

May you find all your ear tags.

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BeefTalk 477: Do You Know Your IMPS numbers?

Meat is not chunks of product chopped at random.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Understanding beef is critical to how we, as producers, obtain value in the industry. Are we getting back the value we have worked to produce through genetic and managerial inputs?

Are we simply selling calves and allowing that value to be dispersed to others? Are we getting our fair share of the value or are others taking advantage of us?

The answers are unknown. Considerable conjecture can be floated through most conversations as we seek to find what beef is truly worth.

Let's look at a forequarter of beef. I pulled out some data sheets and noted a steer simply called No. 2.

No. 2 calf was a short, blocky black steer that is typical of many fed steers across the country. The steer never won any blue ribbons or paraded around for many to see.

No. 2 was the product of an astute producer interested in converting grass to beef and meeting the demands of today's consumer. The steer weighed 1,375 pounds, with an estimated live weight minus 4 percent shrink of 1,320 pounds.

Shrink and pounds paid are another puzzling factor for producers, but it is real. From the moment the steer is sold, the only parts that count are what can be sold.

Shrink cannot be sold because no one is going to buy it. However, the 805 pounds of hot carcass weight No. 2 placed on the rail has value.

Let's start at the forequarter. In order to get a proper understanding, a good processor of beef needs to be contacted for the appropriate fabrication of the carcass into fresh beef products that correspond to the "institutional meat purchase specifications" (IMPS) numbers.

The forequarter of beef yielded 12.48 pounds of ribeye roll. The ribeye roll was IMPS item number 112A (beef rib, ribeye roll, lip-on). In other words, as described in the U.S. Department of Agriculture's IMPS documentation, a 112A is beef rib that is further processed from IMPS 108 (beef rib, oven-prepared and boneless) and IMPS 112 (beef rib and ribeye roll).

The proper description of IMPS 112 is a ribeye roll that includes the longissimus dorsi, spinalis dorsi, comlexus and multifidus dorsi muscles. The "lip" (serratus dorsalis and longissimus costarum muscles and related intermuscular fat) on the short plate side is removed. All other muscles, bones, cartilages, backstrap and the exterior fat cover also are removed.

In the case of IMPS 112A (beef rib, ribeye roll and lip-on), the "lip" is left attached on the short plate side. There is the possibility that one gets lost reading the descriptions, so read it again and again.

Meat, in this case fresh beef, is not chunks of product chopped at random. It is very select, properly fabricated portions of specific muscle or groups of muscle that are priced according to demand. Some cuts have less demand and bring less money. Other cuts or specific muscles have considerable demand and bring more money.

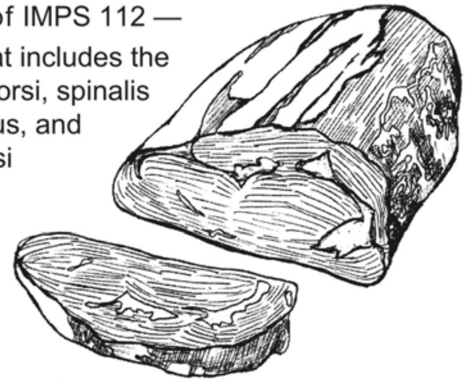
The rest of No. 2's forequarter yielded IMPS 124 (shortribs/back ribs), IMPS 109B (cap/wedge meat), IMPS 114A (chuck clod), IMPS 116A (boneless chuck roll), IMPS 116B (chuck tender), IMPS 121C (outer skirtsteak), IMPS 121D (inner skirtsteak) and IMPS 120 (bonelesss brisket).

In addition, the arm deep pectoralis was packaged along with neck bones and 50/50 trim, 90/10 trim, fat and bone for a total of 15 saleable retail products.

Now that the specific products from the forequarter have been identified, pounds and value can be added to obtain the overall value of the forequarter of beef from steer No. 2. Let's go back to the Web site and start gathering the value of boxed beef.

The truth is the value is in the pieces, not in the whole. However, we must understand the pieces first, so a review of the IMPS certainly would be in order.

Get to Know Your Ribeye Roll



Description of IMPS 112 — Ribeye roll that includes the longissimus dorsi, spinalis dorsi, comlexus, and multifidus dorsi muscles. The "lip" (serratus dorsalis and longissimus costarum muscles and related intermuscular fat) on the short plate side is removed. All other muscles, bones, cartilages, backstrap and the exterior fat cover also are removed.

May you find all your ear tags.

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BeefTalk 478: Collaborative Thought Is Better Than Competitive Strategy

Answers to survival in the beef industry will take collaborative thought, not competitive strategy.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Steer No. 2 was sold for $84.76 per hundredweight of live weight minus shrink (Oct. 23 six-state average price published by CattleFax). The steer weighed 1,375 pounds. Minus the 4 percent shrink, the steer's pay weight was 1,320 pounds, or $1,118.83.

Is this a fair price to whoever owns No. 2? The start of this discussion on calf value rests with the fairness. However, the question is complicated and fairness is only one piece of a very large equation.

Regardless, the owner of the steer got a check. To determine if the value is fair, the carcass has to be fabricated, the cuts labeled and appropriate value determined for each part and then added up for the value of the whole.

The value of these cuts can be determined by visiting http://www.ams.usda.gov/mnreports/lm_xb459.txt. This site is the national weekly boxed beef cutout and boxed beef cuts negotiated sales report from the U.S. Department of Agriculture's Agricultural Marketing Service. Other related Web sites can be accessed as well for other market values of the beef products, such as trim, and byproduct drop value.

No. 2 had 420 pounds of forequarter, which was fabricated into 14 products. The most valued cut was 25 pounds of ribeye roll at $126.78. The 46 pounds of boneless chuck roll brought $84.37.

There was $105.47 worth of fresh 50/50 and 90/10 processed trim. The total value of the two forequarters was $464.87.

No. 2 had 17 retail products from 372 pounds of hindquarter. They were defatted tenderloin, boneless short-cut strip loin, top sirloin butt, bottom sirloin butt/flap, bottom sirloin butt/ ball tip, bottom sirloin butt/tri-tip, knuckle, top inside round, eye of round, bottom round flat, heel of round, flank steak, kidney, 50/50/ trim, 90/10 trim, fat and bone.

The most valued cut was 23 pounds of strip loin at $94.81. This was followed by 13.3 pounds of defatted tenderloin at $93.51 and 39 pounds of top inside round at $65.15. The total value of the two hindquarters was $533.03.

Now with one bold move, we can add up the value of the 31 retail products fabricated from steer No. 2. The value of the two front quarters was $464.87 and the two hindquarters brought $533.03. This gives us a grand total of $997.90. That number should make beef producers ponder because somebody paid $1,118.83 for No. 2.

The obvious is not the obvious. For the entity that purchased the steer, the main fabricated cuts do not add up to the purchased value. Consumer willingness to purchase red meat comes up $120.93 short.

There are other parts of the beef that may seem small but are pretty important. These parts are what are referred to as the drop credit or the total value per hundredweight of byproducts produced from a beef carcass.

The drop credit as of last week was $8.33 per hundredweight of live steer. That means No. 2 had an additional value of 13.2 hundredweight of live weight, generating an additional $109.96.

As Eric Berg, North Dakota State University meat scientist, points out, "What most producers don't realize is packing plants rarely make money on the meat. Sure, they have to have that, but the profit margin is often driven by the 'drop credit' or value of products that typically are not utilized domestically but have value in the international market. There is an old saying in the meat industry that 'money is made in the basement of the packing plant.'"

Keep in mind that harvest and fabrication costs need to be added to the equation. The bottom line is that the beef business is tight for all concerned.

Understanding our product is critical to better knowledge of how value is obtained in the industry. The truth is that values of the pieces do not add up. Answers to survival in the beef industry will take collaborative thought, not competitive strategy.

May you find all your ear tags.

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BeefTalk 479: We Too Are Resting in Someone's Hand

Today there are more important things to do than the numerous processes we embark on in our daily routines.

[Editors: Kris Ringwall teaches at Dickinson State University along with being the Dickinson Research Extension Center’s director. Three DSU students recently died after the vehicle they were in went into a pond. In this week’s column, Ringwall reflects on life and death.]

By Kris Ringwall, Beef Specialist
NDSU Extension Service

There is a time to set aside the business of life and simply do. Even the best-run business, cattle or otherwise, cannot deny that, in the end, someone else is in control, regardless of who we are, and really does not ask for input.

What may seem like important notes in our daily lives and our definition of success simply may be tiny specks of irrelevant thoughts in the big picture. Many times we miss the important points until we get slammed with the realities of life and death.

We all cling to hope and, with each passing thought, there is no end, simply a continuation of hope. With that hope and the desire for a positive ending, the news of a tragic death literally shatters our inner core.

The fragile feelings fed by hope are released as despair and we cannot stop. None of us can escape the loss and emptiness of death.

Our lives will go on, but at this point and time, we simply exist. The realization of someone being absent is startling.

As one's mind wanders for some rational thought, normalcy departs. In its place, one is filled with a deep sense of wandering with a seemingly pointless destination. The present seems so raw, the future somewhat gone.

Our own hopes are gone and no matter where one looks, only emptiness looms. The need for reassurance remains. There are memories of good times and not so good times, but life does go on. Death never has been a stranger to the prairies.

Today there are more important things to do than the numerous processes we embark on in our daily routines.

Sure, our daily path remains, the first acquaintance only met with eyes, words left lost in fields afar. Finally, a resemblance of desire may surface, only to be tucked away in Northern silence. It seems safer that way, for what reason one does not know, but containment seems to be the need and so we do what we do.

Yes, a tough day. A day reflective of all that is and all that is not, but, fueled by the omnipresent, the day goes on. Unexpected death challenges us all to a self-examination as we continue the work of those who touched our lives.

My memory slips to a previous time, recalling a young, tragic death. I remember returning from the funeral and picking up an egg that was about to hatch.

Emerging from that egg was a new life, totally unknowing of the day's events. Earlier in the day, the youngster, with all its might, started breaking through from the only life it had ever known.

There was no reason. The youngster had been well cared for and all its needs met. However, the youngster kept on pecking. At first a crack, then a second crack, a split and finally a hole.

Through the hole came the most beautiful light the youngster had ever seen. So the pecking continued. With unending persistence, the youngster encircled the egg, with only faith that a better life existed on the other side.

As the outer shell began to give, the youngster stretched with the power of Samson. Gradually, the egg gave way in my hand. With toes clenching the large half of the egg, the youngster gave a final thrust and was free.

Blind, unending faith brought the youngster from the security of the egg to the vastness of a new world. In my hand, the youngster had no knowledge of how tough this life can be, but only a brightness of a new life that was ready, willing and able to secure tomorrow's future.

What were tears for me is morning dew to a youngster with nowhere to go but up. In each of our worlds, there are good things, but sometimes we need to look carefully and remind ourselves that each of us, too, not unlike the egg, is resting in someone's hand.

May you find all your ear tags.

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We Too Are Resting in Someone's Hand

BeefTalk 480: The Value of Beef: More Figures and More Headaches

A discussion was initiated as to where one should look to find out why the value that the producer receives for beef seems to be questioned. It goes without much discussion that this topic is complicated and difficult.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Recently, the data on a steer that was utilized in a previous demonstration was reviewed to help find an answer to the question. In summary, the 1,375-pound steer (steer No. 2) was priced at $84.76 per hundredweight of live weight minus 4 percent shrink (Oct. 23 six-state average price published by CattleFax). This set the live value at $1,118.83.

After adding up the 31 retail products fabricated from steer No. 2, the total came to $997.90. The value of the retail cuts came up $120.93 short, but was supplemented by $109.96 worth of drop credit, so, in reality, the carcass value was $10.97 below the purchased price.

So what happened? As Rob Maddock, North Dakota State University associate professor and meat scientist, points out, "Part of the answer is the dressing percentage was poor. Even accounting for cooler shrink of 2 percent to 4 percent of hot carcass weight, the animal appeared to dress around 61 percent."

When buying cattle live, dressing percent is a huge factor in determining profitability. Maddock did the math. "A 1,320-pound steer in average condition and with minimal mud should dress at around 63.5 percent for an 838-pound hot carcass, he said. The carcass will lose weight in the cooler. The average weight loss in a large plant is around 2 percent to 4 percent, which gives us a cold carcass weight of 805 pounds."

In this case, the total retail product was 792 pounds, which is 13 pounds less than the hanging rail weight.

Maddock went on to conclude that, "If the steer was above average and dressed closer to 65 percent, then the processor made money buying the steer live."

Following up on that point, the same steer could have been sold in the meat rather than live. That same week, this carcass on the rail would have brought $135 per hundredweight, or $1,086.75, for the hanging 805-pound carcass. Now, instead of being $10.97 short, the value of the retail cuts would be $21.11 greater than the purchase price. The $21.11 would be available to help offset the harvest and fabrication costs. This figure is more commonly called gross margin or the difference between the value of the product (revenue) and the cost of the steer.

One question that often is asked is what the current harvest and fabrication costs are for beef processors. After considerable searching, the answer was revealed at http://www.ams.usda.gov/mnreports/nw_ls410.txt. When one says considerable searching, there is little wonder why a producer may have a lot of frustration trying to account for the beef he or she sells. A simple search on the Internet will yield mind-boggling results.

For example, a search of "beef pricing" yielded more than 2.63 million hits. There is no need to feel frustrated because most everyone else is. Data overload, a delete key and we are back to just feeding the cows. However, the above site did hit pay dirt, and as of Monday, Nov. 9, the average processing cost per hundredweight of carcass was $12. So for steer No. 2, the fabrication cost would be estimated at $96.60. The per-head slaughter costs are estimated at $50.50 for a total harvest and processing cost of $147.10. The gross margin for steer No. 2 was pretty dismal at $21.11 and is not close to covering the additional cost above the value of the live steer in producing beef.

The point is, one steer does not indicate the state of the industry because the industry self-corrects on a daily bases. In other words, in order to stay in business, any logical businessperson will decrease the price paid for beef until the gross margin will cover the costs of harvesting and processing. Of course, when demand goes up and the price starts to move upward, optimism returns to all phases of the business. Both options exist in a free marketplace.

Right now, the best bet is to follow the numbers. The bottom line remains; the beef business is tight for all concerned.

May you find all your ear tags.

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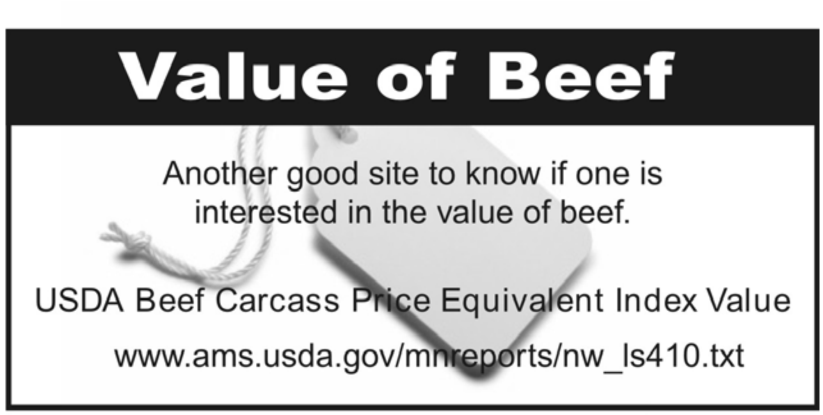


BeefTalk 481: With Every Ear Tag, There Should Be a Cow Attached

The utilization and incorporation of animal identification within a herd is best left as an individual decision.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

At a recent meeting, the only item on the agenda was to determine what to print on next year's ear tags. What made the meeting exciting were the new tags the printing was going on.

Animal identification is not new. North Dakota Beef Cattle Improvement Association members have been tagging (identifying) cattle since 1963. The Dickinson Research Extension Center has been conducting research on cattle tags for nearly a decade.

In reality, animal identification has been around since animals were domesticated and will continue as long as we own animals. As soon as the new family dog arrives at home, the discussion turns to naming the new pet, along with the purchase of a collar and tags.

In the beef industry, some will say that every tag should have a cow attached. However, not everyone will agree. In fact, some producers actually get a little irritated.

It is important to remember that the focus of the current public discussion is how animal identification is used, not in how animals are identified. Those are two separate issues.

The utilization and incorporation of animal identification within a herd is best left as an individual decision. In reality, there are many uses and reasons why ear tags are placed in cattle.

The ear tag is overlooked in the tool chest of cattle supplies. However, the ear tag is a critical component of a cattle operation. Tags are utilized for many routine management processes involving ranches and feedlots.

That is one of the reasons it is very difficult to keep tags on cattle. The ear runs out of room and something needs to go.

Watching from the fence the other day, I could see two larger tags that were very evident as the cows were walking past. Both tags had the cow's identification number.

After a closer look, the cow also had a steel clinch brucellosis vaccination tag, DNA tag, steel clinch ranch identification tag and a low-frequency RFID tag.

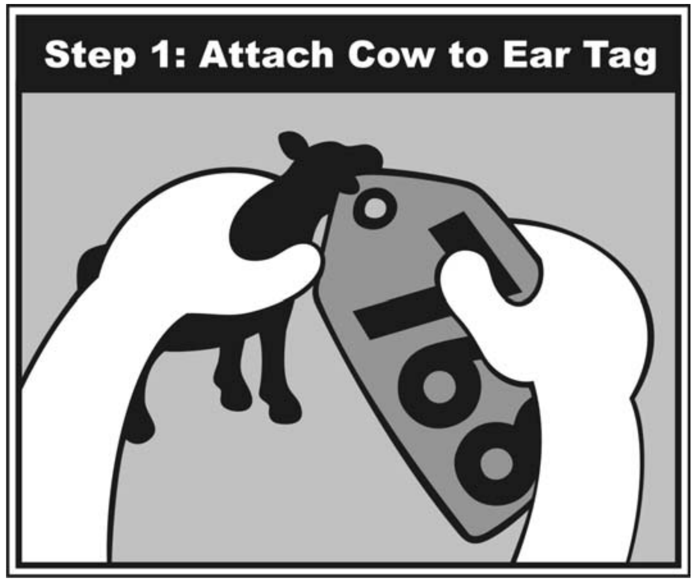
One could argue the cow was excessively identified. Perhaps that is the real root of the problem. There is a lack of any coordination or recommendations about the many competing branches within cattle systems. As cattle are monitored in one system, the movement of the same cattle to another system generally means starting over.

Plus, many ranches color code groups of cattle on a temporary basis and will place a plain, colored tag in the ear to ease tracking chute side. Tags of this nature allow for location monitoring of the cow simply by checking for colored tags in a pasture or pen.

Tags also are used to pair a cow and a calf by placing a tag on the calf that fits the ranch's tagging system at calving. Issues involving lost or miss-mothered calves can be resolved on the spot.

Ranchers who employ temporary help often have a simple system of color tags to keep cattle straight and reduce communication issues. The green tags going to pen four is a lot easier done than a list of numbers that need to be read.

It does not take long to realize that most livestock operations would struggle without a means to suitably identify individual animals. Plus, tags serve as a mechanism to control external parasites as well.



Future products that a tag may carry are unknown. The bottom line is that tags will be part of the livestock system and the importance of the tags will be paramount.

As was noted earlier, the meeting was held and we decided to go with a paired numbering of a five-digit number on the two tags. However, the numbering is not what makes this new tag exciting. More on that later.

In the meantime, a student asked me what I mean when I say, “May you find all your ear tags.” I simply said that he would know once he understands.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

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BeefTalk 482: Young Minds, More Questions

Virtually every segment of the industry lives on limited, small margins.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

How does someone reach out and make a living in the beef business?

There are many paths. Knowing which path will be the most profitable and fulfill one's dreams is difficult to predict.

Finding the value in beef production is difficult. Blaming or pointing fingers at segments in the industry is counterproductive. Virtually every segment of the industry lives on limited, small margins.

The difference between money going out and money coming in is small. As a result, efficiency and size are major components of many beef operations.

Dickinson State University offers a course in solving cow-calf management problems. Students are challenged to review their own and cooperating North Dakota Beef Cattle Improvement Association producer herds and develop improvement plans in each herd.

The process involves reviewing various management and operational activities in each ranch and then finding opportunities for improvement. These opportunities are defined as best management practices.

This is a great exercise for the student and producer, especially as one sits back and looks at the concerns of younger minds. As a start, students are challenged to identify potential issues and expand on thoughts behind these issues as they prepare to meet their mentor herds.

Students presented several questions, which is an indication of the diversity of managerial questions and potential answers that are posed to beef producers throughout the production cycle. What follows are the questions and a broad generic answer from the student who asked the question.

Why should one ear tag a calf? It is the bottom line that counts. If more money is not returned, then why ear tag or participate in the age and source verification of calves?

Why should a producer utilize more than one breed of cattle? Uniformity sells cattle and a uniform set of cattle is more easily obtained within a single breed.

Are your facilities ready for the upcoming winter? Herd facilities need to be weather- proofed, accessible and workable to ensure survival, regardless of the weather.

Why not eat locally grown beef? Local producers would benefit and it would be for the greater good of the community as well.

Are expected progeny differences (EPDs) the best way to select a bull? EPDs are an effective and accurate method to predict future offspring performance.

What is the future of the farm and ranch work force? Local community-based labor encourages a sense of community and strengthens the local economy.

What is the future of beef operations? The current trend is one of fewer, but larger, beef operations.

Should bulls have a breeding soundness exam? A preventative reproductive evaluation of bulls saves money in the future.

Should cattle be grass- or grain-fed? The answer is traditional; people like grain-fed beef, but grass-fed still remains a niche market.

Why perform a pregnancy evaluation on cows? Feeding open cows costs money with no return.

How is the best way to handle cattle? Cattle are not people, so producers need to learn and understand how cattle see and hear the world around them to be better cattle handlers.

Is there an advantage in raising natural beef versus traditional beef production? Although there is a niche market for natural beef, a substantial premium is needed to justify natural beef production.

How do I get more involved in a family operation? Generational changeover in any farm or ranch is difficult, but it starts with open, honest communication surrounded by realistic fiscal projections.

When Asked, What Do Young People Ask Within the Beef Business?

Why should one ear tag a calf?

Why should a producer utilize more than one breed of cattle?

Are your facilities ready for the upcoming winter?

Why not eat locally grown beef?

Are EPDs the best way to select a bull?

What is the future farm and ranch work force?

What is the future of beef operations?

Should bulls have a breeding soundness exam?

Should cattle be grass fed or grain fed?

Why perform a pregnancy evaluation on cows?

How is the best way to handle cattle?

Is there an advantage in raising natural beef versus traditional beef production?

How do I get more involved in a family operation?

There is no shortage of questions. The students explored and probed best management practices. In the end, the students slowly were absorbed into the reality of the beef business.

The answers to the questions were hidden in the scattered data that is seldom fully analyzed. The young minds were able to review old problems. New solutions to the old problems are always somewhere and need to be found.

Once found, old minds need to ponder and deal with an inescapable question. How does one implement young thoughts within old thinking?

Not easy, plus the new thoughts always must be seasoned with wisdom.

May you find all your ear tags.

Your comments are always welcome at http://www.BeefTalk.com.

For more information, contact the NDBCIA Office, 1041 State Ave., Dickinson, ND 58601, or go to http://www.CHAPS2000.com on the Internet.

BeefTalk 483: Understanding and Proactive Is Better Than Defensive and Average

One could conclude that given the extreme amount of variation within beef prices, it is futile to try to make sense of it. That would be wrong.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

Tracking the value of beef is interesting. No matter where one turns, there is considerable variation that results in a value spread.

This occurs to feeder calves, backgrounded calves or at harvest. On the rail, similar variations occur all the way to the box.

One could conclude that given the extreme amount of variation within beef prices, it is futile to try to make sense of it. Well, that would be wrong, but unfortunately, that is too often the chosen path.

It is unfortunate because when we choose to not pursue a further understanding, we tend to get defensive. Remember steer No. 2 that we sold a while back for $84.76 per hundredweight of live weight minus shrink (Oct. 23 six-state average price published by CattleFax)?

The steer weighed 1,375 pounds. However, with an estimated 4 percent shrink, the total came to 1,320 pounds. In other words, steer No. 2 returned $1,118.83 live.

Was this a fair price? The answer was in the average value of the 31 retail products fabricated from steer No. 2. The value was $464.87 for the two front quarters and $533.03 for the two hind quarters, which gave us a grand total of $997.90.

Given average prices, the steer sold for more than it was worth on the rail. However, an additional question could be asked about values based on the reported lows and highs for the week of Oct. 23.

The weekly boxed-beef sales report from the U.S. Department of Agriculture's Agricultural Marketing Service is the price basis. So, let's revisit the 420 pounds of forequarter for steer No. 2.

The forequarter was fabricated into 14 products. Based on the average price, the most valued cut was 25 pounds of ribeye roll at $126.79. However, the range of reported values was a low of $118.81 to a high of $143.77. The second greatest value was 46 pounds of boneless chuck roll that brought $84.37. The range in reported values was a low of $76.66 to a high of $92.08.

The total value of the two forequarters had an average value of $464.87. However, if one valued the forequarters at the reported low prices, the value would be $426.93. If selling at the reported high value, the price would jump to $512.92.

Of the 372 pounds of hindquarter, 17 retail products were generated. The most valued cut was 23 pounds of strip loin at an average price of $94.81. The low reported value was $88.01, while the high value came in at $108.52.

The second greatest value was 13.3 pounds of defatted tenderloin at $93.51. The low reported value was $87.91 and the high value was $108.85.

The total value of the two hindquarters was $533.03. The hindquarters had a low value of $496.41 and a high value of $587.92. The average value for the total carcass was $997.90.

The range in total product value would have been at a low of $923.34 to a high of $1,100.84. We only can guess at the price for each fabricated product.

If all the products sold based on the average reported price for the week, the buyer of steer No. 2 would be hard pressed to demonstrate a positive return on investment. The sum of the average value of the 31 fabricated products is less than the sale price.

Steer #2

Boxed Beef Prices — October 23, 2009

	Carcass Value
Low	$923.34
Average	$997.90
High	$1,100.84

Source: USDA Agricultural Marketing Service Archives www.ams.usda.gov/AMSv1.0/Marketnews

Some products actually sold for less, resulting in a potential loss of $74.56. However, there also was the opportunity that week to sell the fabricated cuts at an additional $102.94.

There is variation in all beef products. Understanding variation at the packer level, as well as our management and genetic programs is important. To access the top side of the beef market, is an important goal, but not always under our control.

In this case, once all the additional credits are added to the carcass value, steer No. 2 moves from the loss column to the profit column. Understanding and being proactive is better than being defensive and average. May you find all your ear tags.

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BeefTalk 483: You Got to Know When to Hold‘em, Know When to Fold‘em

As cow-calf producers, it is easy to be suspicious of the unknown, but it is a choice some make.

By Kris Ringwall, Beef Specialist
NDSU Extension Service

The deck is not stacked, but the cow-calf producer does hold a good hand. As producers, we have a choice when to “call” the hand and turn the reins over to the next segment of the industry. While some say producers are in the driver's seat, others say the producer of the calf or owner of the cow is at the bottom of the deck and has to take whatever is offered.

A discussion can be made for both positions. One common thread extends through both options, which is the need to better understand the complexities of the entire industry.

As cow-calf producers, it is easy to be suspicious of the unknown, but it is a choice some make. An experienced feedlot procurement specialist (cattle buyer) noted that a system of identifying cattle that will work and be efficient for the producer, feeder and packer requires considerable knowledge. In the end, many of us run out of time to take in all the knowledge needed.

The numbers add up quickly and the relationship between the numbers soon becomes overbearing. Most cow-calf producers turn to doing what they know best, which is producing calves. However, the question from last summer still nags us. How do we know if we are getting our fair share?

A good way to end the discussion relative to determining calf value is to listen to Tim Petry, NDSU Extension Service livestock marketing economist. Tim says the simple answer is supply and demand.

Tim says most packing plants have people whose job it is to sell the meat in the cooler. Demand for certain cuts can be very seasonal and very competitive because cooler space is limited. A new set of cuts will be arriving after the daily harvest.

On a daily basis, sales people will get a printout of what there is to sell and contact potential customers. The desire is to sell for the highest price, but the customer wants to pay the lowest price.

As with everyone involved in the beef industry, we negotiate. Tim goes on to explain that customers negotiate with several plants for the best deal. Large-volume orders may be accepted at a lower price. The large order could be a truckload of IMPS (institutional meat purchase specifications) 180 loin, strip, boneless, 0x1 versus just a box or two.

If sales is having trouble selling a particular IMPS cut (let's say IMPS 120A brisket, point/off, boneless) due to the season of the year or other factors, the sale people may negotiate to sell the customer a high-demand cut, such as an IMPS 112A rib, ribeye or boneless, right near the high end of the market, but then is willing to throw in the brisket near the low end of the market. In many cases, the high or low price is a very low volume trade, such as one box.

At the end of the day, the weighted average is closer to the market where most cuts are sold and the bottom and top of the range are unique trades related more to negotiations on specific orders. Welcome to the world of selling meat.

The bottom line is supply and demand. Sometimes that is hard to swallow. As producers, it seems like there is a lot of jostling in this business.

Eric Berg, NDSU meat scientist, noted that plants offer a bid price based on sale projections (demand) and compete with available supply. The meat plants need to make enough money to keep the lights on in a business that operates on small margins (sometimes pennies) within larger commodities of scale.

The beef business is not an easy business. Cow-calf producers may hold the reins in their hands, but as Kenny Rogers sang,"you got to know when to hold‘em, know when to fold‘em."

May you find all your ear tags.

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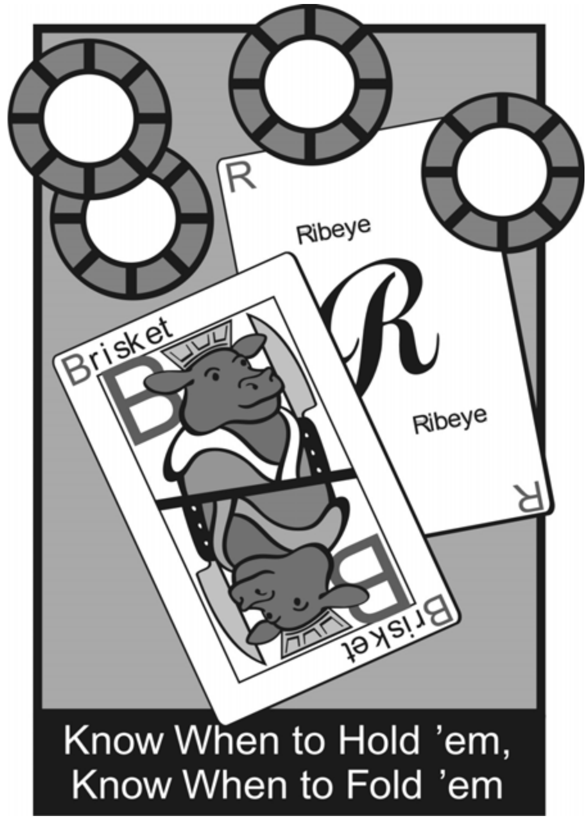


BeefTalk 467: Why Are the Raspberries Still Here?

If we are going to feed the world, we at least need to engage the world.

In food production, things are never the same because many variables come into play on a daily basis.

The other day I noticed the raspberry bushes were full of raspberries. Most would say that they are supposed to be. However, the real answer is that the raspberries are not supposed to be there because the birds always eat them.

One could put bird netting on the raspberries to protect them and make a modest attempt to harvest them for eating. In the end, the wind seems to have a different opinion, so Mother Nature wins and the birds eat the raspberries.

The only thing gained by the netting effort is a dash of frustration not there before attempting to save the raspberries. As I stood eating the raspberries, I could not help but wonder just where the birds are.

There are a few more cats around. Last year's winter appeared to have killed off all the territorial tomcats. However, Mother Nature provided a new class of cats that are sleek and ready to hunt. In fact, one ran past the shop carrying a gopher the other day. The only remorse was that it was not a pocket gopher. Still, birds always seem to keep ahead of the cats.

The low temperature the other night was 39 degrees, so I had to take a quick glance at the calendar to remind myself it was still August.

Last year at this time, the cows were hungry and the main points of discussion were how to cull the herd before all the grass was gone. By year's end, the grass and many of the cows were gone. Probably the biggest regret was not selling more cows.

This year, it is still raining, the grass is plentiful and the hay is wet. The occasional dry day allows for rolling hay.

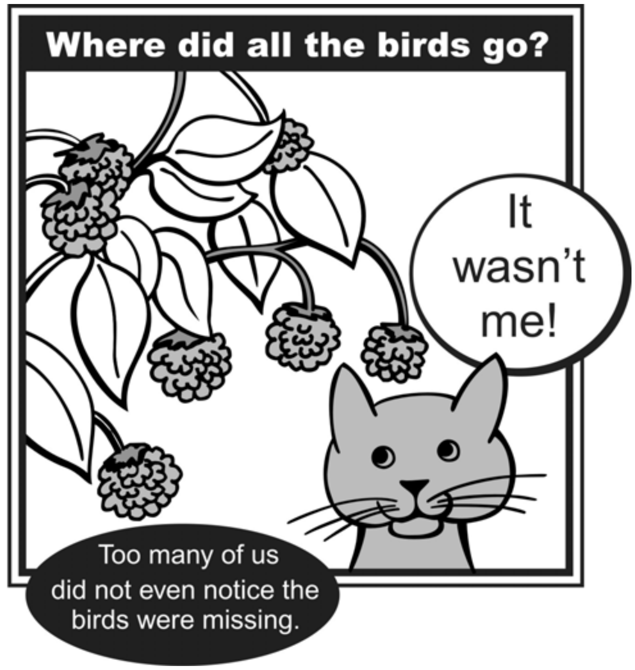
The next question will be: “How do I feed moldy hay?” The answer: “You don’t, at least not without a proper lab test to understand what living organisms inhabit your hay pile.”

Water does some interesting things. The greatest is the enhanced diversity of all living things. Life that seems to fade away in dry years remarkably reappears with the rain.

Anyway, I still don't know where the birds are, but anyone who actually knows how to put up hay will shine this year. In the big picture, food production takes a lot of experience.

Those neatly wrapped packages in the grocery store do not just appear. Food production takes a lot of experience.

It is the experience that we cherish and look for, but unfortunately it often is hard to find. How many times can a summer be different?



Very few summers are ever the same. The process of making a living out of each summer is complicated.

For the beef producer, the increasing challenge is to find time to mix and match all that Mother Nature throws our way, but still fulfill the expectation of the consumer who desires to pick up those neatly wrapped packages in the grocery store.

The expectation of the consumer is real. Just try working the counter of a quick-service restaurant and run out of a menu item. Mother Nature can be frustrating, but an irritated consumer can be downright mean.

Let's return to four things that as beef producers we should keep thinking about. The four are food safety, seamless regionalized calf-to-feedlot health connectivity, implementation of improved RFID (radio frequency identification) technology and value capture for the producer.

The world is changing. If we are going to feed the world, we at least need to engage the world. Perhaps that means giving a little, which also means we get a little.

Beef production makes sense. Eating beef makes sense.

We just need to make sense of a more complicated system that still does not know where the birds went. What really worries me is that too many of us did not even notice the birds were missing.

May you find all your ear tags.

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BeefTalk 486: Maybe We Should Slow Down and Ask for Directions

Perhaps now is the time to stop, ponder a bit and appreciate what we have.

As the year comes to a close, many thoughts come to mind. These thoughts are embedded with questions. What makes these thoughts unique for each person is a combination of time and place.

Questions for older or younger people are anchored at a different point in time. Of course, someone living in Argentina is going to view things differently than someone living in the United States.

We are products of our environment, locally anchored and educated. And then, from within ourselves, we each derive a concept of what should and what should not be.

We live differently. We eat differently. We even may have different fundamental values. There is little wonder that some days we find ourselves puzzled as we peek into the world but then return to our own safe havens.

The world is a good place, but the busyness of the world tends to drive us hard. Often, it is with an opinionated position that we envision to help those we encounter and ourselves. These encounters often are mixed with good and bad feelings. Nevertheless, the close of day tends to bring us some rest and feelings of accomplishment.

But the busyness does not end. With the passing of time, even our roots tend to start to be transparent and those anchors we cling to slowly disappear.

Perhaps now is the time to stop, ponder a bit and appreciate what we have, at least until the next train arrives.

I like to ponder a return to the barn that we have left. The old, large, red, hip-roofed barn was meant to shelter the obvious and the unnoticed.

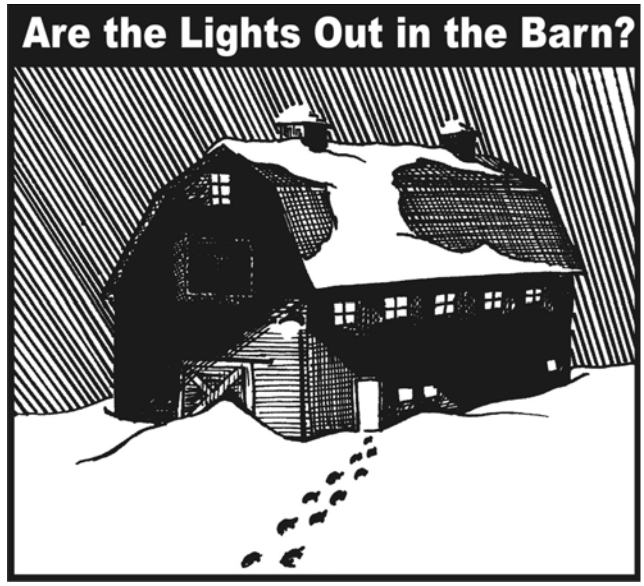
Perhaps the anticipation was heightened when, after a walk through cold, blowing winds and significant snow, the barn doors brought a sense of welcome. There were 12 cow stanchions and, when filled, each cow quickly would look and then return to what cows do, which is eat and chew their cuds.

The horses were stalled on the other side of the barn, with various calves penned throughout. Add in some cats, a dog, maybe a guest or two and that was pretty much the barn.

Other livestock had their quarters, but the barn was the hub. Morning and evening brought the buckets for milking, setting the daily schedule of cleaning the gutters, feeding the cows and all the other chores that needed to be done.

The day would end when all the chores were done. When we heard mom ask if the lights were out in the barn and the answer was yes, we knew supper soon would be served. Evening did not arrive until the barn lights went out and all were settled.

Those times were tough, too, and hardships were more average than rare. Modern times have allowed for certain hardships to lessen with the more food that is produced.



Yes, the work is still there, but it is different. The barn no longer has the cows and no one waits for the lights to go out.

The busyness remains. Production agriculture is more productive and there are fewer daily chores. Where did all this busyness go?

The answer will not be in tomorrow's paper or the next or even next week's. Until we figure things out, we should hope that somewhere there remains a barn with a stable waiting for new life.

This barn, when the door opens, will find the cows passing the time between feedings by quietly rechewing the current meal and trying to get comfortable. These cows will stretch their necks in anticipation of another feeding but quickly settle again with no concerns.

Perhaps that is why we need to pause as our year ends to ask some questions, take time to ponder the answers and, above all, look for the stable with a manger.

There is so much we do not know. Maybe we should slow down and ask for directions.

May you find all your ear tags.

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Report on North Dakota SARE – 2009

Frank Kutka, North Dakota SARE Coordinator and DREC Assistant Director

All in all 2009 was a very busy and successful year for SARE in the Dakotas. Representatives from SDSU decided to pull out of the two-state arrangement which we have had for many years, so some of the work this year was to help get the South Dakota program up and running and to finish joint efforts for the two states. Here is a list of activities I undertook to promote the SARE Program in the Dakotas in 2009:

Updates of Dakota SARE website

Forwarding SARE news releases across the Dakotas

Answering emails and telephone calls concerning SARE grant and information opportunities

Answering emails and telephone calls concerning SARE grant applications

Monthly SD NRCS professional development program calls

Burleigh County Soil Conservation District Soil Health Workshop

Northern Great Plains Research Laboratory Customer Focus Group Meeting

Booth and programming assistance for NPSAS Winter Conference in Huron, SD

Cover Crops presentation in Williston, ND

Presentation and display at Indigenous Farming Conference in Calloway, MN

Programming assistance for Sitting Bull College Sustainable Agriculture Conference (cancelled due to weather)

Science Fair regional championship judge in Bowman, ND

SARE presentation to west region Extension educators in Dickinson, ND

SARE update for Extension Specialists via IVN from Dickinson, ND

Sustainable Ag and SARE presentation to Farm Business Management program educators in Bismarck, ND

SARE R and E grant discussion in Watertown, SD

North and South Dakota SARE meeting with Gary Lemme, the new SD Coordinator, in Jamestown, ND

SARE display and presentation at Unity Conference in Fort Yates, ND

SARE representative on local food panel in Bismarck, ND

SARE update for SDSU Extension Ag educators in Pierre, SD

SARE Native American Sustainable Agriculture Grant discussion in Bismarck, ND

SARE Native American Sustainable Agriculture Grant discussion in Fort Yates, ND (twice)

SARE Native American Sustainable Agriculture Grant discussion in New Town, ND (twice)

SARE Native American Sustainable Agriculture Grant discussion in Sisseton, SD

SARE Native American Sustainable Agriculture Grant discussion in Belcourt, ND

SARE presentation at NDSU Organic Field Day

SARE representative on NPSAS research and education committee and program committee

SARE presentation at NPSAS/NRCS organic farm tour in Selby, SD

SARE display at Tristate Meat Goat Conference in Fargo, ND

No-till garden presentation at NDSU Extension Conference in Fargo, ND

Sustainable Agriculture presentations at SDSU in Brookings, SD

Youth and Youth Educator Grant Reviewer and Technical Review Panel participant

The SARE Sustainable Agriculture Workshops at Tribal Colleges Initiative did not get as far as desired in 2009 due to bad weather and also staff turnover at NDSU and the Tribal Colleges. Activities are falling into place in 2010 to achieve those goals, but there were some good outcomes already in 2009. Meetings in Fort Yates allowed me to connect NPSAS and SD NRCS with Ron Brown Otter, a successful cattleman who is investigating organic beef and improved forage management in northern South Dakota. He spoke at a tour NPSAS put on for SD NRCS.

Assistance to the Soil Health Workshop for Vo-Ag teachers was in the form of facilitation among speakers and organizers of the Bismarck meetings. Books ordered to be provided as the background for teachers who will be presenting soil health concepts to students will arrive in their hands at their March 2010 conference. An exciting outcome of this effort was both the SARE Youth Educator grant to Marcus Lewton which helped him to organize this program and also the posting of Kris Nichols' soil health activities packet on the national FFA website. This packet is also the basis for the new 4H Soil Health Activities Trunk that will be presented at the 2010 Extension Spring Conference.

The Organic Agriculture Initiative attracted two educators with travel assistance to attend the NDSU Organic Field Day and they learned a great deal. (Some of the educational materials that would have gone to other attendees have gone to SD NRCS and other NDSU Specialists.) The organic field day July was moved indoors but still brought in 208 attendees from North Dakota and across North America. That was an exceptional turn out and great exposure for both NDSU and the DREC. The organic field day was a joint effort between NDSU, the Northern Plains Sustainable Agriculture Society, and the North Dakota Organic Crop Improvement Association. I facilitated informal programs the evening before and I also spoke about SARE Farmer Rancher Grants during the program. Pat Carr, NDSU, and Marilyn Isaacson, NPSAS, were the critical organizers whom I assisted. Outcomes included discussions on a partnership of a Mexican Maize improvement program with NDSU's Marcelo Carena, new ideas about reduced tillage presented to ND organic farmers, and a greater connection between two NDSU Extension Agents and the organic research community.

The New Audiences Initiative did reach two young educators with funds to attend the CSA and Greenhouse Management Workshop held at FARRMS in Medina in fall of 2009. Remaining funds will be spent on a tour for interns in 2010.

Funds for earlier SARE initiatives funded an amazing amount of work in 2009. Nine mini-grants supported workshops and field days on straw-bale construction, small acreage management, testing forage for nitrate, value added marketing of grains, soil health, winter feeding options for livestock, the place of nutrition in sustainable agriculture discussions, a soil health workshop for agriculture teachers in SW ND, and a gardening/local foods program in NE ND. Travel scholarships covered the travel of twenty six educators to attend programming across a range of topics. Some of these opportunities have already resulted in new regional contacts, the development of new programs, and support of new bulletin development.

Monthly Inventory for DREC Cows 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
Females	261	261	261	257	249	249	249	248	248	248	241	197	2969
Males	15	15	15	22	29	30	36	35	24	21	21	20	283
Purchased Females													0
Value $													$0
Purchased Males			7	7	1	6							21
Value $			$12,600	$17,390	$1,700	$12,500							$44,190
Transferred In Females												78	78
Value $												$7,566	$7,566
Transferred In Males													0
Value $													$0
Butchered Females													0
Butchered Males													0
Sold Females			4	8						7	44	1	64
Value $			$2,457	$5,113						$3,877	$42,151	$750	$54,348
Sold Males								11	3		1		15
Value $								$11,655	$2,583		$602		$14,840
Transferred Out Females													0
Value													$0
Transferred Out Males													0
Value $													$0
Females Died							1						1
Males Died							1						1
End Female	261	261	257	249	249	249	248	248	248	241	197	274	249
End Male	15	15	22	29	30	36	35	24	21	21	20	20	
Animals to Weaning	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**Totals**
First of Month		0	11	105	226	238	238	237	211	211	71	0	1548
Purchased													0
Weight													0
Value $													$0
Born		13	106	128	12								259
Transferred In													0
Weight													0
Value $													$0
Sold													0
Weight													0
Value $													$0
Butchered													0
Weight													0
Value $													$0
Transferred Out							1	24		140	70		235
Weight							506	12,106		81,457	45,354		139,423
Value $							$541	$12,953		$78,526	$42,732		$134,752
Died		2	12	7				2			1		24
End of Month	0	11	105	226	238	238	237	211	211	71	0	0	1548

Monthly Inventory for DREC Backgrounding Calves 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
First of Month	0	0	0	0	0	0	0	0	24	24	71	101	220
Purchased													0
Weight													0
Value $													$0
Born													0
Transferred In								24		47	54		125
Weight								10,804		26,289	33,462		70,555
Value $								$11,344		$26,144	$33,529		$71,017
Sold												5	5
Weight												2,450	2450
Value $												$2,254	$2,254
Butchered													0
Weight													0
Value $													$0
Transferred Out											24	72	96
Weight											15,074	47,691	62,765
Value $											$14,855	$45,306	$60,161
Died													0
End of Month	0	0	0	0	0	0	0	24	24	71	101	24	19

Monthly Inventory for DREC Replacement Heifers 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
First of Month	149	149	149	149	217	210	209	210	205	205	245	223	2320
Purchased				69									69
Weight													0
Value $				$47,253									$47,253
Born													0
Transferred In							1			93	16		110
Weight							506			55,168	10,096		65,770
Value $							$541			$52,382	$9,203		$62,126
Sold					7			5		53	37	34	136
Weight					3,865								3,865
Value $					$3,230			$2,842		$38,231	$33,953	$35,125	$113,381
Butchered												1	1
Weight													0
Value $													$0
Transferred Out												78	78
Weight													0
Value $												$7,566	$7,566
Died				1		1					1		3
End of Month	149	149	149	217	210	209	210	205	205	245	223	110	187

Monthly Inventory for Heifer Development 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
First of Month		0	0	0	0	0	0	0	0	0	0	0	0
Purchased													0
Weight													0
Value $													$0
Born													0
Transferred In												97	97
Weight												61,288	61,288
Value $												$54,424	$54,424
Sold													0
Weight													0
Value $													$0
Butchered													0
Weight													0
Value $													$0
Transferred Out													0
Weight													0
Value $													$0
Died													0
End of Month	0	0	0	0	0	0	0	0	0	0	0	97	7

Monthly Inventory for DREC Decatur Feedlot Cattle 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
First of Month	149	149	148	145	123	65	10	0	12	12	12	36	861
Purchased													0
Weight													0
Value $													$0
Born													0
Transferred In								12			24	72	108
Weight								6,034			15,948	47,691	69,673
Value $								$6,336			$15,127	$45,306	$66,769
Sold				21	58	55	10						144
Weight				59,059	72,364	55,288	11,980						198,691
Value $				$25,379	$64,511	$57,707	$10,676						$158,273
Butchered													0
Weight													0
Value $													$0
Transferred Out													0
Weight													0
Value $													$0
Died		1	3	1									5
End of Month	149	148	145	123	65	10	0	12	12	12	36	108	75

Monthly Inventory for DREC Horses 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
Females	14	14	14	13	3	3	3	3	3	3	3	3	79
Males	1	1	1	0	0	0	0	0	0	0	0	0	3
Purchased Females													0
Value $													$0
Purchased Males													0
Value $													$0
Transferred In Females													0
Value $													$0
Transferred In Males													0
Value $													$0
Butchered Females													0
Butchered Males													0
Sold Females				10									10
Value $				$500									$500
Sold Males			1										1
Value $			$60										$60
Transferred Out Females													0
Value													$0
Transferred Out Males													0
Value $													$0
Females Died			1										1
Males Died													0
End Female	14	14	13	3	3	3	3	3	3	3	3	3	6
End Male	1	1	0	0	0	0	0	0	0	0	0	0	
Animals to Weaning	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**Totals**
First of Month	11	0	0	0	0	3	3	3	3	3	3	3	32
Purchased													0
Weight													0
Value $													$0
Born					3								3
Transferred In													0
Weight													0
Value $													$0
Sold													0
Weight													0
Value $													$0
Butchered													0
Weight													0
Value $													$0
Transferred Out	11												11
Weight													0
Value $	$7,975												$7,975
Died													0
End of Month	0	0	0	0	3	3	3	3	3	3	3	3	24

Monthly Inventory for DREC Yearling Foals 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
Females	14	0	0	1	1	9	9	9	9	9	9	9	79
Males	3	2	2	3	3	3	3	3	3	3	3	3	34
Purchased Females													0
Value $													$0
Purchased Males													0
Value $													$0
Transferred In Females	4		1		8								13
Value $	$2,900		$725		$5,800								$9,425
Transferred In Males	7		1										8
Value $	$5,075		$725										$5,800
Butchered Females													0
Butchered Males													0
Sold Females													0
Value $													$0
Sold Males													0
Value $													$0
Transferred Out Females	18												18
Value	$13,050												$13,050
Transferred Out Males	8												8
Value $	$5,800												$5,800
Females Died													0
Males Died													0
End Female	0	0	1	1	9	9	9	9	9	9	9	9	10
End Male	2	2	3	3	3	3	3	3	3	3	3	3	

Monthly Inventory for DREC Foals at Fargo 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
Females	2	20	12	8	8	0	0	0	0	0	0	0	50
Males	0	8	3	0	0	0	0	0	0	0	0	0	11
Purchased Females													0
Value $													$0
Purchased Males													0
Value $													$0
Transferred In Females	18												18
Value $	$13,050												$13,050
Transferred In Males	8												8
Value $	$5,800												$5,800
Butchered Females													0
Butchered Males													0
Sold Females		8	3										11
Value $		$950	$1,620										$2,570
Sold Males		5	2										7
Value $		$500	$120										$620
Transferred Out Females			1		8								9
Value			$725		$5,800								$6,525
Transferred Out Males			1										1
Value $			$725										$725
Females Died													0
Males Died													0
End Female	20	12	8	8	0	0	0	0	0	0	0	0	5
End Male	8	3	0	0	0	0	0	0	0	0	0	0	

Monthly Inventory for DREC Geldings and Draft Horses 2009

1st of Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Totals
Gelding	6	6	6	6	6	6	6	6	6	6	6	6	72
Draft	5	5	5	5	5	5	5	5	5	5	5	5	60
Purchased Geldings													0
Value $													$0
Purchased Draft													0
Value $													$0
Transferred In Geldings													0
Value $													$0
Transferred In Draft													0
Value $													$0
Butchered Geldings													0
Butchered Draft													0
Sold Geldings													0
Value $													$0
Sold Draft													0
Value $													$0
Transferred Out Geldings													0
Value													$0
Transferred Out Draft													0
Value $													$0
Geldings Died													0
Draft Died													0
End Geldings	6	6	6	6	6	6	6	6	6	6	6	6	11
End Draft	5	5	5	5	5	5	5	5	5	5	5	5	

Region 4 West ND

Farm/Ranch Business Management Education

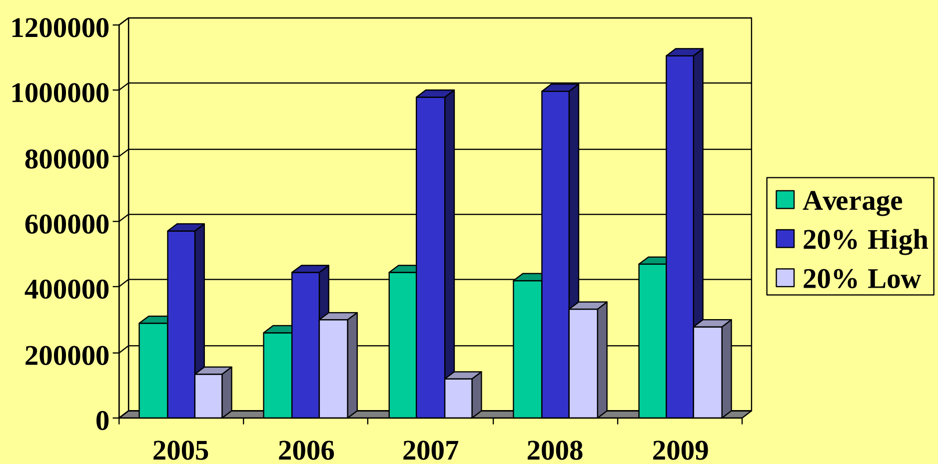
Year 2009

Jerry Tuhy, Instructor

Bismarck State College at DREC

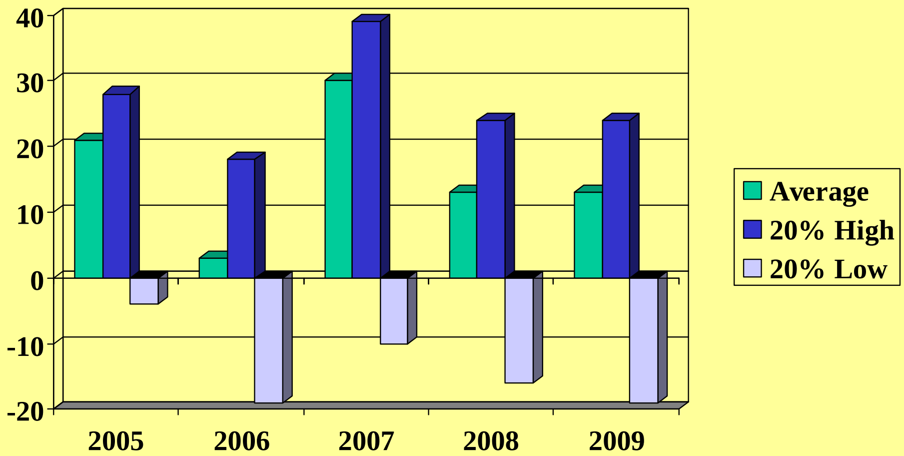
Gross Income (Accrual)

Per farm for year

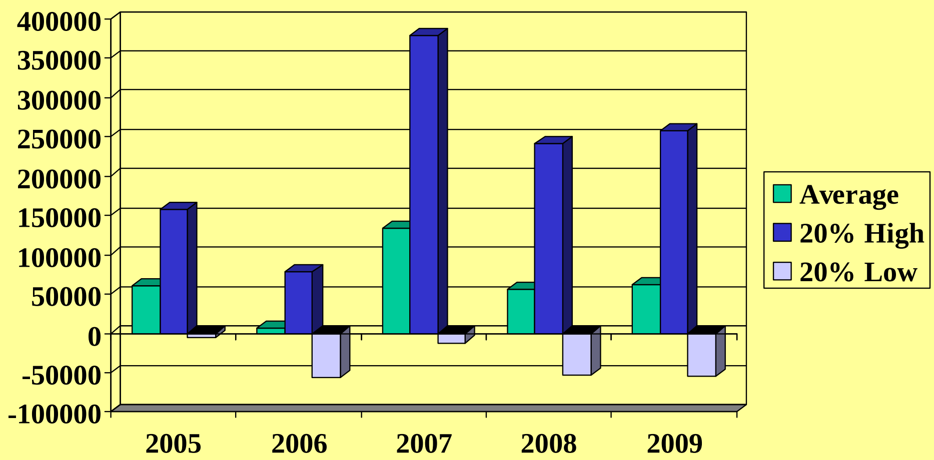


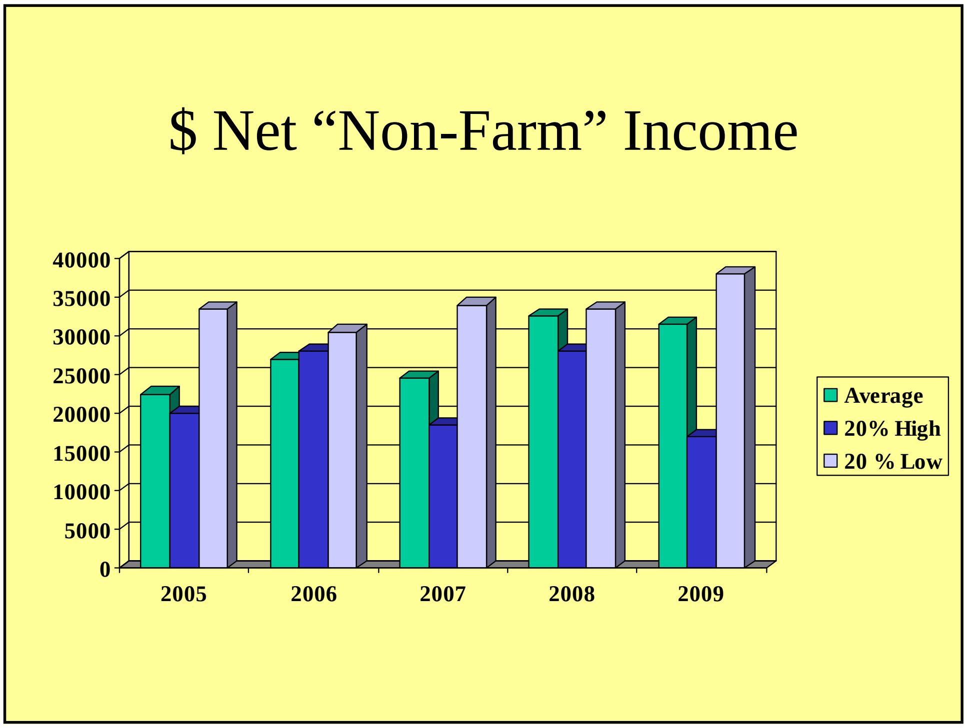
Net Income Ratio (%)

percentage of gross $ that is net $

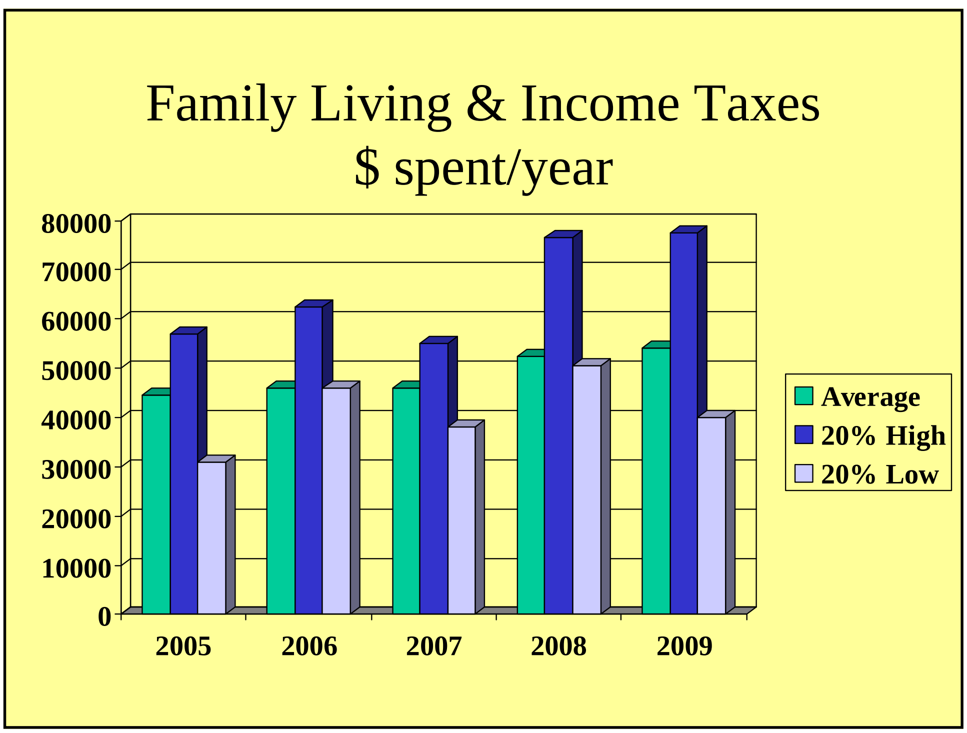


$ Net Farm Income "Profit"

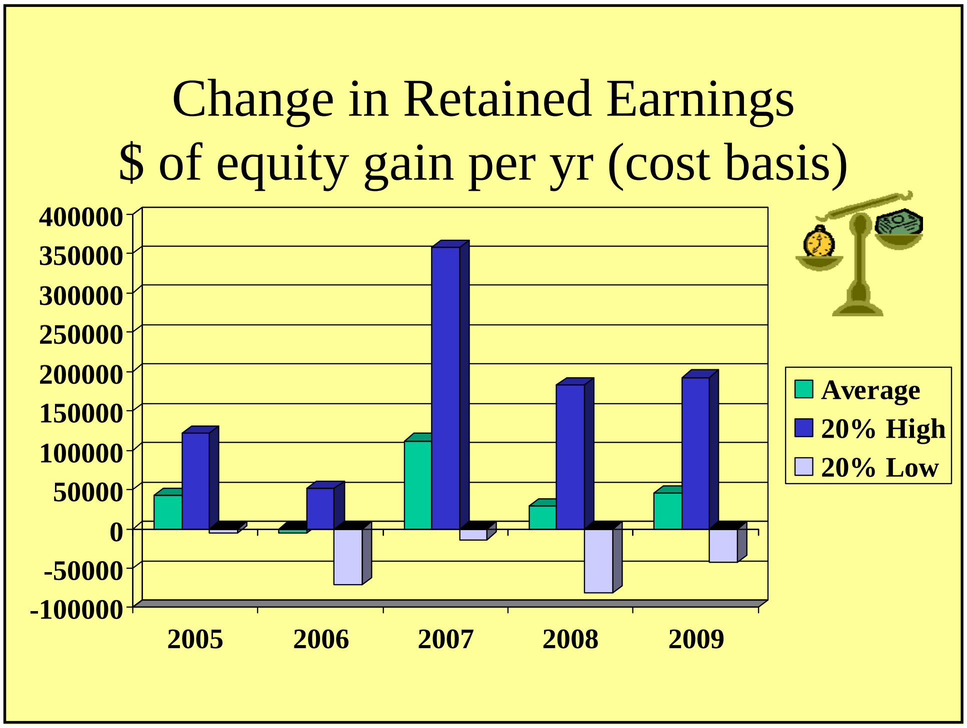


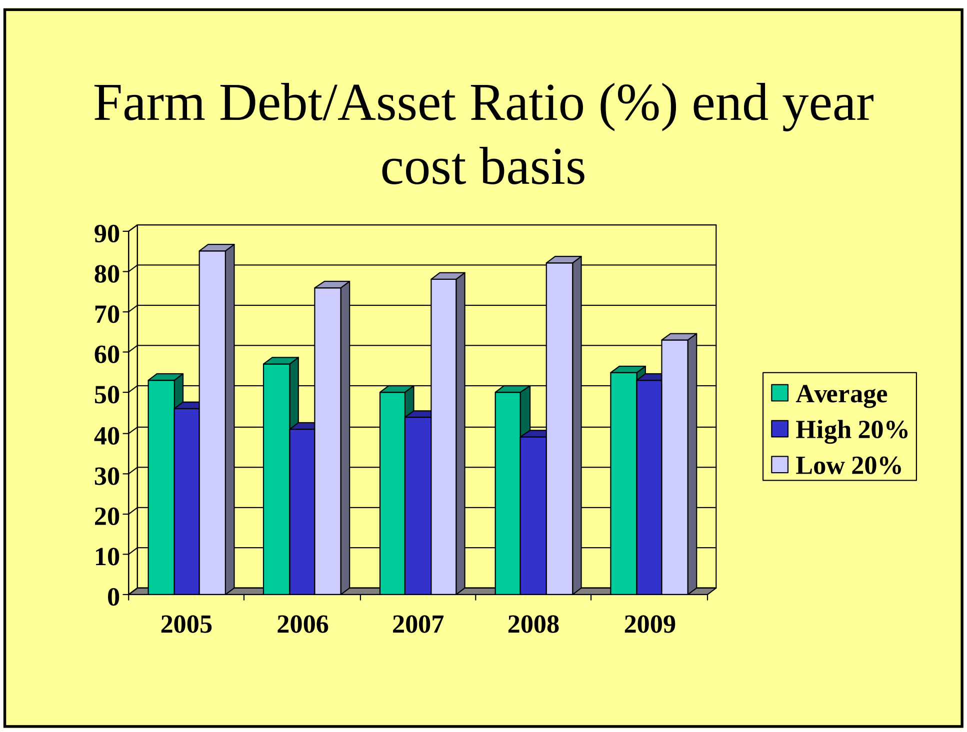


$ Net "Non-Farm" Income
40000
35000
30000
25000
20000
15000
10000
5000
0
2005
2006
2007
2008
2009
Average
20% High
20 % Low

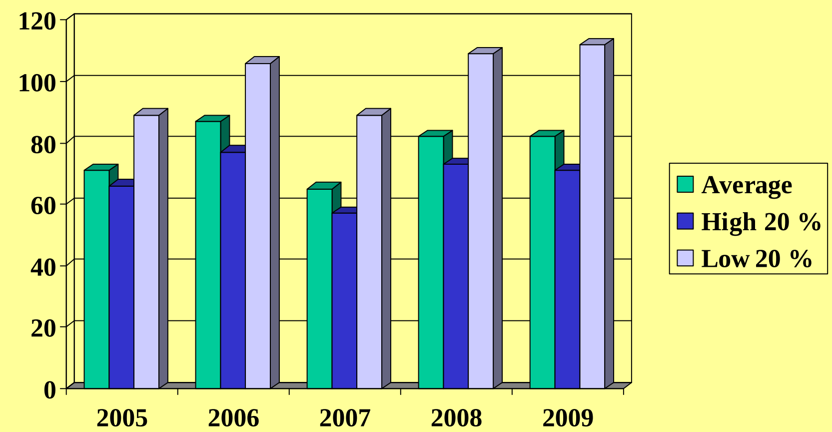


Family Living & Income Taxes
$ spent/year
80000
70000
60000
50000
40000
30000
20000
10000
0
2005
2006
2007
2008
2009
Average
20% High
20% Low


Change in Retained Earnings
$ of equity gain per yr (cost basis)
400000
350000
300000
250000
200000
150000
100000
50000
0
-50000
-100000
2005
2006
2007
2008
2009
Average
20% High
20% Low

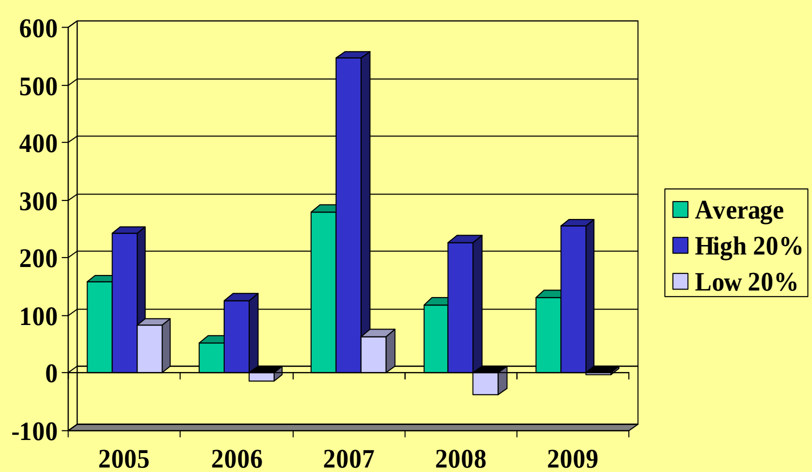

Farm Debt/Asset Ratio (%) end year
cost basis
90
80
70
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
Average
High 20%
Low 20%

Expense (oper+ Int) as % of Accrual Income



Term Debt Coverage Ratio

a 100% ratio means "we can make all debt payments"

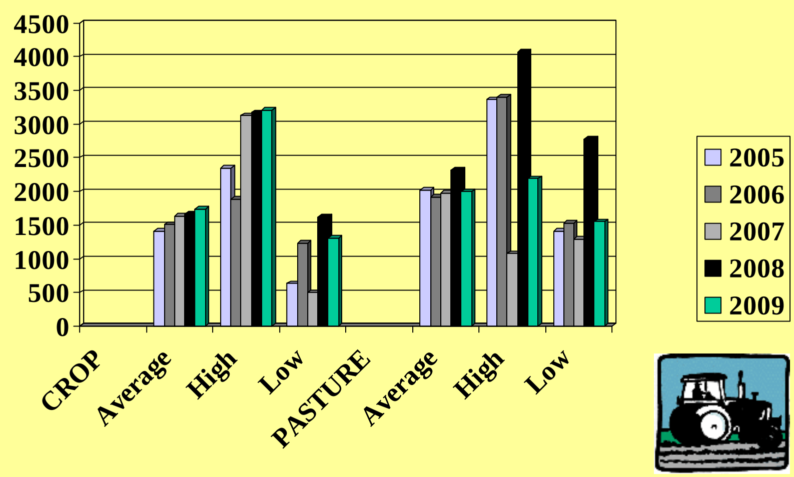


Cash Flow 2009

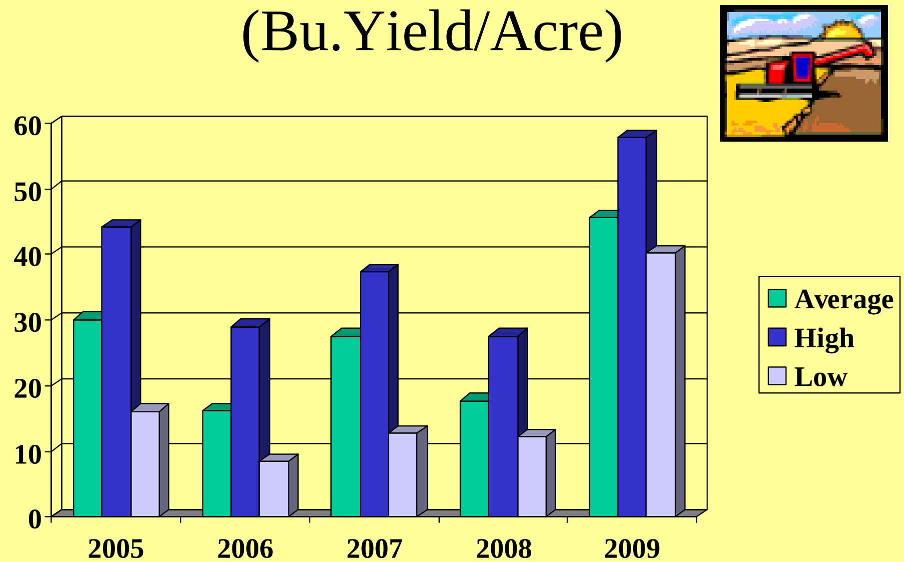
	Average	Low Profit	High Profit
Gross Farm Income	393111	309241	783227
Non-Farm Income	31265	37828	16849
Cash Farm Expenses	369086	302768	748578
Family Living	48043	36438	67711
Income, SS Tax	5893	3683	9594
Net Capital Purchases	101287	48219	251411
Money Borrowed	432389	356792	906069
Principal Payments	340912	317932	678329

For more info – see www.finbin.umn.edu

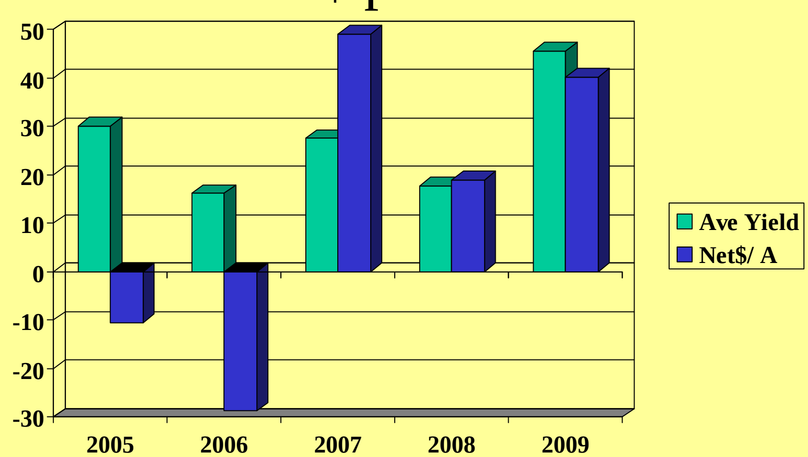
Crop and Pasture Acres



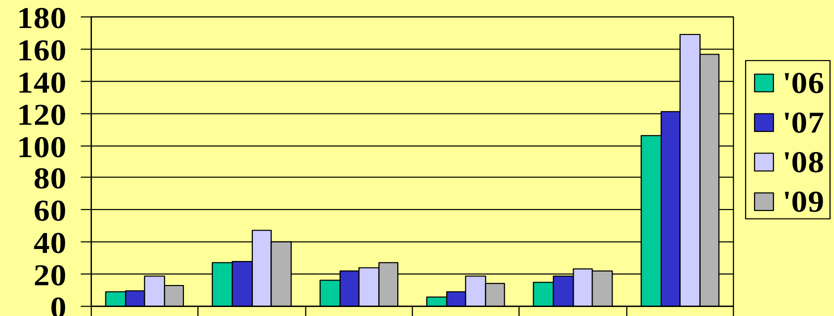
Spring Wheat on Cash Rented (Bu.Yield/Acre)



Spring Wheat Ave Yields and Net $ per Acre

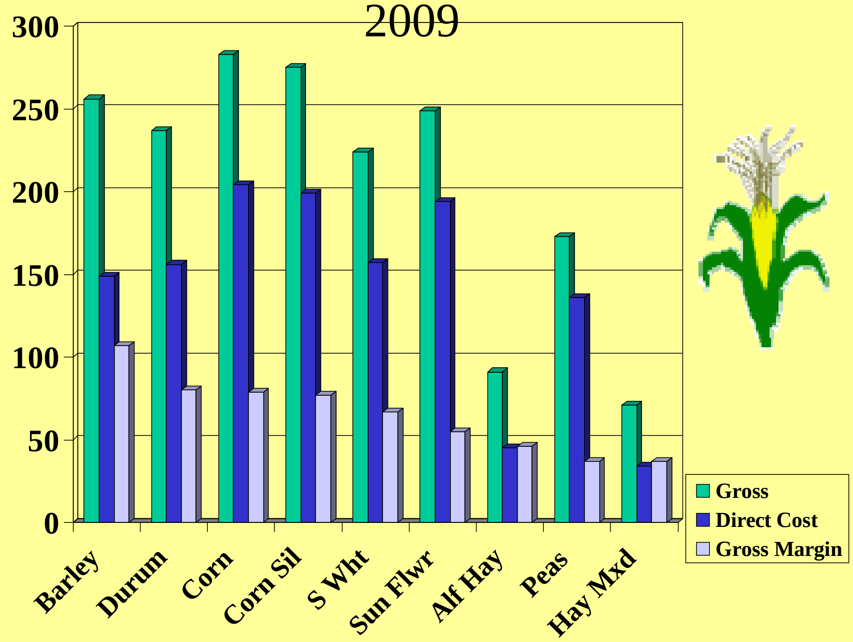


Costs /acre for Spring Wheat comparing 06,07,08.09

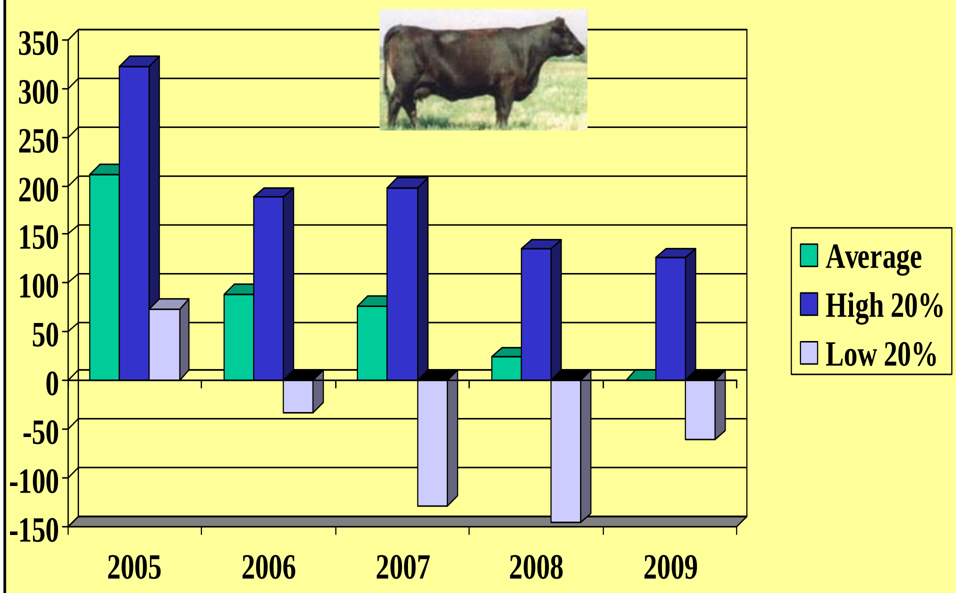


	Seed	Fert.	Chem.	Insur.	Fuel+ Repair	Total Direct
'06	9	27	16	6	15	106
'07	10	28	22	9	19	121
'08	19	47	24	19	23	169
'09	13	40	27	14	22	157

Crop Contributions to Overheads Year 2009



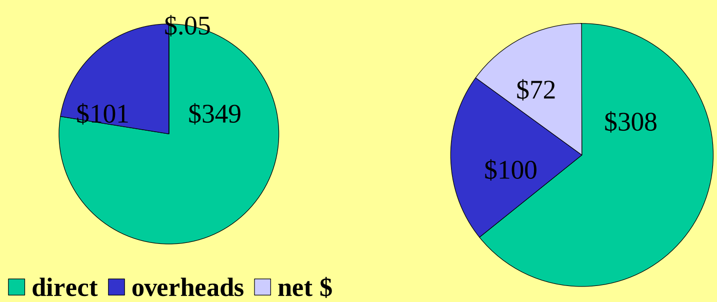
$ Net income /Beef Cow



Beef cow costs, returns 2009 per cow (fuel&repairs in OVHD)

average

high profit



How are low profit and high profit
Beef herds different ? For 2009 year

	Low Profit	High Profit
Value of calf/cow	$469	$521
Depreciation per cow	$66	$64
Direct cost/cow	$465	$355
Overhead expense/cow	$79	$53
Cost per cwt (D&Ovhd)	$112	$78
Net Income per Cow	-$141	+$72