Expanding annual forage production and use in the Northern Great Plains

- Final Report -

Chip Poland, Area Livestock Specialist and Pat Carr, Research Agronomist
Dickinson R/E Center ~ North Dakota State University

Justification

Economists at North Dakota State University project dismal economic returns for many annual crops in southwestern North Dakota. Economic reality suggests that new production and marketing methods are needed for annual crops to be grown profitably. Preliminary data indicate that forage production from annual crops has the potential of generating greater returns per acre than traditional grain production.

Cost associated with winter feeding the cow herd is a major expense associated with cow/calf operations in ND. Procurement and feeding of harvested forages account for a large portion of this total expense. Forage production systems developed to minimize unit costs of production and extend periods of time when higher quality forages are available could substantially lower overall operating costs of beef production. Reducing overall costs of production while maintaining productivity should provide an opportunity to increase the profitability of cow/calf enterprises.

Optimizing forage production and use requires a careful balance between forage production and quality. This project was designed to complement and expand upon the existing data on forage production in southwestern ND. Specific objectives address 1) if forage production can be enhanced by interseeding winter and spring cereals, 2) if annual forages are superior to perennial grasses for forage production, and 3) current forage management and production parameters to assess where improvements can realistically occur.

The intent of this project is to further identify factors that may be used to increase the value (quality and/or quantity) of forages produced in the Northern Great Plains. Results obtained should provide crop and livestock producers information necessary for matching forage production with marketing/use objectives. In areas where hay is marketed on a quality basis, increasing forage quality could translate into increased economic value per unit. Livestock can be used to convert higher-quality forage into economic value in the absence of an active hay market. Conversely, beef cows producers should be able to merge production and quality criteria to reduce the overall costs of providing harvested winter feeds.

Previous research

Small-grains are popular annual forages in the Great Plains. According to the 1997 Census of Agriculture, small-grains were harvested for forage from 686,606 ac across Montana, North Dakota, and South Dakota (USDA, 1999). Of the small grains, oat is the most popular, cool-season, annual forage grown in the Great Plains, particularly in the northern tier states of the USA. For example, oat comprised approximately 80% of the small-grain area devoted to hay production in 1997 in North Dakota (E. Stabenow, 2000, per. comm.). The remaining area consisted of barley (14%) and other (e.g. rye, wheat) small-grain crops. Oat comprised approximately 90% of small-grain hay production in South Dakota, and almost 50% in Montana. These data demonstrate the popularity of oat among small-grain crops when grown for forage.

Research indicates that barley produces higher-quality forage compared with oat in sub-humid regions. Barley had greater nutritive value than oat, triticale, and wheat in Minnesota (Cherney and Martin, 1982a). Barley forage was highest in digestible dry matter and lowest in acid detergent fiber concentrations. Crude protein (CP) concentration of barley forage was 16 $g \cdot kg^{-1}$ greater than oat forage.

The superior quality of barley forage compared with oat and other small-grain forages probably results from a greater proportion of dry matter consisting of the inflorescence in barley. Over 25% of the dry matter of barley forage consisted of inflorescence compared with 20% for oat, triticale, and wheat forage across six maturity stages (Cherney and Marten, 1982b). The inflorescence is more digestible and nutritious than other plant components. The leaf blade and sheath of barley also had a lower percentage lignified area than did oat.

The CP concentration of barley and barley-pea forage has been shown to be superior to that of oat and oat-pea forage in a study at Dickinson, ND (Carr et al., 1998). Additionally small-grain quality data have been compared in sub-humid regions (Cherney and Marten, 1982b), but not extensively in the Great Plains. Factors in addition to CP concentration are important in determining the nutritive and economic value of forage. Energy, digestibility, and mineral data are needed for comparisons among annual crops grown for forage in the Northern Great Plains.

Barley forage yield has been equal or superior to forage yield of oat in sub-humid regions, whether grown alone (Cherney et al., 1982a) or with pea as a companion crop for alfalfa (Medicago sativa L.) establishment (Chapko et al., 1991). Barley forage yield has been inconsistent compared with oat in the Great Plains. 'Dumont' and 'Magnum' oat were superior to 'Bowman' and 'Horsford' barley for yield when the cultivars were grown alone and in combination with field pea in 1993 and 1994 (Carr et al., 1998). However, differences in yield between 'Chopper', 'Haybet', and 'B 7518' barley cultivars and Dumont oat did not exist in a subsequent study (Carr et al., 1996). These data indicate that cultivar selection impacts forage yield. Additional research is needed to determine the forage potential of barley and oat in the Great Plains. This is particularly true at the producer level.

Typical nutritional summaries (e.g. NRC, 1984) of hays that are fed to livestock are reported in table 1. These data would not suggest a quality advantage to small grain forage compared to perennial sources of hay. Recent data collected at the Dickinson R/E Center suggest that the quality of small grain forage is as good or better than "book values" and can be improved with proper management (e.g. seeding rates, cultivar and varietal selection, physiological stage at harvest). Thus, the potential of small grain crops to produce forage in the Northern Great Plains may not be completely appreciated. An assessment of typical yield and composition among small grain forages and between annual and perennial forages at the producer level has not been done. This type of comparison is needed to determine the current state of affairs in forage production. This assessment would also provide clues as to where substantial improvements in forage yield and/or quality can be made.

This project will include experiments where 1) winter and spring cereals are intercropped in an attempt to increase forage yield and extend the period when higher quality forage is available for harvest and 2) annual and perennial forage production are compared under experimental and field conditions. Results of these experiments will be used to identify crops that are the best adapted and most profitable for forage production in the Northern Great Plains.

Project objectives

a) Determine if interseeding winter and spring cereals increases overall forage production and quality compared to spring cereals.
b) Compare annual and perennial grasses with respect to forage production and quality.
c) Survey current management and production parameters of annual forages produced in southwestern ND.

Materials and Methods

Winter-Spring Cereals. A spring barley (*Hordeum vulgare*), oat (*Avena sativa*) and triticale (X *Tritiosecale*) cultivar were seeded in monoculture and with a winter rye (*Secale cereale*), triticale or wheat (*Triticum aestivum*) at the NDSU Dickinson R/E Center in 2001. These same treatments were repeated in the spring of 2002. The treatments were arranged in a randomized complete block design (RCBD) with each treatment represented in each of four (4) blocks. Acceptable agronomic procedures reflecting local climatic and edaphic conditions were used to initiate and manage the study. Weeds and other pests were controlled, as needed.

Forage was harvested in plots when spring cereal cultivars were at the early heading to soft dough stages of development. Plots were harvested again in mid- to late-September of the seeding year, and in mid- to late-May of the following year. A North Dakota Automated Weather Network station located within .5 km of the study area was used to determine growing-degree-days for wheat that coincide with specific harvest dates.

Forage yield was determined by harvesting 4.6-m^2 area from the center of each plot and recording fresh weight. A subsample of approximately 900 g was randomly selected from the harvested portion of each plot. Forage samples were dried at 50°C until a constant weight was attained. Dry matter percentage of harvested material was determined. Forage crude protein (CP) and acid- and neutral-detergent fiber (ADF and NDF, respectively) concentrations were determined by a commercial chemical laboratory using standard procedures (AOAC, 1990) from three randomly selected blocks.

Annual/Perennial Grasses. Five (5) perennial grasses plots were established in the spring of 2000. Entries included crested wheatgrass (*Agropyron desertorum*), western wheatgrass (*Pascopyrum smithii*), perennial rye (*Lolium perenne*), Russian wildrye (*Psathyrostachys junce*), and meadow bromegrass

(*Bromos riparius*). Plots of spring barley and oat were also included as annual forages. The treatments were arranged in a randomized complete block design (RCBD) with each treatment represented in each of four (4) blocks. Acceptable agronomic procedures reflecting local climatic and edaphic conditions were used to initiate and manage the study. Weeds and other pests were controlled, as needed. Plots of western wheatgrass did not adequately establish and were subsequently dropped from the study.

In 2002 and 2003, forage was harvested when plots were at approximately 50% heading. Any regrowth in plots was harvested again at the same stage of physiological development. Forage yield and composition were be determined similarly to that described in previous study.

Forage survey. A management and production survey of annual forages in southwestern ND was conducted in 2002 and 2003. Forage samples (189) were collected from producers over the two year period (Table 2). County extension agents were used in locating participating producers. Forage samples were collected in late summer and early fall and, when requested, results used in helping producers development specific winter feeding programs. When submitting each sample, producers were asked to complete a questionnaire. The questionnaire (Figure 1) addressed agronomic (e.g. seeding rates, fertilization practices, development stage with harvested) and production (e.g. yield) issues related to that particular sample. Forage samples were analyzed for dry matter (DM), crude protein (CP), acid (ADF) and neutral (NDF) detergent fibers, calcium (Ca) and phosphorus (P) using standard procedures (AOAC, 1990) in a commercial laboratory.

Summarization of questionnaire provided a basis from which to describe typical forage production practices in southwestern ND. Forage quality and yield data were used to compare the potential of annual and perennial forages as feed sources for beef cattle at the producer level. Results were also used to identify strengths and limitations of annual forage production.

Categorical data from the questionnaire were described using frequency and/or percentage of occurrence. When possible, a chi-square analysis was used to test for independence among categories. Notations were made when expected category frequencies render the chi-square test marginal (i.e. percentage of cells with expected frequencies of less than 5). A fischers exact test for independence among categories was applied whenever specific conditions deemed this test appropriate.

Numerical data were analyzed in two restricted data sets. The first data set (n = 169) excluded the overall forage category labeled “OTHER” (Table 2). The second data set (n = 58) contained only the small grains oat and barley. Each data set was analyzed as a completely random design with main effects and specific interactions. Sources of variation used with the first data set included year (YEAR; 2002 and 2003), forage type (TYPE; alfalfa, grass, mixed alfalfa/grass, small grain, millet and corn silage), physiological stage of development at harvest (STAGE; boot/early bud, heading/late bud, flower/first flower, milk/10% flower, soft dough/50% flower, hard dough/100% flower and ripe/mature), time of day at harvest (CUTTIME; all day, morning, morning.afternoon, afternoon and evening) and the interactions TYPE*STAGE and TYPE*CUTTIME. Sources of variation used with the second data set included those used previously, as well as, weed control (WEED; yes or no) and TYPE*WEED. TYPE was redefined in this data set to include barley and oat.

Results and Discussion

Winter-Spring Cereals. Spring barley, oat, and triticale each were compared for forage yield and quality when seeded alone and with winter cereals (rye, triticale, and wheat) during 2001 and 2002. Yield of the spring cereals ranged from 3.1 Mg DM/ha for `Haybet' barley to 5.7 Mg DM/ha for `2700' triticale across both years. Forage yield of spring cereals was reduced by 16% or more when intercropped with winter cereals. Additional forage (avg. = 0.5 Mg DM/ha) was produced when spring cereals were intercropped with winter cereals in the fall, with smaller amounts of forage also being produced in the spring when spring cereals were intercropped with winter rye. Total forage yield (summer plus fall plus spring forage production) was reduced by 10% by intercropping spring with winter cereals compared with growing spring cereals alone. However, forage CP and TDN concentrations increased an average of 10 and 22 g/kg, respectively, by intercropping spring and winter cereals rather than producing spring cereal crops alone. Results of this 2-yr study suggest that intercropping winter cereals with spring cereals enhances forage quality and provides limited quantities of high quality forage that can extend the fall grazing period. However, total forage production is reduced when spring and winter cereals are seeded together compared with seeding spring cereals alone.

Annual/Perennial Grasses. Two wheatgrass species (Crested and Western), meadow brome, Russian wildrye, and an experimental perennial rye genotype were compared with barley and oat for forage yield and quality during 2001 and 2002. Russian wildrye produced equal or greater amounts of forage compared with other grass species both in 2001 (3.6 Mg DM/ha) and 2002 (5.1 Mg DM/ha). Perennial rye produced only 2 Mg DM/ha in 2001 and < 1 Mg DM/ha in 2002. Differences in forage production were not detected between the other grass species included in the study in either year ($P > 0.05$). Forage ADF and NDF concentrations for barley tended to be equal or lower than other grass species when harvested at the early heading stage. However, forage CP concentration sometimes was equal or greater for perennial grass species compared with either cereal species when harvested at the early heading growth stage. Results of this study suggest that CP can be relatively concentrated in perennial grass forage when harvested at the early heading stage, even under low soil-N conditions like those that existed during this study.

Forage Survey (annual vs perennial forages). Sample frequencies of all forage samples are provided in Table 2. Of the total number of samples collected, 49% were perennial forages, 41% were annual forages and 10% were classified as other. Small grain forages were the largest group represented and included oat, barley and wheat. Other annuals included millet and corn. Perennial forages included alfalfa, grass and mixed grass/alfalfa. In the final analysis (169 samples), 58% of the samples were submitted in 2002 and 42% in 2003. Furthermore, 37, 21, 21, 12, 5 and 4% of the total samples were of small grain, alfalfa, mixed grass/alfalfa, grass, corn and millet forage, respectively (Table 3).

A breakout of TYPE and county of submission is given in Table 4. The top three submitting counties included McKenzie (20%), Bowman (13%) and Stark (12%). Three of the submitting counties (Burleigh, Divide and Ward; combined samples were 5% of total submitted) were either north or east of the Missouri River.

Previous research in a number of forages has shown a difference in forage nutrient composition when harvested at different times of the day. Forages harvested later in the afternoon tend to have greater soluble carbohydrate, and lower fiber, concentrations. There were no differences in harvest time of day among forage types ($P = .5$; Table 5). In general, the most commonly reported harvest time was all-day (37%). This was followed by afternoon (30%) and then morning/afternoon (21%). Notable exceptions were a more uniform distribution of harvest times among grass samples and a earlier in the day harvest time for corn. The least commonly reported harvest time was evening (1.4%).

Recommend stages of development at harvest are late bud to early bloom, boot to early heading, grain milk to soft dough and kernels at 2/3 milk line to black layer for alfalfa, grass and grass/alfalfa mixture, small grain and millet, and corn (for silage), respectively (Bolsen, 1995). Stage of development at harvest was affected by forage type ($P < .01$; Table 6). The majority of alfalfa (approximately 80%) was harvested between the first and 50% flower. Grass and grass/alfalfa mixture were harvested at more advance stages of maturity than alfalfa. Small grains were primarily harvested between milk and soft dough, millet at heading and corn at hard dough. Deviations in these data from typical recommendation were less (more) advanced stages of development at harvest for millet (grass and grass/alfalfa mixtures).

A round baler was used to harvest a majority (82.5%) of the forages in this study ($P < .01$; Table 7). With the exception of corn being cut for silage (89%), round baler use ranged from 60% for millet to 100% for grass forage. Use of fertilization ($P < .01$), weed control ($P < .01$), pesticide ($P < .01$) and cutter type ($P < .01$) were also affected by forage type (Table 8). The incidence of fertilization and weed control were greater in the production of annual than perennial forages. However, the use of both was lower in millet than small grain or corn production. Pesticides were used in the production of 44% of alfalfa, and 11% of corn, forage samples. A forage swather was the cutter type of choice for all forages (80 - 100%) with the exception of corn (0%). This largely reflects the difference in predominately hay versus silage production.

Sources of variation and associated probability values and least squares means for effects of Year and TYPE for field size, DM yield and forage composition are listed in Tables H and I, respectively. Field sizes ($P = .06$) were larger in 2003, while DM yield ($P = .04$) and NDF concentration ($P = .08$) were greater in 2002. Other quality criteria did not differ among YEAR ($P \geq .4$). TIME and STAGE did not affect field size, DM yield or forage quality ($P > .3$), with the exception of CP concentration. CP concentration ($P < .01$) declined with advancing STAGE (Figure 2).

All production and quality measures (Tables 9 and 10) were affected by TYPE, with the exception of field size ($P = .89$). DM yield ($P < .01$) was greatest in corn, intermediate in millet and lowest for small grains and perennial forages. The difference in corn was primarily related to exceptionally high yields in 2002 ($P < .01$; Figure 3). CP concentration ($P < .01$) was greatest in alfalfa and intermediate in millet. Average CP concentration averaged greater than 10.5% DM in all TYPE. ADF concentration ($P < .01$) was greatest in grass and grass/alfalfa mixture, intermediate in millet and alfalfa and lowest in small grain and corn. Nonetheless, TDN concentration ($P < .01$) was greatest in annual, compared to perennial, forages with no differences among TYPE within annual/perennial grouping. NDF concentration ($P < .01$) was highest in grass, intermediate in grass/alfalfa mixture and millet and lowest in small grain, corn and alfalfa. Although RFV ($P < .01$) should not be directly compared across diverse forage types, annual forages had greater RFV than perennial forages and RFV in alfalfa was greater than other perennial forages.

Forage Survey (small grain forage). The distribution of small grain forage samples between TYPE and YEAR and county of submission are listed in Table 11. A summary of the distribution of forage samples among TYPE and specific management practices is provided in table 12 and figures 4 and 5. Most samples of small grain forage experienced some level of fertilization (90%) and a swather (94%) and a round baler (87%) during harvest. Time of day at harvest was most commonly reported to be all day (49%), followed by afternoon (24%). A lesser proportion of samples had weed control (38%) and no pesticide application was reported in these samples. Use of fertilization, weed, pesticide, swather, round baler and time of day at harvest did not differ ($P > .16$) among TYPE.

The cumulative distribution of samples among TYPE across STAGE is shown in figure 6. Although there were not statistical difference in STAGE among TYPE ($P = .7$), numerically oat was harvested at an earlier STAGE. Given the strong influence advancing STAGE has on depressing forage quality in small grain, this numerical difference is worthy of notation. Any improvement in forage quality in barley over oat should not be confounded with earlier maturity at harvest. Soft dough was the most common (approximately 35%) STAGE reported.

Sources of variation and associated probability values for field size, DM yield and forage composition of small grain forage production are listed in table 13. Field size (Table 14) in small grain forage production was not affected by YEAR ($P = .4$), but was greater when weed control was practiced ($P = .02$). There were interactions (Figure 7) between TYPE and YEAR ($P = .01$) and WEED ($P < .01$). Although statistically significant, neither of these interactions appeared to have interpretative significance. Barley fields were greater in 2002 and when no weed control was used; while oat fields were greatest in 2003 and when weed control was used. DM yield ($P = .67$) did not differ among TYPE.

Crude protein concentration was greater in barley compared to oat ($P = .03$) and tended to be greater when no weed control was used ($P = .1$). Concentrations of ADF ($P < .01$) and NDF ($P < .01$) were lower, and TDN ($P < .01$) greater, in barley compared to oat. RFV ($P < .01$) was also greater in barley reflecting lower fiber concentrations. The differences in ADF ($P = .02$) and TDN ($P = .02$) concentration among TYPE increased with later stages of development (Figure 8). Differences in NDF concentration among TYPE was greater in forage harvested in the morning/afternoon and afternoon periods than in forage classified as being harvested all day (Figure 9).

Summary

Intercropping winter cereals with spring cereals enhanced forage quality and provided limited quantities of high quality forage that could be used to extend a fall grazing period. However, total forage production was reduced when spring and winter cereals were seeded together compared with seeding spring cereals alone. In small plots, Russian wild rye produced equal or greater amounts of forage compared with other annual or perennial grass species. Otherwise, forage yield was similar among small grain and perennial grasses. Barley forage had lower fiber concentrations when compared to other grasses and perennial forage had equal or greater amounts of CP compared to small grain forage. In field- scale comparisons, annual forage production utilized fertilization and weed control more often than perennial forage production. Pesticides were used exclusively in alfalfa, and to a lesser degree corn, forage production A swather and round baler were the predominate implements for harvesting hay. There are opportunities to improve forage quality at the field-scale by manipulating stage of development and time of day at harvest. However, producers will need to balance the magnitude of forage harvest with appropriate windows for forage quality enhancement. Forage yield was greatest with corn, and to a lesser degree millet, compared to small grain and perennial forages. CP concentration was greatest in alfalfa and similar between small grain and other perennial forages. Average CP concentration for all forages was greater than 10.5%. ADF concentrations were lowest in small grain and corn forage and greatest in grass and grass/alfalfa forage. Energy concentrations were greater in annual than in perennial forage. Although barley forage was better quality (increased CP and TDN, and decreased ADF and NDF, concentration) than oat forage, the production characteristics and yield of small grain forage was very similar at the field scale.

Implications

Although opportunities exist for improving forage production in southwestern ND, annual forages offer a viable means of producing forage within an annual cropping system. Small grain forage, and in particular barley forage, offers tremendous potential for increasing high quality forage production compared to other forage alternatives.

Table 1. Nutritional composition (% dry matter) of common forages harvested as hay[a].

Forage	TDN	Crude Protein	Calcium	Phosphorus
Perennial				
Alfalfa	50-60	13-18	1.1-1.4	.18-.22
Brome	55-60	10-16	.29-.32	.28-.37
Crested Wheatgrass	53	12.4	.33	.21
Annual				
Oat	55	9.3	.24	.22
Barley	56	8.7	.23	.26
Wheat	58	8.5	.15	.20
Millet	59	8.6	.33	.19
Corn (silage)	62-70	8.0-8.5	.23-.34	.19-.22

[a] NRC, 1984.

Table 2. Sample frequency of each forage type[a].

Type	Frequency	Percent
Perennial		
Alfalfa	36	19.4
Grass-alfalfa	35	18.5
Grass	21	11.1
Annual		
Small grain	62	32.8
- oat	(34)	-
- barley	(24)	-
- wheat	(4)	-
Millet	6	3.2
Corn silage	9	4.8
Other	20	10.6
- corn stalks	(1)	-
- mixed hay (unknown)	(4)	-
- oat grain	(2)	-
- oat-pea hay	(2)	-
- slough hay	(1)	-
- straw	(3)	-
- sudan hay	(1)	-
- sweet clover	(4)	-
- unknown	(2)	-

[a] Frequencies based upon all samples collected.

Table 3. Distribution (%) of annual and perennial forage samples among forage type and collection year[a].

Type	Year 2002	Year 2003	Total
Perennial			
Alfalfa	11.8	9.5	21.3
Grass-alfalfa	12.4	8.3	20.7
Grass	8.9	3.6	12.4
Annual			
Small grain	19.6	17.2	36.7
Millet	2.4	1.2	3.6
Corn silage	3.0	2.4	5.3
Total	58.0	42.0	

[a] Distribution based upon the exclusion of the forage samples classified as "OTHER" in table 2.

Table 4. Frequency of annual and perennial forage samples among forage type and county of submission.

	Perennial			Annual			
County	Alfalfa	Grass-alfalfa	Grass	Small grain	Millet	Corn silage	Total
Adams	3	-	2	4	1	1	11
Billings	-	2	5	-	-	-	7
Bowman	4	8	1	9	-	-	22
Burleigh	1	1	-	-	-	-	2
Divide	-	1	-	1	1	-	3
Dunn	3	2	3	4	-	-	12
Golden Valley	-	-	-	6	-	-	6
Grant	-	2	-	3	-	-	5
McKenzie	8	5	2	11	3	4	33
Mercer	6	1	3	5	-	2	17
Morton/Oliver	3	2	-	5	1	2	13
Slope	2	4	3	6	-	-	15
Stark	6	6	2	6	-	-	20
Ward	-	1	-	2	-	-	3

Table 5. Distribution (%) of annual and perennial forage samples among harvest time of day[a].

	Harvest time of day class				
Type	All day	Morning	Morning/ afternoon	Afternoon	Evening
Perennial					
Alfalfa	27.8	5.6	33.3	30.6	2.8
Grass-alfalfa	31.3	6.3	15.6	46.9	-
Grass	33.3	20.0	20.0	26.7	-
Annual					
Small grain	45.8	10.4	16.7	25.0	2.0
Millet	33.3	-	33.3	33.3	-
Corn silage	55.6	22.2	22.2	-	-
Total	37.0	9.6	21.9	30.1	1.4

[a] Chi-square analysis ($P = .50$; 67% of cells have expected counts less than 5, thus this analysis may not be a valid test of independence).

Table 6. Distribution (%) of annual and perennial forage samples among stages of development at harvest[a].

	Stage of development at harvest						
Type	Boot (early bud)	Heading (late bud)	Flower (first flower)	Milk (10% flower)	Soft dough (50% flower)	Hard dough (100% flower)	Ripe (mature)
Perennial							
Alfalfa	8.3	2.8	22.2	25.0	33.3	8.3	-
Grass-alfalfa	3.6	3.6	17.9	-	17.9	25.0	32.1
Grass	-	-	-	6.7	33.3	20.0	40.0
Annual							
Small grain	-	3.7	5.6	25.9	33.3	20.4	11.1
Millet	-	50.0	16.7	-	16.7	-	16.7
Corn silage	-	-	-	12.5	12.5	62.5	12.5
Total	2.7	4.8	11.6	17.0	28.6	19.7	15.7

[a] Chi-square analysis ($P < .01$; 74% of cells have expected counts less than 5, thus this analysis may not be a valid test of independence).

Table 7. Distribution (%) of annual and perennial forage samples among harvest forms[a].

	Harvest form					
	Hay					
Type	Round	Large square	Small square	Stack hand	Silage	Other
Perennial						
Alfalfa	85.3	5.9	2.9	2.9	-	2.9
Grass-alfalfa	90.0	3.3	-	6.7	-	-
Grass	100.0	-	-	-	-	-
Annual						
Small grain	88.0	4.0	2.0	2.0	4.0	-
Millet	60.0	-	-	-	20.0	20.0
Corn silage	-	-	-	-	88.9	11.1
Total	82.5	3.5	1.4	2.8	7.7	2.1

[a] Chi-square analysis (P < .01; 86% of cells have expected counts less than 5, thus this analysis may not be a valid test of independence).

Table 8. Distribution (%) of annual and perennial forage samples among various management practices[a].

Type	Fertilization[a]	Weed control[a]	Pesticide[a]	Swather[a]
Perennial				
Alfalfa	25.7	2.9	44.1	85.7
Grass-alfalfa	12.1	0.0	0.0	87.1
Grass	0.0	0.0	0.0	80.0
Annual				
Small grain	90.4	41.2	0.0	94.4
Millet	66.7	0.0	0.0	100.0
Corn silage[b]	100.0	100.0	11.1	0.0
Total	48.7	21.0	11.0	84.5

[a] Fishers exact test for independence (P < .01).
[b] Corn silage was harvested with a corn chopper (100%).

Table 9. Model sources of variation and associated probability values for annual and perennial forage production.

Sources of variation	Field size (ac)	DM yield (ton/ac)	Crude Protein (%DM)	Detergent fibers Acid (%DM)	Detergent fibers Neutral (%DM)	Total Digestible Nutrients (% DM)	Relative Feed Value
Year (Yr)	.06	.04	.51	.94	.08	.40	.91
Forage Type (FT)	.89	<.01	<.01	<.01	<.01	<.01	<.01
Yr*FT	.31	<.01	.36	.69	.82	.99	.97
Harvest Time (HT)	.88	.55	.73	.35	.39	.35	.37
HT*FT	.89	.98	.80	.99	.93	.99	.97
Harvest Stage (HS)	.52	.87	<.01	.47	.43	.52	.66
HS*FT	.91	.79	.69	.93	.75	.95	.81

Table 10. Effects of year and forage type on field size and yield and nutrient concentrations of annual and perennial forage.

Sources of variation	Field size (ac)	DM yield (ton/ac)	Crude Protein (%DM)	Detergent fibers Acid (%DM)	Detergent fibers Neutral (%DM)	Total Digestible Nutrients (% DM)	Relative Feed Value
Year							
2002	91	1.7	12.0	38.4	58.2	59.4	96.7
2003	138	1.4	12.3	38.9	55.6	58.9	-[a]
Forage type							
Perennial							
Alfalfa	105	1.3[x]	15.6[y]	41.4[yz]	53.7[x]	56.6[x]	99.4[y]
Grass-alfalfa	121	1.1[x]	11.2[x]	42.7[z]	61.2[yz]	55.6[x]	85.3[x]
Grass	117	1.2[x]	11.2[x]	43.9[z]	64.2[z]	54.7[x]	79.6[x]
Annual							
Small grain	131	1.3[x]	11.4[x]	34.6[x]	54.0[x]	61.9[y]	108.3[z]
Millet	79	1.7[xy]	12.7[xy]	36.3[xy]	55.9[xy]	61.5[y]	104.0[yz]
Corn silage	135	2.7[y]	10.7[x]	32.9[x]	52.6[x]	64.5[y]	-[a]
RMSE	103.8	.73	2.58	4.68	5.36	3.60	14.5

[a] Relative feed values for corn silage were not report in 2003. Thus, least square means could not be calculated.

[x,y,z] Forage type means with differing superscripts within a column differ ($P < .05$).

Table 11. Frequency of forage samples among small grain forage type and county of submission.

	Barley	Oat	Total
Year			
2002	12	18	30
2003	12	16	28
County			
Adams	3	1	4
Bowman	4	3	7
Divide	0	1	1
Dunn	0	4	4
Golden Valley	2	4	6
Grant	2	1	3
McKenzie	6	4	10
Mercer	3	2	5
Morton/Oliver	0	5	5
Slope	3	2	5
Stark	0	6	6
Ward	1	1	2
Total	24	34	

Table 12. Distribution (%) of small grain forage samples among forage type and management prcatices[a].

Type	Fertilization[a]	Weed control[b]	Pesticide[c]	Swather[d]
Barley	86.4[e]	45.0	0.0	100.0
Oat	92.3	33.0	0.0	89.0
Total	89.6	38.3	0.0	93.9

[a,b,c,d] Fishers exact test for independence (P < .65, .55, 1.0 and .16, respectively).
[e] Percentage of samples using a particular practice.

Table 13. Model sources of variation and associated probability values for small grain forage production.

Sources of variation	Field size (ac)	DM yield (ton/ac)	Crude Protein (%DM)	Detergent fibers		Total Digestible Nutrients (% DM)	Relative Feed Value
				Acid (%DM)	Neutral (%DM)		
Year (Yr)	.42	.88	.68	.12	.13	.12	.82
Forage Type (FT)	.35	.67	.03	<.01	<.01	<.01	<.01
Yr*FT	.01	.54	.29	.33	.20	.33	.27
Weed Control (WC)	.02	.31	.10	.51	.91	.51	.99
WC*FT	<.01	.43	.99	.53	.19	.53	.51
Harvest Time (HT)	.44	.63	.83	.68	.32	.68	.70
HT*FT	.72	.44	.24	.93	.06	.93	.21
Harvest Stage (HS)	.57	.59	.43	.25	.71	.53	.83
HS*FT	.19	.39	.80	.02	.19	.02	.19

Table 14. Effects of year, forage type and weed control on field size and DM yield and nutrient concentrations of small grain forage.

Sources of variation	Field size (ac)[b]	DM yield (ton/ac)	Crude Protein (%DM)	Detergent fibers		Total Digestible Nutrients (% DM)[b]	Relative Feed Value
				Acid (%DM)[b]	Neutral (%DM)		
Overall Mean	111	1.3	11.3	34.4	54.0	62.1	108
Year							
2002	119	1.2	11.1	33.8	54.1	62.6	110
2003	105	1.5	11.5	37.3	52.0	59.8	109
Forage Type							
Barley	126	1.3	12.1[y]	31.9[x]	49.6[x]	64.1[x]	119[y]
Oat	98	1.3	10.4[x]	39.2[y]	56.6[y]	58.3[y]	100[x]
Weed Control							
Yes	138[x]	-	9.7[t]	-	-	-	-
No	86[y]	-	12.8[u]	-	-	-	-
RMSE	85	0.6	2.1	2.8	4.1	2.2	11

[t,u] Means within a source of variation and column with differing superscripts differ (P = .10).
[x,y] Means within a source of variation and column with differing superscripts differ (P < .05).

Defining Forage Production in SW North Dakota
Production Questionnaire
Dickinson RE Center, NDSU and
Department of Ag. and Tech. Studies, DSU

Name:

Address:

Phone:
Email:

Sample ID:
County where produced:

Type:	☐ Annual forage	☐ Grass
	☐ Alfalfa	☐ Grass/Alfalfa
	☐ Other:	

Species:
Variety:

Seeding date (annual forage):
Seeding rate (annual forage):

Years established (perennial forage):

☐ 1	☐ 2	☐ 3
☐ 4-5	☐ 6-7	☐ >7
Fertilization:	☐ Yes	☐ No
Weed control:	☐ Yes	☐ No
Insect or Disease problem (specify):	☐ Yes	☐ No

Harvest date:

Time of cutting:	☐ morning	☐ afternoon
	☐ evening	☐ other

Stage of development at harvest: grass stage *(alfalfa stage)*

☐ boot *(early bud)*	☐ soft dough *(50% flower)*
☐ heading *(late bud)*	☐ hard dough *(100% flower)*
☐ flowering *(first flower)*	☐ ripe *(mature)*
☐ milk *(10% flower)*	☐ other:

Cutter:	☐ swather	☐ mower/rake
Package:	☐ large round	☐ large square
	☐ small square	☐ other

Size of field (acres):
Estimate yield (ton/acre):

Comments:

Figure 1. Questionnaire used to collect production information related to each forage sample submitted.

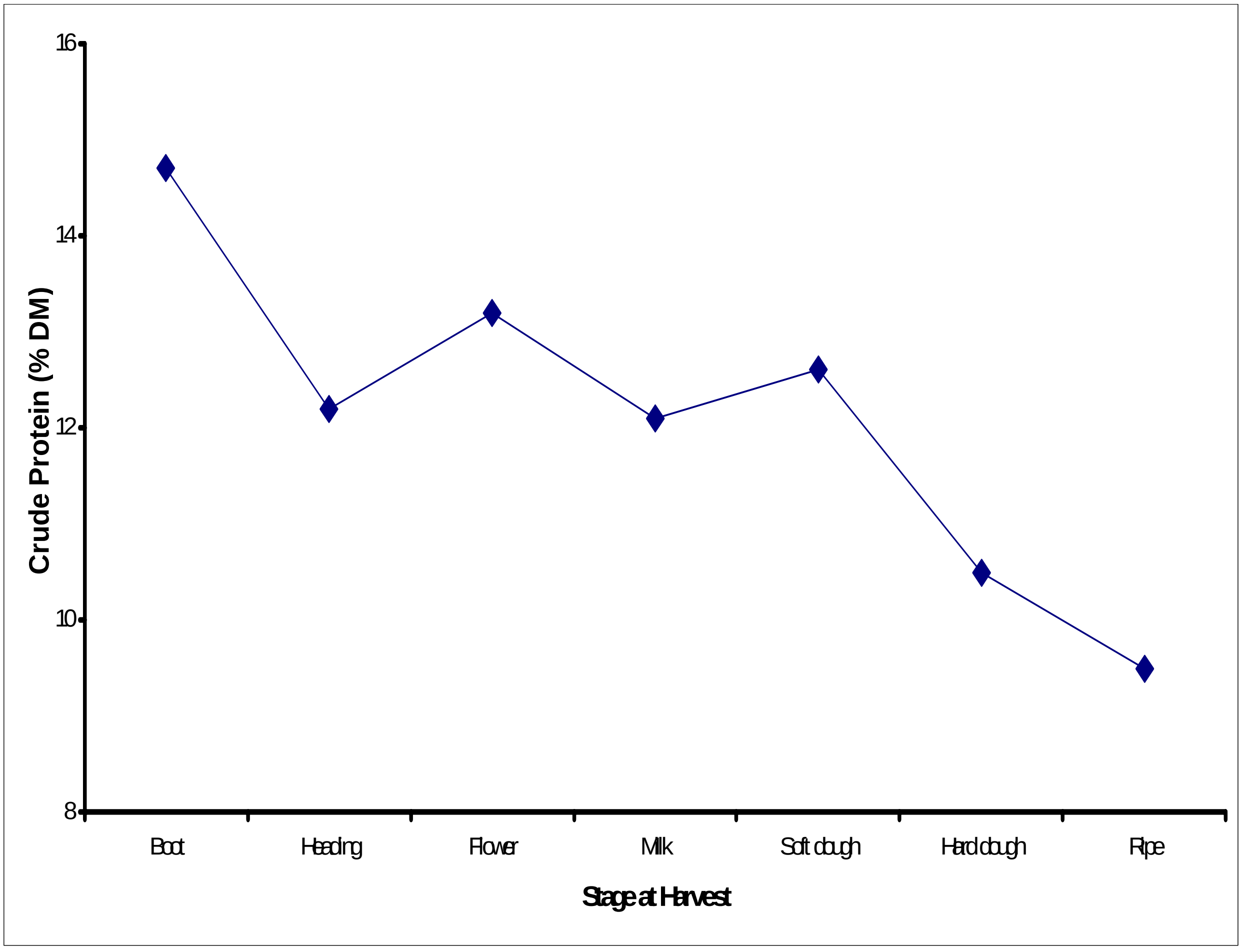

Figure 2. Effect of stage at harvest on crude protein (CP) concentration (P < .01) across all forage types.

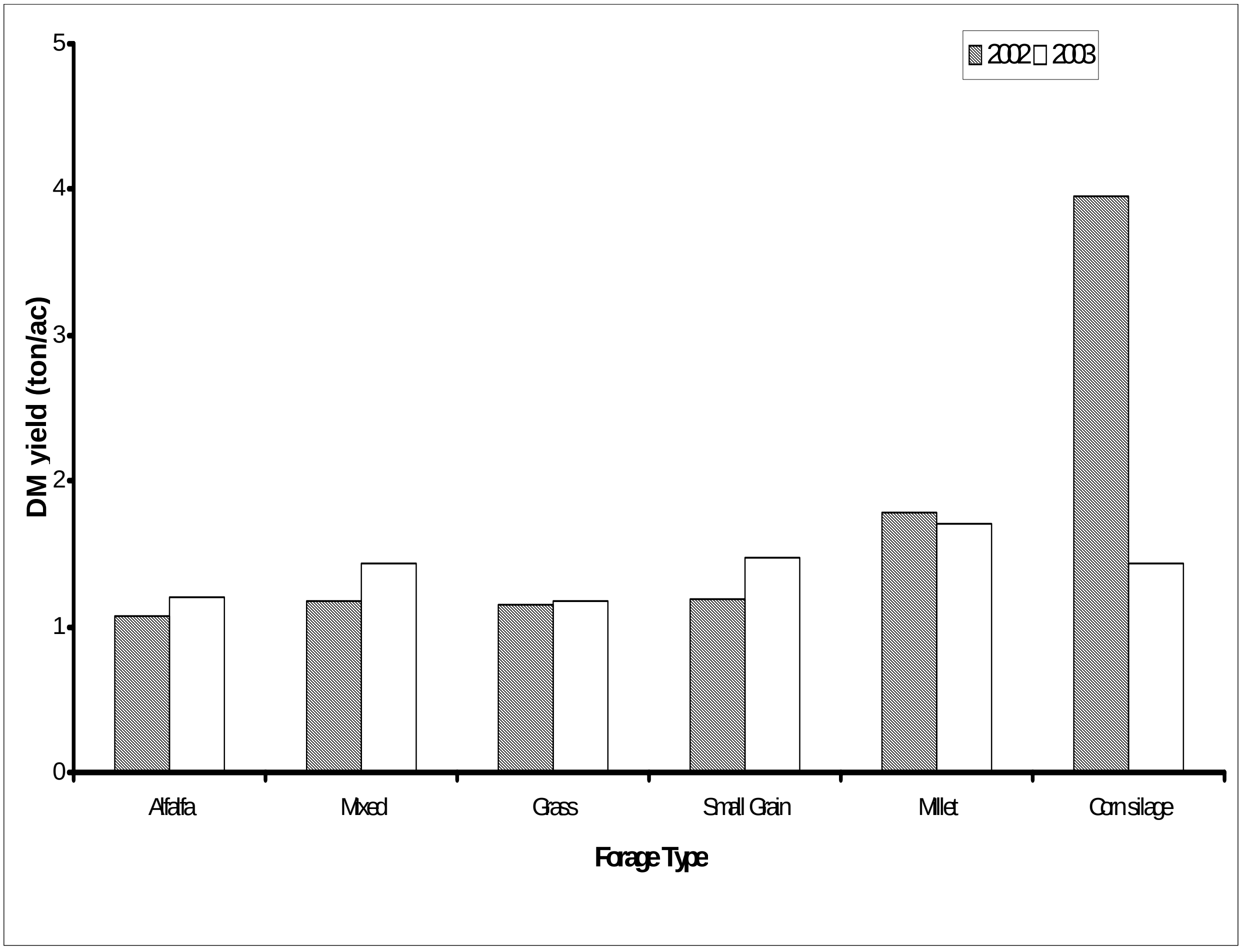

Figure 3. Effects of year within forage type on dry matter yield (P < .01).

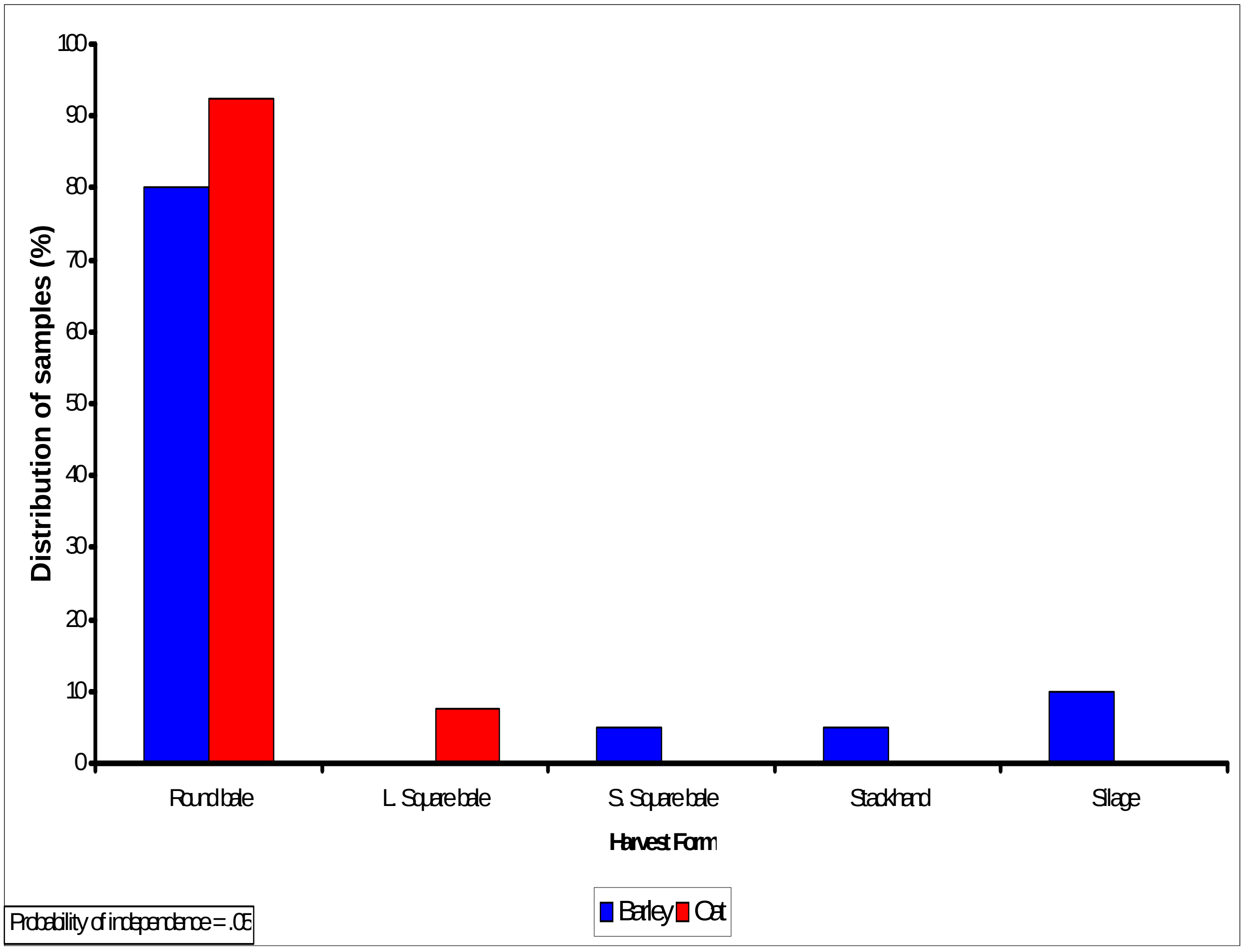

Figure 4. Distribution of harvest form among small grain forage type.

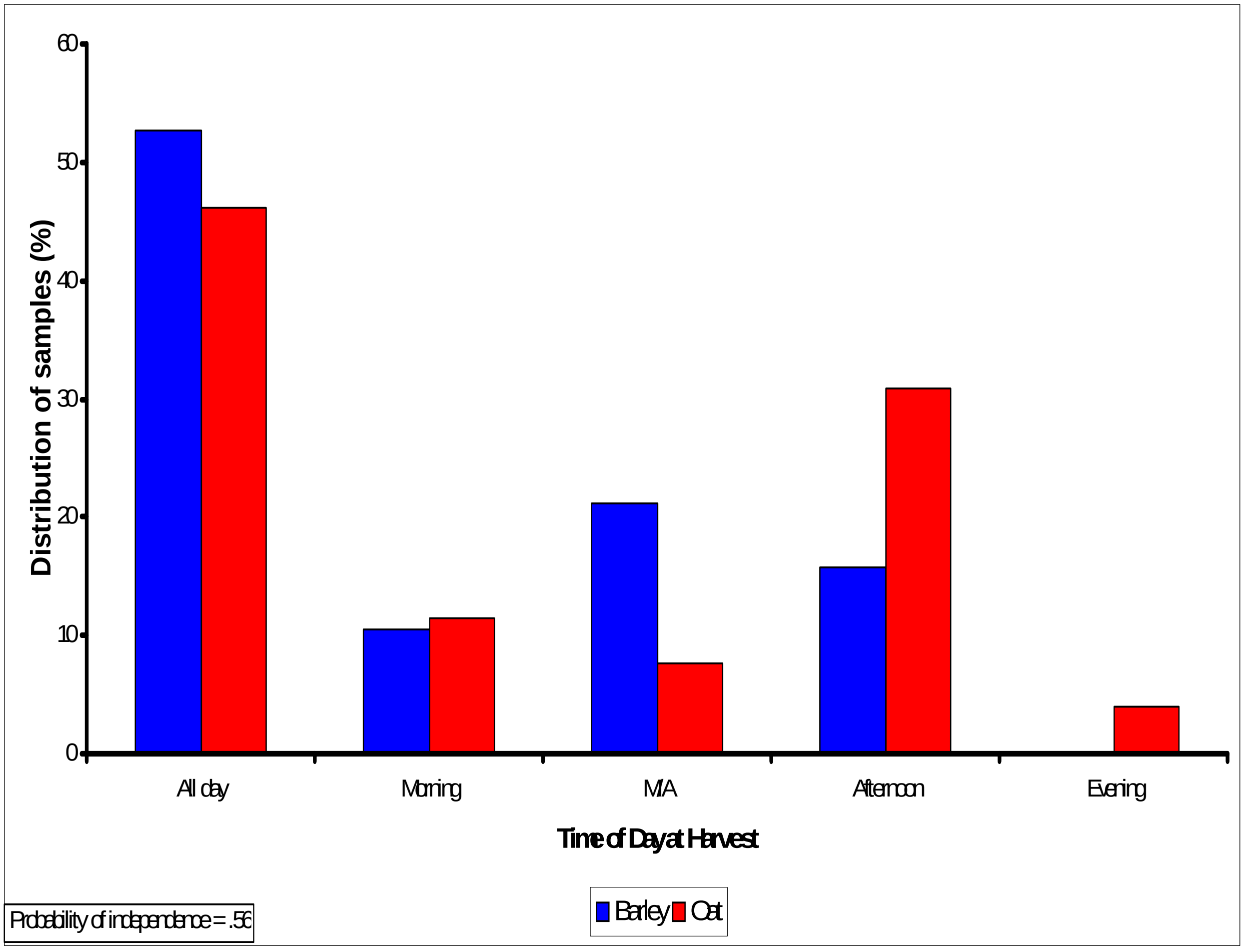

Figure 5. Distribution of harvest time of day among small grain forage type.

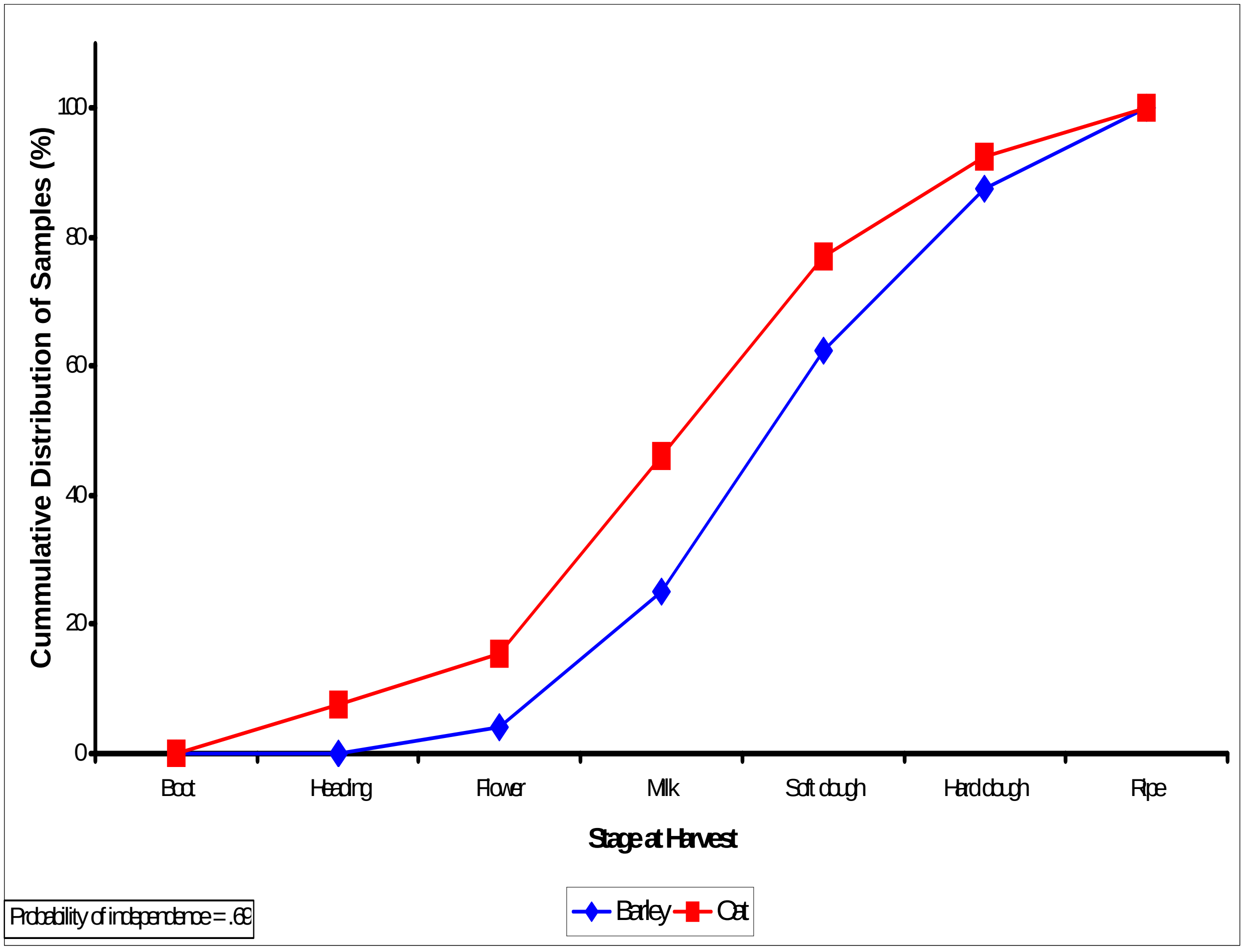

Figure 6. Distribution of physiological stage of develop at harvest among small grain forage type.

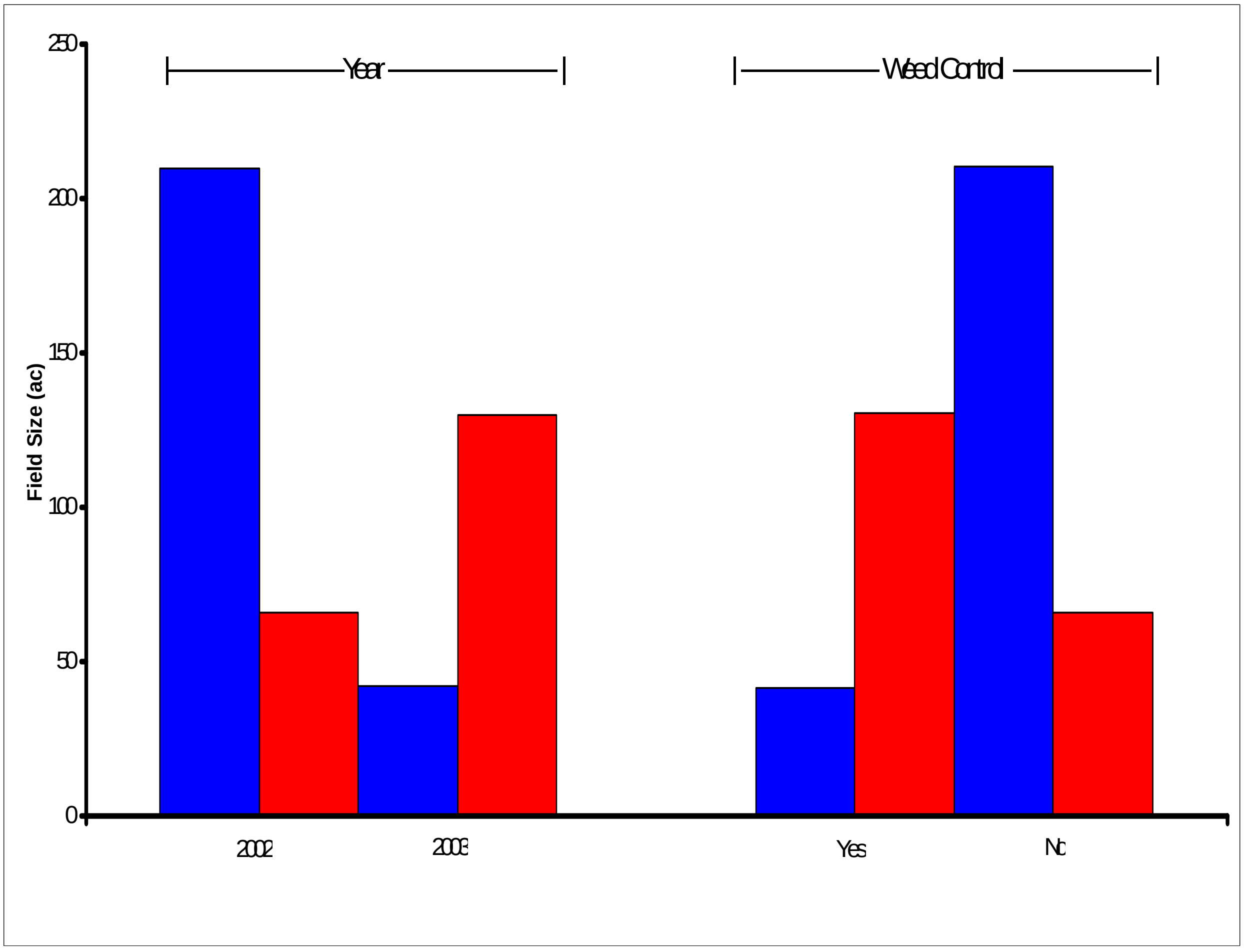

Figure 7. Effects of year (P = .01) and weed control (P < .01) on field size among small grain forage type.

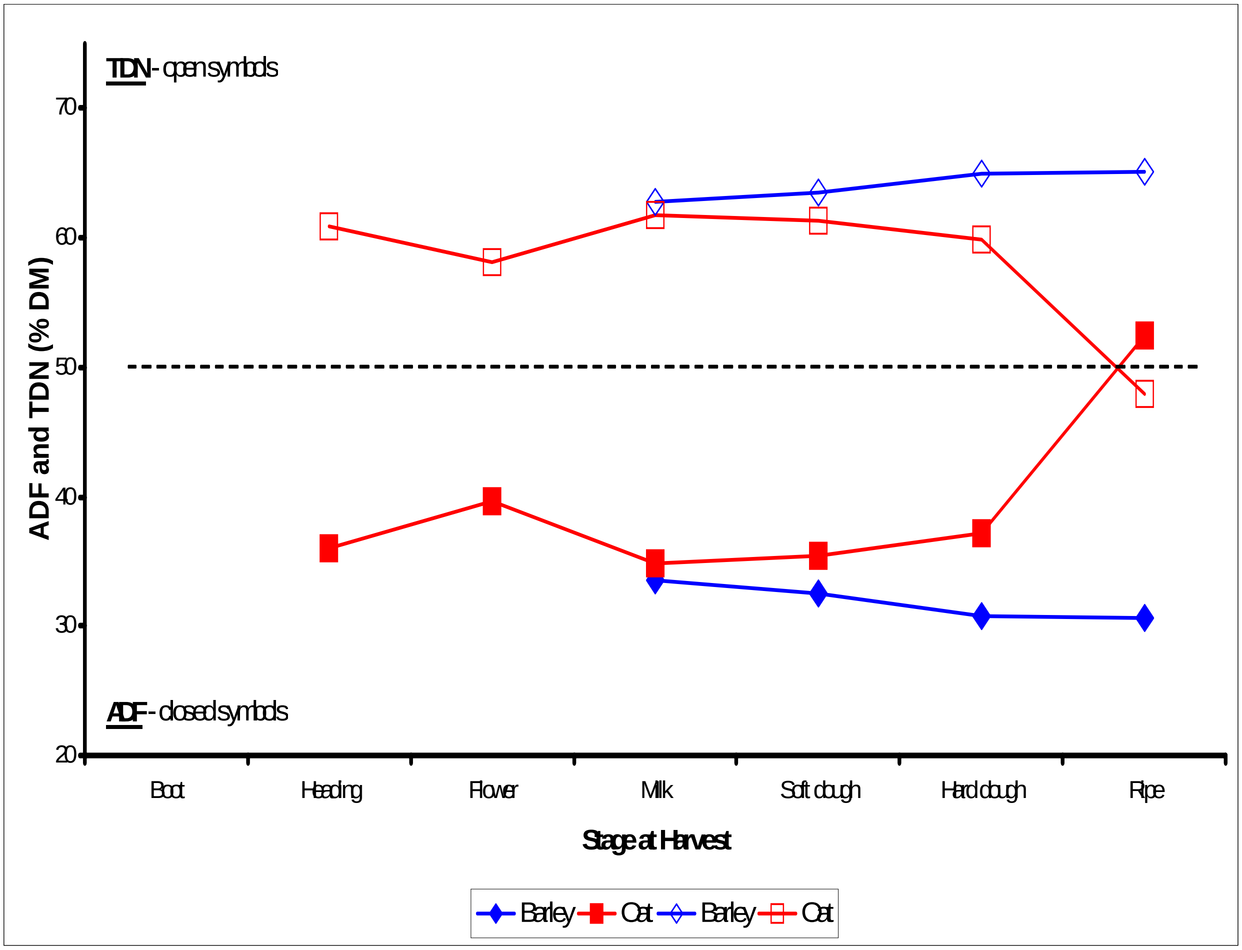

Figure 8. Effect of physiological stage of development at harvest amongst small grain forage type on acid detergent fiber (ADF; P = .02) and total digestible nutrient (TDN; P = .02) concentration.

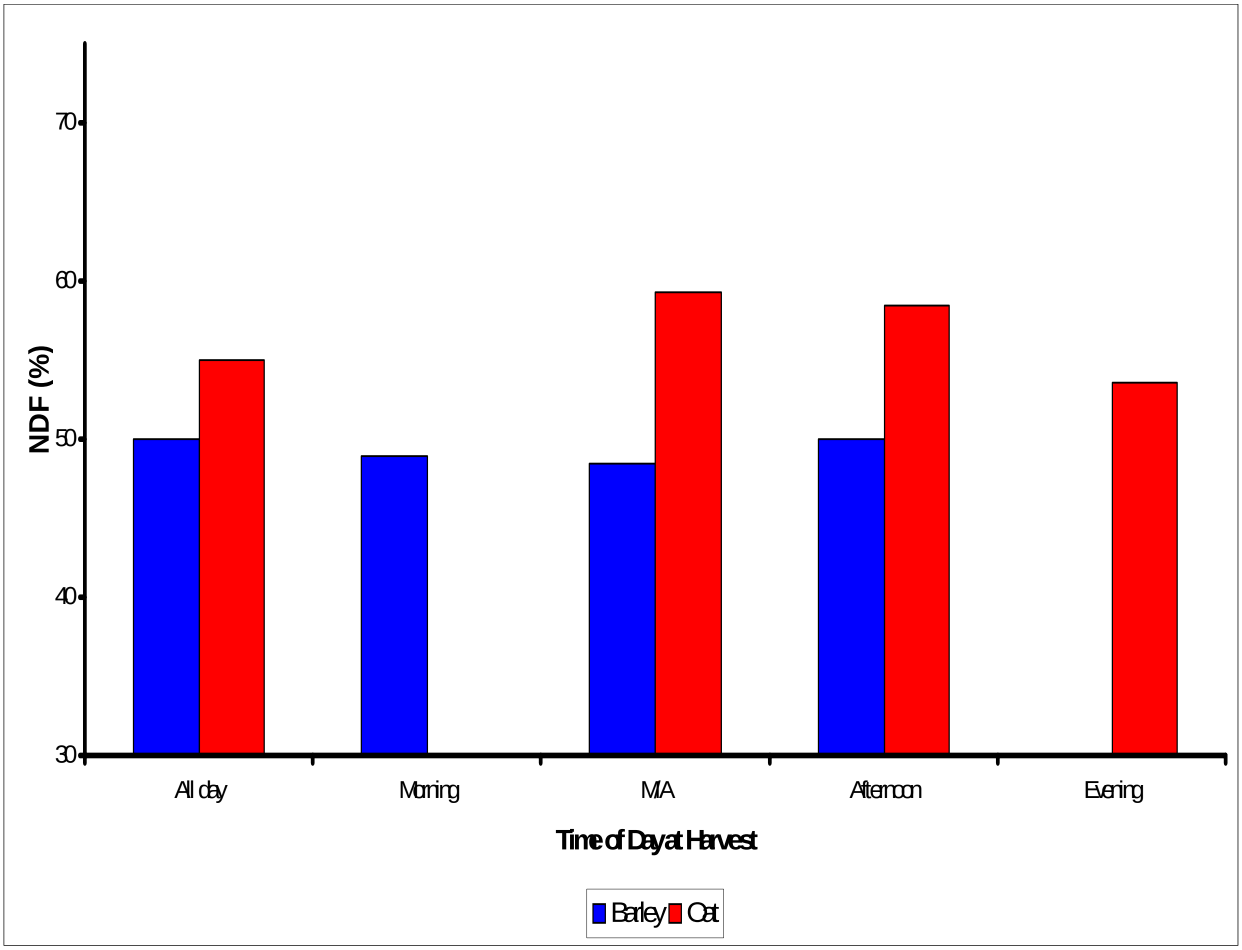

Figure 9. Effect of harvest time of day among small grain forage type on neutral detergent fiber (NDF) concentration (P = .06).