EVALUATION of ALFALFA INTERSEEDING TECHNIQUES

North Dakota State University
Dickinson Research Extension Center
2005

4008

North Dakota State University *2005*
Dickinson Research Extension Center
Rangeland Research Outreach Program DREC 05-4008

Evaluation of Alfalfa Interseeding Techniques

Llewellyn L. Manske PhD
Range Scientist

Project Assistants

Sheri A. Schneider

Amy M. Kraus

North Dakota State University
Dickinson Research Extension Center
1041 State Avenue
Dickinson, North Dakota 58601

Tel. (701) 456-1118
Fax. (701) 456-1199

CONTENTS

Preface

This report summarizes the twenty years of research that scientists at the North Dakota State University Dickinson Research Extension Center dedicated to investigation of the problems related to procedures of interseeding plant material into existing plant communities and to the management of interseeded grassland pastures. Three research programs pertaining to the development of techniques to interseed plant material into grassland plant communities were conducted between 1969 and 1989. The first techniques study, conducted from 1969 to 1978 by Dr. Harold Goetz and Dr. Warren C. Whitman, evaluated the feasibility of interseeding native and tame grass species and legume species by mechanical treatment into native grassland to increase herbage production. The second techniques study, conducted from 1976 to 1980 by Paul E. Nyren, developed and tested modifications of no-till drills for interseeding native and tame grass species and legume species into native grassland. The third techniques study, conducted from 1982 to 1989 by Dr. Llewellyn L. Manske, evaluated the component processes of interseeding techniques and identified the portions with advantages. Selected segments were combined to develop techniques and mechanical processes performed by a rugged simple machine that could be used to interseed alfalfa into grassland ecosystems. A pasture management study, conducted from 1977 to 1981 by Paul E. Nyren and Dr. Harold Goetz and continued from 1984 to 1988 by Dr. Llewellyn L. Manske, evaluated grazing alfalfa interseeded native grassland pastures.

Concept Changes Regarding the Use of Interseeding Practices to Correct Problems in Grassland Ecosystems

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 05-3039

Grass plants, grazing mammals, and grassland ecosystem processes have evolved together. During the long period of coevolution, grass plants developed mechanisms that provide resistance to grazing. A complex system of symbiotic rhizosphere organisms that has numerous trophic levels and is critical for ecosystem functions and for energy and nutrient flow through the ecosystem developed in conjunction with the evolution of plants. Defoliation by herbivores that is properly timed with grass phenological growth stages beneficially manipulates grass growth and development and rhizosphere organism activity (Manske 1999). Grassland ecosystems with a high biomass of active rhizosphere organisms produce greater quantities of herbage biomass than ecosystems with low rhizosphere organism biomass. Stimulating the defoliation resistance mechanisms and rhizosphere organism activity with biologically effective grazing management increases herbage biomass production on grassland ecosystems an average of 30% to 45% greater than the herbage biomass production on grasslands managed with traditional practices (Manske 2003).

Traditional grazing management practices designed for the primary purpose of providing forage for livestock do not beneficially stimulate the defoliation resistance mechanisms of grass plants. After long-term use of traditional management practices, herbage production on native grassland ecosystems decreases substantially below potential. This reduction in herbage biomass is a major detriment to the beef production industry.

The low herbage production observed on grasslands managed with traditional practices has long been assumed to be the result of problems inherent within the grassland ecosystem, and it was commonly believed that if alfalfa could be seeded into these degraded grasslands, their herbage production would be greatly increased. Efforts to achieve this increase in herbage biomass were confounded because interseeding productive plant material into grasslands is considerably more problematic than seeding into cropland.

Investigations into the development of techniques and mechanical processes for interseeding plant material within existing plant communities and into the development of strategies to manage interseeded grassland pastures were perceived to be justified because of the potential magnitude of the benefits that would result from improving herbage production on grassland ecosystems. A combination of techniques and mechanical processes that result in the best potential for successful establishment of alfalfa plants interseeded into native grassland ecosystems was developed during the interseeding research program at the Dickinson Research Extension Center.

Interseeding alfalfa into native range pastures, however, does not solve the problem of low herbage production on grasslands. Low herbage production is not the problem itself but a symptom of the problem: antagonistic grazing management practices lead to low activity of the symbiotic rhizosphere organisms. The reduced rhizosphere activity causes decreased nutrient flow in the ecosystem, and this restriction of nutrients leads to the decrease in herbage biomass production.

Research results designed to treat a symptom of a problem do not correct the problem. The problem of low herbage production on grassland ecosystems can be corrected with the implementation of biologically effective grazing management that coordinates defoliation with grass phenological growth stages (Manske et al. 2003) to stimulate the defoliation resistance mechanisms (McNaughton 1979, 1983; Briske and Richards 1994, 1995) and the activity of the symbiotic rhizosphere organisms (Coleman et al. 1983, Manske 1994). Biologically effective grazing management corrects the biological and ecological problems caused by antagonistic management of grassland ecosystems and thereby eliminates the need for interseeding alfalfa into native grassland pastures.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript.

Literature Cited

Briske, D.D., and J.H. Richards. 1994. Physiological responses of individual plants to grazing: current status and ecological significance. p. 147-176. *in* M. Vavra, W.A. Laycock, and R.D. Pieper (eds.). Ecological implications of livestock herbivory in the west. Society for Range Management. Denver, CO.

Briske, D.D., and J.H. Richards. 1995. Plant responses to defoliation: a physiological, morphological and demographic evaluation. p. 635-710. *in* D.J. Bedunah and R.E. Sosebee (eds.). Wildland plants: physiological ecology and developmental morphology. Society for Range Management. Denver, CO.

Coleman, C.D., C.P.P. Reid, and C.V. Cole. 1983. Biological strategies of nutrient cycling in soil ecosystems. Advances in Ecological Research 13:1-55.

Manske, L.L. 1994. Ecological management of grassland defoliation. p. 130-136. *in* F.K. Taha, Z. Abouguendia, and P.R. Horton (eds.). Managing Canadian rangelands for sustainability and profitability. Grazing and Pasture Technology Program. Regina, Saskatchewan, Canada.

Manske, L.L. 1999. Can native prairie be sustained under livestock grazing? p. 99-108. *in* J. Thorpe, T.A. Steeves, and M. Gollop (eds.). Proceedings of the fifth Prairie Conservation and Endangered Species Conference. Provincial Museum of Alberta. Natural History Occasional Paper No. 24. Edmonton, Alberta, Canada.

Manske, L.L. 2003. Effects of grazing management treatments on rangeland vegetation. NDSU Dickinson Research Extension Center. Summary Range Research Report DREC 03-3027. Dickinson, ND. 6p.

Manske, L.L., A.M. Kraus, S.A. Schneider, and L.J. Vance. 2003. Biologically effective management of grazinglands. NDSU Dickinson Research Extension Center. Rangeland Research Extension Program 4005. 268p. www.GrazingHandbook.com

McNaughton, S.J. 1979. Grazing as an optimization process: grass-ungulate relationships in the Serengeti. American Naturalist 113:691-703.

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. Oikos 40:329-336.

Interseeding into Native Grassland with a Two-Row Lister Machine

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3028

The first native grassland interseeding techniques study at the Dickinson Research Extension Center was conducted by Dr. Harold Goetz and Dr. Warren C. Whitman from 1969 to 1978. The objective was to determine the feasibility of interseeding native and tame grass species and legume species by mechanical treatment into native grassland to increase herbage production.

The established vegetation was mixed grass prairie on Morton fine sandy loam soil. The species interseeded included western wheatgrass (*Agropyron smithii*), green needlegrass (*Stipa viridula*), crested wheatgrass (*Agropyron cristatum*), Russian wildrye (*Elymus junceus*), smooth bromegrass (*Bromus inermis*), Ladak, Vernal, and Travois alfalfa (*Medicago sp.*), Eski sainfoin (*Onobrychis sp.*), and Emerald crown vetch (*Vicia sp.)*. Two additional treatments were included in the study: check plowed, plots receiving mechanical treatment with no seeding, and check control, plots receiving no mechanical treatment and no seeding (Goetz and Whitman 1971).

The interseeded species were seeded October 1969 in 40-inch rows on 50 X 150 foot plots replicated three times. Interseeding was performed with a two-row lister machine mounted on a farm tractor by a standard three-point hitch (figure 1). Two 14-inch lister blades opened two furrows by scalping the sod from 35% of the land area, rolling the sod back in strips or chunks and depositing the sod clods onto the unplowed portion on both sides of each furrow. The overturned sod covered the remaining intact plant community at some percentage close to but probably less than 35%; the result was a damaged and chaotically undulating landscape. Seed from individual seed boxes that utilized a fluted seed metering wheel was gravity-fed through stationary seed tubes mounted behind the shank of each blade and was deposited near the center of the seedbed. The seed was covered and the seedbed firmed by metal pack wheels. All of the interseeded species were handled satisfactorily by this machine; however, the small-seeded legumes were planted at a higher-than-normal seeding rate. The legumes were seeded at 8 lbs/acre and the grasses at 15 lbs/acre (Goetz and Whitman 1978). No fertilizer was applied to these plots.

Forage yield data were collected during August from 1971 to 1978. Nine 12 X 80 inch frames per plot were placed across the rows and clipped. Percent composition of the individual species was estimated for each frame. The forage material was separated into grasses, forbs, and interseeded species and oven dried at 150°F (Goetz and Whitman 1978).

Germination and seedling establishment of the interseeded species were generally high early in the first growing season (1970). A week of hot weather later that spring caused a high mortality of seedlings, however, and extensive reduction of seedlings on the western wheatgrass, Russian wildrye, Eski sainfoin, and Emerald crown vetch treatments terminated data collection for those species. Stand establishment was poor during the first two growing seasons (1970 and 1971) for the other interseeded species except Travois and Vernal alfalfas (Goetz and Whitman 1971).

Travois, Ladak, and Vernal alfalfas, smooth bromegrass, and crested wheatgrass had large increases in herbage weight during the third growing season (1972). The herbage weight of fringed sage and annual forbs increased greatly during the third growing season. Populations of invading grass species, primarily western wheatgrass and smooth bromegrass, increased substantially and became established in all the plowed areas of the treatment plots. The release of nitrogen by the decaying organic matter in the overturned sod, the reduction in competition from short grasses, and the increase in availability of water allowed the invading grasses and forbs to increase and become established in the plowed treatments (Goetz and Whitman 1972).

Travois alfalfa had the greatest herbage production of the interseeded species throughout the eight years of data collection (table 1). The eight-year mean total herbage production was not different among the three alfalfa treatments. Travois, Ladak, and Vernal alfalfa treatments had significantly greater herbage production than the interseeded grasses and control treatments (Goetz and Whitman 1978, Nyren et al. 1978, Nyren et al. 1981).

Smooth bromegrass had the greatest herbage production of the interseeded grasses throughout the eight years of data collection (table 1). The eight-year mean total herbage production did not differ among the three interseeded grasses. The total herbage production on the smooth bromegrass, crested wheatgrass, and green needlegrass treatments did not differ from the herbage production on the check plowed and control treatments (Goetz and Whitman 1978, Nyren et al. 1978, Nyren et al. 1981).

The plant species that invaded the plowed treatments produced an average of 206 pounds of herbage per acre (tables 1 and 2). The quantity of herbage produced by the invader plants did not differ from the quantity of herbage produced by the interseeded smooth bromegrass and crested wheatgrass plants (Goetz and Whitman 1978, Nyren et al. 1978, Nyren et al. 1981). The intact native plant community produced 813 pounds of herbage per acre on the same amount of land area plowed by the mechanical interseeding treatment and occupied by the invader plants.

The portion of the land area that remained as an intact plant community was affected by the ecological changes the mechanical treatment caused. Plants in different biotype categories on the intact community did not all respond the same. Mid grasses and annual forbs increased, while short grasses and perennial forbs decreased.

Mid grass herbage production averaged 20.6% greater on the interseeded treatments than on the control treatment (tables 1 and 2). Crested wheatgrass was the only treatment with a decrease in mid grass yield. Short grass herbage production on all interseeded treatments decreased greatly and averaged 52.0% lower than short grass herbage production on the control treatment (tables 1 and 2). Most perennial forb species decreased; the exception was fringed sage, which increased. Perennial forb herbage production averaged 13.8% greater on the crested wheatgrass and green needlegrass treatments than on the control treatment because the increase in fringed sage was greater than the decrease in the other perennial forbs. Perennial forb herbage production averaged 25.9% lower on the smooth bromegrass and three alfalfa treatments than on the control treatment because the decrease in the perennial forbs was greater than the increase in fringed sage (Goetz and Whitman 1972). Annual forb herbage production averaged 32.4% greater on the interseeded treatments than on the control treatment. Annual forb herbage production averaged 15.0% lower on the smooth bromegrass and Ladak alfalfa treatments than on the control treatment (tables 1 and 2) (Goetz and Whitman 1978, Nyren et al. 1978, Nyren et al. 1981).

The results from this study showed that establishing native grass species by interseeding was difficult and that native grasses established by interseeding produced less herbage than the previously intact native plant community. Establishing Russian wildrye by interseeding was shown to be difficult. Smooth bromegrass and crested wheatgrass were readily established by interseeding; however, the quantity of herbage produced was not greater than that produced by the previously intact native plant community, and the study indicated that those two tame grasses could and would invade native plant communities following mechanical disruption. Sainfoin and crown vetch were far more difficult to establish by interseeding than alfalfa. Alfalfa could be interseeded and established readily into native grassland, and the quantity of alfalfa herbage along with the quantity of herbage produced by the remaining plants was 32% (Nyren et al. 1978) to 36% (table 2) (Goetz and Whitman 1978) greater than the quantity of herbage produced on the control treatment.

The combined herbage production of the grasses and forbs from the intact plant community on the interseeded treatments that had 35% of the established plant community mechanically removed averaged 8% to 9% below the herbage production of the grasses and forbs from the intact plant community on the undisturbed control treatment (table 2). Production of nearly as much herbage on 65% of the land area as the average quantity of herbage produced on the undisturbed control treatment required an increase of 30% to 45% in herbage biomass production from the intact grasses and forbs on the mechanically disturbed treatments. This important scientific finding indicates that if the correct combination of ecological disturbances that increase available nitrogen and soil water infiltration is applied through biologically effective management, intact native grassland plant communities have the potential to increase herbage production 30% to 45% above the level of herbage production typical on traditionally managed grasslands.

The purpose of the interseeding procedures was to directly seed into established plant communities grass or legume species that would produce greater herbage biomass than that produced on the area before the established plant community was destroyed during the execution of the treatments. Production from the interseeded species needed to offset the herbage loss caused by the interseeding sod control technique in order for the treatment to be successful. None of the interseeded grass species reached that level of herbage production. The interseeded alfalfa varieties in combination with the grasses and forbs on the intact portion of the treatments had mean total herbage production 32% to 36% greater than the mean herbage production of the control treatment.

The lister interseeding machine achieved excellent sod control, reducing the competition from the established plants and opening a furrow that presumably decreased runoff and aided water infiltration. The overriding disadvantage of this mechanical treatment was that it scalped a large portion of the land area, causing major destruction to the established plant community, physically exposing the soil surface to wind and water erosion, and creating an extremely rough land surface.

The terrain on the study plots was too rough to drive across 35 years after the mechanical treatments had been conducted. The plowed areas were vegetated, but the furrows had depths ranging between two and six inches. The study plots had lost almost all of the native plant component and were dominated by smooth bromegrass with a subdominant of crested wheatgrass. Alfalfa grew on some plots at about a plant per meter of row. Some remnant native plants remained on the unplowed control plots and alleyways between the replications.

The long-term results from interseeding into native grassland with a lister machine did not meet the desired goals of the study. The ecological processes that were changed by the mechanical treatments in autumn 1969 had not recovered 35 years later. The perennial forb and short grass species were diminished greatly, and their reduction created open spaces for invading species to increase and replace the native plant component. The short-term increase in herbage production on the alfalfa treatments did not persist.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figure. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Lisa J. Vance for digitizing the figure.

Table 1. Mean dry weight yields in lbs/acre for native grassland interseeding study, 1971-1978.

Treatments	Grasses Mid	Grasses Short	Grasses Total	Forbs Perennial	Forbs Annual	Forbs Total	Grasses and Forbs	Interseeded Species	Total Production
Check control	1179	787	1966	327	30	357	2323	NA	2323
Check plowed	1333	415	1748	320	38	358	2106	206	2312
Crested wheatgrass	1095	478	1573	355	52	407	1980	250	2230
Smooth bromegrass	1584	358	1942	239	23	262	2204	260	2464
Green needlegrass	1326	456	1782	389	60	449	2231	79	2310
Vernal alfalfa	1540	373	1913	221	30	250	2163	934	3097
Ladak alfalfa	1641	375	2016	283	28	311	2327	855	3182
Travois alfalfa	1436	192	1628	226	47	273	1901	1292	3193

Data from Goetz and Whitman 1978

Table 2. Percent increase or decrease in herbage yield on interseeded treatments compared to herbage yield on the control treatment.

Treatments	Grasses Mid	Grasses Short	Grasses Total	Forbs Perennial	Forbs Annual	Forbs Total	Grasses and Forbs	Interseeded Species	Total Production
Check control	1179	787	1966	327	30	357	2323	-	2323
Check plowed	+13.06	-47.27	-11.09	-2.14	+26.67	+0.28	-9.34	+8.87	-0.47
Grasses	+13.23	-45.28	-10.19	+0.20	+50.00	+4.39	-7.95	+4.69	+0.50
Alfalfas	+30.54	-60.18	-5.78	-25.59	+16.67	-22.13	-7.96	+398.54	+35.92

Summary of data from Goetz and Whitman 1978

Fig. 1. Two-row lister machine.

Literature Cited

Goetz, H., and W.C. Whitman. 1971. Native grassland interseeding. 22nd Annual Livestock Research Roundup. Dickinson Experiment Station. Dickinson, ND.

Goetz, H., and W.C. Whitman. 1972. Native grassland interseeding. Annual Report. Dickinson Experiment Station. Dickinson, ND.

Goetz, H., and W.C. Whitman. 1978. Interseeding of native mixed prairie in western North Dakota. Annual Report. Dickinson Experiment Station. Dickinson, ND.

Nyren, P.E., H. Goetz, and D.E. Williams. 1978. Interseeding of native mixed prairie in the Great Plains. Proceedings of the First International Rangeland Congress. p. 636-638.

Nyren, P.E., H. Goetz, and D.E. Williams. 1981. A comparison of fertilization and interseeding on native mixed grass prairie in western North Dakota. Proceedings of the North Dakota Academy of Science 35:1.

Interseeding Machine Development by Modification of No-Till Drills

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3029

The second native grassland interseeding techniques study at the Dickinson Research Extension Center was conducted by Paul E. Nyren from 1976 to 1980. The objective was to develop and test modifications of no-till drills for interseeding native and tame grass species and legume species into native grassland. The two most important aspects of the interseeding process that were considered in the design modifications were preparation of a suitable seedbed and control of competition from established vegetation without major destruction of the landscape.

The established vegetation was mixed grass prairie. The species interseeded included green needlegrass (*Stipa viridula*), crested wheatgrass (*Agropyron desertorum*), Russian wildrye (*Elymus junceus*), and Travois alfalfa (*Medicago sp.*).

The three no-till machines evaluated during this interseeding study were the John Deere 1500 Powr-Till Seeder, the Melroe 701 No-Till Drill, and the Melroe 702 3D Drill.

The John Deere Powr-Till Seeder used power-driven cutter wheels to cut through the sod and prepare a seedbed three-fourths inch to one inch wide and three-fourths inch to two and one-fourth inches deep. The fluted force-feed seed-volume metering system was ground driven. Pack wheels firmed the soil above the seed. A sprayer attachment that applied liquid herbicide in bands of variable width ahead of the cutter wheels provided sod control (Nyren et al. 1977, Nyren 1980).

Two trials were conducted with the John Deere drill. The first trial was seeded the first week of May 1976. Russian wildrye and Travois alfalfa were interseeded separately into two native grassland pasture plots. The sod control strips were 12 inches wide and treated with 0.62 lbs AI/acre of glyphosate (Nyren 1980). The second trial was seeded in early June 1977. Green needlegrass and Russian wildrye were seeded in 18-inch rows, with herbicide sod control by glyphosate at 2.0 lbs AI/acre or paraquat at 0.5 lbs AI/acre applied in band widths of 6, 8, and 12 inches, and Travois alfalfa was seeded in 24-inch rows, with herbicide sod control by glyphosate at 2.0 lbs AI/acre or paraquat at 0.5 lbs AI/acre applied in band widths of 9, 12.5, and 14 inches (Nyren et al. 1977, Nyren 1980).

Effectiveness of sod control from the herbicides was evaluated from data collected with the 10-pin point frame method, with the frames placed across the treated rows. Counts of seedlings per meter of row were conducted during the fall of the first and third growing seasons (Nyren 1980).

Neither trial with the John Deere drill was successful. The first interseeding trial was unsuccessful because of low soil moisture, inadequate growth of native plants, and lack of sod control from the herbicide (Nyren 1980). The second interseeding trial with the John Deere drill indicated that neither herbicide at any band width provided sod control (Nyren 1980). Seedling counts of interseeded grasses did not differ among the treatments. Seedling counts of interseeded alfalfa (table 1) differed on the plots of some treatments (Nyren 1980). The reasons for the differences in numbers of alfalfa seedlings per meter of row were not determined, but the differences were not caused by any herbicide treatment effect. The cutter wheel action stirred up a tremendous amount of dust and dirt that fell back onto the sprayed foliage and deactivated the herbicide that had been applied (Welty and Stewart 1980).

The John Deere 1500 Powr-Till Seeder did not perform satisfactorily for interseeding plants into native grassland in western North Dakota. Possible problems with seed-soil contact may have resulted from poor seedbed preparation and inadequate soil firming by lightweight pack wheels. The herbicides were an additional cost for the practice, and the herbicide treatments were ineffective at controlling the competition from established vegetation. The results from this trial indicated that for interseeding plants successfully into native grassland, chemical sod control posed more and greater obstacles than mechanical sod control.

The Melroe 701 No-Till Drill was designed with individual 2.5-inch square steel tubes attached to the lower front of the drill frame to allow the mounted tools that prepared the seedbed and controlled the sod to follow the contour of the land independently for each row. Seeding rates were regulated by non-corrosive twin neoprene sponge rollers located at the bottom of each of the two hoppers. The stock unit tools that came with the drill were a single straight coulter ahead of double disk furrow openers. Pack wheels were not standard.

Four design modifications of the mounted tools were made to adapt the Melroe 701 No-Till Drill for interseeding into grasslands. Modification #1 had two straight coulters placed side by side and set 2.25 inches apart ahead of a 12-inch cultivator sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. A seeding shoe from a Planet Jr. seeder followed the cultivator sweep, and a pack wheel was mounted behind the seeding shoe. Modification #2 had a single straight coulter ahead of two half sweeps mounted on separate square steel tubes, one on each side of the seeded furrow so that sod control was achieved without soil disturbance in the seedbed. A seeding shoe from a Planet Jr. seeder followed the half sweeps, and a pack wheel was mounted behind the seeding shoe. Modification #3 had a standard double disk furrow opener assembly to cut and spread the sod ahead of a 12-inch cultivator sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. Following the cultivator sweep was a seeding shoe from a Planet Jr. seeder; the seeding shoe was fitted with two iron side fins to spread the sod and leave an open furrow wider than one inch. A pack wheel was mounted behind the seeding shoe. Modification #4 had a single straight coulter ahead of a 12-inch cultivator sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. Behind the cultivator sweep was a stock double disk furrow opener followed by a pack wheel (Nyren et al. 1977, Nyren 1980, Nyren et al. 1981).

One trial was conducted with the Melroe 701 No-Till Drill. Crested wheatgrass was interseeded into native grassland in October 1977 and May 1978. Three replications were interseeded with the stock machine tools and the four modification designs. Seedling counts per meter of row were conducted in the fall of 1978 (Nyren et al. 1981).

The combination of tools in modifications #1 and #2 resulted in growth of the greatest number of seedlings (table 2). Modifications #1 and #2 prepared the better seedbeds (Nyren et al. 1981). Treatments interseeded by the stock unit and modification #4 had the smallest number of seedlings (table 2). The October seeding date had a greater number of crested wheatgrass seedlings than the May seeding date for all tool combinations except modification #3 (Nyren et al. 1981).

The modifications that used pack wheels to firm the soil above the seed generally produced treatments with more seedlings than did the stock unit that had no pack wheels. Treatments interseeded by the stock unit and modification #4, which used a double disk furrow opener to deliver seed into the seedbed, had poor seedling establishment because of the uneven seed distribution that resulted from a lack of ground contact and the failure of the disks to turn evenly (Nyren et al. 1977). Treatments that undercut the sod with a 12-inch cultivator sweep achieved 75% to 90% control of the established vegetation within 2 to 3 days (Nyren et al. 1978) without turning the sod over as the old lister blade treatment did. Modifications #3 and #4 made only single cuts into the sod ahead of a 12-inch cultivator sweep and did not remove the sod from the seeded furrow. With the sod remaining in place, the sweep caused seedbed disturbance that resulted in reduced seedling emergence and fewer seedlings per meter of row. These problems were diminished by modifications #1 and #2. In modification #1, the double coulters that cut and removed a strip of sod ahead of a 12-inch cultivator sweep reduced the seedbed soil disturbance under the sweep. In modification #2, the mounting of a half sweep on each side of the seeded row eliminated the sweeps' disturbance of soil in the seedbed.

The Melroe 702 3D Drill had several improved design features over previous models. It retained individual 2.5-inch square steel tubes that were attached to the lower front of the drill frame and allowed the mounted tools that prepared the seedbed and controlled the sod to follow the contour of the land independently for each row. Seeding and fertilizer rates were regulated by non-corrosive twin neoprene rollers located at the bottom of each of the two hoppers. The stock unit tools that came with the drill were two single straight coulters placed one behind the other ahead of double disk furrow openers. Pack wheels were not standard.

The Melroe 702 stock unit was not used for interseeding. The mounted tools were modified for interseeding with three designs. Modification #5 had a single straight coulter ahead of a void slot in which a sweep, if present, would have been located. This empty slot was followed by a seeding shoe that made a one-inch furrow. Modification #6 had a double coulter ahead of a 2-inch sweep followed by a seeding shoe. Modification #7 had a double coulter ahead of a 12-inch cultivator sweep followed by a seeding shoe (Nyren 1980).

One trial was conducted with the Melroe 702 3D Drill. Green needlegrass, Russian wildrye, and Travois alfalfa were each interseeded into native grassland in late June 1978 with each of the three modifications to the Melroe 702 drill. In addition, each plant species was interseeded with modification #7 and a low or a high rate of fertilizer was placed in the seedbed with the seed. The two fertilization rates were 50 lbs N/acre plus 20 lbs P/acre and 89 lbs N/acre plus 40 lbs P/acre. A check treatment with no interseeding and no fertilizer was used as the control (Nyren 1980).

Counts of interseeded grass seedlings per meter of row were conducted during the fall of 1978. Alfalfa seedling height was measured in 1978, and counts of alfalfa seedlings per meter of row were conducted during the fall of 1978 and 1979. Herbage biomass production data from the alfalfa interseeded treatments were collected in August 1978, 1979, and 1980. Three 12 X 40 inch frames per plot were placed across the rows and clipped. The material was separated into grassland vegetation and alfalfa, then oven dried (Nyren 1980).

Green needlegrass seedling counts (table 3) did not differ between the 2-inch sweep and the 12-inch sweep interseeding treatments and did not differ between the two fertilizer treatments (Nyren et al. 1981). The high fertilizer treatment had more seedlings per meter of row than the other treatments (table 3). The lowest seedling count was on the interseeding treatment with no sod control (Mod #5) (table 3).

Russian wildrye seedling counts (table 3) were greatest on the 2-inch sweep treatment and the 12-inch sweep with either of the two fertilizer treatments (Nyren et al. 1981). The lowest seedling count was on the interseeding treatment with no sod control (Mod #5) (table 3).

Seedling counts of the green needlegrass and Russian wildrye treatments were not conducted at the end of the second growing season, presumably because of the lack of sufficient numbers of surviving plants. The late-June seeding date may have caused a suppression in some of the early plant development. Establishing green needlegrass and Russian wildrye into native grasslands by interseeding proved to be extremely difficult. Russian wildrye did not compete well with established native plants, and the young wildrye plants declined rapidly following the seeding year.

Travois alfalfa seedlings were more vigorous than the green needlegrass and Russian wildrye seedlings (tables 3 and 4). The number of alfalfa seedlings per meter of row was significantly lower on the two fertilizer treatments than on the unfertilized treatments (Nyren et al. 1981). The height of the alfalfa seedlings was significantly greater on the two fertilizer treatments than on the unfertilized treatments (Nyren et al. 1981). The alfalfa seedlings on the no-sweep (Mod #5) treatment showed significantly lower height as a result of the greater competition from native plants (Nyren et al. 1981). The no-sweep (Mod #5) and the narrow-sweep (Mod #6) treatments had more seedlings per meter of row in the fall of the first growing season than did the two fertilizer treatments (table 4). Seedlings on the no-sweep and narrow-sweep treatments were smaller and less vigorous than the seedlings on the treatments with 12-inch cultivator sweeps (Nyren et al. 1978), and the greatest percent reduction in seedling numbers between the first and second growing seasons occurred on the no-sweep and narrow-sweep treatments (table 4). The smallest percent reduction in seedling numbers between the first and second growing seasons occurred on the two fertilizer treatments (table 4).

The three-year mean total herbage production on all of the interseeded treatments was lower than that on the control treatment (table 5). The average herbage biomass produced by the interseeded alfalfa ranged between 5.7% and 10.7% of the herbage biomass produced on the control treatment. The average grassland herbage biomass produced during the three growing seasons following the interseeding treatments ranged between 9.9% and 34.2% less than the grassland herbage biomass produced on the control treatment. Treatments interseeded with the combination of modification #7, which had a 12-inch cultivator sweep, and no fertilizer added provided the greatest amount of sod control; use of this treatment resulted in the greatest reduction in grassland herbage biomass (table 5) and the greatest three-year mean alfalfa herbage production.

The problems that occurred on the treatments that had fertilizer added may have been caused more by the placement of the fertilizer directly in contact with the seed than by the practice of adding fertilizer at the time of seeding.

The purpose of the modifications to no-till drills was to directly seed into established plant communities grass or legume species that would produce greater herbage biomass than the herbage biomass produced on the same portion of the established plant community that was destroyed during the execution of the treatments. Production from the interseeded species needed to offset the herbage loss caused by the interseeding sod control technique in order for the treatment to be successful. None of the modifications to no-till drills resulted in the interseeded species' reaching that desired level of herbage production.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript.

Table 1. Travois seedlings per meter of row interseeded June 1977 with the John Deere 1500 Powr-Till Seeder.

Treatment Herbicide and band width (in)	Fall 1977	Fall 1979
Check-no herbicide		
0	10.8	2.5
Paraquat 0.5 lbs AI/acre		
9	14.6	2.6
12.5	8.9	3.6
14	6.1	3.2
Glyphosate 2.0 lbs AI/acre		
9	21.6	4.8
12.5	13.3	2.3
14	12.6	3.6

Data from Nyren et al. 1981

Table 2. Crested wheatgrass seedlings per meter of row interseeded October 1977 and May 1978 with the stock unit and four modifications of the Melroe 701 drill.

Tool Modifications	Fall 1978 October 1977	May 1978
Stock Unit (coulter-double disk-no packer)	2.3	0.4
Mod #1 (double coulter-sweep-shoe-packer)	49.3	17.0
Mod #2 (coulter-half sweeps-shoe-packer)	21.7	5.8
Mod #3 (double disk-sweep-shoe & fins-packer)	8.3	5.0
Mod #4 (coulter-sweep-double disk-packer)	4.3	0.0

Data from Nyren et al. 1981

Table 3. Green needlegrass and Russian wildrye seedlings per meter of row interseeded June 1978 with three modifications of the Melroe 702 drill and three fertilization rates.

		Fall 1978	
Tool Modifications	Fertilization Rates (lbs/ac)	Green needlegrass	Russian wildrye
Mod #5 (coulter-no sweep-shoe)	0N + 0P	1.3	1.0
Mod #6 (double coulter-2 in. sweep-shoe)	0N + 0P	1.9	7.6
Mod #7 (double coulter-12 in. sweep-shoe)	0N + 0P	2.1	3.0
Mod #7	50N + 20P	2.2	7.5
Mod #7	89N +40P	4.7	4.5

Data from Nyren et al. 1981

Table 4. Travois alfalfa seedling height and seedlings per meter of row interseeded June 1978 with three modifications of the Melroe 702 drill and three fertilization rates.

Tool Modifications	Fertilization Rates (lbs/ac)	Fall 1978 Seedling height (in.)	Fall 1978 Seedlings per row	Fall 1979 Seedlings per row	Percent reduction in seedlings per row
Mod #5 (coulter-no sweep-shoe)	0N + 0P	4.0	35.8	9.7	-72.9%
Mod #6 (double coulter-2 in. sweep-shoe)	0N + 0P	4.8	31.2	9.1	-70.8%
Mod #7 (double coulter-12 in. sweep-shoe)	0N + 0P	5.0	21.3	7.3	-65.7%
Mod #7	50N + 20P	8.2	13.0	5.6	-56.9%
Mod #7	89N +40P	8.8	9.6	4.0	-58.3%

Data from Nyren 1980, Nyren et al. 1981

Table 5. Grassland and Travois herbage production (lbs/ac) on plots interseeded June 1978 with three modifications of the Melroe 702 drill and three fertilization rates.

Tool Modifications	Fertilization Rates (lbs/ac)	1978 Total	1979 Grassland	1979 Alfalfa	1979 Total	1980 Grassland	1980 Alfalfa	1980 Total	Three Year Mean Total
Mod #5	0N + 0P	2604	1516	231	1748	799	70	870	1741
Mod #6	0N + 0P	2854	1946	212	2159	830	85	914	1976
Mod #7	0N + 0P	2085	1573	391	1964	665	76	741	1597
Mod #7	50N + 20P	2821	1854	286	2140	1036	114	1149	2037
Mod #7	89N +40P	2720	2055	158	2212	1144	91	1235	2056
Control	0N + 0P	3597	1923	0	1923	1050	0	1050	2190

Data from Nyren 1980

Literature Cited

Nyren, P.E., H. Goetz, and D.E. Williams. 1977. Techniques for interseeding native range. Annual Report. Dickinson Experiment Station. Dickinson, ND.

Nyren, P.E., H. Goetz, and D.E. Williams. 1978. Techniques for interseeding native range. Annual Report. Dickinson Experiment Station. Dickinson, ND.

Nyren, P.E. 1980. North Dakota Report. Development of sod-seeding methods for establishment of small seeded grasses and legumes. Termination Report to Old West Regional Commission. p. 23-29.

Nyren, P.E., H. Goetz, and D.E. Williams. 1981. A comparison of techniques for interseeding native mixed grass prairie in western North Dakota. North Dakota Farm Research 39:17-21.

Welty, L.E., and V.R. Stewart. 1980. Montana Report. Development of sod-seeding methods for establishment of small seeded grasses and legumes. Termination Report to Old West Regional Commission. p. 4-15.

Evaluation of Alfalfa Varieties Solid Seeded into Cropland

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3030

An alfalfa variety trial that included both *Medicago sativa* and *Medicago falcata* was conducted to evaluate the performance of hay- and pasture-type alfalfas under the environmental conditions of western North Dakota. The performance of the alfalfa varieties was compared to the performance of Vernal, which was selected as the standard variety because of its long record of high production across the northern United States. The study was conducted at the Dickinson and the Hettinger Research Extension Centers from 1979 through 1985. Results from the study were presented in papers by Manske and Goetz (1984a and 1984b), Manske (1985), and Manske and Conlon (1986), which are summarized in this report.

Procedure

Alfalfa variety plots of 10 X 25 feet were arranged in a randomized block design with four replications at Dickinson and three replications at Hettinger. Alfalfa was solid seeded into cropland that had been previously used for annual cereal production. The Dickinson site was seeded May 1979, and the Hettinger site was seeded May 1981. The alfalfa plots were managed with a simple one-cut system, and the alfalfa was swathed and baled for hay at the full flower stage, usually during late July or early August. Alfalfa variety herbage biomass production data were collected by the clipping method. Five quarter-meter frames per plot were clipped at the early flower stage, during late June or early July. Herbage samples were oven dried at 140°F. Alfalfa plant density was determined by a count of individual plants rooted within each quarter-meter frame before the herbage biomass was clipped. Mean stem weight was determined from the weight of one hundred individual stems selected from the oven-dried herbage material.

Root rot damage was determined from three to six plants excavated from each plot during August of the seventh growing season. The crown and primary root were divided into two pieces by a cut on the center line. The outside diameter of the main root and the diameter of the infected and damaged portions were measured across the root at the base of the crown. The length of the damaged root tissue was determined in one-third inch increments starting at the point where the root could be identified from the crown. An index scale rating relative severity of damage caused by alfalfa root rot was developed to assist with evaluation of the damage levels observed in alfalfa plants.

Results

Twenty-four varieties of alfalfa were evaluated during this study. Fourteen varieties were developed by university or government plant breeders working at public research facilities, and ten varieties were developed by plant breeders in private industry (table 1). The alfalfa varieties were categorized into types based on the sources of the parent material (table 2). The four alfalfa types were northern pasture types, Ladak hay types, Vernal hay types, and a general group of Mid West hay types.

Precipitation during the study period occurred at the regional extremes from drought to wet conditions (table 3). The spring months, April through June, had rainfall that ranged from 2% to greater than 200% of the long-term mean monthly precipitation. The seeding year at the Dickinson site, 1979, had low rainfall during May. The following year was considered to have a drought growing season with water deficiencies in April and May, and the precipitation was less than half the normal level during April through June. Seeding at the Hettinger site was postponed in 1980 because of the low soil water that spring. Low rainfall occurred in April and May of 1981. High rainfall occurred in April and May of 1982, and greater-than-normal precipitation occurred in June. Very high rainfall occurred in August, September, and October of 1982. In 1983, low rainfall occurred during April and May, and greater-than-normal precipitation occurred in June. April and June of 1984 were wet months, and a water deficiency occurred in May. Low rainfall occurred during April and June of 1985, and May was a wet month.

Precipitation levels during April through June influenced the herbage production of the alfalfa varieties. Herbage production during the drought year of 1980 was very low, with most varieties producing between 200 and 400 pounds per acre. During 1981, a recovery year that had two spring months with low rainfall, alfalfa herbage production was about a third of the potential production. Herbage production was high during 1982, 1983, and 1984 as a result of favorable conditions, including high precipitation during at least one spring month or high rainfall during the fall of the previous year. In 1985, the herbage production was less than half the potential. Some of this reduction resulted from low rainfall during two spring months, and some of the reduction was caused by other factors.

The annual aboveground herbage biomass production for each variety (table 4) was very similar. No significant differences among the varieties were found at the Hettinger site (Manske and Goetz 1984a) or at the Dickinson site, except that one variety, Kane, had greater herbage biomass than the other varieties in 1982 (Manske and Goetz 1984b).

Most alfalfa varieties had mean herbage production greater than 4000 lbs/ac during the three years with favorable precipitation, 1982 to 1984 (table 4). Three varieties produced an average of less than two tons of herbage per acre, Agate, Polar II, and 532. The three-year mean herbage biomass produced by the pasture types, Ladak types, Mid West hay types, and Vernal types was 4569, 4484, 4214, and 4198 pounds per acre, respectively. Vernal produced an annual average of 4190 lbs/ac during 1982 to 1984. The varieties with three-year mean herbage production 105% or greater than that of Vernal (table 5) were Drylander (4800 lbs/ac), Spredor II (4792 lbs/ac), Ladak 65 (4659 lbs/ac), Kane (4634 lbs/ac), Ladak (4576 lbs/ac), Prowler (4545 lbs/ac), Nugget (4541 lbs/ac), Norseman (4488 lbs/ac), 520 (4468 lbs/ac), Rangelander (4466 lbs/ac), Polar I (4461 lbs/ac), and Travois (4440 lbs/ac) (table 4).

Vernal has performed well in western North Dakota. Most of the varieties in the trial performed as well as or better than Vernal (table 5). Only three varieties, Agate, Polar II, and 532, consistently performed more poorly than Vernal. The pasture-type alfalfas and the Ladak-type alfalfas generally performed at levels greater than Vernal under a one-cut system in western North Dakota. Both the pasture- and Ladak-type alfalfas have *M. falcata* at 45% to 100% of their parentage. Vernal has *M. falcata* at about 33% of its parentage.

The amount of herbage biomass produced per acre is determined by the height and weight of each stem and by the density of the alfalfa plants. The mean weight of individual stems did not differ among the alfalfa varieties: the stems of most varieties weighed between 0.25 and 0.50 ounces, with between 64 and 32 stems required to weigh one pound (table 6). The plant density per square foot did not differ among the alfalfa varieties. The density of most alfalfa varieties was between 3.0 and 4.0 plants per square foot (table 7).

The performance of alfalfa varieties can be influenced by attacks from pests. The major pests of alfalfa include fungi, bacteria, viruses, nematodes, and insects. These pests can cause plant diseases and tissue injury that can result in substantial reductions in herbage production and quality. The vulnerability of plants to attacks from pests varies greatly among the different alfalfa varieties, which range from susceptible (S) to resistant (R) to the attack of individual pest types.

Resistance to bacterial wilt was the first physiological trait alfalfa breeders tested and reported as showing variations in response to plant pests among alfalfa varieties. The resistance ratings for the alfalfa varieties in this trial are included in table 8. Most alfalfa varieties grown in the Northern Plains are resistant to bacterial wilt. This disease is generally not a problem for dryland alfalfas in North Dakota because the bacterium requires warm, moist conditions to develop serious infections.

Root rot, a disease caused by soil-borne fungi, is widespread across North America. The disease infects the woody centers of the roots and slowly progresses outward. The extent of root rot damage to the primary root ranged between 35% and 50% of the root diameter at the base of the crown for most alfalfa varieties in this trial (table 8). Travois had the lowest percent damage to the root, 26.8%. The length of the root rot damage ranged between 1.00 and 2.33 inches into the root from the base of the crown. This level of tissue damage from root rot was considered moderate. Every variety in the trial had some root rot damage; however, none of the varieties had severe damage. Moderate levels of root rot damage could cause reductions in herbage production, decreases in tolerance to cold and dry conditions, and diminished resistance to other diseases and pests.

Discussion

The similarity in performance among the varieties in this trial resulted because of the similarities in the sources of parental germplasm. The alfalfa varieties that perform well in Canada and the northern United States have a high proportion of parental material originating from a few accessions, Grimm (*M. media*), Cossack (*M. media*), Don Siberian (*M. falcata*), Orenburg Siberian (*M. falcata* creeper), Semipalatinsk Siberian (*M. falcata* creeper), and Ladak (*M. falcata*).

Vernal was developed in Wisconsin from parental material selected from plants that had survived the environmental extremes of the Plains in old fields that had been planted with seed produced from the early accessions of plant material introduced from Siberia and southern Asia into North America during the first decades of the 1900's. Vernal has performed well under a wide range of environmental conditions of the United States and Canada and has become the standard variety to which alfalfa breeders and researchers compare all other varieties.

The improved performance level of the pasture- and Ladak-type alfalfa varieties appeared to be related to the amount of *M. falcata* in their parentage. The two major species of perennial alfalfa grown in North America are *M. sativa,* which has dark blue or purple flowers, and *M. falcata,* which has white or yellow flowers. The natural cross between them is *M. media*, which has variegated flowers. The *M. sativa* alfalfas have large rounded leaves and tend to have one main tap root growing from a narrow raised crown. The *M. falcata* alfalfas (Ladak types) have lanceolate leaves and have numerous branching roots growing from a moderately wide crown. The *M. falcata* alfalfas (pasture types) have smaller narrow lanceolate leaves and an extensive branching root system that grows from a wide crown located mostly below ground level. The pasture types are creeping alfalfas and can reproduce vegetatively from rhizomes, which are horizontal underground stems.

The varieties with high proportions of *M. falcata* perform well when managed with a one- or two-cut system because they recover relatively slowly after cutting and reduce aboveground production during late summer and early fall. The varieties with a high percentage of *M. falcata* parentage have very high tolerance to cold and dry conditions and persist through adverse conditions.

The varieties with high proportions of *M. sativa* tend to produce greater quantities of herbage than *M. falcata* varieties during growing seasons with favorable precipitation because *M. sativa* varieties recover rapidly after cutting and can be harvested several times per year. However, during dry growing seasons, herbage production of *M. sativa* varieties tends to be much lower than that of *M. falcata* varieties. The varieties with a high percentage of *M. sativa* parentage have lower cold tolerance and are susceptible to winterkill in the Northern Plains; these traits result in short stand longevity.

Conclusion

The alfalfa varieties included in this study had been previously tested at other locations in North America and had performed well. The objective of this trial was to determine if these varieties also performed well in western North Dakota. All of the varieties performed as well as or slightly better than Vernal. The parental origins of the varieties in this trial were similar, and the varieties that performed a little better had sources with a higher percentage of *M. falcata*. The traits that predispose plants to tolerance of adverse cold and dry conditions are derived from the *M. falcata* germplasm. The alfalfa varieties that can be successfully grown under the conditions of western North Dakota have high percentages of *M. falcata* in their parentage.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Development of alfalfa varieties.

Alfalfa Variety	Development Agency	Year Available
Northern Pasture Types		
Anik	Agriculture Canada	1975
Drylander	Agriculture Canada	1971
Kane	Agriculture Canada	1971
Prowler	Northrup, King, and Co.	1980
Rangelander	Agriculture Canada	1978
Spredor II	Northrup, King, and Co.	1980
Travois	South Dakota AES	1963
Ladak Hay Types		
Ladak	Introduced from India	1910
Ladak 65	Montana AES	1964
Norseman	Brazen of Minneapolis	1964
Ramsey	Minnesota AES and USDA	1972
Vernal Hay Types		
Vernal	Wisconsin AES and USDA	1953
Agate	USDA and Minnesota AES	1972
Iroquois	Cornell University	1966
Nugget	North American Plant Breeders	1974
Polar I	Northrup, King, and Co.	1974
Polar II	Northrup, King, and Co.	1980
Mid West Hay Types		
Baker	Nebraska AES and USDA	1976
Ranger	USDA and Nebraska AES	1942
Thor	Northrup, King, and Co.	1970
Trek	Agriculture Canada	1975
520	Arnold-Thomas Seed Service	1968
524	Pioneer Hi-Bred International Inc.	1977
532	Pioneer Hi-Bred International Inc.	1979

Table 2. Parental origin of alfalfa varieties.

Alfalfa Variety	Parental Varieties
Northern Pasture Types	
Anik	M. falcata
Drylander	M. falcata, M. media, M. sativa, Rambler
Kane	Beaver, M. falcata, Rambler
Prowler	Spredor I, Travois, Kane, Rambler, M. sativa
Rangelander	Rambler, Roamer, Drylander, M. falcata
Spredor II	Rambler, Travois, Vernal, M. sativa
Travois	Cossack X Semipalatinsk (M. falcata), Rambler
Ladak Hay Types	
Ladak	Ladak
Ladak 65	Ladak
Norseman	Ladak
Ramsey	Cossack, Ladak
Vernal Hay Types	
Vernal	Cossack, M. falcata X Ladak, Kansas Common
Agate	Ramsey, Vernal
Iroquois	Narragansett, Vernal
Nugget	Alfa, Tuna, Vernal
Polar I	Cardinal, Ladak, Lahontan, Meeker Baltic, Narragansett, Vernal
Polar II	Polar I, Iroquois
Mid West Hay Types	
Baker	Atlantic, Baltic, Cossack, Grimm, Kansas Common, Ladak, Nebraska Common, Ranger, Turkistan, Vernal
Ranger	Cossack, Ladak, Turkistan
Thor	Cardinal, Glacier, Saranac
Trek	Beaver, Lahontan
520	Arnim, Culver, Narragansett, Vernal, selection population
524	Saranac, Vernal, 4 experimentals
532	Flemish, fall dormant type

Table 3. Precipitation in inches for growing-season months.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.41	2.04	3.36	2.75	1.85	1.39	1.24	14.04
1979	1.28	0.91	3.06	2.22	2.21	1.27	0.17	11.12
% of LTM	90.8	44.6	91.1	80.7	119.5	91.4	13.7	79.2
1980	0.03	0.12	2.67	1.43	3.31	0.76	2.41	10.73
% of LTM	2.1	5.9	79.5	52.0	178.9	54.7	194.4	76.4
1981	0.66	1.30	3.71	1.57	4.05	2.75	0.23	14.27
% of LTM	46.8	63.7	110.4	57.1	218.9	197.8	18.5	101.6
1982	1.85	4.32	3.43	2.02	2.63	1.77	6.51	22.53
% of LTM	131.2	211.8	102.1	73.5	142.2	127.3	525.0	160.5
1983	0.32	1.15	3.43	2.81	1.16	1.06	0.25	10.18
% of LTM	22.7	56.4	102.1	102.2	62.7	76.3	20.2	72.5
1984	2.90	0.05	4.98	0.66	2.92	0.91	1.19	13.61
% of LTM	205.7	2.5	148.2	24.0	157.8	65.5	96.0	96.9
1985	0.87	4.31	2.13	1.91	1.75	1.61	2.05	14.63
% of LTM	61.7	211.3	63.4	69.5	94.6	115.8	165.3	104.2

Table 4. Alfalfa herbage production (lbs/ac) under a one-cut system.

Alfalfa Variety	1980	1981	1982	1983	1984	1985	1982-1984 Mean
Northern Pasture Types							
Anik	171	1978	4563	4459	3892	1606	4305
Drylander			4604	5528	4267		4800
Kane	402	1655	4892	5191	3819	1929	4634
Prowler			5244	5212	3178		4545
Rangelander	400	1642	4583	4692	4122	1585	4466
Spredor II	369	1289	5123	4827	4427	1728	4792
Travois	372	1277	5134	4384	3803	1788	4440
Ladak Hay Types							
Ladak	320	1351	4769	4414	4546	1740	4576
Ladak 65	337	1407	4627	5274	4077	1958	4659
Norseman	445	1556	4808	4282	4374	1628	4488
Ramsey	307	1195	4416	4832	3387	1768	4212
Vernal Hay Types							
Vernal	372	1572	4097	4488	3986	1512	4190
Agate	329	1401	3870	4253	3435	1578	3853
Iroquois	401	1422	4788	4109	3975	1803	4291
Nugget	374	1391	4659	5205	3760	1360	4541
Polar I	244	1519	4649	4862	3881	1606	4464
Polar II			4016	4036	3493		3848
Mid West Hay Types							
Baker	233	1662	4281	4945	3480	1779	4235
Ranger	403	1239	4377	4668	3901	1666	4315
Thor	284	1554	4087	4660	3937	1916	4228
Trek	335	1362	4222	4569	3771	1904	4187
520	180	1485	4393	5275	3736	2059	4468
524	339	1518	4281	5232	3597	1684	4370
532			3832	4165	3095		3697

Table 5. Alfalfa herbage production as a percentage of the standard, Vernal.

Alfalfa Variety	1980	1981	1982	1983	1984	1985	1982-1984 Mean
Northern Pasture Types							
Anik	46	126	111	99	98	106	103
Drylander			112	123	107		115
Kane	108	105	119	116	96	128	111
Prowler			128	116	80		108
Rangelander	108	104	112	105	103	105	107
Spredor II	99	82	125	108	111	114	114
Travois	100	81	125	98	95	118	106
Ladak Hay Types							
Ladak	86	86	116	98	114	115	109
Ladak 65	91	90	113	118	102	129	111
Norseman	120	99	117	95	110	108	107
Ramsey	83	76	108	108	82	117	101
Vernal Hay Types							
Vernal	100	100	100	100	100	100	100
Agate	88	89	94	95	86	104	92
Iroquois	108	90	117	92	100	119	102
Nugget	101	88	114	116	94	90	108
Polar I	66	97	113	108	97	106	107
Polar II			98	90	88		92
Mid West Hay Types							
Baker	63	106	104	110	87	118	101
Ranger	108	79	107	104	98	110	103
Thor	76	99	100	104	99	127	101
Trek	90	87	103	102	95	126	100
520	48	94	107	118	94	136	107
524	91	97	104	117	90	111	104
532			94	93	78		88

Table 6. Alfalfa stem dry weight (ounces) and the number of stems per pound.

Alfalfa Variety	1983		1984		1985		1983-1985	
	stem weight (oz)	number of stems per lb	stem weight (oz)	number of stems per lb	stem weight (oz)	number of stems per lb	Mean stem weight (oz)	Mean number of stems per lb
Northern Pasture Types								
Anik	0.41	39.0	0.48	33.3	0.32	50.0	0.45	35.6
Drylander	0.75	21.3	0.55	29.1			0.65	24.6
Kane	0.49	32.7	0.42	38.1	0.26	61.5	0.46	34.8
Prowler	0.46	34.8	0.34	47.1			0.40	40.0
Rangelander	0.40	40.0	0.48	33.3	0.26	61.5	0.44	36.4
Spredor II	0.48	33.3	0.48	33.3	0.21	76.2	0.48	33.3
Travois	0.41	39.0	0.45	35.6	0.33	48.5	0.43	37.2
Ladak Hay Types								
Ladak	0.57	28.1	0.62	25.8	0.29	55.2	0.60	26.7
Ladak 65	0.47	34.0	0.44	36.4	0.32	50.0	0.46	34.8
Norseman	0.45	35.6	0.51	31.4	0.25	64.0	0.48	33.3
Ramsey	0.45	35.6	0.38	42.1	0.26	61.5	0.42	38.1
Vernal Hay Types								
Vernal	0.52	30.8	0.44	36.4	0.22	72.7	0.48	33.3
Agate	0.44	36.4	0.43	37.2	0.29	55.2	0.44	36.4
Iroquois	0.49	32.7	0.47	34.0	0.28	57.1	0.48	33.3
Nugget	0.51	31.4	0.45	35.6	0.30	53.3	0.48	33.3
Polar I	0.61	26.2	0.58	27.6	0.38	42.1	0.60	26.7
Polar II	0.38	42.1	0.34	47.1			0.36	44.4
Mid West Hay Types								
Baker	0.49	32.7	0.42	38.1	0.26	61.5	0.46	34.8
Ranger	0.45	35.6	0.42	38.1	0.28	57.1	0.44	36.4
Thor	0.50	32.0	0.58	27.6	0.34	47.1	0.54	29.6
Trek	0.57	28.1	0.44	36.4	0.40	40.0	0.51	31.4
520	0.57	28.1	0.43	37.2	0.34	47.1	0.50	32.0
524	0.52	30.8	0.44	36.4	0.31	51.6	0.48	33.3
532	0.34	47.1	0.28	57.1			0.31	51.6

Table 7. Alfalfa plant density per square foot.

Alfalfa Variety	1983 plants per ft^2	1984 plants per ft^2	1985 plants per ft^2	1983-1984 Mean plants per ft^2
Northern Pasture Types				
Anik	4.90	2.93	1.88	3.92
Drylander	3.16	3.60		3.38
Kane	3.72	3.43	2.46	3.58
Prowler	4.16	3.41		3.79
Rangelander	4.28	3.13	2.23	3.71
Spredor II	3.97	3.40	3.07	3.69
Travois	4.25	3.27	1.95	3.76
Ladak Hay Types				
Ladak	3.26	2.70	2.19	2.98
Ladak 65	4.08	3.67	2.21	3.88
Norseman	2.08	3.34	2.37	2.71
Ramsey	3.94	3.41	2.46	3.68
Vernal Hay Types				
Vernal	3.32	3.40	2.53	3.36
Agate	3.92	2.97	1.95	3.45
Iroquois	3.72	3.20	2.37	3.46
Nugget	3.92	3.09	1.67	3.51
Polar I	2.99	2.65	1.53	2.82
Polar II	4.09	3.78		3.94
Mid West Hay Types				
Baker	3.80	3.28	2.51	3.54
Ranger	3.91	3.49	2.19	3.70
Thor	3.64	2.83	2.04	3.24
Trek	3.06	2.98	1.72	3.02
520	3.85	3.33	2.19	3.59
524	3.58	3.09	2.00	3.34
532	4.46	4.03		4.25

Table 8. Root rot damage to the primary root and level of resistance to bacterial wilt.

Alfalfa Variety	Resistance to Bacterial Wilt	Diameters of root at base of crown Total root (in)	Infected portion (in)	Percent of root diameter infected (%)	Length of root damage (in)
Northern Pasture Types					
Anik	S	0.54	0.34	63.2	2.33
Drylander	R				
Kane	R	0.41	0.17	42.3	1.00
Prowler	R				
Rangelander	S	0.40	0.20	49.5	1.00
Spredor II	R	0.46	0.22	50.0	2.33
Travois	R	0.32	0.09	26.8	1.00
Ladak Hay Types					
Ladak	MR	0.45	0.18	40.4	1.66
Ladak 65	R	0.41	0.15	36.4	1.33
Norseman	R	0.43	0.17	40.7	1.66
Ramsey	R	0.40	0.19	46.5	2.00
Vernal Hay Types					
Vernal	R	0.43	0.19	42.7	1.66
Agate	R	0.50	0.26	52.3	2.00
Iroquois	R	0.44	0.20	45.1	1.66
Nugget	R	0.47	0.19	40.3	1.66
Polar I		0.50	0.23	45.3	2.00
Polar II	R				
Mid West Hay Types					
Baker	R	0.48	0.22	45.1	2.00
Ranger	R	0.42	0.17	39.6	1.66
Thor	R	0.41	0.22	54.4	1.66
Trek	R	0.55	0.22	40.3	2.00
520	R	0.50	0.19	37.5	1.33
524	MR	0.52	0.25	48.9	2.00
532	R				

Index of
Alfalfa Root Rot
Damage

Llewellyn L. Manske PhD
Range Scientist

North Dakota State University
Dickinson Research Extension Center
1089 State Avenue
Dickinson, North Dakota 58601

Tel. (701) 483-2076
Fax. (701) 483-2073

Root Rot Damage Index

None	0	no injury
Light	1-3	less than 1 inch injured
Moderate	4-6	1 to 2 inches injured
Severe	7-9	more than 2 inches injured
Dead	10	plant is dead

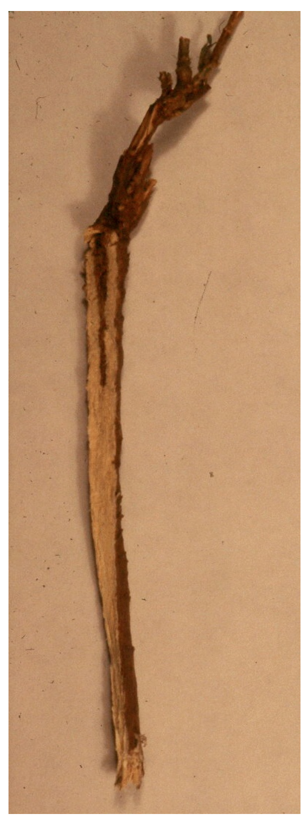
Root Rot Damage Index 0

Root Rot Damage Index 1

Root Rot Damage Index 2

Root Rot Damage Index 3

Root Rot Damage Index 4



Root Rot Damage Index 5

Root
Rot
Damage
Index
6

Root
Rot
Damage
Index
7

Root
Rot
Damage
Index
8

Root
Rot
Damage
Index
9

Literature Cited

Manske, L.L., and H. Goetz. 1984a. Alfalfa variety trial, 1982-1984, at the Hettinger Experiment Station. Progress Report. North Dakota State University Agricultural Experiment Station. Fargo, ND. 7p.

Manske, L.L., and H. Goetz. 1984b. Alfalfa variety trial, 1980-1984, at the Dickinson Experiment Station. Progress Report. North Dakota State University Agricultural Experiment Station. Fargo, ND. 8p.

Manske, L.L. 1985. Alfalfa variety trial, 1980-1985. Range Research Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 297-303.

Manske L.L., and T.J. Conlon. 1986. Alfalfa variety performance trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 36-39.

Evaluation of Alfalfa Varieties Broadcast Sod-Seeded into Native Rangeland

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3031

The peak aboveground herbage biomass produced by native rangeland is less than the peak biomass produced by domesticated pasture grasses. It has long been assumed that the peak herbage biomass on native rangeland would be increased if alfalfa could be seeded into the established plant community.

The famous alfalfa horticulturist N.E. Hansen suggested in the early 1900's that *Medicago falcata* alfalfas would probably be able to hold their own with any native range plants if introduced as wild plants into the prairie (Rumbaugh circa 1979). During the first two decades of the 1900's, South Dakota Agricultural Experiment Station attempted to help increase production on the prairie by making alfalfa seed packets available to Northern Plains homesteaders, who were informed that alfalfa could be grown as a cultivated crop or introduced as wild plants into the prairie (Rumbaugh circa 1979). Spreading alfalfa seed over an intact plant community with a method that imitated seed distribution of wild plants seemed to be a feasible planting technique. Alfalfa seed from innumerable packets was undoubtedly scattered onto prairie sod across the region. Even though there are a few known locations that have *Medicago falcata* alfalfa plants growing in grassland communities, the outcomes of these alfalfa seeding efforts were never reported and the effectiveness of broadcast seeding alfalfa into sod is unknown.

The possibility of using a broadcast sod-seeding method would make the practice of introducing alfalfa into existing plant communities more attractive to producers by simplifying the process and greatly reducing the costs. A trial was conducted to evaluate the performance of *Medicago falcata* alfalfa varieties seeded by a broadcast technique and to determine the feasibility of broadcast sod-seeding alfalfa into native rangeland without chemical or mechanical sod control.

Procedure

The alfalfa variety broadcast sod-seeding trial was established at the Dickinson Research Extension Center Ranch Headquarters, NE¼, NW¼, SW¼, sec. 23, T. 143 N., R. 96 W., in 1983. Thirty 10 X 10 foot plots were arranged in a randomized block design with three replications (figure 1). The established vegetation was mixed grass prairie on Vebar fine sandy loam soil. The alfalfa varieties were Anik, Drylander, Kane, Prowler, Rangelander, Spredor II, Travois, Ladak 65, and Vernal. The seed was inoculated with rhizobium bacteria. The varieties were seeded by a broadcast technique at a rate of 1.0 lb PLS/ac on 29 April 1983. The plots were closely examined monthly in June, July, and August. The observed alfalfa seedlings were counted and the data were recorded (Manske 1983).

Results and Discussion

Nine alfalfa varieties were evaluated during this trial (table 1). The portion of parental material originating from *M. falcata* sources ranged from 45% to 100% for the varieties. Vernal, the standard control variety, has *M. falcata* at a level of about 33% of its parentage.

Precipitation levels during the growing season of 1983 were near normal (table 2). A water deficiency occurred during April, and May had below-normal rainfall. June and July had precipitation at normal levels, and August was wet. A water deficiency occurred during September, and October was dry.

The number of seedlings for each alfalfa variety that grew from seed broadcast into native rangeland is shown in table 3. Kane was the only variety that produced a seedling by the broadcast sod-seeding method. The one alfalfa seedling observed in July did not survive even though high rainfall occurred in August.

The conditions needed for an alfalfa seed to develop into an established plant within an intact grassland community include access to mineral soil, adequate soil water, sufficient quantities of nutrients and minerals, and abundant sunlight. Disruption in the supply of any of these necessities to the alfalfa seedling terminates further plant development.

Although there is a remote possibility that all of the conditions needed for a seedling to survive could occur, the rate of successful establishment of alfalfa plants by broadcast sod-seeding into native rangeland is phenomenally low. The results from this trial showed that interseeding techniques with greater potential for success than the broadcast sod-seeding technique need to be developed.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figure. I am grateful to Lisa J. Vance for digitizing the figure.

Table 1. Parental origin of alfalfa varieties.

Alfalfa Variety	Parental Varieties
Anik	M. falcata
Drylander	M. falcata, M. media, M. sativa, Rambler
Kane	Beaver, M. falcata, Rambler
Prowler	Spredor I, Travois, Kane, Rambler, M. sativa
Rangelander	Rambler, Roamer, Drylander, M. falcata
Spredor II	Rambler, Travois, Vernal, M. sativa
Travois	Cossack X Semipalatinsk (M. falcata), Rambler
Ladak 65	Ladak (M. falcata)
Vernal	Cossack, M. falcata X Ladak, Kansas Common

Table 2. Precipitation in inches for growing-season months at DREC Ranch Headquarters.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.41	2.15	3.27	2.72	1.80	1.44	1.22	14.01
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59
% of LTM	14.9	71.2	100.0	94.1	247.2	59.7	59.0	97.0

Table 3. Alfalfa variety seedlings established by broadcast seeding into native rangeland.

Alfalfa Variety	20 Jun	18 Jul	22 Aug
Anik	0.0	0.0	0.0
Drylander	0.0	0.0	0.0
Kane	0.0	1.0	0.0
Prowler	0.0	0.0	0.0
Rangelander	0.0	0.0	0.0
Spredor II	0.0	0.0	0.0
Travois	0.0	0.0	0.0
Ladak 65	0.0	0.0	0.0
Vernal	0.0	0.0	0.0

Fig. 1. Alfalfa broadcast sod-seeded into native rangeland.

Literature Cited

Manske, L.L. 1983. Alfalfa variety establishment by broadcast seeding into rangeland. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 183-186.

Rumbaugh, M.D. circa 1979. N.E. Hansen's contributions to alfalfa breeding in North America. South Dakota State University Agricultural Experiment Station. B 665. Brookings, SD. 11p.

Summary of the Development of the South Dakota State University Pasture Interseeding Machine

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 05-3040

Improving pasture production through interseeding grass or legume species with minimal disturbance of existing vegetation has long been a goal of South Dakota State University Agricultural Experiment Station researchers.

South Dakota State University agricultural engineers and agronomists at Brookings and Norbeck, South Dakota, developed and tested several early experimental pasture interseeder models between 1965 and 1968. Between 1969 and 1971, researchers developed and modified the 1969 model of the SDSU pasture interseeder. This interseeder cut four furrows spaced 24 inches apart. The interseeder used a pair of discs to cut each furrow approximately 6 inches wide and 3 inches deep. This machine was used in all of the interseeding research conducted in South Dakota from 1969 through 1979. The machine was quite complex, the components were difficult to obtain, fertilizer could be applied only at one constant rate, and the machine had excessive breakdown time (Vigil 1980).

A new and improved pasture interseeder was developed in 1979. The 1979 model of the SDSU pasture interseeder was a relatively simple fabricated toolbar for four chisel plow shanks (figure 1). Plans for the improved machine (Chisholm et al. circa 1980) provided instructions for its construction. The main frame was made of two 10.6-foot lengths of 4 X 4 inch steel tubing placed fourteen inches apart. The front toolbar held the three-point hitch assembly and the parking stand. The back toolbar held the four chisel plow shanks and the two gauge wheels. A 5 X 3 inch steel tube was mounted three feet above the back toolbar to hold four hydraulically driven jumbo hopper boxes with two spouts each. The boxes could be adjusted independently to regulate the flow of seed or fertilizer. Plastic hose connected the spouts of the boxes to the solid seed pipe mounted behind each plow shank. A regular drag chain was attached at the bottom and to the rear of the seed tube, just above the level of the seedbed (Chisholm et al. circa 1980).

The chisel plow shovels used on the SDSU pasture interseeder were 4 inches and 6 inches wide, and each had a right-hand or a left-hand twist. The shovels were mounted on the shanks so that the twist of the chisels would throw the soil from the furrows away from the center of the machine (figure 2). The furrows from the 4-inch shovels were usually 5 to 6.5 inches wide and 3 to 5 inches deep. The wider, 6-inch, shovels were used in dry areas or areas with heavy sod. The furrows from the 6-inch shovels were usually 8 to 9 inches wide and 3 to 5 inches deep. The furrows made by both the 4- and 6-inch shovels were wide enough to eliminate the competition from the existing vegetation long enough to allow seedlings to become established. Furrows that were 3 to 5 inches deep protected young seedlings from being grazed to ground level. The furrows also conserved moisture, and they could increase soil water when they were cut with the contour of the land (Chisholm et al. circa 1980).

The South Dakota State University interseeding research project worked from 1965 though 1979 on the development and continual improvement of a pasture interseeding machine that would be suitable for use in semi-arid environments. As a result of a failed alfalfa interseeding field demonstration in 1979, the focus of the interseeding project changed to an investigation of the diseases that affect alfalfa stand establishment and of the methods for control of the pathogens (Vigil 1980).

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the figures. I am grateful to Lisa J. Vance for digitizing the figures.

Fig. 1. South Dakota State University pasture interseeding machine.

Fig. 2. Pasture interseeding using SDSU toolbar machine.

Literature Cited

Chisholm, T.S., F.R. Vigil, T.M. Klosterman, and G. Orcutt. circa 1980. Interseeding and plans for SDSU's new machine for better pasture production. South Dakota State University Agricultural Experiment Station. B 680. Brookings, SD. 14p.

Vigil, F.R. 1980. South Dakota Report. Development of sod-seeding methods for establishment of small seeded grasses and legumes. Termination Report to Old West Regional Commission. p. 67-111.

Evaluation of Alfalfa Varieties Interseeded into Grassland

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center
Report DREC 04-3032

Two trials conducted at the Dickinson Research Extension Center evaluated the performance of alfalfa varieties for the feasibility of their use as plant material to be interseeded into established grassland plant communities. Trial I started in 1983 and trial II started in 1986.

Procedure

A toolbar-type interseeder was constructed during the winter of 1982-1983 according to published plans (Chisholm et al. circa 1980) for the South Dakota State University pasture interseeder model 1979. Improvements to the interseeding machine were made as indicated from the results of concurrently conducted trials that developed and tested interseeding machine design modifications.

Interseeded alfalfa variety trial I was established on 13 acres located on the S½, SE¼, SW¼, sec. 23, and SW¼, SE¼, sec. 23, T. 140 N., R. 97 W., at the Dickinson Research Extension Center. The 48 X 390 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. Scattered crested wheatgrass plants grew throughout the study site. The soils were Vebar fine sandy loam, Morton silt loam, and Regent silty clay loam. The alfalfa varieties included in the study were Anik, Drylander, Kane, Prowler, Rangelander, Spredor II, Travois, and Vernal. The seed was inoculated with rhizobium bacteria. The alfalfa varieties were interseeded 27 and 28 April 1983 at the seeding rate of 0.50 lbs PLS per row per acre. The unmodified toolbar interseeding machine with four plow shanks set at 3-foot row spacings was used. The furrows were opened with 3-inch twisted chisel plow shovels (Manske 1983).

Interseeded alfalfa variety trial II was established on 0.59 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 80 X 320 foot plots were arranged in a block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. The alfalfa varieties included in the study were Anik, Drylander, Kane, Mandan A1801, Rangelander, Spredor II, Travois, and Ladak. The seed was inoculated with rhizobium bacteria. The alfalfa varieties were interseeded 22 April 1986 at the seeding rate of 0.50 lbs PLS per row per acre. A modified toolbar interseeding machine with two plow shanks set at 10-foot row spacings was used. The furrows were opened with double straight coulters spaced 3-inches apart, followed by a 3-inch twisted chisel plow shovel that was set at a 3-inch depth and had an alfalfa seed tube and a pack wheel behind the shanks, followed by a 12-inch cultivator sweep that had the point removed and was set to undercut the sod about one inch above the seedbed (Manske 1986).

Alfalfa density was determined by counting plants per meter of row. Plant heights were determined by measuring from soil surface to top of plant. Data were collected monthly during June, July, and August each year for both trial I and trial II, with the growing season of 1989 the termination year for each study.

The plots for trial I were reevaluated during the growing season of 2004, 22 years after the plots had been seeded. All of the alfalfa plants growing within a 48 X 300 foot area of each plot were counted. The plants were separated into three size categories: small--single stem, medium--less than 6-inch diameter crown, and large--greater than 6-inch diameter crown. The color of the flowers was recorded for each plant. Differences between means of alfalfa varieties were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results

Six pasture-type alfalfas were evaluated in both trial I and trial II. Each trial had an additional pasture-type alfalfa that was not included in the reciprocal trial. The standard control varieties were Vernal and Ladak for trial I and trial II, respectively.

Seedling densities were high in 1983, during the first growing season of trial I (table 1). Anik, Travois, Drylander, Kane, Spredor II, and Rangelander had the greatest number of seedlings per meter of row. Plant densities decreased greatly between the first and second growing seasons. During the second year, Travois, Spredor II, Rangelander, Prowler, and Kane had the greatest number of plants per meter of row. Plant densities were generally low, ranging between 0.40 and 1.35 plants per meter of row in trial I from 1985 to 1989, and plant densities were not different among the alfalfa varieties during each growing season from 1985 to 1988 (table 1). A severe drought occurred during 1988, and the plant densities were between 5% and 37% lower during 1989. Travois, Spredor II, and Drylander had the greatest number of plants per meter of row during 1989. Between 1989 and 2004, plant densities decreased slightly for each alfalfa variety except Prowler, which showed a slight increase in density. Spredor II, Prowler, Drylander, and Travois had the greatest number of plants per meter of row, and Vernal had the lowest number of plants per meter of row during 2004 (table 1).

Seedling densities were excellent in 1986, during the first growing season of trial II, and there were no differences in the number of seedlings per meter of row among the alfalfa varieties (table 2). Plant densities decreased between the first and second growing seasons. From 1987 to 1988, plant densities ranged between 2.95 and 6.26 plants per meter of row in trial II. Kane, Travois, Ladak, Spredor II, and Rangelander had high mean plant densities during the 1987 to 1989 growing seasons (table 2). A severe drought occurred during 1988, and plant densities were between 40% and 65% lower during 1989. Plant densities in trial II were greater than densities in trial I even though the younger plants in trial II had greater percent reductions in plant densities as a result of the drought conditions of 1988 than the percent reductions of the older plants in trial I. Anik in trial II increased 5% in plant density following the drought.

Plant heights among the alfalfa varieties were not very different during each growing season for both trial I (table 3) and trial II (table 4). Plant heights in both trials were greater during 1987.

Plant density of the pasture-type alfalfas decreased an average of 42% between 1989 and 2004. The range of decrease was 1% to 67%. The density of only one variety did not decrease: Prowler increased 22% in plants per meter of row. Between 1989 and 2004, plant density of the control variety, Vernal, decreased 88%, the greatest decrease for all of the varieties.

The large plants, those with crowns greater than 6 inches in diameter, had the greatest density (table 5) and formed the highest percentage of the plant population (table 6) for all alfalfa varieties in 2004. For most alfalfa varieties, the densities of the small and medium-sized plants were similar (table 5). For Drylander, Prowler, and Spredor II, plant densities were lower for the small plants than for the medium-sized plants (table 5).

Most of the plants for the varieties Prowler, Rangelander, Spredor II, Travois, Vernal, and Kane had dark or medium shades of purple or blue flowers during the 2004 growing season (table 7). Most of the plants for the varieties Anik and Drylander had yellow flowers in 2004 (table 7).

The species composition of the plant community shifted from a mixed grass prairie with crested wheatgrass plants scattered throughout in 1983 to a community dominated by crested wheatgrass with a few remnant native grasses and forbs growing in scattered locations in 2004.

Discussion

The results from these two trials, with emphasis on the 1987 to 1989 and the 2004 data from trial I and the 1987 to 1989 data from trial II, showed that Travois and Spredor II had superior performances. Drylander and Prowler performed well. Rangelander and Kane performed well in the trials through 1988, but their plant densities decreased greatly between 1989 and 2004. The alfalfa varieties that could be used as plant material to be interseeded into established grassland plant communities were pasture-type (*Medicago falcata*) alfalfas and included Travois, Spredor II, Drylander, Prowler, Rangelander, Kane, and Anik. The varieties with a high percentage of *M. falcata* parentage persist through adverse conditions: these varieties have traits that result in long stand longevity.

Anik generally had lower plant densities, and the plant heights usually ranked in the medium to short categories. In the herbage production trials, Anik was rarely among the high-producing varieties. However, Anik should not be omitted from a list of varieties to be used as plant material to be interseeded into established grassland communities. Anik is 100% *Medicago falcata* and has golden-yellow flowers. Its fine stems seem to maintain their leaves well, and Anik appears to hold its own against the competition from grassland plants. Anik was the only variety in trial II to increase in plant density the first growing season after a drought season.

Vernal had plant densities and plant heights comparable to those of the pasture-type alfalfas during the first seven years of data collection. However, results of the reevaluation of the study plots 22 years after seeding showed that Vernal interseeded into grassland communities did not perform as well over the long term as the pasture-type alfalfas. Stand longevity would be expected to be shorter for Vernal than for *M. falcata* varieties. The alfalfa varieties with a high percentage of *M. sativa* parentage would not be expected to perform well when interseeded into grassland communities.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript.

Table 1. Plant density per meter of row for trial I.

Alfalfa Variety	1983	1984	1985	1986	1987	1988	1989	2004
Anik	71.34a	0.22c	0.58a	0.40a	0.63a	0.62a	0.54b	0.23b
Drylander	56.70ab	0.38bc	0.62a	0.51a	0.91a	1.01a	0.96ab	0.80a
Kane	47.03b	0.57b	0.65a	0.43a	0.93a	0.64a	0.54b	0.18bc
Prowler	31.86d	0.81ab	0.81a	0.56a	0.89a	0.79a	0.68b	0.83a
Rangelander	37.22b	0.81ab	1.17a	0.64a	0.91a	0.69a	0.46b	0.23b
Spredor II	38.79c	0.88a	0.92a	0.61a	0.96a	1.09a	0.98a	0.97a
Travois	57.39a	2.08a	1.35a	0.81a	1.21a	1.31a	1.01a	0.41a
Vernal	29.28d	0.44bc	0.95a	0.56a	0.98a	1.08a	0.68b	0.08c

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

Table 2. Plant density per meter of row for trial II.

Alfalfa Variety	1986	1987	1988	1989
Anik	14.09a	3.58d	2.95c	3.11a
Drylander	17.20a	4.47c	2.96c	1.54a
Kane	24.73a	6.22ab	5.31ab	2.53a
Mandan A1801	14.20a	3.38d	5.58a	2.53a
Rangelander	11.84a	4.45c	4.09bc	2.44a
Spredor II	16.55a	5.33abc	4.49b	2.09a
Travois	25.80a	6.26a	4.78b	1.67a
Ladak	16.22a	5.58b	4.49b	1.95a

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

Table 3. Mean plant height (inches) for trial I.

Alfalfa Variety	1986	1987	1988	1989
Anik	12.46b	17.93b	10.91b	15.15a
Drylander	14.93ab	20.91ab	12.69ab	16.56a
Kane	14.07ab	19.48ab	9.26b	14.51a
Prowler	15.85a	20.48ab	12.22ab	15.28a
Rangelander	14.99ab	18.11b	12.97ab	14.63a
Spredor II	15.73a	20.30ab	12.78a	15.38a
Travois	15.30a	22.41a	13.27ab	15.66a
Vernal	15.93a	22.16a	13.99a	14.53a

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

Table 4. Mean plant height (inches) for trial II.

Alfalfa Variety	1986	1987	1988	1989
Anik	5.15a	8.22b	7.85a	6.74a
Drylander	4.87a	10.59ab	6.48a	7.10a
Kane	5.12a	11.96a	7.43a	6.90a
Mandan A1801	4.69a	8.36b	7.40a	7.45a
Rangelander	3.91a	11.75a	6.41a	7.74a
Spredor II	5.19a	10.81a	7.98a	7.20a
Travois	5.09a	12.40a	7.38a	8.02a
Ladak	5.30a	12.78a	7.94a	8.10a

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

Table 5. Density per meter of row of small, medium, and large sized plants for trial I, 22 years after seeding.

Alfalfa Variety	Small single stem	Medium <6 in. diameter	Large >6 in. diameter	Total
Anik	0.04b	0.05b	0.14b	0.23b
Drylander	0.14a	0.18a	0.47a	0.80a
Kane	0.05b	0.04bc	0.10bc	0.18bc
Prowler	0.14a	0.24a	0.46a	0.83a
Rangelander	0.06b	0.08b	0.10b	0.23b
Spredor II	0.24a	0.28a	0.46a	0.97a
Travois	0.05b	0.06b	0.30a	0.41a
Vernal	0.01c	0.02c	0.06c	0.08c

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

Table 6. Percent of plants in three size categories and the number of plants per acre for trial I, 22 years after seeding.

Alfalfa Variety	Small single stem	Medium <6 in. diameter	Large >6 in. diameter	Plants per acre
Anik	17.09	23.05	59.86	997
Drylander	18.02	22.83	59.15	3525
Kane	24.23	21.15	54.62	786
Prowler	16.44	28.61	54.95	3652
Rangelander	24.31	34.02	41.17	1029
Spredor II	24.23	28.26	47.52	4304
Travois	10.75	15.20	74.06	1801
Vernal	11.57	17.36	71.07	366

Table 7. Percent flower color of alfalfa plants for trial I, 22 years after seeding.

Alfalfa Variety	Purple and Blue Flowers %	Pale Blue Flowers %	White Flowers %	Yellow Flowers %
Anik	7.08	1.11	2.12	89.69
Drylander	14.30	1.74	4.63	79.32
Kane	62.38	21.60	10.06	5.96
Prowler	88.37	0.44	3.49	7.70
Rangelander	81.08	6.27	2.65	10.00
Spredor II	79.69	4.93	1.73	13.66
Travois	63.97	20.38	1.97	13.68
Vernal	63.36	5.79	1.65	29.20
Total Plants	58.08	5.32	3.15	33.45

Literature Cited

Chisholm, T.S., F.R. Vigil, T.M. Klosterman, and G. Orcutt. circa 1980. Interseeding and plans for SDSU's new machine for better pasture production. South Dakota State University Agricultural Experiment Station. B 680. Brookings, SD. 14p.

Manske, L.L. 1983. Interseeded alfalfa variety response to grazing trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 176-182.

Manske, L.L. 1986. Interseeded alfalfa variety response trial II. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 244-248.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Evaluation of Interseeding Row-Spacing Techniques

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Report DREC 04-3033 Dickinson Research Extension Center

Previous interseeding research studies conducted in western North Dakota showed alfalfa to be the plant material type that had the greatest potential for interseeding into grassland ecosystems. Some of the researched techniques contributed to an improvement in the rate of success of plant establishment. However, none of the early studies on interseeding techniques developed methods that consistently produced successful results. Additional research on development of interseeding techniques would be required before the alfalfa interseeding concept could progress to practical implementation by beef producers.

Successful interseeding of alfalfa into grassland ecosystems requires the use of methods that mechanically disturb a small portion of the land area without creating a rough terrain and that produce a furrow large enough to provide growing alfalfa plants with access to mineral soil, adequate soil water, sufficient quantities of nutrients and minerals, and abundant sunlight. The established plant community between the furrow rows needs to remain intact and to continue functioning at its previous capacity or at an improved level. The objective of the interseeding row-spacing techniques trial was to evaluate the effects of mechanically produced furrows and the variable distances between the furrow rows on the establishment of alfalfa plants and on the performance of the intact plant community in order to select a row-spacing distance that improved plant performance and caused the fewest detrimental changes to the treated area.

Procedure

The interseeding row-spacing techniques trial was conducted from 1983 to 1988 on one acre located on the NE¼, NW¼, SW¼, sec. 23, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 33 X 50 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Vebar fine sandy loam. Travois alfalfa was used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 21 April 1983 at the seeding rate of 0.50 lbs PLS per row per acre. The unmodified double toolbar interseeding machine constructed according to published plans (Chisholm et al. circa 1980) for the South Dakota State University pasture interseeder model 1979 was used with four plow shanks (figure 1) set at two-, three-, and four-foot row spacings or with two plow shanks (figures 2, 3, and 4) set at five-, eight-, and ten-foot row spacings. The furrows were opened with four-inch twisted chisel plow shovels. A control plot with no interseeding treatment was included in each replication (Manske 1983).

Alfalfa density was determined by counting plants per meter of row. Plant heights were determined by measuring from soil surface to top of plant. Alfalfa density and height data were collected monthly during June, July, and August. Aboveground herbage biomass production was sampled by the clipping method during the period with peak herbage (late July to early August). Six quarter-meter frames were clipped to ground level for each treatment. The clipped frames were placed central to the furrows, on the intact plant community, for each row-spacing treatment. Herbage was separated into biotype categories: short cool-season grasses, short warm-season grasses, mid cool-season grasses, mid warm-season grasses, sedges, and forbs. The samples were oven dried at 140°F. Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method. The frames were placed across the furrows. Differences between means were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Soil water depletion by alfalfa plants was determined from 1986 to 1988 by the gravimetric soil water method with a one-inch Veihmeyer soil tube. Circular plots with a radius of five feet and a single mature alfalfa plant at the center were established on interseeded native rangeland for each replication. Three replications of soil moisture data were collected to a four-foot depth during mid July. Each replication consisted of a set of five holes placed on a transect perpendicular to the interseeded furrow at one-foot intervals from one foot to five feet from the crown of the solitary established interseeded alfalfa plant. These soil water data were compared to soil water data collected from adjacent native rangeland with the same soil type but without the interseeded alfalfa.

Results and Discussion

Most of the growing seasons during the interseeding row-spacing techniques trial (1983-1989) received low-normal precipitation (table 1). The growing season of 1986 had four months with high rainfall. One growing season, that of 1988, received less than 40% of normal rainfall and was considered to have severe drought conditions.

The alfalfa plant densities (table 2) in the row-spacing techniques trial were generally low and ranged between 3.01 and 0.07 plants per meter of row during the growing seasons after the first year. There was very little difference in interseeded alfalfa densities among the row-spacing treatments during each year of the study. All of the row-spacing treatments used 4-inch twisted chisel plow shovels to open the furrows, and the environment in the furrows and the quality of the seedbed should have been similar for each row. Typically, a large reduction in plant density occurs on alfalfa interseeding treatments between the seedling year and the second growing season. In the row-spacing trial, a great reduction in plant density also occurred between the first and second growing seasons.

Alfalfa plant heights (table 3) were not very different among the row-spacing treatments during each growing season of the study. All of the row-spacing treatments used 4-inch twisted chisel plow shovels to open the furrows, and the environment in the furrows and the quality of the seedbed should have been similar for each row, regardless of the variable distance between rows. Alfalfa plant heights were greater during 1987 than during the other growing seasons.

Planning for interseeding treatments is quite different from planning for solid-seeding treatments because with interseeding, the area of the actual seedbed is some fraction of the total area receiving treatment. Evaluation of the effects from interseeding treatments is very different from interpretation of data collected from undisturbed plant communities, because the disturbed portion of the interseeded study area is different from the intact portion of the treatment area. The data collected from the intact portion and the data collected from the disturbed area represent variable proportions of the entire treatment. The size of the seedbed, the size of the total area disturbed, and the size of the intact plant community need to be determined for each treatment, and the values for the collected data require appropriate adjustments in order to correspond to the proportions of the different areas within the total treatment plot.

In theory, a chisel plow shovel would cut a straight edge on the sod and create a furrow the same width as the chisel. For different row spacings, the theoretical size of the interseeded seedbed in square feet and the percent of land area per acre can be determined based on the furrow width and the number of rows per rod (table 4).

In practice, the furrow width is usually larger than the furrow opener because chisel plow shovels do not cut clean edges but rip the sod pieces from underneath so that a greater amount of material than the width of the chisel is removed. The strips of sod do not usually roll out smoothly, landing upside down and lying flat. They are generally a jumbled assortment of contorted sod clods lying on edge and at various angles and occupying less land area than the area of the furrow. Chisel plow shovels four and six inches wide increase the size of the furrow to somewhere around 25% to 65% larger than the width of the chisel. The total area of actual disturbance, including the width of the furrow and the area of the deposited sod clods, ranges roughly between 2% and 5% greater than the theoretical calculations.

The measured percent area of disturbance on the treatment plots for the row-spacing trial (table 5) was greater than the theoretical calculations but near the expected level of increase for chisel plow shovel mechanical sod-control treatments. There were differences in the measured percent area of disturbance among the row-spacing treatments (table 5), caused primarily by the differences in the number of furrow rows on each study plot (figures 5, 6, 7, and 8). The row-spacing treatment plots were 33 feet wide and allowed 16 furrow rows for the 2-foot row-spacing, 12 rows for the 3-foot row-spacing, 8 rows for the 4-foot row-spacing, 6 rows for the 5-foot row-spacing, and 4 rows for the 8-foot and 10-foot row-spacing treatments. The chisel plow shovels used to open all the furrows on the row-spacing treatment were the same size, and the shovels should not have caused any appreciable differences in the size of the individual furrows of each treatment.

The treatment with the 2-foot row spacing had the greatest number of rows per plot; as a result, this treatment had the greatest area of disturbance and the smallest area of intact native plant community (table 5). The treatment with the 3-foot row spacing had 25% fewer rows than the treatment with the

2-foot row spacing and had the second-greatest area of disturbance and the second-lowest area of intact native plant community (table 5). The smallest area of seedbed and the greatest area of intact native plant community were on the treatments with 8-foot and 10-foot row spacing (table 5). The measured area of disturbance and percent area of intact native plant community on the treatments with 8-foot and 10-foot row spacing were similar because both treatments had four furrow rows on each study plot.

The variable proportions of land area disturbed by the mechanical treatment and undisturbed, with an intact plant community, require that the data sets collected from each portion be properly prorated. Goetz and Whitman (1978) solved this potential problem by collecting data from a sample quadrat size that was double the treatment spacing and clipping 12 X 80 inch frames placed across 40-inch row spacings. Because several wide row spacings were used in the row-spacing techniques trial, a ten-pin point frame was used with the frames placed across the rows to determine the percent area disturbed and the percent area of intact plant community.

Herbage production data were collected from frames placed central to the furrows, on the intact plant community portion of the plots. The raw data from this method provided information on the herbage biomass production for the intact portion of the treatment only. Prorating these values to reflect the percent land area with an intact plant community provided information on herbage biomass production for the entire treatment area.

The effects of the interseeding mechanical treatment did result in increased herbage production by the plants on the intact plant community of all of the treatments compared to production on the control treatment (table 6). Herbage production on the interseeded treatments ranged from about 10% to 25% greater than herbage production on the control treatment, which had no mechanical disturbance. A portion of each treatment area except the control was disturbed by interseeding and produced no grassland herbage. The loss of herbage production from the disturbed area was greater than the percent herbage increase on the intact portion for all row-spacing treatments except the treatment with 10-foot row spacing, which had an increase in herbage greater than the percent land area disturbed and produced 2% more herbage than the control treatment (table 6). The increase in herbage production on the intact portion of the interseeded treatments was presumably caused by the increase in the amount of nitrogen released by the decaying organic matter in the overturned sod and the increase in availability of soil water from the removal of some plant competition during the mechanical interseeding treatment.

The herbage biomass produced by each biotype category for all of the row-spacing treatments was not significantly different ($P<0.05$) from the herbage biomass produced by the same biotype category on the control treatment (table 7). The sedge biotype category produced less herbage on all of the row-spacing treatments than on the control treatment (table 7). All of the row-spacing treatments produced greater warm-season short grass herbage than the control treatment (table 7).

Grass basal cover and total plant basal cover (table 8) on the treatments with 2-, 3-, and 4-foot row spacing were significantly lower ($P<0.05$) than the respective basal cover on the control treatment. The basal cover on the treatments with 5-, 8-, and 10-foot row spacing was not significantly different ($P<0.05$) from that on the control treatment (table 8). All of the row-spacing treatments except the treatment with 10-foot row spacing had less grass, forb, and total plant basal cover than the control treatment. The treatment with 10-foot row spacing had about 3% greater grass basal cover and about 2% greater total plant basal cover than the control treatment (table 8). Total forb basal cover for each of the row-spacing treatments was not significantly different ($P<0.05$) from that for the control treatment (table 8). The basal cover of late-succession forbs on the treatments with 2- and 3-foot row spacing was 15% to 20% lower than that on the control treatment. The basal cover of early succession forbs on the treatments with 2-, 3-, and 4-foot row spacing was 20% to 50% greater than that on the control treatment.

The growing season of 1988 had drought conditions, with precipitation 62.17% below the long-term mean rainfall. The reduction in herbage biomass production caused by the drought conditions was greater on the row-spacing treatment plots than on the control treatment plots. The mean reduction in herbage production on the control treatment was 61.25%. The mean reduction in herbage production was 64.47% on the treatments with 10-, 8-, and 5-foot row spacing and 70.28% on the treatments with 4-, 3-, and 2-foot row spacing.

The amount of soil water in the soil profile from the surface to a depth of four feet was lower for the soil at one-foot intervals from one foot to five feet away from the crown of an interseeded alfalfa plant than the amount of soil water in the soil profile of native rangeland without alfalfa (table 9). The depletion of soil water by the alfalfa plant averaged 34.98% greater over a three-year period than the soil water depletion by native rangeland plants without alfalfa. An established alfalfa plant is a serious source of competition for soil water for the adjacent native plants.

Conclusion

This alfalfa interseeding techniques trial evaluated the effects of variable distances between the furrow rows. Two-, three-, four-, five-, eight-, and ten-foot row spacings were considered. When the furrow widths are similar, the widest row spacing causes the least amount of disturbance per acre. The widest practical row spacing with a 10.6-foot toolbar interseeding machine is a 10-foot spacing. Wider spacings could be accomplished by moving the two shanks in to the center of the machine and maintaining a selected wide distance between the furrow pairs during the interseeding operation.

All of the interseeding treatments showed an increase in herbage biomass production on the intact plant community portion of the treatment area. However, the loss of herbage production from the disturbed area was greater than the percent increase on the intact area, and all row-spacing treatments except the 10-foot row-spacing treatment had net reductions in herbage production. The treatment with 10-foot row spacing averaged about a 2% net increase in herbage production. During the drought growing season, all of the row-spacing treatments had greater percent reductions in herbage production than the control treatment. The wider row spacings had less reduction in herbage than the narrow row spacings.

The treatments with narrow row spacings, 2, 3, and 4 foot, had lower basal cover for grasses and total live plants than the control treatment. The treatment with 10-foot row spacing was the only treatment with basal cover values greater than those of the control treatment. The treatment with 10-foot row spacing had about 3% greater grass basal cover and about 2% greater total plant basal cover than the control treatment.

The narrow row-spacing treatments averaged a 31% decrease in desirable perennial forbs and a 29% increase in weedy-type forbs compared to the control treatment (figure 9). The treatment with 10-foot row spacing had 4% less weedy forbs than the control treatment and about 25% less total forbs than the control treatment (figure 10).

Alfalfa plants use greater amounts of soil water than range plants. Soil water depletion by interseeded alfalfa plants extends at least 5 feet from the crown of each plant. The depletion of soil water around each alfalfa plant causes reductions in range plant basal cover and herbage biomass production. With row spacings of less than 10 feet, intensified soil water depletion in the soil profile between the rows could be expected as a result of the water use by alfalfa plants growing in both rows.

The evaluation of the effects caused by various row-spacing treatments indicates that row spacings of 4 feet and less cause considerable degradation to the treated area and that row spacings of 10 feet cause the fewest detrimental changes to the treated areas.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Precipitation in inches for growing-season months at DREC Ranch Headquarters, North Dakota.

Years	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.41	2.15	3.27	2.72	1.80	1.44	1.22	14.01
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59
% of LTM	14.9	71.2	100.0	94.1	247.2	59.7	59.0	97.0
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69
% of LTM	203.5	0.0	162.1	4.0	106.7	36.8	78.7	83.4
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80
% of LTM	87.9	151.2	48.3	39.3	102.2	117.4	174.6	91.4
1986	3.13	3.68	2.58	3.04	0.46	6.32	0.18	19.39
% of LTM	222.0	171.2	78.9	111.8	25.6	438.9	14.8	138.4
1987	0.15	1.38	1.15	5.39	2.65	0.78	0.08	11.58
% of LTM	10.6	64.2	35.2	198.2	147.2	54.2	6.6	82.7
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30
% of LTM	0.0	86.0	52.0	32.4	1.7	50.7	9.0	37.8
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60
% of LTM	207.1	80.5	49.8	47.8	75.6	48.6	78.7	75.7

Table 2. Alfalfa plant density per meter of row for the row-spacing trial.

Row Spacing	1st year 1983	2nd year 1984	3rd year 1985	4th year 1986	5th year 1987	6th year 1988
2 foot	14.01a	3.01a	0.42ab	0.67a	0.88a	0.72ab
3 foot	11.25a	2.15ab	0.18ab	0.65ab	0.57ab	0.47ab
4 foot	9.84a	0.56b	0.07b	0.15b	0.33ab	0.28ab
5 foot	14.10a	2.80ab	0.49a	0.90a	0.96a	0.94a
8 foot	10.71a	1.00ab	0.14ab	0.24ab	0.10b	0.24b
10 foot	10.80a	0.96ab	0.13ab	0.28b	0.46ab	0.22b

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

Table 3. Alfalfa plant height (inches) for the row-spacing trial.

Row Spacing	3rd year 1985	4th year 1986	5th year 1987	6th year 1988
2 foot	9.17a	13.70a	16.14a	9.11b
3 foot	7.63ab	12.54a	17.53a	9.08b
4 foot	8.61ab	11.90a	15.43a	9.16b
5 foot	7.51b	14.03a	18.31a	10.59ab
8 foot	9.27ab	14.05a	14.37a	13.94a
10 foot	8.20ab	12.71a	15.22a	10.24ab

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

Table 4. Theoretical calculations for land area of seedbed prepared by interseeding machine in square feet and percentage of an acre for six row spacings and six furrow widths.

Row Spacing		2 inch furrow	3 inch furrow	4 inch furrow	6 inch furrow	12 inch furrow	14 inch furrow	# Rows per rod
2 foot	sq ft	3703	5445	7187	10890	21780	25410	8.25
	%	8.50	12.50	16.50	25.00	50.00	58.33	
3 foot	sq ft	2468	3630	4792	7260	14520	16940	5.50
	%	5.67	8.34	11.00	16.67	33.34	38.89	
4 foot	sq ft	1854	2726	3598	5452	10904	12721	4.13
	%	4.26	6.25	8.26	12.52	25.00	29.20	
5 foot	sq ft	1481	2178	2875	4356	8712	10164	3.30
	%	3.40	5.00	6.60	10.00	20.00	23.30	
8 foot	sq ft	925	1362	1795	2723	5446	6354	2.06
	%	2.12	3.13	4.12	6.25	12.50	14.59	
10 foot	sq ft	741	1089	1437	2178	4356	5082	1.65
	%	1.70	2.50	3.30	5.00	10.00	11.67	

Table 5. Theoretical and measured percent seedbed, total disturbance, and intact area per acre of row-spacing treatments.

Row Spacing	Percent seedbed area per acre		Percent total disturbance per acre		Percent intact area per acre	
	Theoretical calculation (%)	Measured (%)	Theoretical calculation (%)	Measured (%)	Theoretical calculation (%)	Measured (%)
Control		0.0		0.0		100.00
2 foot	16.50	20.50a	33.00	35.03a	67.00	64.97a
3 foot	11.00	14.56b	22.00	24.93b	78.00	75.07b
4 foot	8.26	10.00bc	16.52	15.91c	83.48	84.09c
5 foot	6.60	9.77c	13.20	17.01bc	86.80	82.99c
8 foot	4.12	6.21d	8.24	10.16c	91.76	89.84c
10 foot	3.30	5.69d	6.60	11.17c	93.40	88.83c

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

Table 6. Total herbage biomass determined for only the intact portion and for the combined intact and disturbed portions of each treatment.

Row Spacing	Total herbage biomass on only the intact portion of each treatment		Total herbage biomass on the combined intact and disturbed areas of each treatment	
	lbs/ac	% of control	lbs/ac	% of control
Control	1198.80	100.00	1198.80	100.00
2 foot	1416.30	118.14	920.17	76.76
3 foot	1501.92	125.29	1127.49	94.05
4 foot	1431.46	119.41	1203.71	100.41
5 foot	1315.30	109.72	1091.57	91.06
8 foot	1329.76	110.92	1194.66	99.65
10 foot	1370.26	114.30	1217.20	101.53

Table 7. Mean herbage biomass production (lbs/ac) from intact and disturbed areas of row-spacing treatments and percentage of herbage biomass from control treatments.

Row Spacing		Cool Short	Warm Short	Cool Mid	Warm Mid	Sedge	Forb	Total
Control	lbs/ac	156.68a	149.68ab	318.34ab	85.02ab	226.58a	250.50a	1198.80a
2 foot	lbs/ac	123.75a	303.15a	163.11b	8.39b	186.35a	137.39a	920.17a
	%	78.98	202.53	51.24	9.87	82.24	54.85	76.76
3 foot	lbs/ac	194.88a	225.00a	257.64ab	69.18ab	182.93a	197.85a	1127.49a
	%	124.38	150.32	80.93	81.37	80.74	78.98	94.05
4 foot	lbs/ac	108.59a	200.12b	335.59a	157.18a	207.89a	194.38a	1203.71a
	%	69.31	133.70	105.42	184.87	91.75	77.60	100.41
5 foot	lbs/ac	174.69a	237.95ab	271.76ab	35.10b	162.88a	209.09a	1091.57a
	%	111.49	158.97	85.37	41.28	71.89	83.47	91.06
8 foot	lbs/ac	144.98a	194.93ab	370.12ab	56.02ab	206.61a	222.03a	1194.66a
	%	92.53	130.23	116.27	65.89	91.19	88.63	99.65
10 foot	lbs/ac	206.14a	296.92ab	204.52b	43.60b	184.59a	283.79a	1217.20a
	%	131.89	198.37	64.25	51.28	81.47	113.29	101.53

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

Table 8. Mean basal cover for grasses, forbs, and total live plants (including woody and succulent species) for row-spacing treatments and percentage of basal cover for control treatments.

	Grasses		Forbs		Total	
Row Spacing	Basal Cover	% of Control	Basal Cover	% of Control	Basal Cover	% of Control
Control	24.73a		3.00a		27.97a	
2 foot	18.84b	76.18	2.49a	83.00	21.42b	76.58
3 foot	20.99c	84.88	2.78a	92.67	23.94c	85.59
4 foot	19.83bc	80.19	2.98a	99.33	23.05bc	82.41
5 foot	23.47a	94.90	2.97a	99.00	26.67a	95.35
8 foot	23.65a	95.63	2.55a	85.00	26.42a	94.46
10 foot	25.41a	102.75	2.74a	91.33	28.37a	101.43

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

Table 9. Mean inches of soil water during mid July at one-foot intervals from crown of interseeded alfalfa plant compared to native rangeland without alfalfa.

Year Depth (inches)	Distance from interseeded alfalfa plant (feet)						Native Range
	1	2	3	4	5	Mean	Control
1986							
0-6	0.67	0.70	0.73	0.67	0.83	0.72	0.71
6-12	0.66	0.70	0.69	0.67	0.69	0.68	0.67
12-24	1.24	1.06	1.20	1.32	1.16	1.20	1.10
24-36	0.80	0.83	0.92	1.07	1.02	0.93	1.91
36-48	0.80	0.77	1.24	1.16	1.00	0.99	0.56
Total	4.17	4.06	4.78	4.89	4.70	4.52	4.95
1987							
0-6	1.01	0.99	0.98	1.07	0.99	1.01	1.05
6-12	0.58	0.61	0.61	0.53	0.58	0.58	0.89
12-24	0.56	0.68	0.60	0.66	0.61	0.62	3.79
24-36	1.06	0.67	0.65	0.61	0.60	0.72	2.74
36-48	0.52	-	0.19	0.84	0.74	0.57	-
Total	3.73	2.95	3.03	3.71	3.52	3.50	8.47
1988							
0-6	0.80	0.77	0.82	0.76	0.79	0.79	0.86
6-12	0.61	0.54	0.44	0.53	0.58	0.54	0.50
12-24	0.74	0.72	0.61	0.79	0.91	0.75	0.72
24-36	1.01	0.83	0.85	0.85	0.96	0.90	0.94
36-48	0.73	0.98	0.80	0.70	0.82	0.81	0.98
Total	3.89	3.84	3.52	3.63	4.06	3.79	4.00
Three Year Mean							
0-6	0.83	0.82	0.84	0.83	0.87	0.84	0.87
6-12	0.62	0.62	0.58	0.58	0.62	0.60	0.69
12-24	0.85	0.82	0.80	0.92	0.89	0.86	1.87
24-36	0.96	0.78	0.81	0.84	0.86	0.85	1.86
36-48	0.68	0.88	0.74	0.90	0.85	0.79	0.77
Total	3.94	3.92	3.77	4.07	4.09	3.94	6.06

Fig. 1. Interseeding machine with two toolbars and four shanks.

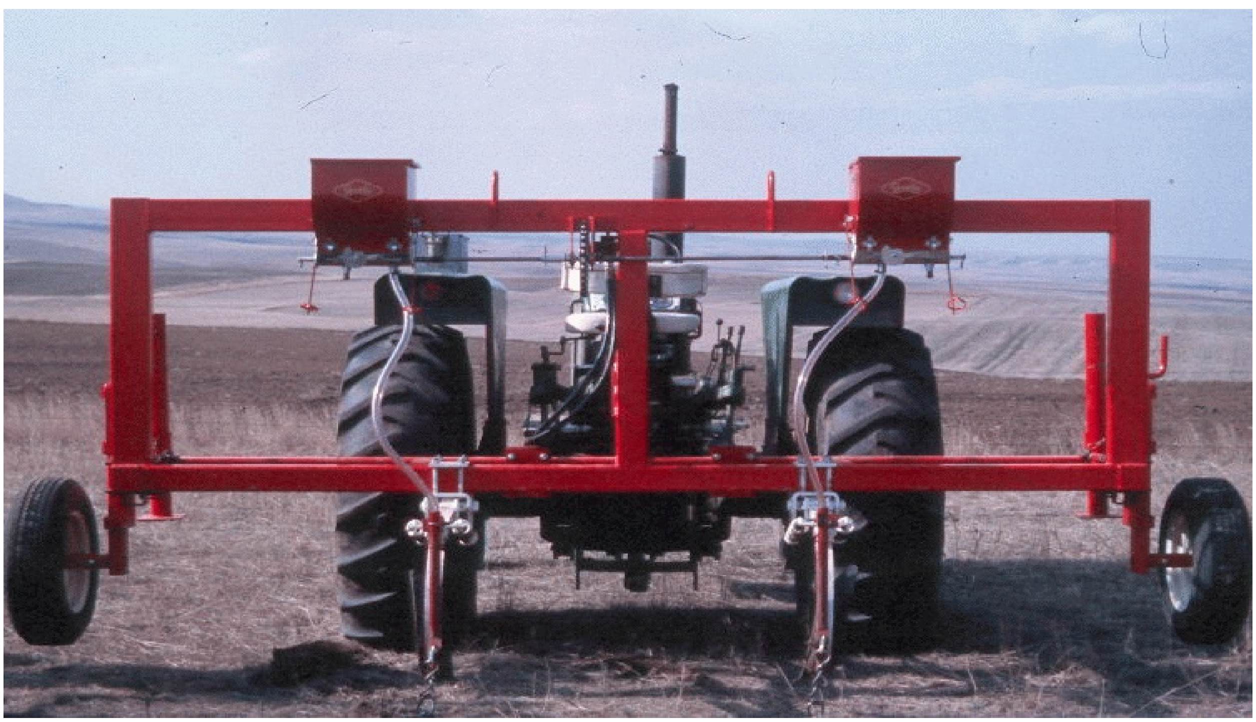


Fig. 2. Interseeding machine with two toolbars and two shanks.

Fig. 3. Interseeding machine with two shanks at ten-foot row spacings.

Fig. 4. Interseeding machine at ten-foot row spacings.

Fig. 5. Grassland interseeded with two-foot row spacing.

Fig. 6. Grassland interseeded with three-foot row spacing.

Fig. 7. Grassland interseeded with five-foot row spacing.

Fig. 8. Grassland interseeded with ten-foot row spacing.

Fig. 9. Interseeding with three-foot row spacing, year three.

Fig.10. Interseeding with ten-foot row spacing, year three.

Literature Cited

Chisholm, T.S., F.R. Vigil, T.M. Klosterman, and G. Orcutt. circa 1980. Interseeding and plans for SDSU's new machine for better pasture production. South Dakota State University Agricultural Experiment Station. B 680. Brookings, SD. 14p.

Goetz, H., and W.C. Whitman. 1978. Interseeding of native mixed prairie in western North Dakota. Annual Report. Dickinson Experiment Station. Dickinson, ND.

Manske, L.L. 1983. Alfalfa interseeding row spacing techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 137-159.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Evaluation of Interseeding Seedbed Preparation and Sod Control Techniques

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3034

Successful interseeding of alfalfa into grassland ecosystems requires the use of methods that prepare a suitable seedbed and effectively control the competition for soil water, nutrients, and sunlight from the established plant community. Both of these important conditions need to be produced mechanically by a set of toolbar plow shank tools that do not cause major destruction to the existing landscape. The interseeding seedbed preparation and sod control techniques trial evaluated variable furrow widths, variable widths of undercutting for sod control, the use of cultivator sweeps with the tip removed or left on to control competition from established sod, the effects of firming the seedbed with pack wheels or drag chains, and efforts to conserve soil moisture by covering the furrow with typical types of mulches. The objective of this study was to select a combination of toolbar plow shank tools that would prepare an adequate seedbed, control competition from the established sod effectively, and cause a minimum of landscape destruction.

Procedure

An interseeding seedbed preparation and sod control techniques furrow-width trial I was conducted from 1983 to 1988 on 0.60 acres located on the NE¼, NW¼, SW¼, sec. 23, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 33 X 50 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Vebar fine sandy loam. Travois alfalfa was used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 21 April 1983 at the seeding rate of 0.50 lbs PLS per row per acre. The unmodified toolbar interseeding machine constructed according to published plans (Chisholm et al. circa 1980) for the South Dakota State University pasture interseeder model 1979 was used with four plow shanks set at three-foot row spacings. The furrows were opened with 2-inch straight, 3-inch twisted, and 4-inch twisted chisel plow shovels (figures 1, 2, 3, 4, 5, and 6). A control plot with no interseeding treatment was included in each replication (Manske 1983).

An interseeding seedbed preparation and sod control techniques furrow-width trial II was conducted from 1985 to 1989 on 0.70 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 50 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Anik, Kane, Rangelander, and Travois alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 11 April 1985 at the seeding rate of 0.50 lbs PLS per row per acre. The double toolbar interseeding machine developed by SDSU was modified by the addition of a third toolbar 30 inches behind the second toolbar. The modified toolbar interseeder was used with the plow shanks set at ten-foot row spacings. Seedbeds were prepared and the sod was controlled with various combinations of plow shank tools. Double straight coulters spaced 3 inches apart cut the sod ahead of 3-inch twisted chisel plow shovels that removed the sod from the furrow; the chisels were followed by cultivator sweeps set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. Furrows were opened with 2-inch straight, 3-inch twisted, 4-inch twisted, and 6-inch twisted chisel plow shovels without additional sod control from cultivator sweeps. The 3-inch chisel plow shovels were used with 6-, 12-, and 16-inch cultivator sweeps. A control plot of no interseeding treatments was included in each replication (Manske 1985).

An interseeding techniques cultivator sweep tip trial that evaluated the performance of the cultivator sweeps with the tip intact or with the tip removed was conducted from 1986 to 1989 on 0.28 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 22 April 1986 at the seeding rate of 0.50 lbs PLS per row per acre. The modified interseeding machine with three toolbars was used with the plow shanks set at ten-foot row spacings. Double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep with the tip intact or with the tip removed, were used to prepare the seedbed and control the sod. The cultivator sweep tip was cut in a reverse "V" shape that mirrored the angle of the sweep, with the widest part of the cut at three inches (Manske 1986).

An interseeding techniques seedbed-firming trial that evaluated the performance of pack wheels (figure 11) and drag chains (figure 12) was conducted from 1986 to 1989 on 0.28 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 22 April 1986 at the seeding rate of 0.50 lbs PLS per row per acre. The modified interseeding machine was used with the plow shanks set at ten-foot row spacings. The furrows were opened with double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel with a pack wheel or a drag chain behind the shank, followed by a 12-inch cultivator sweep (Manske 1986).

An interseeding techniques furrow-mulch trial (figures 13, 14, 15, 16, 17, and 18) that evaluated the performance of various types of mulches was conducted from 1988 to 1989 at the Dickinson Research Extension Center Ranch Headquarters. The plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 13 April 1988 at the seeding rate of 0.50 lbs PLS per row per acre. The modified interseeding machine was used with the plow shanks set at ten-foot row spacings. The furrows were opened with double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep that had the point removed. Crested wheatgrass hay and oat straw were ground by a hay chopper and applied into the interseeded furrows of selected plots immediately after seeding. Strips of black plastic sheets were pinned to the ground to cover the selected furrows for a period of two weeks following seeding. A control interseeded treatment with no mulch added to the furrows was included in each replication (Manske 1988).

Alfalfa density was determined by counting plants per meter of row. Plant heights were determined by measuring from soil surface to top of plant. Alfalfa density and height data were collected monthly during June, July, and August.

Additional data were collected from the treatment plots of techniques trial I (Manske 1983). Aboveground herbage biomass production was sampled by the clipping method during the period with peak herbage (late July to early August). Six quarter-meter frames were clipped to ground level for each treatment. The clipped frames were placed central to the furrows, on the intact plant community, for each furrow-width treatment. Herbage was separated into biotype categories: short cool-season grasses, short warm-season grasses, mid cool-season grasses, mid warm-season grasses, sedges, and forbs. The samples were oven dried at 140°F. Quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method. The frames were placed across the furrows. Forb density was determined by identifying to species each plant rooted within 25 one-tenth-meter-square quadrats per plot (Manske 1987). Differences between means were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results and Discussion

Most of the growing seasons during the interseeding seedbed preparation and sod control techniques trial (1983-1989) received low-normal precipitation (table 1). The growing season of 1986 had four months with high rainfall, and the growing season was considered wet. One growing season, that of 1988, received less than 40% of normal rainfall and was considered to have severe drought conditions.

The alfalfa plant densities (table 2) on the furrow-width techniques trial I were low and ranged between 0.76 and 0.15 plants per meter of row after the first growing season. During each year of the study, there was no difference in interseeded alfalfa densities among the furrow-width trial I treatments with the furrows opened by 2-, 3-, and 4-inch chisel plow shovels. The alfalfa plant densities (table 3) on the furrow-width trial II treatments with the furrows opened by 2-, 3-, 4-, and 6-inch chisel plow shovels were generally low and ranged between 2.97 and 0.50 plants per meter of row. The 3-inch twisted chisel plow shovel was the narrowest tool that produced a suitable furrow and seedbed. The 4-inch and 6-inch twisted chisels were wider than the 3-inch chisel, but their use did not improve the density of established alfalfa plants. The furrows opened by three-inch chisel plow shovels followed by cultivator sweeps that undercut the sod had satisfactory plant densities that ranged between 6.87 and 0.87 plants per meter of row (table 3). During the first two years of the trial, alfalfa plant densities were not significantly different ($P<0.05$) among treatments with the three sizes of cultivator sweeps (table 3). During the following three years, alfalfa plant densities were significantly greater ($P<0.05$) on the 12-inch sweep treatments than on the 6-inch sweep treatments (table 3). Alfalfa plant densities on the 12-inch sweep and the 16-inch sweep treatments were not significantly different ($P<0.05$) during the first four years of the trial. During the fifth year of the trial, alfalfa plant densities were significantly greater ($P<0.05$) on the 12-inch sweep treatments than on the 16-inch sweep treatments (table 3). The 16-inch sweep undercut a larger area of the established plant community than the 12-inch sweep, but use of the larger sweep did not improve the density of established alfalfa plants. The treatment with 12-inch cultivator sweeps had the greatest plant density during each year of the study (figures 7, 8, 9, and 10).

Alfalfa plant heights (table 4) were not significantly different ($P<0.05$) among the furrow-width trial I treatments during each growing season of the study. Alfalfa plant heights (table 5) were not significantly different ($P<0.05$) among the furrow-width trial II treatments during each growing season after the first year. Alfalfa plant heights were greater during 1987 than during the other growing seasons on both furrow-width trials (tables 4 and 5).

Evaluation of the effects from interseeding treatments is very different from interpretation of data collected from undisturbed plant communities, because the disturbed portion of the interseeded study area is different from the intact portion of the treatment area. The data collected from the intact portion and the data collected from the disturbed area represent variable proportions of the entire treatment. The size of the seedbed, the size of the total area disturbed, and the size of the intact plant community need to be determined for each treatment, and the values for the collected data require appropriate adjustments in order to correspond to the proportions of the different areas within the total treatment plot. The theoretical size of the interseeded seedbed in square feet and the percent of land area per acre can be determined based on the furrow width and the number of rows per rod (table 6).

The measured total area of actual disturbance, including the width of the furrow and the area of the deposited sod clods, was greater than the theoretical calculations for the disturbed portion of the treatment plots of furrow-width trial I (table 7). The differences between the measured percent disturbance and the calculated theoretical area of disturbance increased as the width of the chisels decreased. The percent seedbed area disturbed was 36.3%, 77.5%, and 115% greater than the width of the chisel for the 4-inch, 3-inch, and 2-inch chisels, respectively. Chisel plow shovels do not cut clean edges but rip out areas of sod wider than the chisel (figures 1, 2, 3, 4, 5, and 6). The problem of creation of a furrow width larger than the chisel width can be corrected by cutting the sod with two straight coulters placed side by side ahead of chisel plow shovels; the chisels will then remove the cut furrow sod strips cleanly.

Herbage production data were collected from frames placed central to the furrows, on the intact plant community portion of the plots. The raw data from this method provided information on herbage biomass production for the intact portion of the treatment only. Prorating these values to reflect the percent land area with an intact plant community provided information on herbage biomass production for the entire treatment area.

The effects of the interseeding mechanical treatment did result in increased herbage production by the plants on the intact plant community of the 3- and 4-inch chisel treatments (table 8). Herbage production for the interseeded treatments ranged from about 2% to 11% greater than the herbage production on the control treatment, which had no mechanical disturbance. A portion of each treatment area except the control was disturbed by interseeding and produced no grassland herbage. The loss of herbage production from the disturbed area was greater than the percent herbage increase on the intact portion for all furrow-width treatments. The prorated herbage biomass production was greatest on the 3-inch twisted chisel plow shovel treatment (table 8). The increase in herbage production on the intact portion of interseeded treatments was presumably caused by the increase in the amount of nitrogen released by the decaying organic matter in the overturned sod and the increase in availability of soil water from the removal of some plant competition during the mechanical interseeding treatment.

Herbage biomass produced by each biotype category for all of the furrow-width trial I treatments was not significantly different ($P<0.05$) from the herbage biomass produced by the same biotype category on the control treatment (table 9), except the 3-inch treatment produced greater warm-season short grass herbage and less warm-season mid grass herbage than the control treatment, and the 2- and 3-inch treatments produced less sedge herbage than the control treatment. The 4-inch treatment produced more warm-season mid grass herbage than the 3-inch treatment. The 3-inch treatment produced more cool-season short grass and warm-season short grass herbage than the 4-inch treatment. The 3-inch treatment produced more cool-season mid grass herbage than the 2-inch treatment (table 9).

Grass basal cover and total plant basal cover (table 10) on the 4-inch furrow width treatments were significantly lower ($P<0.05$) than the respective basal cover on the control treatment. The grass basal cover and total plant basal cover on the 2- and 3-inch furrow-width treatments were not significantly different ($P<0.05$) from those on the control treatment (table 10). Total forb basal cover for each of the furrow-width treatments was not significantly different ($P<0.05$) from that for the control treatment (table 10). All of the furrow-width treatments had less grass, forb, and total plant basal cover than the control treatment. The 3-inch treatment had greater grass basal cover and total plant basal cover than the 4-inch treatment (table 10).

Cool-season grass basal cover on the 4-inch furrow-width treatment was greater than, but not significantly different from, that on the control treatment (table 11). Cool-season grass basal cover on the 2- and 3-inch furrow-width treatments was less than, but not significantly different from, that on the control treatment (table 11). Warm-season grass basal cover on the 4-inch furrow-width treatment was significantly less ($P<0.05$) than that on the control treatment (table 11). Warm-season grass basal cover on the 2- and 3-inch furrow-width treatments was greater than, but not significantly different from, that on the control treatment (table 11). Sedge basal cover on the 2-, 3-, and 4-inch furrow-width treatments was less than, but not significantly different from, that on the control treatment (table 11). The 2-inch treatment had less cool-season grass basal cover than the 4-inch treatment. The 3-inch treatment had greater warm-season grass basal cover than the 4-inch treatment (table 11).

Late-succession forb basal cover on the 2-, 3-, and 4-inch furrow-width treatments was less than, but not significantly different from, that on the control treatment (table 11). Mid and early succession forb basal covers on the 2-, 3-, and 4-inch furrow-width treatments were not significantly different ($P<0.05$) from those on the control treatment (table 11).

Late-succession forb density per square meter on the 2-, 3-, and 4-inch furrow-width treatments was lower than, but not significantly different from, that on the control treatment (table 12). Mid and early succession forb density on the 2-, 3-, and 4-inch furrow-width treatments was greater than, but not significantly different from, that on the control treatment (table 12). Total forb density per square meter on the 2-, 3-, and 4-inch furrow-width treatments was lower than, but not significantly different from, that on the control treatment (table 12).

The 2-inch straight spike prepared a furrow that was extremely narrow at the bottom and much wider near the soil surface. The sides of the furrow were irregular because the 2-inch spike ripped out large pieces of sod. The sod did not roll out of the furrow onto the intact plant community. Instead, the straight spike directed the sod strips into the air above the furrow and some of the sod clods fell back into the furrow.

The 3-inch twisted chisel plow shovel prepared an excellent seedbed with a “V” bottom, and the furrow had adequate width near the soil surface. The sod strips were removed from the furrow, and the sod clods were deposited on the adjacent intact plant community satisfactorily.

The 4-inch twisted chisel plow shovel removed the sod strips from the furrow and deposited the sod clods on the adjacent intact plant community satisfactorily. The quality of the seedbed produced by the 4-inch chisel was less than desirable because the tool had a flat cutting edge like the plowshare on a moldboard plow.

The 6-inch twisted chisel plow shovel removed the sod strips from the furrow satisfactorily. The furrow had a “V” bottom, but the furrow was wider than necessary and the great width of the chisel caused a large portion of the treatment area to be disturbed.

Alfalfa plant density per meter of row on the treatment with the tip of the cultivator sweep removed was 33.6% greater than, but not significantly different ($P<0.05$) from, alfalfa plant density on the treatment with the tip of the cultivator sweep left on (table 13).

Alfalfa plant height (table 13) was not significantly different (P<0.05) between the cultivator sweep tip treatments. The results of this small study did not conclusively show the importance of removing the tip from the cultivator sweeps.

The function of the cultivator sweep is sod control of the established plant community adjacent to both sides of the furrow. The sweep fins undercut the sod and separate the crowns of grass plants from a large portion of the grass plants' roots. The undercut sod remains in place, and the result is a relatively smooth land surface unlike the extremely rough terrain produced by lister-type interseeding machines. The grass plants are not killed, but their growth processes are greatly impaired, and the result is a reduction in competition from the established plant community for soil water and nutrients. The 6-inch sweeps do not undercut a large enough area on each side of the furrow to reduce the competition from the established plant community adequately. The area the 12-inch sweeps undercut on each side of the furrow is adequate to reduce the competition sufficiently. The 16-inch sweeps undercut an area larger than the 12-inch sweeps, but the effects are not greater than those resulting from use of the 12-inch sweep.

The cultivator sweeps follow the 3-inch twisted chisel plow shovels, which are set to produce a furrow 3 inches wide and 3 inches deep. The cultivator sweeps are set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. The cultivator sweep passes over the seedbed, 1 to 1.5 inches above the deposited alfalfa seed. The portion of the sweep directly over the furrow serves no function and can cause seedbed disturbance that results in reduced seedling emergence and fewer seedlings per meter of row. Removal of the tip of the cultivator sweep by cutting a reverse "V" shape that mirrors the angle of the sweep, with the widest part of the cut at three inches, the same width as the furrow, can eliminate potential seedbed disturbances.

Alfalfa plant density per meter of row and alfalfa plant height were not different (P<0.05) between the pack wheel (figure 11) and drag chain (figure 12) treatments (table 14). The small seeds of grasses and legumes can desiccate easily when they are directly exposed to air. The rate of desiccation is greatly reduced when the seeds are covered completely with soil. A drag chain used following the deposition of the seeds into the seedbed helps cover the small seeds with soil. A pack wheel used following the deposition of seeds into the seedbed firms the soil above the seed; the firming helps the soil act like a blotter, allowing moisture to move upward and helping maintain moisture closer to the soil surface (Goplen et al. 1980).

Alfalfa plant density per meter of row (table 15) on the crested wheatgrass hay and the oat straw mulch treatments was significantly lower (P<0.05) during the first year of the trial than that on the control treatment with no mulch. During the second year, the alfalfa plant density per meter of row on the crested wheatgrass hay mulch treatment was significantly lower (P<0.05) than that on the control treatment, but the alfalfa density on the oat straw mulch treatment was not significantly different (P<0.05) from that on the control treatment. Alfalfa plant height (table 16) on the crested wheatgrass hay and the oat straw mulch treatments was not significantly different (P<0.05) from that on the control treatment. Alfalfa plant density per meter of row on the black plastic mulch treatment was lower than, but not significantly different from, that on the control treatment (table 15). Alfalfa plant height on the black plastic mulch treatment was greater than, but not significantly different from, that on the control treatment (table 16).

The intention of the mulch treatments (figures 13, 14, 15, 16, 17, and 18) was to conserve soil moisture in the furrows and increase the amount of available water to the alfalfa seedlings. The hay and straw mulch treatments were very detrimental to alfalfa plant establishment. The black plastic mulch treatment was less detrimental than the hay and straw mulch treatments but also did not benefit alfalfa plant establishment.

Conclusion

The combination of toolbar plow shank tools that prepared an adequate seedbed and effectively controlled competition from the sod required the addition of a third toolbar onto the interseeding machine (figure 19). The plow shank on the front toolbar carried double straight coulters that were placed side by side and three inches apart and were set to cut the sod to a 3-inch depth. The plow shank on the middle toolbar carried a 3-inch twisted chisel plow shovel set to produce a furrow 3 inches wide and 3 inches deep, with the "V" point extending a little deeper. The plow shank on the back toolbar carried a 12-inch cultivator sweep with the tip removed by a cut in a reverse "V" and the fins of the sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Precipitation in inches for growing-season months at DREC Ranch Headquarters, North Dakota.

Years	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.41	2.15	3.27	2.72	1.80	1.44	1.22	14.01
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59
% of LTM	14.9	71.2	100.0	94.1	247.2	59.7	59.0	97.0
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69
% of LTM	203.5	0.0	162.1	4.0	106.7	36.8	78.7	83.4
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80
% of LTM	87.9	151.2	48.3	39.3	102.2	117.4	174.6	91.4
1986	3.13	3.68	2.58	3.04	0.46	6.32	0.18	19.39
% of LTM	222.0	171.2	78.9	111.8	25.6	438.9	14.8	138.4
1987	0.15	1.38	1.15	5.39	2.65	0.78	0.08	11.58
% of LTM	10.6	64.2	35.2	198.2	147.2	54.2	6.6	82.7
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30
% of LTM	0.0	86.0	52.0	32.4	1.7	50.7	9.0	37.8
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60
% of LTM	207.1	80.5	49.8	47.8	75.6	48.6	78.7	75.7

Table 2. Alfalfa plant density per meter of row for the furrow-width trial I.

Furrow Width	1st year 1983	2nd year 1984	3rd year 1985	4th year 1986	5th year 1987	6th year 1988	Means of growing seasons after 1st year
2 inch	14.82a	0.76a	0.15a	0.29a	0.51a	0.35a	0.41a
3 inch	13.85a	0.74a	0.20a	0.31a	0.34a	0.32a	0.38a
4 inch	11.47a	0.63a	0.24a	0.26a	0.46a	0.38a	0.39a

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

Table 3. Alfalfa plant density per meter of row for the furrow-width trial II.

Furrow Width	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	5th year 1989	Means of growing seasons after 1st year
2 inch	16.93a	2.97bc	1.57c	1.37c	1.02b	1.73ab
3 inch	14.88a	1.77c	0.83cd	0.80d	0.50b	0.98ab
4 inch	14.12a	1.33c	0.67d	0.87d	0.88b	0.94b
6 inch	15.93a	1.17c	0.70d	0.73d	0.76b	0.84b
6 inch sweep	24.98a	4.30ab	1.60bc	1.73bc	0.93b	2.14ab
12 inch sweep	29.72a	6.87a	3.23a	2.37a	1.90a	3.59a
16 inch sweep	28.87a	6.87a	2.83ab	2.07ab	0.87b	3.16ab

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

Table 4. Alfalfa plant height (inches) for the furrow-width trial I.

Furrow Width	3rd year 1985	4th year 1986	5th year 1987	6th year 1988	Means of growing seasons
2 inch	7.68a	13.62a	16.99a	10.19a	12.12a
3 inch	8.63a	12.82a	18.52a	9.88a	12.46a
4 inch	7.30a	11.64a	14.71a	9.58a	10.81a

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

Table 5. Alfalfa plant height (inches) for the furrow-width trial II.

Furrow Width	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	5th year 1989	Means of growing seasons after 1st year
2 inch	1.53ab	6.65a	15.74a	10.20a	12.25a	11.21a
3 inch	1.61ab	5.69a	14.71a	7.75a	10.71a	9.72a
4 inch	1.41b	6.01a	16.33a	10.14a	11.23a	10.93a
6 inch	1.10b	5.64a	16.02a	10.15a	9.85a	10.42a
6 inch sweep	1.49b	5.58a	14.20a	8.89a	10.51a	9.80a
12 inch sweep	1.77ab	6.19a	14.97a	8.25a	10.44a	9.96a
16 inch sweep	1.81a	5.86a	15.11a	7.49a	9.33a	9.45a

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

Table 6. Theoretical calculations for land area of seedbed prepared by interseeding machine in square feet and percentage of an acre for four furrow widths and six row spacings.

		Row Spacing					
Furrow Width		2 foot	3 foot	4 foot	5 foot	8 foot	10 foot
2 inch	sq ft	3703	2468	1854	1481	925	741
	%	8.50	5.67	4.26	3.40	2.12	1.70
3 inch	sq ft	5445	3630	2726	2178	1362	1089
	%	12.50	8.34	6.25	5.00	3.13	2.50
4 inch	sq ft	7187	4792	3598	2875	1795	1437
	%	16.50	11.00	8.26	6.60	4.12	3.30
6 inch	sq ft	10890	7260	5452	4356	2723	2178
	%	25.00	16.67	12.52	10.00	6.25	5.00

Table 7. Theoretical and measured percent seedbed, total disturbance, and intact area per acre of furrow-width treatments.

	Percent seedbed area per acre		Percent total disturbance per acre		Percent intact area per acre	
	Theoretical Calculation	Measured	Theoretical Calculation	Measured	Theoretical Calculation	Measured
Furrow Width	%	%	%	%	%	%
Control		0.0		0.0		100.00
2 inch	5.67	12.19	11.34	22.73	88.66	77.27
3 inch	8.34	14.80	16.68	23.11	83.32	76.89
4 inch	11.00	14.99	22.00	26.85	78.00	73.15

Table 8. Total herbage biomass determined for only the intact portion and for the combined intact and disturbed portions of each treatment.

	Total herbage biomass on only the intact portion of each treatment		Total herbage biomass on the combined intact and disturbed areas of each treatment	
Furrow Width	lbs/ac	% of control	lbs/ac	% of control
Control	1075.40	100.00	1075.40	100.00
2 inch	1072.50	99.73	795.55	73.98
3 inch	1191.90	110.83	897.99	83.50
4 inch	1093.45	101.68	764.60	71.10

Table 9. Mean herbage biomass production (lbs/ac) from intact and disturbed areas of furrow-width treatments and percentage of herbage biomass from control treatments.

Furrow Width		Cool Short	Warm Short	Cool Mid	Warm Mid	Sedge	Forb	Total
Control	lbs/ac	167.20ab	135.75b	244.00ab	59.75a	233.15a	235.55a	1075.40a
2 inch	lbs/ac	167.80ab	192.38ab	139.63b	22.08ab	132.82b	140.83a	795.55a
	%	100.36	141.72	57.23	36.95	56.97	59.79	73.98
3 inch	lbs/ac	187.47a	261.02a	188.04a	4.05b	118.67b	138.77a	897.99a
	%	112.12	192.28	77.07	6.78	50.90	58.91	83.50
4 inch	lbs/ac	123.73b	102.87b	227.04a	37.90a	138.45ab	134.63a	764.60a
	%	74.00	75.78	93.05	63.43	59.38	57.16	71.10

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

Table 10. Mean basal cover for grasses, forbs, and total live plants (including woody and succulent species) for furrow-width treatments and percentage of basal cover for control treatments.

	Grasses		Forbs		Total	
Furrow Width	Basal Cover	% of Control	Basal Cover	% of Control	Basal Cover	% of Control
Control	24.73a		3.00a		27.97a	
2 inch	21.91ab	88.60	2.25a	75.00	24.29ab	86.84
3 inch	24.32a	98.34	2.48a	82.67	27.02a	96.60
4 inch	20.38b	82.41	2.27a	75.67	22.85b	81.69

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

Table 11. Mean basal cover for graminoid and forb biotypes and percentage of the control treatment for furrow-width treatments.

	Graminoids			Forbs		
Furrow Width	Cool Season	Warm Season	Sedge	Late Succession	Mid Succession	Early Succession
Control	6.02ab	11.68a	7.03a	2.80a	0.10a	0.10a
2 inch	4.28b	12.70ab	4.92b	2.09a	0.10a	0.06a
% of Control	71.10	108.73	69.99	74.64	100.00	60.00
3 inch	5.80ab	13.29a	5.23b	2.26a	0.20a	0.02a
% of Control	96.35	113.78	74.40	80.71	200.00	20.00
4 inch	7.36a	8.45b	4.58b	2.08a	0.12a	0.07a
% of Control	122.26	72.35	65.15	74.29	120.00	70.00

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

Table 12. Forb density per square meter and percentage of control treatment for furrow-width treatments.

Furrow Width	Forbs Late Succession	Mid Succession	Early Succession	Mid and Early Succession	Total Forbs
Control	64.8a	6.9	2.8	9.7a	74.5a
2 inch	33.6a	10.9	1.8	12.7a	46.3a
% of Control	51.85			130.93	62.15
3 inch	24.7a	10.9	3.7	14.6a	39.4a
% of Control	38.12			150.52	52.89
4 inch	37.8a	12.9	0.6	13.5a	51.3a
% of Control	58.33			139.18	68.86

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

Table 13. Alfalfa plant density per meter of row and plant height (inches) for the cultivator sweep tip trial.

Sweep Tip Status	1986	1987	1988	1989	Mean
Plants/meter of row					
Sweep Tip off	21.01a	5.92a	4.64a	1.81a	8.35a
Sweep Tip on	13.55a	5.15b	4.57a	1.72a	6.25a
Plant height (in)					
Sweep Tip off	4.61x	12.59x	7.66x	8.06x	8.23x
Sweep Tip on	5.08x	12.60x	8.08x	7.22x	8.24x

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

Table 14. Alfalfa plant density per meter of row and plant height (inches) for the seedbed firming trial.

Treatment Type	1986	1987	1988	1989	Mean
Plants/meter of row					
Pack wheel	25.80a	6.26a	4.78a	1.67a	9.63a
Drag chain	23.70a	5.98a	4.91a	2.02a	9.15a
Plant height (in)					
Pack wheel	4.54x	12.40x	7.38x	8.02x	8.09x
Drag chain	4.98x	13.81x	8.22x	7.38x	8.60x

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

Table 15. Alfalfa plant density per meter of row for the furrow mulch trial.

Mulch Type	1988	1989	Mean
Control	11.62a	1.15a	6.39
Black Plastic	10.14a	0.59a	5.36
% of Control	87.26	51.30	83.88
Crested Wheat Hay	0.77b	0.17b	0.47
% of Control	6.63	14.78	7.36
Oat Straw	0.58b	0.78a	0.68
% of Control	4.99	67.83	10.64

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

Table 16. Alfalfa plant height (inches) for the furrow mulch trial.

Mulch Type	1988	1989	Mean
Control	1.02a	6.56a	3.79
Black Plastic	1.23a	9.51a	5.37
% of Control	120.59	144.97	141.69
Crested Wheat Hay	1.03a	6.07a	3.55
% of Control	100.98	92.53	93.67
Oat Straw	0.87a	6.22a	3.55
% of Control	85.29	94.82	93.40

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

Fig. 1. Two-inch straight spike chisel.

Fig. 2. Furrow made with two-inch straight spike chisel.

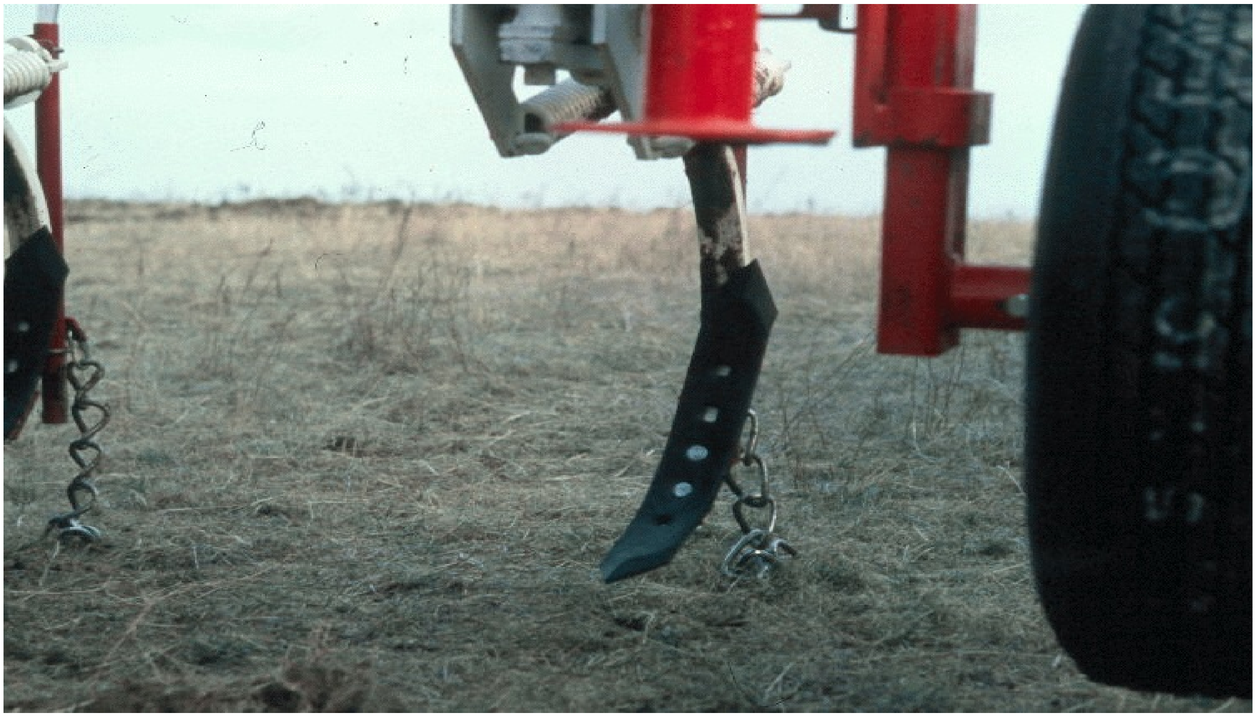


Fig. 3. Three-inch twisted chisel plow shovel.

Fig. 4. Furrow made with three-inch twisted chisel plow shovel.

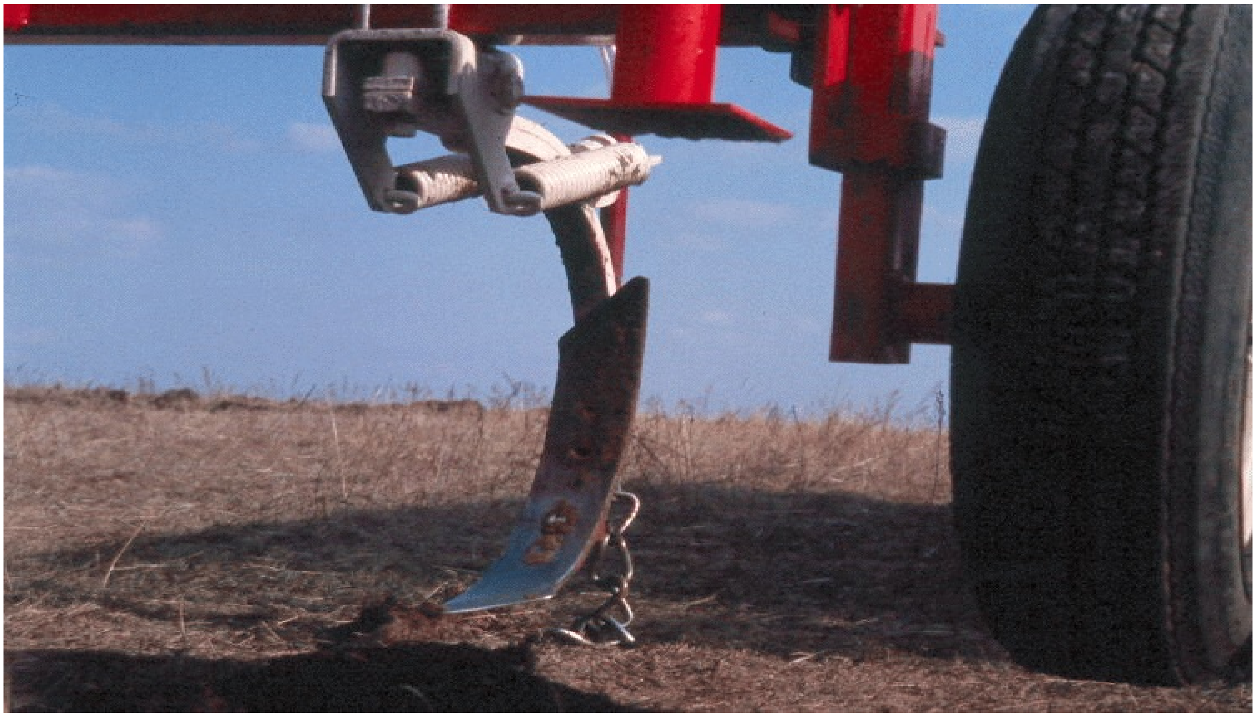


Fig. 5. Four-inch twisted chisel plow shovel.

Fig. 6. Furrow made with four-inch twisted chisel plow shovel.

Fig. 7. Interseeded furrow, year one.

Fig. 8. Interseeded furrow, year two.

Fig. 9. Interseeded furrow, year three.

Fig. 10. Interseeded mature alfalfa plant.

Fig. 11. Seedbed firmed with pack wheel.

Fig. 12. Seedbed firmed with drag chain.

Fig. 13. Black plastic furrow mulch.

Fig. 14. Furrow mulched with black plastic.

Fig. 15. Chopped crested wheatgrass hay furrow mulch.

Fig. 16. Furrow mulched with chopped hay.

Fig. 17. Chopped oat straw furrow mulch.

Fig. 18. Furrow mulched with chopped straw.

Fig. 19. Modified three toolbar interseeding machine. The front toolbar carries the double straight coulters placed side by side and three inches apart. The middle toolbar carries the three-inch twisted chisel plow shovel, the seed tube, and the pack wheel. The back toolbar carries the 12-inch cultivator sweep with the tip removed and the fertilizer tube.

Literature Cited

Chisholm, T.S., F.R. Vigil, T.M. Klosterman, and G. Orcutt. circa 1980. Interseeding and plans for SDSU's new machine for better pasture production. South Dakota State University Agricultural Experiment Station. B 680. Brookings, SD. 14p.

Goplen, B.P., H. Baenziger, L.D. Bailey, A.T.H. Gross, M.R. Hanna, R. Michaud, K.W. Richards, and J. Waddington. 1980. Growing and managing alfalfa in Canada. Agriculture Canada. Publication 1705. 50p.

Manske, L.L. 1983. Alfalfa interseeding furrow width techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 160-175.

Manske, L.L. 1985. Alfalfa interseeding furrow width techniques trial II. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 176-180.

Manske, L.L. 1986. Alfalfa interseeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 220-224.

Manske, L.L. 1987. Alfalfa interseeding furrow width techniques trial I. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 266-280.

Manske, L.L. 1988. Alfalfa interseeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 253-260.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Evaluation of Interseeding Fertilization-Rate Techniques

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center
Report DREC 04-3035

Successful interseeding of alfalfa into grassland ecosystems requires that sufficient quantities of nutrients be available for the growing alfalfa plants. The objectives of the interseeding fertilization-rate techniques trials were to determine whether nitrogen or phosphate fertilization provided an advantage for alfalfa plant establishment and, if an advantage were indicated, to determine a thrifty fertilization rate that provided benefits for the alfalfa plant.

Procedure

An interseeding fertilization-rate techniques trial I was established in 1984 on 1.65 acres located at three study sites on the SW¼, NW¼, SE¼, sec. 21; SW¼, NW¼, NE¼, sec. 28; and SE¼, NW¼, NE¼, sec. 28; T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 200 foot plots were randomly located within each of six replications. The established plant community was mixed grass prairie. The soils were loam and sandy loam. Anik, Kane, Rangelander, and Travois alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 19 November 1984, 15 April 1985, and 15 May 1985, at the seeding rate of 0.50 lbs PLS per row per acre. The nitrogen (N) and phosphate (P_2O_5) fertilizers were tested in separate treatments and applied at the time of seeding as a band in the furrow rows at the rates of 60 lbs N per acre and 50 lbs and 100 lbs P_2O_5 per acre. A control treatment was interseeded with alfalfa and no fertilizer was added. The furrows were opened with three-inch twisted chisel plow shovels set at ten-foot row spacings (Manske 1985).

An interseeding fertilization-rate techniques trial II was established in 1986 on 0.41 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 22 April 1986, at the seeding rate of 0.50 lbs PLS per acre per row. The nitrogen (N) and phosphate (P_2O_5) fertilizers were mixed together and applied at the rates of 60 lbs N and 60 lbs P_2O_5, 30 lbs N and 30 lbs P_2O_5, and 0 lbs N and 0 lbs P_2O_5 per acre. The modified interseeding machine was used with the plow shanks set at ten-foot row spacings. The furrows were opened with double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep with the tip removed (Manske 1986). Alfalfa seed from a hydraulically driven jumbo hopper box was delivered to the seedbed through plastic hose and a solid pipe mounted behind the plow shank of the 3-inch twisted chisel plow shovel. Fertilizer from a hydraulically driven jumbo hopper box was delivered to the seedbed, one inch above the alfalfa seed, through plastic hose and a solid pipe mounted behind the plow shank of the 12-inch cultivator sweep. Fertilization rates for trial I and trial II were determined for the land area of the seedbed in the furrow rows.

Alfalfa density was determined by counting plants per meter of row. Plant heights were determined by measuring from soil surface to top of plant. Alfalfa density and height data were collected monthly during June, July, and August. Differences between means were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results and Discussion

Alfalfa plant densities (table 1) on the nitrogen (N) fertilizer treatments in fertilization-rate techniques trial I were not significantly different ($P<0.05$) between the 60 lbs N/acre rate and the 0 lbs N/acre control treatments during the first growing season for the April, May, and November seeding dates. During the second, third, and fourth growing seasons, alfalfa densities were significantly greater ($P<0.05$) on the 60 lbs N/acre rate treatment than on the 0 lbs N/acre control treatment for the April seeding date. During the second growing season, alfalfa densities were significantly greater ($P<0.05$) on the 60 lbs N/acre rate treatment than on the 0 lbs N/acre control treatment for the May seeding date. During the third and fourth growing seasons, alfalfa densities were significantly greater ($P<0.05$) on the

60 lbs N/acre rate treatment than on the 0 lbs N/acre control treatment for the November seeding date. Alfalfa plant heights (table 2) on the nitrogen (N) fertilizer treatments in fertilization-rate techniques trial I were not significantly different ($P<0.05$) between the 60 lbs N/acre rate and the 0 lbs N/acre control treatments during each growing season for the April, May, and November seeding dates, except that plant heights on the 60 lbs N/acre rate treatments were significantly greater ($P<0.05$) than those on the 0 lbs N/acre control treatments during the second growing season for the May seeding date and the first growing season for the November seeding date.

Alfalfa plant densities (table 3) on the phosphate (P_2O_5) fertilizer treatments in fertilization-rate techniques trial I were not significantly different ($P<0.05$) among the 100 lbs P/acre rate, 50 lbs P/acre rate, and the 0 lbs P/acre control treatments during each growing season for the April, May, and November seeding dates, except that alfalfa densities on the 0 lbs P/acre control treatments were significantly less ($P<0.05$) than those on the 100 lbs P/acre rate and 50 lbs P/acre rate treatments during the fourth growing season for the May and November seeding dates. Alfalfa plant heights (table 4) on the phosphate (P_2O_5) fertilizer treatments in fertilization-rate techniques trial I were not significantly different ($P<0.05$) among the 100 lbs P/acre rate, 50 lbs P/acre rate, and the 0 lbs P/acre control treatments during each growing season for the April, May, and November seeding dates.

Alfalfa plant densities (table 5) on the nitrogen (N) and phosphate (P_2O_5) fertilizer treatments in fertilization-rate techniques trial II were not significantly different ($P<0.05$) between the 30 lbs N and 30 lbs P/acre rate and the 60 lbs N and 60 lbs P/acre rate treatments during each growing season for the Ladak and Travois alfalfa varieties seeded in April, except that plant densities on the 60 lbs N and 60 lbs P/acre rate treatment were significantly greater ($P<0.05$) than those on the 30 lbs N and 30 lbs P/acre rate treatment during the third and fourth growing seasons for the Travois alfalfa variety. Alfalfa densities on the 0 lbs N and 0 lbs P/acre control treatments were significantly less ($P<0.05$) than those on the 30 lbs N and 30 lbs P/acre rate and 60 lbs N and 60 lbs P/acre rate treatments during the second and third growing seasons for the Ladak alfalfa variety and during the second growing season for the Travois alfalfa variety. Alfalfa plant heights (table 6) on the nitrogen (N) and phosphate (P_2O_5) fertilizer treatments in fertilization-rate techniques trial II were not significantly different ($P<0.05$) among the 60 lbs N and 60 lbs P/acre rate, 30 lbs N and 30 lbs P/acre rate, and 0 lbs N and 0 lbs P/acre control treatments during each growing season for the Ladak and Travois alfalfa varieties seeded in April.

The alfalfa plant density and plant height data from fertilization-rate techniques trials I and II showed that nitrogen fertilizer helped improve alfalfa plant establishment. The benefits from phosphate fertilizer were less clear from these data, which measured only aboveground parameters. Phosphorus fertilizer helps improve alfalfa seeding success by encouraging root growth.

Evaluation of alfalfa plant density and plant height data for a fertilizer treatment as a percent of the respective values for a nonfertilized control treatment indicates the degree of advantage or disadvantage received from the fertilizer treatment.

The three-year mean alfalfa plant densities on the 60 lbs N/acre rate treatment were 544.8%, 633.3%, and 525.9% of the mean plant densities on the 0 lbs N/acre control treatment for the April, May, and November seeding dates, respectively (table 1). The three-year mean alfalfa plant heights on the 60 lbs N/acre rate treatment were 102.5%, 116.4%, and 97.3% of the mean plant heights on the 0 lbs N/acre control treatment for the April, May, and November seeding dates, respectively (table 2).

The three-year mean alfalfa plant densities on the 50 lbs P/acre rate treatment were 103.5%, 133.3%, and 151.9% of the mean plant densities on the 0 lbs P/acre control treatment for the April, May, and November seeding dates, respectively (table 3). The three-year mean alfalfa plant heights on the 50 lbs P/acre rate treatment were 90.3%, 105.5%, and 98.3% of the mean plant heights on the 0 lbs P/acre control treatment for the April, May, and November seeding dates, respectively (table 4).

The three-year mean alfalfa plant densities on the 100 lbs P/acre rate treatment were 113.8%, 283.3%, and 163.0% of the mean plant densities on the 0 lbs P/acre control treatment for the April, May, and November seeding dates, respectively (table 3). The three-year mean alfalfa plant heights on the 100 lbs P/acre rate treatment were 98.4%, 115.3%, and 88.6% of the mean plant heights on the 0 lbs P/acre control treatment for the April, May, and November seeding dates, respectively (table 4).

The three-year mean alfalfa plant densities on the 30 lbs N and 30 lbs P/acre rate treatment were 149.6% and 114.3% of the mean plant densities on the 0 lbs N and 0 lbs P/acre control treatment, respectively, for the Ladak and Travois alfalfa varieties seeded in April (table 5). The three-year mean alfalfa plant heights on the 30 lbs N and 30 lbs P/acre rate treatment were 107.4% and 100.9% of the mean plant heights on the 0 lbs N and 0 lbs P/acre control treatment, respectively, for the Ladak and Travois alfalfa varieties seeded in April (table 6).

The three-year mean alfalfa plant densities on the 60 lbs N and 60 lbs P/acre rate treatment were 153.4% and 137.5% of the mean plant densities on the 0 lbs N and 0 lbs P/acre control treatment, respectively, for the Ladak and Travois alfalfa varieties seeded in April (table 5). The three-year mean alfalfa plant heights on the 60 lbs N and 60 lbs P/acre rate treatment were 110.6% and 104.8% of the mean plant heights on the 0 lbs N and 0 lbs P/acre control treatment, respectively, for the Ladak and Travois alfalfa varieties seeded in April (table 6).

The treatment with the fertilization rate of 60 lbs N/acre averaged 568.0% of the plant density and 105.4% of the plant height of the 0 lbs N/acre control. The treatment with the fertilization rate of 50 lbs P/acre averaged 129.5% of the plant density and 98.0% of the plant height of the 0 lbs P/acre control. The treatment with the fertilization rate of 100 lbs P/acre averaged 186.7% of the plant density and 100.8% of the plant height of the 0 lbs P/acre control. The treatment with the fertilization rate of 30 lbs N and 30 lbs P/acre averaged 132.0% of the plant density and 104.1% of the plant height of the 0 lbs N and 0 lbs P/acre control. The treatment with the fertilization rate of 60 lbs N and 60 lbs P/acre averaged 145.4% of the plant density and 107.7% of the plant height of the 0 lbs N and 0 lbs P/acre control.

The 60 lbs N/acre rate treatment indicated an advantage for plant density and plant height compared to the nonfertilized control treatment. The 50 lbs P/acre rate and the 100 lbs P/acre rate treatments indicated an advantage for plant density compared to the nonfertilized control treatment, but plant heights were about the same on the fertilized treatments as on the nonfertilized control treatment. The 100 lbs P/acre rate treatment was double the 50 lbs P/acre rate treatment, but the advantage for the 100 lbs P/acre rate was only 44% greater than the advantage for the 50 lbs P/acre rate. The 30 lbs N and 30 lbs P/acre rate and the 60 lbs N and 60 lbs P/acre rate treatments indicated an advantage for plant density and plant height compared to the nonfertilized control treatment. The 60 lbs N and 60 lbs P/acre rate treatment was double the 30 lbs N and 30 lbs P/acre rate treatment, but the advantage for the 60 lbs N and 60 lbs P/acre rate treatment was only 10% greater than the advantage for the 30 lbs N and 30 lbs P/acre rate. The lowest fertilizer rate that indicated an advantage for both plant density and plant height was the 30 lbs N and 30 lbs P/acre rate.

Conclusion

The alfalfa interseeding fertilization-rate techniques trials evaluated both the benefits from nitrogen and phosphate fertilizer on alfalfa plant establishment and the effects on aboveground growth from changes in fertilizer rates. Both nitrogen and phosphate fertilizers can help improve interseeded alfalfa plant growth as long as the fertilizer is not in direct contact with the seed. These trials indicate that low rates, around 30 lbs N and 30 lbs P/acre, would be sufficient to benefit alfalfa plant density and plant height and enhance alfalfa stand establishment (figures 1 and 2).

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Alfalfa plant density per meter of row on nitrogen (N) fertilizer treatments for the fertilization-rate trial I.

Fertilizer Treatment	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	Mean of growing seasons after 1st year
15 Apr 85					
0 lbs N/ac	8.25a	0.37b	0.38b	0.13b	0.29b
60 lbs N/ac	17.49a	2.97a	1.09a	0.69a	1.58ab
% of 0 lbs N/ac	212.00	802.70	286.84	530.77	544.83
15 May 85					
0 lbs N/ac	9.93a	0.07c	0.08c	0.03c	0.06c
60 lbs N/ac	14.37a	0.70b	0.28bc	0.16bc	0.38ab
% of 0 lbs N/ac	144.71	1000.00	350.00	533.33	633.33
19 Nov 84					
0 lbs N/ac	4.98a	0.44b	0.22bc	0.15bc	0.27b
60 lbs N/ac	9.13a	2.32ab	1.26a	0.68a	1.42a
% of 0 lbs N/ac	183.33	527.27	572.73	453.33	525.93

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

Table 2. Alfalfa plant height (inches) on nitrogen (N) fertilizer treatments for the fertilization-rate trial I.

Fertilizer Treatment	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	Mean of growing seasons after 1st year
15 Apr 85					
0 lbs N/ac	0.95b	6.15ab	11.04ab	7.59a	8.26a
60 lbs N/ac	1.52ab	5.93ab	12.55a	6.92a	8.47a
% of 0 lbs N/ac	160.00	96.42	113.68	91.17	102.54
15 May 85					
0 lbs N/ac	0.80b	2.20c	8.31ab	7.36a	5.96a
60 lbs N/ac	1.10b	4.01b	11.90ab	4.91a	6.94a
% of 0 lbs N/ac	137.50	182.27	143.20	66.71	116.44
19 Nov 84					
0 lbs N/ac	1.54b	6.95ab	10.61ab	6.68a	8.08a
60 lbs N/ac	2.23a	6.65ab	10.71ab	6.21a	7.86a
% of 0 lbs N/ac	144.81	95.68	100.94	92.96	97.28

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

Table 3. Alfalfa plant density per meter of row on phosphate (P_2O_5) fertilizer treatments for the fertilization-rate trial I.

Fertilizer Treatment	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	Mean of growing seasons after 1st year
15 Apr 85					
0 lbs P/ac	8.25a	0.37b	0.38b	0.13b	0.29a
50 lbs P/ac	9.24a	0.52bc	0.25bc	0.13b	0.30a
% of 0 lbs P/ac	112.00	140.54	65.79	100.00	103.45
100 lbs P/ac	9.52a	0.61b	0.22bc	0.16b	0.33a
% of 0 lbs P/ac	115.39	164.86	57.89	123.08	113.79
15 May 85					
0 lbs P/ac	9.93a	0.07c	0.08c	0.03c	0.06b
50 lbs P/ac	8.05a	0.07c	0.08c	0.08b	0.08b
% of 0 lbs P/ac	81.07	100.00	100.00	266.67	133.33
100 lbs P/ac	8.29a	0.25bc	0.17bc	0.10b	0.17ab
% of 0 lbs P/ac	83.48	357.14	212.50	333.33	283.33
19 Nov 84					
0 lbs P/ac	4.98a	0.44b	0.22bc	0.15bc	0.27a
50 lbs P/ac	5.25a	0.57bc	0.35b	0.30a	0.41a
% of 0 lbs P/ac	105.42	129.55	159.09	200.00	151.85
100 lbs P/ac	5.31a	0.81bc	0.23bc	0.28a	0.44a
% of 0 lbs P/ac	106.63	184.09	104.55	186.67	162.96

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

Table 4. Alfalfa plant height (inches) on phosphate (P_2O_5) fertilizer treatments for the fertilization-rate trial I.

Fertilizer Treatment	1st year 1985	2nd year 1986	3rd year 1987	4th year 1988	Mean of growing seasons after 1st year
15 Apr 85					
0 lbs P/ac	0.95b	6.15ab	11.04ab	7.59a	8.26a
50 lbs P/ac	1.06b	5.91ab	10.22ab	6.26a	7.46a
% of 0 lbs P/ac	111.58	96.10	92.57	82.48	90.31
100 lbs P/ac	1.32b	7.36a	10.10ab	6.93a	8.13a
% of 0 lbs P/ac	138.95	119.67	91.49	91.30	98.43
15 May 85					
0 lbs P/ac	0.80b	2.20c	8.31ab	7.36a	5.96a
50 lbs P/ac	0.89b	5.32ab	8.08ab	5.48a	6.29a
% of 0 lbs P/ac	111.25	241.82	97.23	74.46	105.54
100 lbs P/ac	1.05b	4.96ab	8.23ab	7.43a	6.87a
% of 0 lbs P/ac	131.25	225.45	99.04	100.95	115.27
19 Nov 84					
0 lbs P/ac	1.54b	6.95ab	10.61ab	6.68a	8.08a
50 lbs P/ac	1.64ab	7.26a	9.53ab	7.03a	7.94a
% of 0 lbs P/ac	106.49	104.46	89.82	105.24	98.27
100 lbs P/ac	1.55ab	6.63a	8.24b	6.62a	7.16a
% of 0 lbs P/ac	100.65	95.40	77.66	99.10	88.61

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

Table 5. Alfalfa plant density per meter of row on nitrogen (N) and phosphate (P_2O_5) fertilizer treatments for the fertilization-rate trial II.

Fertilizer Treatment	1st year 1986	2nd year 1987	3rd year 1988	4th year 1989	Mean of growing seasons after 1st year
22 Apr 86					
Ladak					
0 lbs N & P/ac	9.85b	3.27c	3.38c	1.38b	2.68a
30 lbs N & P/ac	16.22ab	5.58b	4.49b	1.95ab	4.01a
% of 0 lbs N & P/ac	164.67	170.64	132.84	141.30	149.63
60 lbs N & P/ac	14.36ab	4.98b	4.91ab	2.44ab	4.11a
% of 0 lbs N & P/ac	145.79	152.29	145.27	176.81	153.36
Travois					
0 lbs N & P/ac	18.56ab	5.09b	4.33b	1.71ab	3.71a
30 lbs N & P/ac	25.80ab	6.26a	4.78b	1.67b	4.24a
% of 0 lbs N & P/ac	139.01	122.99	110.39	97.66	114.29
60 lbs N & P/ac	26.07a	6.76a	5.85a	2.69a	5.10a
% of 0 lbs N & P/ac	140.46	132.81	135.10	157.31	137.47

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

Table 6. Alfalfa plant height (inches) on nitrogen (N) and phosphate (P_2O_5) fertilizer treatments for the fertilization-rate trial II.

Fertilizer Treatment	1st year 1986	2nd year 1987	3rd year 1988	4th year 1989	Mean of growing seasons after 1st year
22 Apr 86					
Ladak					
0 lbs N & P/ac	3.29a	11.74a	7.55a	7.55a	8.95a
30 lbs N & P/ac	3.45a	12.78a	7.94a	8.10a	9.61a
% of 0 lbs N & P/ac	104.86	108.40	105.17	107.28	107.37
60 lbs N & P/ac	3.94a	13.55a	8.58a	7.58a	9.90a
% of 0 lbs N & P/ac	119.76	115.42	113.64	100.40	110.61
Travois					
0 lbs N & P/ac	2.89a	12.01a	7.86a	7.70a	9.19a
30 lbs N & P/ac	3.42a	12.40a	7.38a	8.02a	9.27a
% of 0 lbs N & P/ac	118.34	103.25	93.89	104.16	100.87
60 lbs N & P/ac	3.46a	12.90a	8.04a	7.96a	9.63a
% of 0 lbs N & P/ac	119.72	107.41	102.29	103.38	104.79

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

Fig. 1. Fertilizer added to furrow above the alfalfa seed.

Fig. 2. Furrow with fertilizer.

Literature Cited

Manske, L.L. 1985. Alfalfa interseeding fertilization techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 181-193.

Manske, L.L. 1986. Alfalfa interseeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 220-224.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Evaluation of Interseeding Seeding-Date, Seeding-Rate, and Rhizobium-Inoculation Techniques

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3036

Successful interseeding of alfalfa into grassland ecosystems requires the use of techniques that place seed into the soil during the best time of the year, at an optimum quantity per furrow row, and with symbiotic rhizobium bacteria combined sufficiently with the alfalfa seed. The interseeding seeding-date, seeding-rate, and rhizobium-inoculation techniques trials evaluated various seeding dates and seeding rates and two inoculation methods. The objective of these studies was to select a preferred seeding date, an adequate seeding rate, and an inoculation method that benefit establishment of interseeded alfalfa.

Procedure

An interseeding seeding-date techniques trial I was conducted from 1983 to 1989 on 0.14 acres located on the SW¼, NW¼, SE¼, sec. 21; on 0.16 acres located on the SE¼, SW¼, SE¼, sec. 22; on 0.15 acres located on the NE¼, NW¼, SW¼, sec. 23; and on 0.14 acres located on the SW¼, NW¼, NE¼, sec. 28; T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 50 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was loam. Travois alfalfa was seeded at the rate of 0.50 lbs PLS per row per acre for all seeding-date treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 21 April 1983, 19 November 1984, 11 April 1985, 15 April 1985, and 15 May 1985. The modified toolbar interseeder was used with plow shanks set at ten-foot row spacings for all seeding dates except 21 April 1983; on that seeding date the row spacing was 3 feet. The furrows were opened with a 3-inch twisted chisel plow shovel on all seeding dates (Manske 1983). No fertilizer was added to the furrows on any of the treatments.

An interseeding seeding-date techniques trial II was conducted from 1986 to 1989 on 0.55 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was loam. Travois alfalfa was seeded at the rate of 0.50 lbs PLS per row per acre for all seeding-date treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 22 April 1986, 15 October 1986, 15 April 1987, and 13 April 1988. The modified toolbar interseeder was used with the plow shanks set at ten-foot row spacings. The furrows were opened with a 3-inch twisted chisel plow shovel followed by a 12-inch cultivator sweep with the tip removed. Fertilizer was added to the furrows at a rate of 30 lbs N and 30 lbs P_2O_5 per acre during the interseeding process for all seeding-date treatments (Manske 1986a).

An interseeding seeding-rate techniques trial was conducted from 1986 to 1989 on 0.83 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. The seed was inoculated with rhizobium bacteria. The plots were interseeded 22 April 1986, 15 October 1986, and 15 April 1987, at the seeding rates of 0.50 lbs and 1.00 lbs PLS per row per acre. Fertilizer was added to the furrows at a rate of 30 lbs N and 30 lbs P_2O_5 per acre during the interseeding process for all three seeding dates of the seeding-rate treatments. The modified interseeding machine with three toolbars was used with the plow shanks set at ten-foot row spacings. The furrows were opened with double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep with the tip removed (Manske 1986b).

An interseeding rhizobium-inoculation techniques trial comparing methods of inoculating alfalfa seed with rhizobium bacteria was conducted from 1986 to 1989 on 0.28 acres located on the SE¼, SW¼, SE¼, sec. 22, T. 143 N., R. 96 W., at the Dickinson Research Extension Center Ranch Headquarters. The 20 X 100 foot plots were arranged in a randomized block design with three replications. The established plant community was mixed grass prairie. The soil was Shambo loam. Travois and Ladak alfalfas were used for all treatments. Two identical batches of seed were separated from one seed lot of each alfalfa variety. One batch of seed for each variety was inoculated with rhizobium bacteria by mixing a fresh bag of commercially available inoculum with the seed in a plastic tub (figure 1), and a second batch of seed for each variety was shipped to a company that applied the rhizobium inoculant and an outer coating to the seed by an industrial process (figure 2). The plots were interseeded 22 April 1986. Seed from both inoculation methods was seeded at the same weight per row per acre. The industrial seed coating added 33% to the weight of the seed. The actual seeding rate was 0.50 lbs PLS per row per acre for the tub-mixed seed and 0.33 lbs PLS per row per acre for the industrial-coated seed. The modified interseeding machine with three toolbars was used with the plow shanks set at ten-foot row spacings. The furrows were opened with double straight coulters spaced 3 inches apart, followed by a 3-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep with the tip removed (Manske 1986b).

Alfalfa density was determined by counting plants per meter of row. Plant heights were determined by measuring from soil surface to top of plant. Alfalfa density and height data were collected monthly during June, July, and August. Differences between means were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results and Discussion

The mean alfalfa plant densities of seeding-date trial I (table 1) were not significantly different ($P<0.05$) among the three April seeding-date treatments. The May seeding-date treatment had significantly lower ($P<0.05$) plant densities than the April seeding-date treatments. The November seeding-date treatment had plant densities that were not significantly different ($P<0.05$) from the three April seeding-date and the May seeding-date treatments. The mean alfalfa densities for 11 April, 15 April, 21 April, and 19 November seeding-date treatments were low and ranged between 0.98 and 0.26 plants per meter of row (table 1).

The mean alfalfa plant densities of seeding-date trial II (table 2) were greater than the plant densities of trial I (table 1). The 22 April seeding date had mean alfalfa densities of 4.24 plants per meter of row, a value significantly greater ($P<0.05$) than the plant densities of 13 April and 15 October seeding-date treatments. The mean alfalfa plant densities for 13 April, 15 April, and 15 October seeding-date treatments were not significantly different ($P<0.05$) and ranged between 1.83 and 1.24 plants per meter of row (table 2).

Mean alfalfa plant heights of seeding-date trial I (table 3) were not significantly different ($P<0.05$) among the seeding-date treatments. Mean alfalfa plant heights of seeding-date trial II (table 4) were not significantly different ($P<0.05$) among the seeding-date treatments.

The mechanical interseeding techniques were not the same for all seeding-date treatments of trial I. The April 1983 seeding date had 3-foot row spacings rather than the 10-foot row spacings of the other seeding dates. The effects on plant density and plant height were not different between 3-foot and 10-foot row spacings (Manske 2004c) and should not affect evaluation of the data in seeding-date trial I.

The mechanical interseeding techniques used in seeding-date trial II were different from the techniques used in seeding-date trial I. A 12-inch cultivator sweep that had the tip removed and followed the 3-inch chisel plow shovel was used on all of the seeding-date treatments of trial II. The 12-inch cultivator sweep was not used on any of the seeding-date treatments of trial I. Fertilizer was added to the furrows during the interseeding process on all seeding-date treatments of trial II. None of the seeding-date treatments of trial I had fertilizer added to the furrows.

The environmental conditions of the Northern Plains influence plant growth and can affect the success of alfalfa interseeding. Both low and high temperatures limit plant growth. The growing season for perennial plants is considered to be generally from mid April through mid October. Periods with deficiencies in precipitation cause water stress in plants. Water deficiency periods occurred during July to October in 92.9% of the past 112 growing seasons. Only 7.1% of the years did not have water deficiency conditions during July to October. Growing seasons with one month with water deficiency occurred during 25.9% of the years, and growing seasons with two or more months with water deficiencies occurred during 67.0% of the years (Manske 2004a).

Potential problems that periods with deficiencies in precipitation caused for establishment of alfalfa seedlings were evaluated for the seeding dates of trials I and II (table 5). The seeding-date treatments of April 1983, 1985, and 1986, and May 1985 had adequate precipitation for alfalfa seedling establishment. The April 1987 seeding-date treatment had two critical months with water deficiencies, April and June; the May, June, and July precipitation was 72.5% of the long-term mean, or only 2.5% below normal levels. The April 1988 seeding-date treatment had water deficiencies during each growing-season month except May, which had precipitation at 86.0% of the long-term mean. The growing-season months (April-October) of 1988 received only 37.8% of the long-term mean precipitation; the precipitation shortfall caused water stress for alfalfa seedlings and for all perennial plants. The seeding-date treatment of October 1986 had a water deficiency during October, but the soil water should have been adequate with the August, September, and October precipitation at 156.1% of the long-term mean. The seeding-date treatment of November 1984 had a water deficiency during the previous September; however, the August, September, and October precipitation of 1984 was adequate, at 76.5% of the long-term mean (Manske 2004b). Most of the seeding-date treatments in trials I and II had growing-season conditions typical in the Northern Plains and had sufficient precipitation for alfalfa seedling establishment; the exception was the 1988 seeding-date treatment, which occurred during the second-driest growing season since 1892 (Manske 2004a).

The interseeding seeding-date techniques trials were conducted to provide information that would assist in determining a seeding period beneficial to alfalfa plant establishment. Spring seeding dates in the Northern Plains need to be early so the seedlings can develop root systems large enough to survive the periods of water deficiencies that usually occur during July to October. Seeds of perennial plants can be placed in cooler soils earlier in the spring than seeds of annual crop plants. The mid to late April seeding dates produced alfalfa plant densities that reached the respective potentials of the mechanical interseeding techniques used (tables 1 and 2). The May seeding dates were too late in the spring and produced plant densities below the potential for the interseeding techniques used (table 1). Spring seeding dates of mid to late April are preferable to May or June seeding dates. Interseeding alfalfa during late summer or early fall has limited potential for success in the Northern Plains because it depends on having conditions with adequate soil moisture to ensure that enough plant development and leaf growth occur and that the seedlings produce and store adequate carbohydrates for the plants to survive the winter period. Water deficiencies great enough to hinder alfalfa plant establishment occur during 67.0% to 92.9% of years. Establishment of an adequate density of alfalfa plants from interseeding during late summer would be expected to occur during only 7.1% to 25.9% of the growing seasons. Dormant seeding of alfalfa seed can occur after soil temperatures have dropped too low for alfalfa seeds to germinate. The October seeding-date treatment was interseeded into nonfrozen soil and had greater plant densities (table 2) than those of the November seeding-date treatment (table 1) that was interseeded into frozen soil. The success of dormant seeding depends on the maintenance of seed viability during the winter until soil temperatures rise above those required for seed germination. Seed exposed to air during the winter can desiccate. Completely covering the alfalfa seed with soil will help prevent desiccation, but this safeguard is extremely difficult to accomplish when the soil is dry or frozen. Dry or frozen soils form into angular blocks that can leave cracks and allow the seeds to contact air, which can remove moisture and kill the seeds by desiccation. Dormant seeding is possible when conditions permit complete seed-soil contact. Interseeding during early spring is more desirable in the Northern Plains than interseeding during the late summer or the dormant-season periods.

Determination of seeding rate for interseeding treatments is quite different from determination of the rate for solid-seeding treatments because with interseeding, the area of the actual seedbed is some fraction of the total area receiving treatment. The interseeding treatment seeding rate can be determined from the row spacings (number of rows per rod) and the interseeding furrow seeding rate. The interseeding treatment seeding rate for a 10-foot row spacing and an interseeding furrow seeding rate of 0.50 lbs PLS per row per acre is 0.82 lbs PLS per acre. Increasing the furrow seeding rate to 1.00 lbs PLS per row per acre increases the treatment seeding rate to 1.65 lbs PLS per acre (table 6). The equivalent solid-seeding rates are 12.38 lbs PLS and 24.75 lbs PLS per acre for furrow seeding rates of 0.50 lbs PLS and 1.00 lbs PLS per row per acre, respectively (table 6).

The interseeding seeding-rate techniques trial compared furrow seeding rates of 0.50 lbs PLS and 1.00 lbs PLS per row per acre on three seeding dates. The alfalfa plant densities on the 1.00 lbs PLS per row per acre seeding-rate treatments were not significantly different ($P<0.05$) from those on the 0.50 lbs PLS per row per acre seeding-rate treatments for all three seeding dates (table 7). The 0.50 lbs PLS per row per acre seeding rate on the April seeding-date treatments resulted in acceptable alfalfa plant densities. The 0.50 lbs PLS per row per acre seeding rate had significantly lower (P<0.05) alfalfa plant densities per meter of row on the October seeding-date treatments than on the April seeding-date treatments. The 1.00 lbs PLS per row per acre seeding rate had significantly greater (P<0.05) alfalfa plant densities per meter of row on the 22 April seeding-date treatment than on the 15 April and October seeding-date treatments. The alfalfa plant heights on the 1.00 lbs PLS per row per acre seeding-rate treatments were not significantly different (P<0.05) from those on the 0.50 lbs PLS per row per acre seeding-rate treatments for all three seeding dates (table 8).

The 1.00 lbs PLS per row per acre seeding rate deposited twice as much seed in each furrow as the 0.50 lbs PLS per row per acre seeding rate, but the results for the greater seeding rate were not greater than those for the 0.50 lbs PLS per row per acre seeding rate. The less-than-ideal seeding conditions produced from interseeding practices and the extremely high seedling loss during the first year suggest the use of a higher seeding rate for interseeding treatments than would be used under normal solid seeding conditions with conventional field practices. The 0.50 lbs PLS seeding rate deposits the same amount of seed per row that solid seeding does when the seeding rate is 12.38 lbs PLS per acre (table 6), which is about double the recommended solid-seeding rate.

Alfalfa plants form symbiotic relationships with rhizobium bacteria. The bacteria live in nodules located on the alfalfa roots and change (or fix) the nitrogen in the air from a form that the alfalfa plant cannot biologically use into a form that the alfalfa plant can use. The plant uses nitrogen fixed by the rhizobium bacteria in the root nodules, along with the mineral nitrogen absorbed from the surrounding soil, for growth and herbage production. The quantity of herbage biomass produced by alfalfa plants growing in soils with low levels of mineral nitrogen is related to the number and size of nodules formed on the roots.

Rhizobium bacteria are mixed with alfalfa seed and deposited into the soil at the same time the alfalfa seed is planted so that the bacteria are placed in the proximity of the developing seedling. This placement facilitates the infection of the seedling roots and the formation of nodules. At the time of this research, rhizobium bacteria and alfalfa seed could be mixed by two methods. The rhizobium bacteria could be purchased in an inoculum and mixed with the alfalfa seed in a tub (figure 1) at planting time, or the alfalfa seed could be shipped to a company that applied the rhizobium inoculum and a protective coating to the seed by an industrial process (figure 2). The interseeding rhizobium-inoculation techniques trial compared the two inoculation methods.

The alfalfa plant densities for the tub-mixed and the seed-coated rhizobium-inoculation methods were not significantly different (P<0.05) during each year of the trial (table 9). The alfalfa plant heights for the tub-mixed and seed-coated rhizobium-inoculation methods were not significantly different (P<0.05) during each year of the trial (table 10).

The seed coating added weight to the alfalfa seed; the addition amounted to approximately one-third of the combined seed-seed coat weight. The alfalfa seed inoculated by both methods was seeded at the same weight per row per acre rate. The actual seeding rate was 0.50 lbs PLS per row per acre for the tub-mixed inoculated seed and 0.33 lbs PLS per row per acre for the seed-coated inoculated seed. The tub-mixed inoculation treatment was seeded at a rate 33% greater than the seed-coated inoculation treatment. The seedling density for the seed-coated inoculated treatment was 33.7% lower during the first growing season than the seedling density for the tub-mixed inoculated treatment. The four-year mean alfalfa densities were 8.35 and 6.29 plants per meter of row for the tub-mixed and seed-coated inoculation methods, respectively (table 9). The mean alfalfa plant density of the tub-mixed inoculation treatment was 32.75% greater than that of the seed-coated inoculation treatment, a relationship nearly the same as that of the actual seeding rate.

The level of nodulation on alfalfa plant roots affects the potential amount of nitrogen fixation and the quantity of plant production. The differences in the amount of nodule formation between the tub-mixed and seed-coated inoculation methods were sampled by examining alfalfa plant roots excavated from randomly selected meter-length portions of interseeded rows.

All of the examined plant roots from both inoculation methods had fewer than three small nodules, and many plants had no nodules. The level of nodulation did not differ between the inoculation methods, and the low numbers of nodules formed would explain why there were no differences measured between the inoculation methods.

Low nodulation rates of interseeded alfalfa plants produced from both inoculation methods indicated that the rhizobium bacteria did not survive in the grassland soil long enough to permit infection and nodulation of the young alfalfa plants after they had grown sufficient root material. Grassland soils have populations of bacteria, protozoa, nematodes, mites, and small insects capable of consuming rhizobium bacteria. Soil organisms exist in cropland soils but not at population biomass levels comparable to levels in grassland soils.

Grassland soil organisms play a major role in the biogeochemical nutrient cycles (i.e. nitrogen, phosphorus, etc.) that are necessary for an ecosystem to function properly. Grassland ecosystems that have a high biomass of active soil organisms produce greater quantities of herbage biomass than ecosystems with low soil organism biomass.

The presence of high populations of soil organisms in grassland ecosystems is a serious hindrance for interseeded alfalfa establishment. The harvest of the inoculated rhizobium bacteria by the indigenous soil organisms and the low levels of nodulation of interseeded alfalfa plants help explain why alfalfa plants interseeded into grasslands develop at much slower rates than alfalfa plants solid seeded into cropland.

The antagonistic relationship of the indigenous soil organisms towards the inoculated rhizobium bacteria creates a management dilemma. If management treatments that would reduce the grassland soil organism populations to levels comparable to cropland soil levels and permit rhizobium nodulation of alfalfa seedlings were used, the grassland ecosystem nutrient cycles would be reduced to rates that would cause severe reductions in grass herbage production; the result would be a forage deficiency that would suggest the need for greater quantities of alfalfa to be interseeded. If management treatments that increased the grassland soil organism populations to their biologically potential levels were used, the ecosystem nutrient cycles would function at potential rates and grass herbage biomass would be produced at potential quantities; the process would eliminate the reason for interseeding alfalfa into grasslands.

The original purpose of interseeding alfalfa or other plant species into grasslands was to increase the quantity of herbage production. Low production on grasslands managed with traditional management practices is the symptom of a problem, not the actual problem. Traditional management practices cause a reduction in the populations of soil organisms that results in reduced nutrient cycling and reduced herbage production. The problem of reduced soil organism populations in grassland soils can be corrected by biologically effective management practices that stimulate soil organism activity.

Conclusion

These alfalfa interseeding techniques trials evaluated effects of seeding-date, seeding-rate, and rhizobium-inoculation method. In the Northern Plains, there are two periods (spring and dormant season) during which interseeding into grassland ecosystems can result in an adequate density of alfalfa. Early spring (mid to late April) is the preferable interseeding period, but dormant-season seeding can be successful when conditions permit complete seed-soil contact. The seeding rate of interseeding treatments should be about double the rate that would be used per row in solid seeding with conventional practices. Seeding rates greater than double the solid-seeding rate per row do not improve stand density. Rhizobium bacteria need to be mixed with the alfalfa seed at the time of seeding to permit nodulation of the alfalfa roots by the rhizobium bacteria. Soil organisms in grassland ecosystems hinder the development of alfalfa plants by inhibiting rhizobium bacteria nodulation, but reduction of grassland soil organisms reduces the herbage production of grasses. Increasing soil organism populations with biologically effective management practices increases grassland herbage production and eliminates the need for interseeding alfalfa into grasslands.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables and figures. I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Alfalfa plant density per meter of row for the seeding-date trial I.

Seeding date	1st year	2nd year	3rd year	4th year	5th year	6th year	Mean of growing seasons after 1st year
11 Apr 85	14.88	1.77	0.83	0.80	0.50		0.98a
15 Apr 85	12.94	0.35	0.48	0.15			0.33a
21 Apr 83	13.85	0.74	0.21	0.31	0.34	0.32	0.38a
15 May 85	13.23	0.04	0.15	0.05			0.08b
19 Nov 84	8.77	0.40	0.33	0.05			0.26ab

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

Table 2. Alfalfa plant density per meter of row for the seeding-date trial II.

Seeding date	1st year	2nd year	3rd year	4th year	5th year	6th year	Mean of growing seasons after 1st year
13 Apr 88	15.53	1.25					1.25b
15 Apr 87	7.42	2.13	1.53				1.83ab
22 Apr 86	25.80	6.26	4.78	1.67			4.24a
15 Oct 86	2.55	1.29	1.18				1.24b

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

Table 3. Alfalfa plant height (inches) for the seeding-date trial I.

Seeding date	1st year	2nd year	3rd year	4th year	5th year	6th year	Mean of growing seasons after 1st year
11 Apr 85	1.61	5.69	14.71	7.75	10.71		9.72a
15 Apr 85	1.06	5.59	10.30	5.96			7.28a
21 Apr 83	-	-	8.63	12.82	18.52	9.88	12.46a
15 May 85	0.52	3.30	10.55	7.36			7.07a
19 Nov 84	1.39	7.07	12.41	4.11			7.86a

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

Table 4. Alfalfa plant height (inches) for the seeding-date trial II.

Seeding date	1st year	2nd year	3rd year	4th year	5th year	6th year	Mean of growing seasons after 1st year
13 Apr 88	1.04	6.89					6.89a
15 Apr 87	3.81	7.35	8.05				7.70a
22 Apr 86	3.42	12.40	7.38	8.02			9.27a
15 Oct 86	5.63	6.74	7.44				7.09a

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

Table 5. Evaluation of seeding-date problem periods caused by deficiencies in precipitation.

Years	Growing-season months with water deficiency	May, June, July precipitation as a percent of long-term mean	August, September, October precipitation as a percent of long-term mean
1983	Apr, Sep	90.3%	135.2%
1984	May, Jul, Sep	100.4%	76.5%
1985	Jul	72.5%	126.9%
1986	Aug, Oct	114.3%	156.1%
1987	Apr, Jun, Sep, Oct	97.3%	78.7%
1988	Apr, Jun, Jul, Aug, Sep, Oct	54.4%	19.5%

Data from Manske 2004b.

Table 6. Determination of seeding rates for interseeded and solid seeded treatments from seven interseeded furrow seeding rates.

Interseeding Furrow seed rate lbs PLS/row/acre	Equivalent Solid seed rate lbs PLS/acre	Interseeding Treatment seed rate lbs PLS/acre								
		Row Spacing								
		1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	8 ft	10 ft	25 ft
0.25	6.19	4.13	2.06	1.38	1.03	0.83	0.69	0.52	0.41	0.17
0.50	12.38	8.25	4.13	2.75	2.07	1.65	1.38	1.03	0.82	0.33
0.60	14.85	9.90	4.95	3.30	2.48	1.98	1.65	1.24	0.99	0.40
0.75	18.56	12.38	6.19	4.13	3.10	2.48	2.06	1.55	1.24	0.50
1.00	24.75	16.50	8.25	5.50	4.13	3.30	2.75	2.06	1.65	0.66
1.50	37.13	24.75	12.38	8.25	6.20	4.95	4.13	3.09	2.48	0.99
2.00	49.50	33.00	16.50	11.00	8.26	6.60	5.50	4.12	3.30	1.32

Table 7. Alfalfa plant density per meter of row for the seeding-rate trial.

Seeding rates	1st year	2nd year	3rd year	4th year	5th year	Mean of growing seasons after 1st year
15 Apr 87						
0.5 lbs/ac	7.42a	2.13a	1.53a			1.83a
1.0 lbs/ac	7.13a	1.64a	1.44a			1.54a
22 Apr 86						
0.5 lbs/ac	25.80b	6.26b	4.78b	1.67b		4.24b
1.0 lbs/ac	38.40b	7.49c	5.13b	1.76b		4.79b
15 Oct 86						
0.5 lbs/ac	2.55c	1.29d	1.18c			1.24c
1.0 lbs/ac	2.74c	1.53d	1.07c			1.30c

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

Table 8. Alfalfa plant height (inches) for the seeding-rate trial.

Seeding rates	1st year	2nd year	3rd year	4th year	5th year	Mean of growing seasons after 1st year
15 Apr 87						
0.5 lbs/ac	3.81	7.35	8.05			7.70a
1.0 lbs/ac	3.64	6.23	7.26			6.75a
22 Apr 86						
0.5 lbs/ac	3.42	12.40	7.38	8.02		9.27b
1.0 lbs/ac	3.36	13.88	7.94	7.17		9.66b
15 Oct 86						
0.5 lbs/ac	5.63	6.74	7.44			7.09c
1.0 lbs/ac	5.68	5.81	8.05			6.93c

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

Table 9. Alfalfa plant density per meter of row for the rhizobium-inoculation techniques trial.

Rhizobium Inoculation Methods	1986	1987	1988	1989	Mean
Tub mixed	21.01a	5.92a	4.64a	1.81a	8.35a
Seed Coated	13.93a	5.27a	4.06a	1.90a	6.29a
% of control	66.30	89.02	87.50	104.97	75.33

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

Table 10. Alfalfa plant height (inches) for the rhizobium-inoculation techniques trial.

Rhizobium Inoculation Methods	1986	1987	1988	1989	Mean
Tub mixed	3.44a	12.59a	7.66a	8.06a	7.94a
Seed Coated	3.35a	12.53a	8.41a	7.60a	7.97a
% of control	97.38	99.52	109.79	94.29	100.38

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

Fig. 1. Alfalfa seed inoculated with rhizobium by mixing in tub.

Fig. 2. Alfalfa seed inoculated with rhizobium by industrial seed coating process.

Literature Cited

Manske, L.L. 1983. Alfalfa interseeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 160-175.

Manske, L.L. 1986a. Alfalfa interseeding time of seeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 225-237.

Manske, L.L. 1986b. Alfalfa interseeding techniques trial. Annual Report. Dickinson Experiment Station. Dickinson, ND. p. 220-224.

Manske, L.L. 2004a. Environmental factors to consider during planning of management for range plants in the Dickinson, North Dakota, region, 1892-2003. NDSU Dickinson Research Extension Center. Range Research Report DREC 04-1018g. Dickinson, ND. 37p.

Manske, L.L. 2004b. Ombrothermic interpretation of range plant water deficiency from temperature and precipitation data collected at the Ranch Headquarters of the Dickinson Research Extension Center in western North Dakota, 1982-2003. NDSU Dickinson Research Extension Center. Range Research Report DREC 04-1019g. Dickinson, ND. 17p.

Manske, L.L. 2004c. Evaluation of interseeding row-spacing techniques. NDSU Dickinson Research Extension Center. Summary Range Research Report DREC 04-3033. Dickinson, ND. 12p.

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Techniques and Mechanical Processes for Interseeding Alfalfa into Grasslands

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3037

Interseeding alfalfa into existing grassland ecosystems poses considerably more problems than seeding alfalfa into cropland. The application of the information collected at the Dickinson Research Extension Center during the twenty years of scientific investigation into problems related to procedures of interseeding plant material with minimal disturbance to existing plant communities is summarized in this report. The summary provides information on procedural techniques and guidelines and on mechanical processes performed by a rugged simple interseeding machine that could be used to interseed alfalfa into semi-arid grassland plant communities.

The conditions needed for an alfalfa seed to develop into an established plant within an existing grassland plant community include access to mineral soil, adequate soil water, sufficient quantities of nutrients and minerals, and abundant sunlight.

Techniques and Mechanical Processes

The method that creates the best potential for successful establishment of alfalfa plants within grassland communities combines several techniques and mechanical processes: the interseeding is performed during mid to late April; an alfalfa variety that has a high percentage of *Medicago falcata* in the parentage, like Travois, is used; the furrow rows are spaced ten feet apart; a seeding rate of 0.50 lbs PLS per row per acre is used; and both nitrogen and phosphate fertilizers are added at low rates, around 30 lbs per acre each, to the furrow row so that the fertilizer and seed are not in direct contact. A simple machine fabricated with three toolbars (figure 1) is used to mechanically prepare a suitable seedbed and control competition from the vegetation of the established sod through treatments performed separately by plow shank tools.

An adequate seedbed is mechanically prepared with double straight coulters that are placed side by side and three inches apart, set to cut the sod to a 3-inch depth, and followed by a 3-inch twisted chisel plow shovel that is set 3 inches deep, with the "V" point extending a little deeper (figure 2). The alfalfa seed is delivered at metered quantities from hydraulically driven hopper boxes, through plastic hose and a solid pipe mounted behind the plow shank with the 3-inch twisted chisel plow shovel, and into the "V" trench in the prepared seedbed (figure 1). The seed is covered and the seedbed is firmed with a pack wheel (figure 2). The competition for soil water, nutrients, minerals, and sunlight from the established vegetation is controlled with a 12-inch cultivator sweep (figure 2) with the tip removed by a cut in a reverse "V" and the fins of the sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface. Mixed nitrogen and phosphate fertilizers are delivered at low metered rates from hydraulically driven hopper boxes, through plastic hose and a solid pipe mounted behind the plow shank with the 12-inch cultivator sweep, and to the seedbed, one inch above the alfalfa seed (figure 1).

Alfalfa Plant Material

Alfalfa was identified as the plant material that had the greatest potential for interseeding treatments because it could be established within grassland plant communities and, on the short term, the combined quantity of herbage the alfalfa produced and the quantity of herbage the remaining intact grassland plants produced was 32% to 36% greater than the quantity of herbage produced on the undisturbed control plant community managed with traditional practices. Nonalfalfa perennial legume, domesticated grass, and native grass plant materials had low potential for interseeding treatments because they were not readily established successfully into grasslands through interseeding and the few plant types that had partial establishment produced less herbage than the previously intact grassland plant community.

The alfalfa varieties that perform the best when interseeded into grassland ecosystems have 45% to 100% *Medicago falcata* in the parentage. These creeping pasture type alfalfas have small narrow lanceolate leaves; variegated, white, or yellow flowers; and an extensive branching root system that grows from a wide crown located mostly below ground level. These alfalfas can reproduce vegetatively from rhizomes, which are horizontal underground stems. Pasture type alfalfas are persistent and have a very high tolerance to cold and dry conditions and, because they recover relatively slowly after grazing or cutting for hay and they reduce aboveground production during late summer and early fall, they perform well when managed with summer grazing or with a one- or two-cut hay harvest system.

Row Spacing

The row spacing that caused the least disturbance and fewest detrimental changes to the intact plant community between the furrow rows is the 10-foot row spacing. The intact plant community on the 10-foot row spacing treatments did not decrease in plant density or in net herbage production compared to the undisturbed plant community during the short term (6 years). The effects from mechanical interseeding treatments of row spacings less than 10 feet apart cause reductions in plant density, increases in open spaces in the plant community, decreases in desirable species, increases in less desirable species, and a net decrease in herbage production.

Established alfalfa plants become a detrimental source of competition for the native grassland plant community between the furrow rows. Increased soil water use from established alfalfa plants extends at least five feet from the crown, causing increased water stress in the adjacent plant community; after a period of several years, this competition results in a shift from native species to domesticated species of smooth bromegrass and crested wheatgrass. The taller alfalfa plants shade a portion of the intact plant community; the competition for sunlight results in losses of some native plants.

Seeding Date

There are two periods in the Northern Plains (spring and dormant season) during which interseeding into grassland ecosystems can result in an adequate density of alfalfa. Interseeding alfalfa during late summer or early fall has limited potential for success in the Northern Plains. Successful interseeding depends on adequate soil moisture to ensure that enough plant development and leaf growth occur and that the seedlings produce and store adequate carbohydrates for the plants to survive the winter period. Water deficiencies great enough to hinder alfalfa plant establishment occur from July to October during 67.0% to 92.9% of the years, and successful establishment from late-season seeding would be expected to occur during only 7.1% to 25.9% of the growing seasons.

Dormant-season seeding can be successful when seed viability is maintained during the winter, until soil temperatures rise above those required for seed germination. Seed exposed to air during the winter can desiccate. Completely covering the alfalfa seed with soil will help prevent desiccation, but this safeguard is extremely difficult to accomplish when the soil is dry or frozen. Dry or frozen soils form into angular blocks that can leave cracks allowing the seeds to contact air, which can remove moisture and kill the seeds by desiccation. Complete seed-soil contact needs to be accomplished to permit successful dormant-season seeding.

Early spring (mid to late April) is the preferable interseeding period. Spring seeding dates in the Northern Plains need to be early so the seedlings can develop root systems large enough to survive the periods of water deficiency that usually occur during July to October. Seeds of perennial plants can be placed in cooler soils earlier in the spring than seeds of annual crop plants. The mid to late April seeding dates produced alfalfa plant densities that reached the respective potentials of the mechanical interseeding techniques used. The May and June seeding dates were too late in the spring and produced plant densities below the potential for the interseeding techniques used.

Seeding Rate

The desired alfalfa plant density after the first year is 3 to 6 plants per meter of row. The less-than-ideal seeding conditions that exist with interseeding practices and the extremely high seedling loss during the first year suggest the use of a higher seeding rate for interseeding treatments than would be used under normal solid seeding conditions with conventional field practices. With proper interseeding techniques, a seeding rate of 0.50 lbs PLS per row per acre can provide the desired alfalfa plant density. The 0.50 lbs PLS seeding rate deposits the same amount of seed per row that solid seeding does when the seeding rate is 12.38 lbs PLS per acre, which is about double the recommended solid-seeding rate. Determination of seeding rate for interseeding treatments is quite different from determination of the rate for solid-seeding treatments because with interseeding, the area of the actual seedbed is some fraction of the total area receiving treatment. The basic seeding unit for interseeding treatments is the seeding rate per furrow row rather than the seeding rate per acre as in solid seeding, because with the potential variation in the number of furrow rows per acre in interseeding treatments, the rates per acre from the same seeding rate per row vary. A furrow seeding rate of 0.50 lbs

PLS per row is 0.82 lbs per acre with 10-foot row spacings, and with 3-foot row spacings it is 2.75 lbs per acre. Increasing the interseeding seeding rate from 0.50 lbs per row to 1.00 lbs per row increases the equivalent solid-seeding rate to 24.75 lbs per acre: the seeding rate with 10-foot row spacings is 1.65 lbs PLS per acre, and with 3-foot row spacings it is 5.50 lbs PLS per acre. Increasing the interseeding rate to 1.00 lbs per row, however, does not increase the number of alfalfa plants per row. The seeding rate of interseeding treatments should be about double the rate that would be used per row in solid seeding with conventional practices. Seeding rates greater than double the solid-seeding rate per row do not improve stand density.

Mechanical Seedbed Preparation

One important aspect of the mechanical interseeding process is the preparation of a suitable seedbed. Seedbed preparation requires the use of methods that mechanically disturb a small portion of the land area without creating a rough terrain and that produce a furrow large enough to provide growing alfalfa plants with access to mineral soil, adequate soil water, sufficient quantities of nutrients and minerals, and abundant sunlight. The 3-inch twisted chisel plow shovel was the narrowest tool that produced a suitable furrow and seedbed. Attempts to sod seed or interseed alfalfa into seedbeds narrower than two inches wide met with problems that attempts using the 3-inch seedbed did not. Broadcast sod-seeding alfalfa into grasslands requires access to mineral soil seedbeds. Grasslands in average or better condition have very low quantities of bare soil because of the plant density and litter cover. Grasslands in poor condition have greater quantities of bare soil but still have relatively low amounts of mineral soil available for seedbeds. The inch-wide seedbeds prepared by modified no-till drills were too narrow to be beneficial for alfalfa seedling development. The actual causes of the problems associated with seedbeds narrower than 2 inches were not identified, and remedies for those causes were not determined. The 2-inch straight spike prepared an inferior seedbed in a furrow that was extremely narrow at the bottom and much wider near the soil surface. The 4-inch twisted chisel plow shovel produced a seedbed of less-than-desirable quality because the tool had a flat cutting edge like a plowshare on a moldboard plow. The 6-inch twisted chisel plow shovel had a “V” bottom, but the furrow was wider than necessary and the great width of the chisel caused a large portion of the treatment area to be disturbed. Both the 4-inch and 6-inch twisted chisels produced furrows wider than the 3-inch chisel, but their use did not improve the density of established alfalfa plants.

Chisel plow shovels do not cut clean edges at the same width as the chisel, but rip out areas of sod wider than the chisel. The narrower chisels enlarge the furrow a greater percentage of the chisel width than larger chisels. The problem of creating a furrow width larger than the chisel width can be corrected by cutting the sod ahead of the chisel with two straight coulters placed side by side at a distance the same as the width of the chisel (figure 3); following the double coulters, the chisel will remove the cut furrow sod strips cleanly (figure 4). The size of the furrow produced with double straight coulters spaced 3 inches apart and placed ahead of a 3-inch twisted chisel plow shovel is 77.5% narrower than the size of the furrow produced with a 3-inch twisted chisel plow shovel without the double coulters.

Seedbed Firming

A pack wheel following the deposition of seeds into the prepared seedbed helps cover the seed and firms the soil above the seeds (figure 3). The small seeds of alfalfa can desiccate easily when they are directly exposed to air. The rate of desiccation is greatly reduced when the seeds are covered completely with soil. Firming the soil above the seed acts like a blotter, allowing moisture to move upward and helping to maintain moisture closer to the soil surface.

Mechanical Sod Control

A second important aspect of the mechanical interseeding process is the control of competition from the established vegetation. Sod control requires the use of methods that mechanically disturb a small portion of the landscape without creating a rough terrain and that reduce competition from the established grassland plants on a large enough area to provide growing alfalfa plants with adequate soil water, sufficient quantities of nutrients and minerals, and abundant sunlight. The function of the cultivator sweep is sod control of the plant community adjacent to both sides of the seedbed furrow. A 12-inch cultivator sweep (figure 2) controls the sod without major destruction of the landscape. The sweep fins undercut the sod that remains in place, and the result is a relatively smooth land surface (figure 4), unlike the extremely rough terrain produced by lister-type interseeding machines. The lister-type machines achieve excellent sod control and reduce the competition from the established plants by scalping a large portion of the land area. These machines completely remove the sod from the lister blade furrow and deposit the sod clods onto the undisturbed portions, causing major destruction of the established plant community, physically exposing the soil surface to wind and water erosion, and creating an extremely rough land surface.

An alternative sod control treatment of chemical herbicides has additional costs and poses more and greater obstacles than mechanical sod control. Because the chemical herbicides are effective only on actively growing plants, interseeding must be delayed into June, too late for adequate alfalfa seedling development before the usual water deficiency period during mid summer. In addition, dust produced from accompanying treatment processes deactivates the herbicide action so that no control of the sod results.

Mechanical sod control by cultivator sweeps is effective and causes a minimum of landscape destruction. The 6-inch cultivator sweep, however, does not undercut a large enough area on each side of the furrow to reduce the competition from the established plant community adequately. The alfalfa density on the treatment with the 6-inch sweep was only 60% of that on the treatment with the 12-inch sweep, but the density that resulted when the 6-inch sweep was used was greater than the density that resulted when the twisted chisel plow shovel was used alone. The 16-inch cultivator sweep undercut an area 44.4% larger than the area of the established plant community undercut by the 12-inch sweep, but the use of the larger sweep did not improve the density of the established alfalfa plants. Adequate sod control is achieved on the area undercut on each side of the furrow by the fins of a 12-inch cultivator sweep (figure 2). The sweep fins cut at a depth of 1.5 to 2 inches below the soil surface and separate the crowns of grass plants from a large portion of the grass plants' roots. The grass plants are not killed, but their growth processes are greatly impaired, and the result is reduced competition from the established plant community for soil water and nutrients. The reduction in competition is beneficial for alfalfa plant establishment, but also for less-desirable perennial plants and annual species. The portion of the sweep that passes directly over the prepared seedbed serves no function and can disturb the furrow so that seedling emergence and the number of seedlings per meter of row are reduced. Removing the tip from the 12-inch cultivator sweep by cutting a reverse "V" shape (figure 2) can eliminate potential seedbed disturbances, and the alfalfa plant density is 33.6% greater on the treatments conducted with the sweep tip removed than on treatments conducted with the sweep tip intact.

Fertilization Rate

Alfalfa plant density and plant height are improved by nitrogen fertilizer. Phosphorus fertilizer helps improve alfalfa seedling success by encouraging root growth. Both nitrogen and phosphate fertilizers help improve interseeded alfalfa plant growth as long as the fertilizer is not in direct contact with the seed. Low fertilization rates of nitrogen and phosphate, around 30 lbs per acre each, would be sufficient to benefit alfalfa plant density and plant height and enhance alfalfa stand establishment. The rates of fertilization on interseeding treatments are determined for the land area of the seedbed in the furrow rows.

Interseeding Machine

The techniques and mechanical processes of interseeding alfalfa into grasslands were performed with a rugged simple triple toolbar machine (figure 1) that was a modification of the innovatively uncomplicated double toolbar interseeding machine developed at South Dakota State University.

The 1979 model of the SDSU pasture interseeder was a relatively simple fabricated double toolbar machine with 4-inch or 6-inch twisted chisel plow shovels mounted on four plow shanks spaced three feet apart. The main frame was made of two 10.6-foot lengths of 4 X 4 inch steel tubing placed fourteen inches apart. The front toolbar held the three-point hitch assembly and the parking stand. The back toolbar held the four plow shanks and the two gauge wheels. A 5 X 3 inch steel tube was mounted three feet above the back toolbar to hold four hydraulically driven hopper boxes with two spouts each for seed or fertilizer (Chisholm et al. circa 1980).

The frame of the SDSU pasture interseeding machine was modified by the addition of a third toolbar 30 inches behind the second toolbar and by the addition of a marker disk on each side. The major modifications were in the plow shank tools and the arrangements of the tools placed on the toolbars. The modified machine held two sets of tools spaced 10 feet apart. The front toolbar carried double straight coulters placed side by side and three inches apart and set to cut the sod to a 3-inch depth (figure 2). The middle toolbar carried a 3-inch twisted chisel plow shovel set to produce a furrow 3 inches wide and 3 inches deep, with the "V" point extending a little deeper (figure 2). The back toolbar carried a 12-inch cultivator sweep with the tip removed by a cut in a reverse "V" and the fins of the sweep set to undercut the sod at a depth of 1.5 to 2 inches below the soil surface (figure 2).

Machine Performance

The standard interseeding machine built according to South Dakota State University plans had a double toolbar and had 4-inch twisted chisel plow shovels mounted on four plow shanks spaced at three feet. The four-year mean alfalfa plant density on the treatments conducted with the standard machine was only 0.39 plants per meter of row (table 1). Changing the 4-inch twisted chisel plow shovels to 3-inch wide twisted chisels increased the alfalfa density 2.6% (table 1). Use of a developmental-stage machine modification with 4-inch twisted chisel plow shovels mounted on two plow shanks spaced ten feet apart resulted in a four-year mean alfalfa plant density of 0.94 plants per meter of row, which was 141.0% greater than the plant density on treatments conducted with the standard machine (table 1). Changing the 4-inch twisted chisel plow shovels to 3-inch wide twisted chisels on plow shanks spaced ten feet apart on a developmental-stage modified machine resulted in an alfalfa plant density 151.3% greater than the alfalfa density on treatments conducted with the standard machine (table 1).

The final-stage modified triple toolbar interseeding machine (figure 1) had double straight coulters placed side by side and three inches apart, followed by a three-inch twisted chisel plow shovel, followed by a 12-inch cultivator sweep with the tip removed, and had the two sets of plow shanks spaced ten feet apart. The treatments conducted with the triple toolbar machine produced a four-year mean alfalfa plant density of 3.59 plants per meter of row, which was 820.5% greater than the plant density on treatments conducted with the standard machine (table 1).

Rhizobium and Rhizosphere Organisms in Grassland Soils

Alfalfa plants form symbiotic relationships with rhizobium bacteria. The bacteria need to be in the proximity of the developing seedling roots in order for infection to occur. Mixing rhizobium bacteria with alfalfa seed inoculates the soil at the same time the alfalfa seed is planted. The rhizobium bacteria infect the seedling roots and form nodules. The bacteria living in the nodules change (or fix) the nitrogen in the air from a form that the alfalfa plant cannot biologically use into a form that the alfalfa plant can use. The plant uses nitrogen fixed by the rhizobium bacteria in the root nodules, along with the mineral nitrogen absorbed from the surrounding soil, for growth and herbage production. The quantity of herbage biomass produced by alfalfa plants growing in soils with low levels of mineral nitrogen is related to the number and size of nodules formed on the roots.

Grassland soils sampled at a single point in time reveal low levels of mineral nitrogen, but grassland soils are not low in nitrogen. Grassland soils contain abundant quantities of nitrogen, although most of it is in the organic form and unavailable for direct use by plants. Grassland rhizosphere organisms play a major role in the biogeochemical nutrient cycles that are necessary for an ecosystem to function properly, like the nitrogen cycle. Rhizosphere organisms have a symbiotic relationship with roots of perennial grass plants and convert organic nitrogen to mineral nitrogen, the form that plants can use. Elevated microorganism activity in the rhizosphere results in increased mineral nitrogen available to the grass plants. Grassland ecosystems that have a high biomass of active rhizosphere organisms produce greater quantities of herbage biomass than ecosystems with low rhizosphere organism biomass.

Cropland soils do not have rhizosphere organisms, and the soil organisms that live in cropland soils do not exist at population biomass levels comparable to the biomass levels in grassland soils. The rhizospheres in grassland soils have populations of bacteria, protozoa, nematodes, mites, and small insects capable of consuming rhizobium bacteria.

Alfalfa plants interseeded into grassland ecosystems have greater seedling mortality and slower rates of growth than the same varieties solid seeded into cropland. The roots of interseeded alfalfa seedlings have low numbers of small nodules. Low nodulation rates of interseeded alfalfa plants indicate that the inoculated rhizobium bacteria were harvested by the indigenous soil organisms and did not survive in the grassland soil long enough to permit infection and nodulation of the young alfalfa plants after they had grown sufficient root material. The presence of rhizosphere organisms in grassland ecosystems is a serious hindrance for interseeded alfalfa establishment.

The revelation that beneficial rhizosphere organisms were the cause of the reductions in the success rates for interseeded alfalfa establishment compared to the rates for alfalfa solid seeded into cropland did not lead to research projects in soil fumigation techniques. Instead, the original problem that the interseeding research program was attempting to solve by introducing alfalfa plants into grassland ecosystems was reassessed. Low herbage production on grasslands is not the actual problem; it is a symptom of low activity and/or low biomass of rhizosphere organisms, which is caused by antagonistic management practices. The research program to evaluate alfalfa interseeding techniques was terminated in 1989, and a research program to evaluate techniques that increase rhizosphere organism activity and biomass was initiated.

Management Implications

The set of techniques, guidelines, and mechanical processes developed during the interseeding research program provides a combination of procedures that produce the best potential for successful establishment of alfalfa plants interseeded into native grassland ecosystems with minimal disturbance to the existing plant communities. However, because rhizosphere organisms harvest inoculated rhizobium bacteria, the alfalfa plant density per meter of row is lower and the rate of growth and development is slower for alfalfa interseeded into grassland than for alfalfa solid seeded into cropland. Interseeding alfalfa into native range pastures does not solve the problem of low herbage production on grasslands. Low herbage production is not the actual problem but a symptom of that problem. The problem is low levels of rhizosphere organism activity that are caused by antagonistic grazing management practices. Implementation of biologically effective grazing management that coordinates defoliation with grass phenological growth stages to stimulate the defoliation resistance mechanisms and the activity of the symbiotic rhizosphere organisms corrects the problems in grassland ecosystems and results in greater herbage biomass production. Interseeding alfalfa into grasslands does not increase aboveground herbage biomass production, and it is not a recommended practice.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the table and figures. I am grateful to Lisa J. Vance for digitizing the figures.

Table 1. Alfalfa plant density per meter of row compared at developmental stages of modified interseeding machines with the standard machine built according to South Dakota State University plans.

Toolbar Plow shanks and spacing Twisted chisel width Cultivator sweep width	1st year	2nd year	3rd year	4th year	5th year	Means of growing seasons after 1st year
Standard Double toolbar 4 shanks spaced 3 foot 4-inch twisted chisel	11.47a	0.63c	0.24c	0.26c	0.42c	0.39c
Double toolbar 4 shanks spaced 3 foot 3-inch twisted chisel	13.85a	0.74bc	0.21c	0.31c	0.38c	0.40c
% of standard	120.8	117.5	87.5	119.2	90.5	102.6
Double toolbar 2 shanks spaced 10 foot 4-inch twisted chisel	14.12a	1.33bc	0.67bc	0.87b	0.88b	0.94b
% of standard	123.1	211.1	279.2	334.6	209.5	241.0
Double toolbar 2 shanks spaced 10 foot 3-inch twisted chisel	14.88a	1.77b	0.83b	0.80b	0.50bc	0.98abc
% of standard	129.7	281.0	345.8	307.7	119.1	251.3
Triple toolbar 2 shanks spaced 10 foot 3-inch twisted chisel 12-inch sweep	29.72a	6.87a	3.23a	2.37a	1.90a	3.59a
% of standard	259.1	1090.5	1345.8	911.5	452.4	920.5

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

Fig. 1. Triple-toolbar interseeding machine.

Fig. 2. Interseeding tools: double straight coulters, 3-inch twisted chisel plow shovel, and 12- inch cultivator sweep with tip removed.

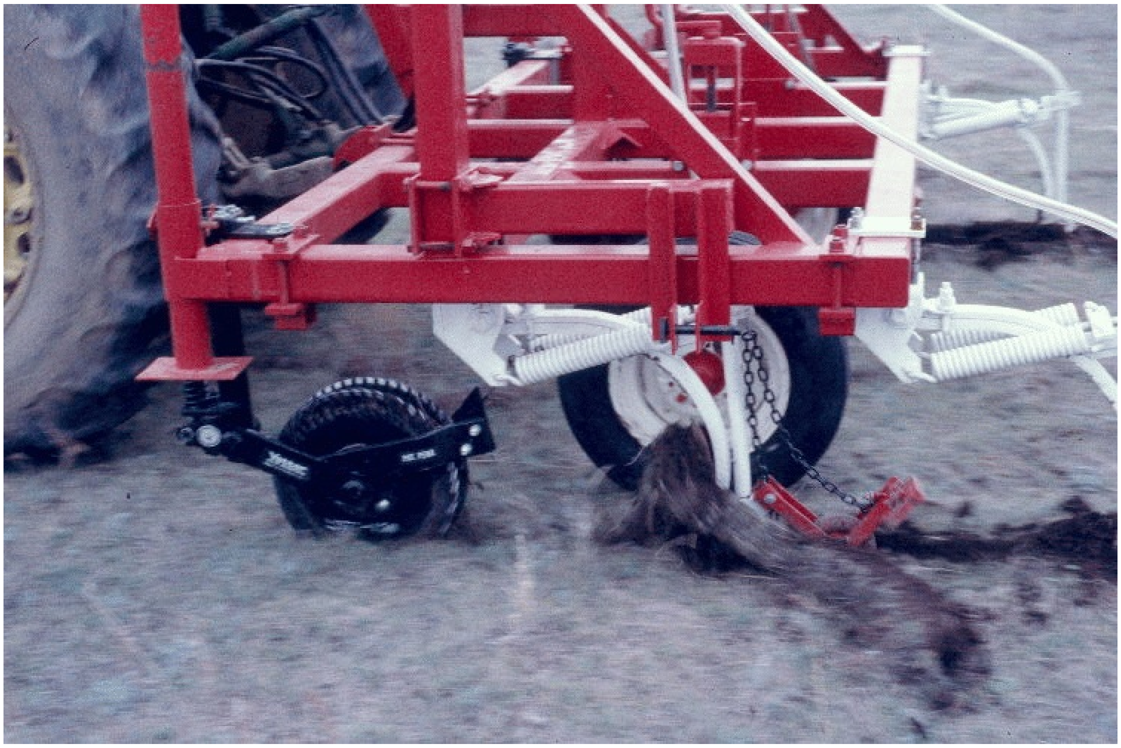


Fig. 3. Interseeding alfalfa into grassland with triple-toolbar machine.

Fig. 4. Three-inch clean furrow row produced by triple-toolbar interseeding machine.

Triple-toolbar interseeding machine with double straight coulters, three-inch twisted chisel plow shovel, and twelve-inch cultivator sweep with tip removed.

Literature Cited

Chisholm, T.S., F.R. Vigil, T.M. Klosterman, and G. Orcutt. circa 1980. Interseeding and plans for SDSU's new machine for better pasture production. South Dakota State University Agricultural Experiment Station. B 680. Brookings, SD. 14p.

Evaluation of Grazing Alfalfa Interseeded Native Grassland Pastures

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Report DREC 04-3038

Low herbage biomass production has long been assumed to be an inherent characteristic of native rangeland. Simple deduction has led to the common belief that herbage and livestock production on grasslands would be increased if alfalfa could be seeded into the established plant community. The performances of herbage and cow-calf pairs on native rangeland and native range interseeded with alfalfa were compared in an alfalfa interseeded pasture grazing study that comprised two trials. Trial I was conducted from 1977 to 1981 by Paul E. Nyren and Dr. Harold Goetz. Trial II was basically a continuation of trial I with a few modifications and was conducted from 1984 to 1988 by Dr. Llewellyn L. Manske.

Procedures

The alfalfa interseeded pasture grazing study was conducted on two pastures located on the SW¼, sec. 23, T. 140 N., R. 97 W., at the Dickinson Research Extension Center. The established 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 native rangeland with no mechanical treatments. The alfalfa interseeded pasture was 10 acres of native rangeland interseeded with Travois alfalfa in May 1977 at the seeding rate of 4 lbs per acre. The interseeding equipment was the Melroe 701 No-Till Drill with modification #4, which had a single straight coulter ahead of a 12-inch cultivator sweep followed by a stock double disk furrow opener followed by a pack wheel (Nyren 1979). The tools of the drill were set at 30-inch row spacings. Both study treatments had one replication each. On trial I, each treatment pasture was managed with one grazing period that started between mid June and mid July and ended between mid July and mid August during the growing seasons of 1979, 1980, 1981, and 1984. On trial II, each treatment pasture was managed with two grazing periods during the growing seasons of 1985, 1986, 1987, and 1988. The first grazing period started between early and mid June and ended between mid and late June. The second grazing period started between mid and late July and ended between mid and late August. The livestock on the alfalfa interseeded pasture were provided a product in block form that guarded against bloat. Research was not conducted on the alfalfa interseeded pasture grazing study during the growing seasons of 1978, 1982, and 1983; however, the pastures were not idle. During 1978, 1982, and 1983, the native range pasture was grazed at a mean stocking rate 133.7% greater than the research stocking rate. During 1978 and 1983, the alfalfa interseeded pasture was grazed at a mean stocking rate 93.6% greater than the research stocking rate. The alfalfa interseeded pasture was not grazed during 1982 because the vegetation had not recovered from the combined effects from the alfalfa interseeding treatment, the grazing treatment, and the drought conditions that occurred during 1980.

Cow and calf performance was 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 at the beginning and end of each grazing period. Vegetation was clipped to ground level in quarter-meter square quadrats located both inside and outside exclosure cages, and the samples were oven dried. 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. On trial II, quantitative species composition was determined by percent basal cover sampled with the ten-pin point frame method. Species composition of the plant community on the alfalfa interseeded treatment was compared to the plant community on the native range control treatment with a percent similarity index method (Mueller-Dombois and Ellenberg 1974). Costs and returns for trial I and trial II were determined from total pasture and forage costs and value of calf weight gain for the grazing periods (Manske et al. 2002). Differences between means from treatment years were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results and Discussion

The mean growing-season precipitation (table 1) during the years of trial I and trial II was normal. During trial I, when the pasture treatments were managed with one grazing period, the mean growing-season precipitation was 91.5% of the long-term mean. During trial II, when the pasture treatments were managed with two grazing periods, the mean growing-season precipitation was 97.8% of the long-term mean. Trial I and trial II each had one drought growing season during the years the treatments were conducted (table 2). During trial I, the growing season of 1980 received 79.0% of the long-term mean precipitation. April received 2.1% of the long-term mean; May, June, and July received 51.8% of the long-term mean; and August, September, and October received 161.2% of the long-term mean. During trial II, the growing season of 1988 received 48.3% of the long-term mean. April received no precipitation; May, June, and July received 65.7% of the long-term mean; and August, September, and October received 30.1% of the long-term mean. The growing-season months of 1980 received 2.9 inches of precipitation less than the long-term mean, and the growing-season months of 1988 received 7.0 inches of precipitation less than the long-term mean. The growing-season months of 1988 received 4.2 inches of precipitation less than the growing-season months of 1980.

The native range control pasture of trial I (table 3) was grazed for an average of 29 days, with one grazing period from 3 July to 1 August. The pasture was grazed by 8 cow-calf pairs and had a stocking rate of 2.21 acres per animal unit equivalent month (AUEM). The alfalfa interseeded pasture of trial I (table 3) was grazed for an average of 25 days, with one grazing period from 3 July to 28 July. The pasture was grazed by 8 cow-calf pairs and had a stocking rate of 1.36 acres per AUEM. The stocking rate on the alfalfa interseeded pasture was 64.4% greater than, but not significantly different (P<0.05) from, the stocking rate on the native range pasture (table 3).

The native range control pasture of trial II (table 3) was grazed for an average of 44 days, with two grazing periods. The pasture was grazed by 6 cow-calf pairs and had a stocking rate of 1.85 acres per AUEM. The first grazing period was 15 days, from 9 June to 24 June. The second grazing period was 29 days, from 22 July to 20 August. The alfalfa interseeded pasture of trial II (table 3) was grazed for an average of 44 days, with two grazing periods. The pasture was grazed by 6 cow-calf pairs and had a stocking rate of 1.01 acres per AUEM. The first grazing period was 15 days, from 9 June to 24 June. The second grazing period was 29 days, from 22 July to 20 August. The stocking rate on the alfalfa interseeded pasture was 80.0% greater than, and significantly different (P<0.05) from, the stocking rate on the native range pasture (table 3).

During the 1980 drought growing season of trial I, the pastures were managed with one grazing period and the stocking rates were reduced greatly. The stocking rate on the native range pasture was reduced 51.1%, and the stocking rate on the alfalfa interseeded pasture was reduced 70.3%. During the 1988 drought growing season of trial II, the pastures were managed with two grazing periods and the stocking rates were only slightly reduced. The stocking rate on the native range pasture was reduced 7.3%, and the stocking rate on the alfalfa interseeded pasture was reduced 8.1% (table 4). The decrease in stocking rate during the drought growing season was greater on the alfalfa interseeded pasture than on the native range pasture on both trial I and trial II.

Cow and calf performances on the native range and alfalfa interseeded pastures managed with one grazing period on trial I were compared using gain per head, gain per day, and gain per acre data (table 5). Cow gain per head on the native range pasture was 84.1% greater than, but not significantly different (P<0.05) from, cow gain per head on the alfalfa interseeded pasture. Cow gain per day on the native range pasture was 278.9% greater than, but not significantly different (P<0.05) from, cow gain per day on the alfalfa interseeded pasture. Cow gain per acre on the native range pasture was 21.9% greater than, but not significantly different (P<0.05) from, cow gain per acre on the alfalfa interseeded pasture. Calf gain per head on the native range pasture was 8.7% greater than, but not significantly different (P<0.05) from, calf gain per head on the alfalfa interseeded pasture. Calf gain per day on the native range pasture was 6.6% greater than, but not significantly different (P<0.05) from, calf gain per day on the alfalfa interseeded pasture. Calf gain per acre on the alfalfa interseeded pasture was 67.8% greater than, but not significantly different (P<0.05) from, calf gain per acre on the native range pasture.

Cow and calf performances on the native range and alfalfa interseeded pastures managed with two grazing periods on trial II were compared using gain per head, gain per day, and gain per acre data (table 6). Cow gain per head on the alfalfa interseeded pasture was 13.6% greater than, but not significantly different (P<0.05) from, cow gain per head on the native range pasture. Cow gain per day on the alfalfa interseeded pasture was 16.8% greater than, but not significantly different (P<0.05) from, cow gain per day on the native range pasture. Cow gain per acre on the alfalfa interseeded pasture was 104.5% greater than, but not significantly different (P<0.05) from, cow gain per acre on the native range pasture. Calf gain per head on the alfalfa interseeded pasture was 11.7% greater than, but not significantly different (P<0.05) from, calf gain per head on the native range pasture. Calf gain per day on the alfalfa interseeded pasture was 10.4% greater than, but not significantly different (P<0.05) from, calf gain per day on the native range pasture. Calf gain per acre on the alfalfa interseeded pasture was 101.1% greater than, and significantly different (P<0.05) from, calf gain per acre on the native range pasture. Cow and calf performances were not significantly different between the native range pasture and the alfalfa interseeded pasture on trial I and trial II except that the calf gain per acre on trial II was greater on the alfalfa interseeded pasture than on the native range pasture.

Cow and calf performance on trial I during the 1980 drought growing season on the native range and alfalfa interseeded pastures managed with one grazing period (table 7) was compared to cow and calf performance during the nondrought growing seasons on the respective treatment pastures, using gain per head, gain per day, and gain per acre data. On the native range pasture, cow gain per head decreased 95.4%, cow gain per day decreased 94.1%, and cow gain per acre decreased 96.6% during the drought growing season. Calf gain per head decreased 42.8%, calf gain per day increased 3.1%, and calf gain per acre decreased 52.2% during the drought growing season. On the alfalfa interseeded pasture, cow gain per head decreased 2128.8%, cow gain per day decreased 1029.4%, and cow gain per acre decreased 653.0% during the drought growing season. Calf gain per head decreased 82.0%, calf gain per day decreased 52.1%, and calf gain per acre decreased 85.3% during the drought growing season.

Cow and calf performance on trial II during the 1988 drought growing season on the native range and alfalfa interseeded pastures managed with two grazing periods (table 7) was compared to cow and calf performance during the nondrought growing seasons on the respective treatment pastures, using gain per head, gain per day, and gain per acre data. On the native range pasture, cow gain per head decreased 20.7%, cow gain per day decreased 10.3%, and cow gain per acre decreased 20.7% during the drought growing season. Calf gain per head decreased 17.4%, calf gain per day decreased 0.3%, and calf gain per acre decreased 17.4% during the drought growing season. On the alfalfa interseeded pasture, cow gain per head increased 7.0%, cow gain per day increased 30.1%, and cow gain per acre increased 7.0% during the drought growing season. Calf gain per head decreased 22.2%, calf gain per day decreased 6.7%, and calf gain per acre decreased 22.2% during the drought growing season. The decrease in cow and calf performance during the drought growing season on trial I was greater on the alfalfa interseeded pasture than on the native range pasture. The cow performance on the native range pasture on trial II decreased more during the drought growing season than the cow performance on the alfalfa interseeded pasture. The decrease in calf performance during the drought growing season on trial II was greater on the alfalfa interseeded pasture than on the native range pasture.

Aboveground herbage biomass on the native range and alfalfa interseeded pastures managed with one grazing period on trial I was compared at the start of the grazing period, at the end of the grazing period, and by the quantity of forage used per acre during the grazing period (table 8). Herbage biomass at the start of the grazing period on the alfalfa interseeded pasture was 63.9% grass and 36.2% alfalfa, and the total herbage biomass per acre was 36.5% greater than, but not significantly different (P<0.05) from, the total herbage biomass at the start of the grazing period on the native range pasture. Grass biomass per acre on the native range pasture was 14.8% greater than that on the alfalfa interseeded pasture. Herbage biomass at the end of the grazing period on the alfalfa interseeded pasture was 47.2% grass and 52.8% alfalfa, and the total herbage biomass remaining per acre was 29.5% greater than, but not significantly different (P<0.05) from, the total herbage biomass remaining at the end of the grazing period on the native range pasture. Grass biomass remaining per acre on the native range pasture was 63.8% greater than that remaining on the alfalfa interseeded pasture. The forage used during the grazing period on the alfalfa interseeded pasture was 14.9% grass and 85.1% alfalfa, and the total quantity of forage used per acre was 46.5% greater than, but not significantly different (P<0.05) from, the quantity of forage used per acre on the native range pasture. Grass forage used per acre on the alfalfa interseeded pasture was 24.7% greater than that used per acre on the native range pasture.

Aboveground herbage biomass on the native range and alfalfa interseeded pastures managed with two grazing periods on trial II was compared at the start of the first grazing period, at the end of the second grazing period, and by the quantity of forage used per acre during both grazing periods (table 9). Herbage biomass at the start of the first grazing period on the alfalfa interseeded pasture was 45.3% grass and 54.7% alfalfa, and the total herbage biomass per acre was 52.0% greater than, but not significantly different (P<0.05) from, the total herbage biomass per acre at the start of the first grazing period on the native range pasture. Grass biomass per acre on the native range pasture was 45.1% greater than that on the alfalfa interseeded pasture. Herbage biomass at the end of the second grazing period on the alfalfa interseeded pasture was 49.0% grass and 51.0% alfalfa, and the total herbage biomass remaining per acre was 73.2% greater than, but not significantly different (P<0.05) from, the total herbage biomass remaining at the end of the second grazing period on the native range pasture. Grass biomass remaining per acre on the native range pasture was 17.9% greater than that remaining per acre on the alfalfa interseeded pasture. The forage used during both grazing periods on the alfalfa interseeded pasture was 32.3% grass and 67.7% alfalfa, and the total quantity of forage used per acre was 42.8% greater than, but not significantly different (P<0.05) from, the quantity of forage used per acre on the native range pasture. Grass forage used per acre on the native range pasture was 117.0% greater than that used per acre on the alfalfa interseeded pasture.

Total herbage biomass at the start and end of the grazing periods was greater on the alfalfa interseeded pasture than on the native range pasture on both trial I and trial II, but the differences were not significant. The grass biomass at the start and end of the grazing periods was greater on the native range pasture than on the alfalfa interseeded pasture on both trial I and trial II. The total forage used per acre was greater on the alfalfa interseeded pasture than on the native range pasture on both trial I and trial II, but the differences were not significant.

Herbage biomass on trial I during the 1980 drought growing season on the native range and alfalfa interseeded pastures managed with one grazing period (table 8) was compared to the herbage biomass during the nondrought growing seasons on the respective treatment pastures at the start of the grazing period, at the end of the grazing period, and by the quantity of forage used per acre during the grazing period. Herbage biomass per acre at the start of the grazing period on the native range pasture was 2.0% less during the drought growing season than during the nondrought growing seasons. Herbage biomass that remained per acre at the end of the grazing period on the native range pasture was 24.5% greater during the drought growing season than during the nondrought growing seasons. Forage used per acre during the grazing period on the native range pasture was 34.9% less during the drought growing season than during the nondrought growing seasons. Total herbage biomass, grass biomass, and alfalfa biomass per acre at the start of the grazing period on the alfalfa interseeded pasture were 58.1% less, 39.7% less, and 86.4% less, respectively, during the drought growing season than during the nondrought growing seasons. Total herbage biomass, grass biomass, and alfalfa biomass that remained per acre at the end of the grazing period on the alfalfa interseeded pasture were 56.8% less, 1.5% less, and 94.6% less, respectively, during the drought growing season than during the nondrought growing seasons. Total forage used, grass forage used, and alfalfa forage used per acre during the grazing period on the alfalfa interseeded pasture were 59.9% less, 62.5% less, and 43.4% less, respectively, during the drought growing season than during the nondrought growing seasons.

Herbage biomass on trial II during the 1988 drought growing season on the native range and alfalfa interseeded pastures managed with two grazing periods was compared to the herbage biomass during the nondrought growing seasons on the respective treatment pastures at the start of the first grazing period, at the end of the second grazing period, and by the quantity of forage used per acre during both grazing periods. Herbage biomass per acre at the start of the first grazing period on the native range pasture was 69.5% less during the drought growing season than during the nondrought growing seasons. Herbage biomass that remained per acre at the end of the second grazing period on the native range pasture was 80.5% less during the drought growing season than during the nondrought growing seasons. Forage used per acre during both grazing periods on the native range pasture was 58.1% less during the drought growing season than during the nondrought growing seasons. Total herbage biomass, grass biomass, and alfalfa biomass per acre at the start of the first grazing period on the alfalfa interseeded pasture were 68.6% less, 70.0% less, and 67.4% less, respectively, during the drought growing season than during the nondrought growing seasons. Total herbage biomass, grass biomass, and alfalfa biomass that remained per acre at the end of the second grazing period on the alfalfa interseeded pasture were 83.3% less, 83.9% less, and 82.7% less, respectively, during the drought growing season than during the nondrought growing seasons. Total forage used, grass forage used, and alfalfa forage used per acre during both grazing periods on the alfalfa interseeded pasture were 51.3% less, 28.9% less, and

63.3% less, respectively, during the drought growing season than during the nondrought growing seasons.

During the 1980 drought growing season, the stocking rates on trial I were reduced 51.1% and 70.3% on the native range and alfalfa interseeded pastures, respectively. By early July, the quantity of grass herbage on the native range pasture during the drought year was only slightly below the quantity on the native range pasture at the start of the grazing period during nondrought years. The stocking rate was reduced more than was needed, and, as a result, greater herbage remained at the end of the grazing period and less forage was used per acre during this season than during nondrought growing seasons. The grass herbage at the start of the grazing period on the alfalfa interseeded pasture was greatly reduced from the effects of low precipitation and the competition for soil water from the alfalfa plants: the quantity of grass herbage on the alfalfa interseeded pasture at the start of the grazing period was lower during the drought season than during nondrought growing seasons. During the drought growing season, the grass herbage biomass production on the alfalfa interseeded pasture was less than the grass herbage biomass production on the native range pasture. The alfalfa herbage on the alfalfa interseeded pasture at the start of the grazing period was greatly reduced from the effects of water stress, and the quantity of the alfalfa herbage at the start of the grazing period was lower during the drought growing season than during nondrought growing seasons. The stocking rate reduction was about correct for the quantity of herbage produced by the grass plants, and about the same amount of grass herbage remained at the end of the grazing period during the drought growing season as during nondrought growing seasons. Most of the alfalfa biomass was grazed, and very little alfalfa herbage remained at the end of the grazing period.

During the 1988 drought growing season, the stocking rates on trial II were reduced 7.3% and 8.1% on the native range and alfalfa interseeded pastures, respectively. The herbage biomass production was greatly reduced on both treatment pastures because the region received no precipitation during April. Near-normal precipitation was received in May. The first grazing period was started in early June, with the herbage biomass below that of nondrought growing seasons. June, July, and August 1988 received precipitation that was 43.8% of the long-term mean. There was very little herbage growth during the 1988 growing season. The cattle on the treatment pastures grazed most of the current year's growth and most of the residual standing biomass from the previous year.

The basal cover (table 10) of cool-season grasses, warm-season grasses, sedges, forbs, and woody species on the alfalfa interseeded pasture was lower than, but not significantly different ($P<0.05$) from, the basal cover of the respective plant biotypes on the native range pasture. The basal cover of invader grass species on the alfalfa interseeded pasture was 1333.3% greater than, and significantly different ($P<0.05$) from, the invader grass basal cover on the native range pasture. The basal cover of alfalfa plants on the alfalfa interseeded pasture was significantly greater ($P<0.05$) than that on the native range pasture. The native range pasture had no alfalfa plants.

The plant species composition on the native range and that on the alfalfa interseeded pastures were compared by the percent similarity index where an 80% similarity indicates that the species compositions are similar, a 20% similarity indicates that the species compositions are dissimilar, and intermediate percentages indicate degree of similarity or dissimilarity. The plant species composition on the native range and that on the alfalfa interseeded pastures had progressively greater dissimilarity over a three-year period (table 11). The trend of the plant community on the alfalfa interseeded pasture was a decrease of the native plant species and an increase of the invader grass species. The ecological processes changed by the mechanical treatment and by the introduction of alfalfa plants in the spring of 1977 had not recovered 28 years later. The regression of the species composition continued toward a degraded plant community that comprises primarily alfalfa, smooth bromegrass, and crested wheatgrass with a few depauperate native species. Interseeding alfalfa into grassland pastures eliminated the advantages of native rangeland over domesticated cool-season grass for summer grazing.

Costs and returns on the native range and alfalfa interseeded pastures on trial I were compared using pasture costs and value of calf weight gain (table 12). On the native range pasture managed with one grazing period on trial I, a cow and calf required 2.10 acres per period, at a cost of $18.39 for the 29-day period, or $0.63 per day. Calf weight gain was 1.97 lbs per day and 26.09 lbs per acre; accumulated weight gain was 56.13 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $39.29 per calf, and the net returns after pasture costs were $20.90 per cow-calf pair and $9.95 per acre. The cost of calf weight gain was $0.33 per pound. On the alfalfa interseeded pasture managed with one grazing period on trial I, a cow and calf required 1.35 acres per period, at a cost of $14.49 for the 25-day period, or $0.58 per day. Calf weight gain was 1.84 lbs per day and 43.77 lbs per acre; accumulated weight gain was 51.23 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $35.86 per calf, and the net returns after pasture costs were $21.37 per cow-calf pair and $19.08 per acre. The cost of calf weight gain was $0.28 per pound.

Pasture cost on the alfalfa interseeded pasture was 21.2% lower than, but not significantly different (P<0.05) from, pasture cost on the native range pasture. Value of calf weight gain on the alfalfa interseeded pasture was 8.7% lower than, but not significantly different (P<0.05) from, calf weight gain value on the native range pasture. Net return per cow-calf pair on the alfalfa interseeded pasture was 2.2% greater than, but not significantly different (P<0.05) from, net return per cow-calf pair on the native range pasture. Net return per acre on the alfalfa interseeded pasture was 91.8% greater than, but not significantly different (P<0.05) from, net return per acre on the native range pasture. Cost per pound of calf accumulated weight on the alfalfa interseeded pasture was 15.2% lower than, but not significantly different (P<0.05) from, cost per pound of calf accumulated weight on the native range pasture.

Costs and returns on the native range and alfalfa interseeded pastures on trial II were compared using pasture costs and value of calf weight gain (table 13). On the native range pasture managed with two grazing periods on trial II, a cow and calf required 2.64 acres per period, at a cost of $23.13 for the 44-day period, or $0.53 per day. Calf weight gain was 2.30 lbs per day and 33.27 lbs per acre; accumulated weight gain was 99.80 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $69.86 per calf, and the net returns after pasture costs were $46.73 per cow-calf pair and $17.70 per acre. The cost of calf weight gain was $0.23 per pound. On the alfalfa interseeded pasture managed with two grazing periods on trial II, a cow and calf required 1.45 acres per period, at a cost of $18.76 for the 44-day period, or $0.43 per day. Calf weight gain was 2.54 lbs per day and 66.89 lbs per acre; accumulated weight gain was 111.48 lbs. When calf accumulated weight was assumed to have a value of $0.70 per pound, the gross return was $78.03 per calf, and the net returns after pasture costs were $59.27 per cow-calf pair and $40.88 per acre. The cost of calf weight gain was $0.17 per pound.

Pasture cost on the alfalfa interseeded pasture was 53.5% lower than, and significantly different (P<0.05) from, pasture cost on the native range pasture. Value of calf weight gain on the alfalfa interseeded pasture was 11.7% greater than, but not significantly different (P<0.05) from, value of calf weight gain on the native range pasture. Net return per cow-calf pair on the alfalfa interseeded pasture was 26.8% greater than, but not significantly different (P<0.05) from, net return per cow-calf pair on the native range pasture. Net return per acre on the alfalfa interseeded pasture was 131.0% greater than, and significantly different (P<0.05) from, the net return per acre on the native range pasture. Cost per pound of calf accumulated weight on the alfalfa interseeded pasture was 26.1% lower than, and significantly different (P<0.05) from, cost per pound of calf accumulated weight on the native range pasture.

Costs and returns on trial I during the 1980 drought growing season on the native range and alfalfa interseeded pastures managed with one grazing period (table 14) were compared to costs and returns during the average growing seasons on the respective treatment pastures. On the native range pasture, pasture cost increased 15.1%, value of calf weight gain decreased 42.8%, net return per cow-calf pair decreased 93.8%, net return per acre decreased 94.6%, and cost per pound of calf accumulated weight increased 100.0% during the drought growing season. On the alfalfa interseeded pasture, pasture cost increased 20.8%, value of calf weight gain decreased 82.0%, net return per cow-calf pair decreased 151.8%, net return per acre decreased 143.0%, and cost per pound of calf accumulated weight increased 578.6% during the drought growing season.

Costs and returns on trial II during the 1988 drought growing season on the native range and alfalfa interseeded pastures managed with two grazing periods (table 14) were compared to costs and returns during the average growing seasons on the respective treatment pastures. On the native range pasture, pasture cost decreased 11.5%, value of calf weight gain decreased 17.4%, net return per cow-calf pair decreased 20.4%, net return per acre decreased 10.2%, and cost per pound of calf accumulated weight increased 8.7% during the drought growing season. On the alfalfa interseeded pasture, pasture cost decreased 10.4%, value of calf weight gain decreased 22.2%, net return per cow-calf pair decreased 25.9%, net return per acre decreased

17.4%, and cost per pound of calf accumulated weight increased 11.8% during the drought growing season.

The costs and returns on the native range and alfalfa interseeded pastures managed with one grazing period on trial I were not different. When the pastures were managed with two grazing periods on trial II, the costs were lower on the alfalfa interseeded pasture than on the native pasture. The returns per acre were greater on the alfalfa interseeded pasture than on the native range pasture, but the returns per cow-calf pair on the two treatments were not different. The increases in pasture cost and costs per pound of calf accumulated gain and the decreases in returns per cow-calf pair and returns per acre during the drought growing seasons were smaller on the native range pasture than on the alfalfa interseeded pasture on both trial I and trial II.

Conclusions

Total herbage biomass was a little greater on the alfalfa interseeded pasture managed with one grazing period than on the native range pasture, but the difference was not significant. Grass herbage biomass was greater on the native range pasture than on the alfalfa interseeded pasture. Stocking rate was a little greater on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. Cow performance was greater on the native range pasture than on the alfalfa interseeded pasture, but the difference was not significant. Calf gain per head and gain per day were a little greater on the native range pasture than on the alfalfa interseeded pasture, but the difference was not significant. Calf gain per acre was greater on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. The decrease in cow and calf performance on the alfalfa interseeded pasture during drought conditions was greater than that on the native range pasture. Pasture cost and cost per pound of calf accumulated weight were slightly less on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. Net returns per cow-calf pair and per acre were slightly higher on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. The increase in pasture cost and cost per pound of calf gain and the decrease in returns per cow-calf pair and per acre during drought conditions were greater on the alfalfa interseeded pasture than on the native range pasture. Herbage and livestock performances on the alfalfa interseeded pasture and the native range pasture managed with one grazing period were not different.

Total herbage biomass was greater on the alfalfa interseeded pasture managed with two grazing periods than on the native range pasture, but the difference was not significant. Grass herbage biomass was greater on the native range pasture than on the alfalfa interseeded pasture. Stocking rate was greater on the alfalfa interseeded pasture than on the native range pasture. Cow performance was greater on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. Calf gain per head and gain per day were greater on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. Calf gain per acre was greater on the alfalfa interseeded pasture than on the native range pasture. The decrease in calf performance on the alfalfa interseeded pasture during drought conditions was greater than that on the native range pasture. Pasture cost and cost per pound of calf accumulated weight were lower on the alfalfa interseeded pasture than on the native range pasture. Net return per cow-calf pair was slightly higher on the alfalfa interseeded pasture than on the native range pasture, but the difference was not significant. Net return per acre was greater on the alfalfa interseeded pasture than on the native range pasture. The increase in pasture cost and cost per pound of calf gain and the decrease in returns per cow-calf pair and per acre during drought conditions were greater on the alfalfa interseeded pasture than on the native range pasture. Herbage performance on the alfalfa interseeded and native range pastures managed with two grazing periods was not different. Stocking rate, calf gain per acre, and net return per acre were greater on the alfalfa interseeded pasture than on the native range pasture. Cow performance and calf gain per head and gain per day on the alfalfa interseeded and native range pastures managed with two grazing periods were not different.

Total herbage biomass, weight gain of cows and calves, and net return per cow-calf pair and per acre were greater on the alfalfa interseeded pasture and native range pasture managed with two grazing periods than on the respective pastures managed with one grazing period.

Management Implications

The alfalfa interseeded pasture managed with two grazing periods had a higher stocking rate, produced more pounds of calf weight per acre, and had greater net returns per acre than the native range pasture on the short term. However, on the long term, the native grassland ecosystem on the alfalfa interseeded pasture was devastated. The mechanical interseeding treatment disrupted ecological processes on the disturbed portions of the pasture. The established alfalfa plants competed with the native plants for soil water and sunlight. The competition caused the native plants to progressively decrease in density and decline in herbage production and permitted invading plants to increase and replace the native plants.

Interseeding alfalfa into native range pastures does not benefit the grassland ecosystem, and it does not increase aboveground herbage biomass production. Low herbage production on native rangeland is not the actual problem; it is a symptom of a problem. The problem is low activity of rhizosphere organisms that is caused by antagonistic management practices. Changing traditional management practices to management methods designed to enhance biological and ecological processes corrects the actual problem and increases herbage biomass production. Biologically effective management applies grazing treatments to grass plants at the appropriate phenological growth stages to stimulate the activity of the symbiotic rhizosphere organisms and the biological processes that increase vegetative tiller development (Manske et al. 2003). Interseeding alfalfa into native range pastures does not solve the problem of low herbage production, and it is not a recommended practice.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 1. Mean precipitation in inches for growing-season months at the Dickinson Research Extension Center, North Dakota.

Years	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.43	2.31	3.58	2.25	1.75	1.33	0.94	13.59
One grazing period								
1979-1981, 1984	1.22	0.60	3.61	1.47	3.12	1.42	1.00	12.44
% of LTM	85.1	25.8	100.7	65.3	178.4	107.0	106.4	91.5
Two grazing periods								
1985-1988	0.84	2.80	2.54	3.10	1.32	1.98	0.71	13.29
% of LTM	58.9	121.2	71.0	137.7	75.3	148.5	75.0	97.8

Table 2. Drought-year precipitation in inches for growing-season months at the Dickinson Research Extension Center, North Dakota.

Years	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season
Long-term mean	1.43	2.31	3.58	2.25	1.75	1.33	0.94	13.59
One grazing period								
1980	0.03	0.12	2.67	1.43	3.31	0.76	2.41	10.73
% of LTM	2.1	5.2	74.6	63.6	189.1	57.1	256.4	79.0
Two grazing periods								
1988	0.00	2.18	1.45	1.72	0.15	0.82	0.24	6.56
% of LTM	0.0	94.4	40.5	76.4	8.6	61.7	25.5	48.3

Table 3. Mean stocking rates on treatments managed with one grazing period and with two grazing periods.

Treatments	Dates Pasture Grazed	Days in Period	Months in Period	No. of cow-calf pairs	No. of AUEM	Stocking Rate AUEM per acre	Stocking Rate Acres per AUEM
One grazing period 1979-1981, 1984							
Native Range	3 Jul-1 Aug	29	0.95	8	8.13a	0.45a	2.21a
Alfalfa Interseeded	3 Jul-28 Jul	25	0.82	8	7.36a	0.74a	1.36a
Two grazing periods 1985-1988							
Native Range	9 Jun-24 Jun	15	1.44	6	9.78x	0.55x	1.85x
	22 Jul-20 Aug	29					
Alfalfa Interseeded	9 Jun-24 Jun	15	1.44	6	9.92x	0.99y	1.01y
	22 Jul-20 Aug	29					

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

Table 4. Mean stocking rates during drought growing seasons on treatments managed with one grazing period and with two grazing periods.

Treatments	Dates Pasture Grazed	Days in Period	Months in Period	No. of cow-calf pairs	No. of AUEM	Stocking Rate AUEM per acre	Stocking Rate Acres per AUEM
One grazing period 1980							
Native Range	7 Jul-23 Jul	16	0.53	7	3.95	0.22	4.56
Alfalfa Interseeded	7 Jul-16 Jul	9	0.30	7	2.22	0.22	4.51
Two grazing periods 1988							
Native Range	6 Jun-21 Jun	15	1.18	6	9.11	0.51	1.98
	22 Jul-12 Aug	21					
Alfalfa Interseeded	6 Jun-21 Jun	15	1.18	6	9.11	0.91	1.10
	22 Jul-12 Aug	21					

Table 5. Mean cow and calf performance on treatments managed with one grazing period.

Treatments	COW			CALF		
	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)
One grazing period 1979-1981, 1984						
Native Range	15.31a	0.52a	7.99a	56.13a	1.97a	26.09a
Alfalfa Interseeded	2.43a	-0.93a	6.24a	51.23a	1.84a	43.77a

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

Table 6. Mean cow and calf performance on treatments managed with two grazing periods.

Treatments	COW			CALF		
	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)
Two grazing periods 1985-1988						
Native Range	47.30x	1.13x	15.77x	99.80x	2.30x	33.27x
Alfalfa Interseeded	53.75x	1.32x	32.25x	111.48x	2.54x	66.89y

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

Table 7. Mean cow and calf performance during drought growing seasons on treatments managed with one grazing period and with two grazing periods.

	COW			CALF		
Treatments	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)	Gain per Head (lbs)	Gain per Day (lbs)	Gain per Acre (lbs)
One grazing period 1980						
Native Range	0.70	0.04	0.27	32.10	2.01	12.48
Alfalfa Interseeded	-49.30	-5.48	-34.51	9.20	1.02	6.44
Two grazing periods 1988						
Native Range	37.50	1.04	12.50	82.40	2.29	27.47
Alfalfa Interseeded	57.50	1.60	34.50	86.70	2.41	52.02

Table 8. Mean aboveground herbage biomass and forage utilized on treatments managed with one grazing period.

Treatments	Aboveground Herbage Biomass Period #1 ungrazed (lbs/acre)	Period #1 grazed (lbs/acre)	Forage Utilized (lbs/acre)	Forage per cow-calf pair (lbs/day)
One grazing period 1979-1981, 1984				
Native Range	1410.83a	832.50a	578.33a	44.87
Alfalfa Interseeded	1925.14a	1077.84a	847.30a	42.37
Drought 1980				
Native Range	1389.10	976.50	412.60	66.31
Alfalfa Interseeded	943.60	543.00	400.60	63.59

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

Table 9. Mean aboveground herbage biomass and forage utilized on treatments managed with two grazing periods.

Treatments	Aboveground Herbage Biomass Period #1 ungrazed (lbs/acre)	Period #1 grazed (lbs/acre)	Period #2 ungrazed (lbs/acre)	Period #2 grazed (lbs/acre)	Forage Utilized (lbs/acre)	Forage per cow-calf pair (lbs/day)
Two grazing periods 1985-1988						
Native Range	1688.77x	948.57x	1357.87x	841.75x	1256.32x	85.66
Alfalfa Interseeded	2567.66x	1911.97x	2595.62x	1457.70x	1793.61x	67.94
Drought 1988						
Native Range	660.60	265.00	475.90	205.50	666.00	55.50
Alfalfa Interseeded	1018.70	471.30	800.30	307.90	1039.80	48.14

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

Table 10. Mean basal cover of biotypes on treatments managed with two grazing periods.

Treatments	Introduced Alfalfa	Introduced Invader Grasses	Grasses Cool Season	Grasses Warm Season	Sedges	Forbs	Woody	Total
Two grazing periods 1985, 1986, 1987								
Native Range	0.0x	0.03x	6.18x	9.94x	10.47x	3.90x	0.07x	30.56x
Alfalfa Interseeded	3.16y	0.40y	5.88x	8.53x	8.42x	3.09x	0.05x	25.97x
% of Control		1333.33	95.15	85.81	80.42	79.23	74.63	84.98

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

Table 11. Percent similarity of the plant species composition between the communities on the native range and alfalfa interseeded treatments managed with two grazing periods.

	Years 1985	1986	1987	Mean
% Similarity	76.83	69.99	67.00	71.27

Table 12. Costs-returns on treatments managed with one grazing period.

Treatments	Acres per Period (Acres)	Cost per Acre ($)	Cost per Period ($)	Calf Gain per Period (lbs)	Calf Value @ $0.70/lb ($)	Net Return per Cow-Calf pair ($)	Net Return per Acre ($)	Cost per pound Accumulated Weight ($)
One grazing period 1979-1981, 1984								
Native Range	2.10a	8.76	18.39a	56.13	39.29a	20.90a	9.95a	0.33a
Alfalfa Interseeded	1.12b	12.94	14.49a	51.23	35.86a	21.37a	19.08a	0.28a

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

Table 13. Costs-returns on treatments managed with two grazing periods.

Treatments	Acres per Period (Acres)	Cost per Acre ($)	Cost per Period ($)	Calf Gain per Period (lbs)	Calf Value @ $0.70/lb ($)	Net Return per Cow-Calf pair ($)	Net Return per Acre ($)	Cost per pound Accumulated Weight ($)
Two grazing periods 1985-1988								
Native Range	2.64x	8.76	23.13x	99.80	69.86x	46.73x	17.70x	0.23x
Alfalfa Interseeded	1.45y	12.94	18.76y	111.48	78.03x	59.27x	40.88y	0.17y

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

Table 14. Costs-returns during drought growing seasons on treatments managed with one grazing period and with two grazing periods.

Treatments	Acres per Period (Acres)	Cost per Acre ($)	Cost per Period ($)	Calf Gain per Period (lbs)	Calf Value @ $0.70/lb ($)	Net Return per Cow-Calf pair ($)	Net Return per Acre ($)	Cost per pound Accumulated Weight ($)
One grazing period 1980								
Native Range	2.42	8.76	21.17	32.10	22.47	1.30	0.54	0.66
Alfalfa Interseeded	1.35	12.94	17.51	9.20	6.44	-11.07	-8.20	1.90
Two grazing periods 1988								
Native Range	2.34	8.76	20.47	82.40	57.68	37.21	15.90	0.25
Alfalfa Interseeded	1.30	12.94	16.80	86.70	60.69	43.89	33.76	0.19

Literature Cited

Manske, L.L., A.M. Kraus, S.A. Schneider, and L.J. Vance. 2002. Evaluation of twelve-month pasture-forage management strategies for range cows. NDSU Dickinson Research Extension Center. Rangeland Research Extension Program 4004. 147p.

Manske, L.L., A.M. Kraus, S.A. Schneider, and L.J. Vance. 2003. Biologically effective management of grazinglands. NDSU Dickinson Research Extension Center. Rangeland Research Extension Program 4005. 268p. www.GrazingHandbook.com

Mosteller, F., and R.E.K. Rourke. 1973. Sturdy Statistics. Addison-Wesley Publishing Co. MA. 395p.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, Inc. New York, NY.

Nyren, P.E. 1979. Sod seeding in western North Dakota. Annual Report. Dickinson Experiment Station. Dickinson, ND.