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.