Evaluation of Interseeding Row-Spacing Techniques

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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 the 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 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 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 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 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.

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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.

	Percent seedbed area per acre		Percent total disturbance per acre		Percent intact area per acre	
Row Spacing	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.

	Total herbage biomass on only the intact portion of each treatment		Total herbage biomass on the combined intact and disturbed areas of each treatment	
Row Spacing	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.

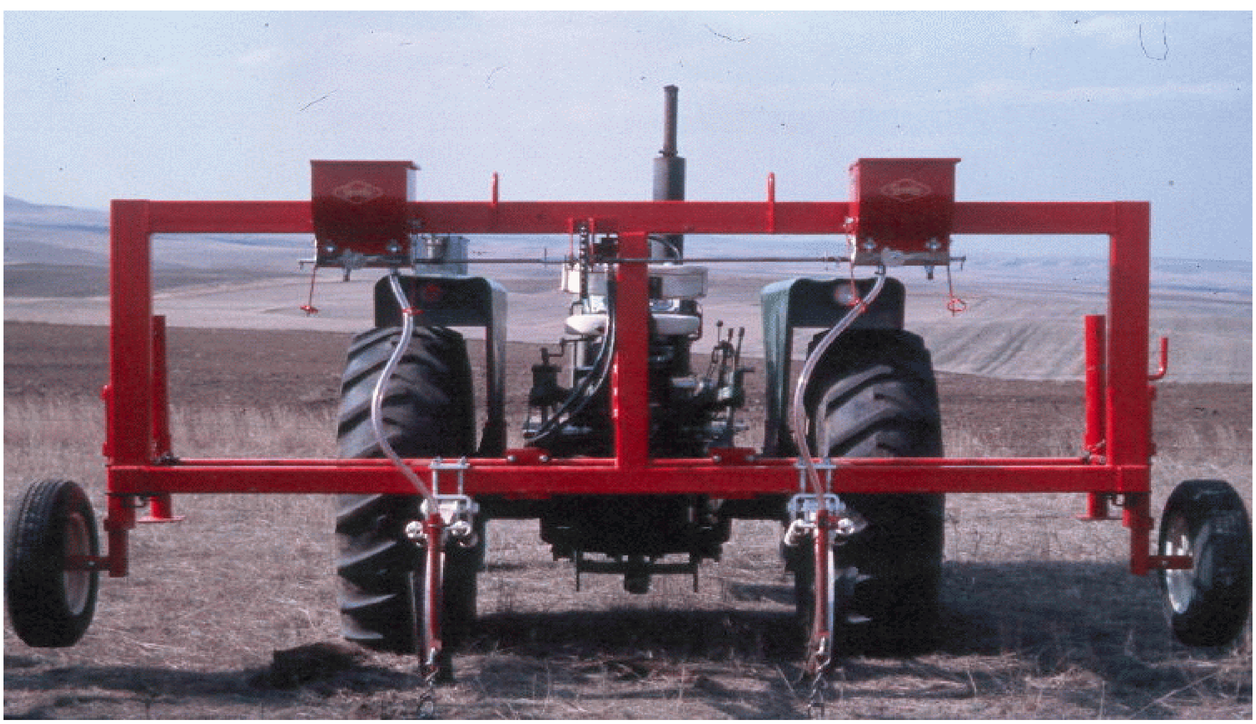

Fig. 2. Interseeding machine with two toolbars and two shanks.

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.

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