Influence of Fertilization and Supplemental Runoff Water on Production and Nitrogen Content of Western Wheatgrass and Smooth Brome

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Highlight: *Simulated water spreading and nitrogen fertilization were studied on soils developed from Pierre Shales in western South Dakota. When both supplemental water and nitrogen fertilizer were applied, forage yields increased almost nine-fold. Western wheatgrass and smooth brome yields ranged from about 1,000 lb/acre on the untreated control to about 8,700 lb/acre with optimum supplemental water and 320 lb/acre nitrogen fertilizer. Forage yields increased with April and June supplemental water as compared with annual application in either April or June.*

Nitrogen content of harvested hay increased as nitrogen application rate increased above 80 lb/acre. Percent nitrogen decreased with increased supplemental water and ranged from about 1.2 to 2.2% in western wheatgrass and from about 1.0 to 2.3% in smooth brome.

Least squares analysis, considering all nitrogen and water treatments, indicated that each lb/acre of nitrogen fertilizer applied increased the forage yield by about 19 lb/acre, and that each inch of additional water increased forage yields by about 50 lb/acre.

Western South Dakota's economy is based primarily on the livestock industry. Productivity in this industry will probably be increased to meet the demand for red meat. Forage production can be increased by applying fertilizer and supplemental water to grasslands so that forage production is not dependent solely on natural fertility and precipitation.

Native grassland research on clay soils of western South Dakota has shown that fertilizer and supplemental water increased forage production and percent crude protein (Cosper and Thomas, 1961). Thomas and Osenbrug (1964) found that production from an old stand of crested wheatgrass and smooth brome in western South Dakota was increased by nitrogen (N) and phosphorus (P) fertilization. Johnson and Nichols (1969) studied productivity of 11 irrigated grasses in western South Dakota and found that grasses with N and alfalfa had greater production than did the grasses alone. They also found that N fertilization increased the protein percentages of the forages with higher protein percentages in the alfalfa-grass combinations than in either the nonfertilized or the N fertilized treatments.

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The report is a contribution from Agr. Res. Serv., U.S. Dep. Agr.; Bureau of Land Management, U.S. Department of the Interior, and Idaho Agricultural Experiment Station, cooperating.

Manuscript received August 23, 1975.

This paper reports a simulated water spreading study at the Newell Irrigation and Dryland Field Station in western South Dakota. This study was conducted to determine the influence of supplemental water and N fertilization on hay production and N content of western wheatgrass (*Agropyron smithii*) and smooth brome (*Bromus inermis*).

Study Area and Experimental Methods

The 63-year (1908 through 1970) average annual precipitation at the Newell Field Station was 15.40 inches, of which 12.08 inches fell from April through September. The 13-year (1958 through 1970) annual pan evaporation averaged 55 inches. The growing season, determined by killing frosts, was approximately 131 days (Spuhler et al., 1968).

Soils in the experimental area were developed from Pierre shale and have been classed in the Pierre-Kyle Association (U.S. Department of Agriculture, 1970). Thomas and Osenbrug (1964) described the top 6 inches of these soils as containing 1.92% organic matter, slightly basic with high cation exchange capacity (37 meg/100 g) and soluble phosphorus of 7.0 ppm. The study site was on a bench leveled field with water available to supply needed supplemental water.

A split-plot design experiment was used with water levels as whole plot treatments (36 × 45 ft) and N rates as subplots (9 × 45 ft). Two grasses, western wheatgrass and brome, were seeded in pure stands and were replicated three times in each water treatment. The whole plot water treatments applied to each species were: (1) no supplemental water (M_1); (2) supplemental water in April every other year, 1967, 1969, and 1971 (M_2); (3) supplemental water in April every year (M_3); (4) supplemental water in June every year (M_4); (5) supplemental water in April and June every year (M_5); and (6) optimum supplemental water (M_6).

Actual amounts of supplemental water for treatments M_2 through M_6 varied with the yearly precipitation. More water was applied if an extended dry period preceded watering. Both precipitation and water application were measured throughout the study.

Initially, a blanket application of 40 lb N/acre and 100 lb P/acre was applied to all plots in March 1965. Nitrogen rates of 0, 20, 40, 80 lb/acre were applied to the grasses in 1966 and repeated in 1967. Nitrogen rates were doubled in 1968, and the same rates applied in 1969. The N rates were increased again in 1970 to 0, 80, 160, and 320 lb/acre and were repeated in 1971. These increasing rates were applied so that plots receiving 20 lb N/acre in 1966 and 1967 received 40 lb N/acre in 1968 and 1969 and 80 lb N/acre in 1970 and 1971.

Nitrogen was applied each year in March before supplemental water application. Water was applied on or near April 10 and June 10 on plots receiving supplemental water, while the optimum treatmet (M_6) was watered in April and June before the first cutting of hay and two or three times after harvesting.

All plots were harvested in late June or early July, with the least-watered plots being harvested first since they were generally the first to mature. The optimum treatment was harvested again in August to determine the regrowth yields. A sickle-bar mower set at a 1-inch height was used to harvest 19.5 ft^2 from each plot. Subsamples were taken from each forage sample for moisture determination and N analysis. Yield for each plot was computed by adjusting the wet forage weight by the percent moisture, as determined from the wet and oven-dried subsample weight. After sampling the entire experimental area was harvested for hay.

A 15-year record of runoff data was analyzed from two small watersheds (W-14 and W-15) located southeast of Newell, S. Dak., to determine the reliability of available water for water spreading. These watersheds were selected for analysis because they represented the hydrologic characteristics of most watersheds on the Pierre shale formation. Detailed information on the soils, geology, and vegetation characteristics of these watersheds can be found in Hanson et al. (1973), and Hobbs and Crammatte (1965).

Results and Discussion

Water

Precipitation for various periods in 1965 through 1971 is shown in Table 1, and supplemental water applied to the various water treatments is shown in Table 2. Precipitation variation within years was moderate, but variation between periods within the growing seasons of the various years was great. April through June 1967 was very wet with a good seasonal distribution, while 1968 had very low precipitation in April.

Watering the area earlier than April 10 would have been advisable because, as observed during this 6-year period, the least amount of precipitation was recorded between March 20 and April 10, while little difference was noted in June.

Table 1. Precipitation (inches) at Newell, S. Dak., 1965 through 1971.

Perior or month	1965	1966	1967	1968	1969	1970	1971
Winter[1]		1.87	1.72	1.55	1.88	1.82	3.05
April		2.00	4.12	0.49	1.98	2.27	2.31
May		0.70	0.95	1.59	2.53	4.07	2.78
June		1.66	4.38	3.87	3.14	1.66	2.54
July-August	3.79	5.32	1.28	2.61	1.58	2.57	0.69
Fall[2]	1.38	2.46	3.68	2.05	0.64	1.03	5.82
Annual		14.01	16.13	12.16	11.75	13.42	17.19

[1]November, December, January, February, and March.
[2]September and October.

Table 2. Supplemental water (inches) applied from 1966 through 1971.

Year	Treatment[1] M_1	M_2	M_3	M_4	M_5	M_6
1966	.00	.00	6.01	8.16	11.56	29.77
1967	.00	8.39	7.37	7.02	12.18	22.59
1968	.00	.00	7.35	7.82	11.91	30.01
1969	.00	6.85	6.78	6.21	9.26	23.02
1970	.00	.00	5.79	7.36	13.36	33.09
1971	.00	7.41	6.19	6.29	10.36	28.04

[1]M_1 = no supplemental water; M_2 = supplemental water in April every other year, 1967, 1969, and 1971; M_3 = supplemental water in April every year; M_4 = supplemental water in June every year; M_5 = supplemental water in April and June every year; M_6 = optimum supplemental water.

Forage Yields

Table 3 shows western wheatgrasses and smooth brome yields, as affected by N fertilization and supplemental water application. Production generally increased as applied N increased within all water treatments. Production also increased as the amount of available water increased. Little difference was noted between the two grass yields. However, yield increases were small when less than the 80 lb N/acre was applied. Total yields were lowest (about 1,000 lb/acre) for 0 or 20 lb N/acre and no supplemental water. Highest yields (between 7,900 and 8,800 lb/acre) were from treatments M_5 and M_6 under the highest N rates.

However, for treatment M_2 yields were as large or larger than from treatments M_3 and M_4 with supplemental water once yearly. Yields on treatments M_2 were always greater than those from treatments M_3 and M_4 for years when supplemental water was applied, except for the smooth brome yields in 1971. This increase may have been due to the increased grass stands during watered years and carry-over effects of N in nonwatered years.

There was no significant difference in yield between treatment M_3 and M_4; however, there seemed to be some yield advantage to applying supplemental water in June (M_4), a trend more pronounced for smooth brome yields than for western wheatgrass yields. Treatments M_2, M_3, and M_4 produced about 1.5 times more forage for each fertilization level than treatment M_1. Treatment M_5 usually produced more forage for each fertilization level than treatments M_3 and M_4.

Forage yields were highest from the optimum supplemental treatment (M_6), which produced about twice the forage harvested from treatment M_1. Yields from treatment M_6 were not significantly greater than from treatment M_5.

Table 3. Production (lb/acre, oven dry) of western wheatgrass and smooth brome under six supplemental water and nitrogen fertilizer (lb/acre) treatments.[1]

Fertilizer	Western wheatgrass						Smooth brome					
N	M_1	M_2	M_3	M_4	M_5	M_6	M_1	M_2	M_3	M_4	M_5	M_6
0	1163 a[2]	2008 a	1734 a	1671 a	1834 a	2386 a	1007 a	1687 a	1490 a	1825 a	2145 a	2209 a
20	1163 a	2085 a	1798 a	1623 a	1523 a	1978 a	1276 a	2216 a	1644 a	1709 a	1616 a	2288 a
40	1739 a	2688 a	2339 ab	2271 ab	2223 ab	2975 ab	2124 ab	2966 ab	2680 ab	2668 ab	2656 a	3271 a
80	2759 ab	4378 ab	3718 b	4119 b	3681 b	4360 b	3466 bc	4528 bc	4139 b	4321 b	4315 b	4911 b
160	3882 bc	6154 b	5799 c	6178 c	6587 c	6812 c	4308 c	5720 c	6366 c	6521 c	7290 c	6859 c
320	5153 c	6698 b	6640 c	6947 c	8228 d	8635 d	4706 c	5715 c	6436 c	7117 c	7944 c	8803 d
Average[3]	2643[1]	4002[2,3]	3671[2]	3802[2]	4013[2,3]	4524[3]	2814[1]	3805[2]	3793[2]	4027[2,3]	4328[2,3]	4724[3]

[1]M_1 = no supplemental water; M_2 = supplemental water in April every other year, 1967, 1969, and 1971; M_3 = supplemental water in April every year; M_4 = supplemental water in June every year; M_5 = supplemental water in April and June every year; M_6 = optimum supplemental water.
[2]Means within each column with the same letters are not significantly different at the 5% level.
[3]Means within this row with the same superscript numbers are not significantly different at the 5% level.

Table 4. Nitrogen content (%) of western wheatgrass and smooth brome under six supplemental water regimes and six fertilizer (lb/acre) treatments.[1]

Fertilizer N	Western wheatgrass M_1	M_2	M_3	M_4	M_5	M_6	Smooth brome M_1	M_2	M_3	M_4	M_5	M_6
0	1.50 a[2]	1.44 a	1.57 ab	1.52 a	1.53 a	1.37 a	1.18 a	1.30 a	1.22 a	1.22 a	1.25 a	1.25 a
20	1.38 a	1.51 a	1.37 a	1.57 a	1.46 a	1.31 a	1.23 a	1.12 a	1.10 a	1.26 a	1.12 a	1.00 a
40	1.55 a	1.55 ab	1.32 a	1.54 a	1.56 a	1.25 a	1.26 a	1.19 a	1.04 a	1.27 a	1.02 a	1.05 a
80	1.69 ab	1.47 a	1.35 a	1.54 a	1.40 a	1.15 a	1.35 a	1.32 a	1.07 a	1.26 a	0.99 a	1.03 a
160	2.04 b	1.64 ab	1.35 a	1.59 a	1.38 a	1.25 a	1.95 b	1.67 ab	1.20 a	1.59 ab	1.04 a	1.13 a
320	2.15 b	1.99 b	1.84 b	2.05 a	1.54 a	1.32 a	2.32 b	2.25 b	1.89 b	1.96 b	1.55 b	1.22 a
Average[3]	1.72[3]	1.60[23]	1.47[2]	1.63[23]	1.48[2]	1.27[1]	1.55[3]	1.48[23]	1.25[12]	1.43[23]	1.16[1]	1.11[1]

[1] M_1 = no supplemental water; M_2 = supplemental water in April every other year; M_3 = supplemental water in April every year; M_4 = supplemental water in June every year; M_5 = supplemental water in April and June every year; M_6 = optimum supplemental water.
[2] Means within each column with the same letter are not significatly different at the 5% level.
[3] Means within each row with the same superscript number are not significantly different at the 5% level.

Nitrogen Content

Table 4 presents N contents of forage samples from the various fertilizer-water treatments.

Water available for plant growth seemed to control the percent N in the forage. The N content in forage from the M_1 treatment increased as applied N increased while the M_6 (optimum supplemental water) showed little effect of increasing N rates even at 320 lb N/acre.

Percentage N in forage from treatments M_1, M_2, M_3, and M_4 tended to remain about the same at low N rates and then increased as N fertilization rates increased above 80 lb N/acre. This trend was most significant at the lower levels of supplemental water.

There was no significant difference between N content at any of the fertilization levels in treatment M_6 for both forages and in treatment M_5 for western wheatgrass. Western wheatgrass forage ranged from 1.15 to 2.15% N. Forage N contents were lowest from the optimum water treatment, and the highest from the no-water (M_1) treatment and 320 lb N/acre. Smooth brome N content ranged from about 1.0% under the two highest water applications (M_5 and M_6) at fertilizer rates of 20 to 80 lb N/acre to 2.32% with no supplemental water (M_1) and 320 lb N/acre.

The N contents for smooth brome agreed quite favorably with those reported by Johnson and Nichols (1969) and with the results for native forage reported by Cosper and Thomas (1961).

Forage Yield Estimates

A least-square fitting technique was used to obtain estimates of the yields expected under the various water and fertilization treatments (Fig. 1). Because the western wheatgrass and smooth brome yields were nearly the same in each water-treatment group, the yields for both forages were included in each water treatment analysis. Separate curves were fitted to the data for treatments M_1, M_3 and M_4 (combined), M_5, and M_6. These curves suggested that an increase of 100 lb N/acre will increase forage yields about 1,350, 1,920, 2,290, and 2,250 lb/acre for treatments M_1, M_3 and M_4, M_5, and M_6, respectively.

The least-squares analysis, using all N and supplemental water treatments, is shown in Figure 2. This figure indicated that each lb/acre of N applied increased the forage yields about 19 lb/acre and each inch of additional water increased the forage yields about 50 lb/acre.

Availability of Supplemental Water

The average monthly runoff (0.01 or more) from the two small watersheds was used to compute the percentage of years

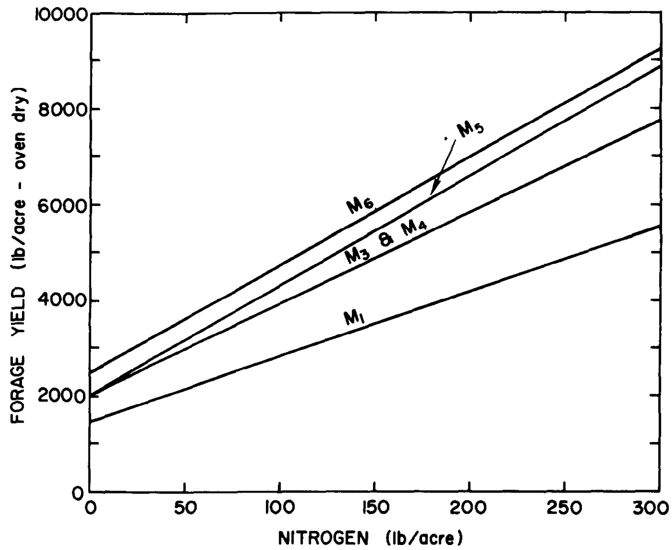

Fig. 1. *Effect of nitrogen fertilization on forage yield at different levels of supplemental water. (M_1 = no supplemental water; M_3 = supplemental water in April every year; M_4 = supplemental water in June; every year; M_5 = supplemental water in April and June every year; and M_6 = optimum.*

with runoff (Table 5). The percentages were computed from the total runoff each year for the periods January through March, April, May, and June. Total January through March snowmelt runoff was used because little if any water was used during this period. About a third of the years (27%) had less than 0.10 inch of runoff during January through March (Table 5). There was also less than 0.10 inch runoff in about one-half of the years during April, May, or June. Between 0.11 and 0.49 inch of runoff can be expected about one-third of the time during any of

Table 5. Percentage of years with runoff (inches) during given time periods, 1958 through 1972.

Period	Runoff ≤ .10	.11–.49	.50 >
Total January–March	27	33	40
April[1]	54	33	13
May	60	27	13
June	47	33	20
January–June[2]	00	27	73
April–June[3]	20	40	40

[1] Based on total monthly runoff for a year.
[2] Values are based on the maximum runoff for any of the periods during a year. The periods were: January–March, total runoff; April, May, and June.
[3] Values are based on the maximum runoff from any of the months each year.

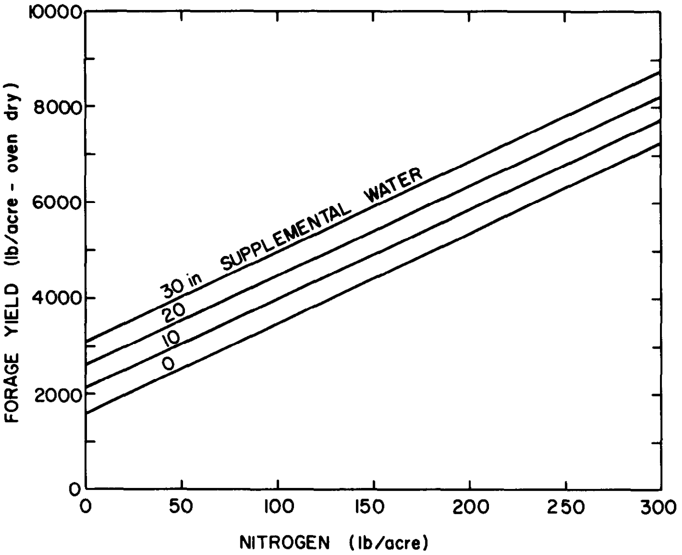

Fig. 2. *Effect of nitrogen fertilization and supplemental water on forage yield.*

the periods considered. About 40% of the years had more than 0.50 inch runoff during January through March, but during April, May, and June only two to three of the years out of 15 had more than 0.50 inch of runoff. This would indicate that there would be at least some available water almost every year and that at least 0.50 inch could be expected about three-fourths of the time.

When the period from April through June was considered, using the maximum from each of the months, 20% of the years did not yield yearly runoff. This statistic should be considered when analyzing the economics of construction of a water spreading system.

Summary

The effects of applying supplementary water and N fertilizer on forage yields and N content of western wheatgrass and smooth brome were investigated on Pierre shale soils in western South Dakota.

Total yields of both grasses were similar. Supplemental water significantly increased the forage yields of both grasses. Yields ranged from about 1,000 lb/acre with no supplemental water and no N fertilizer to about 8,700 lb/acre with optimum supplemental water and 320 lb N/acre. Forage yield increased significantly as supplemental water increased. Yield also increased as fertilization increased within water treatments. There was not a significant yield difference between the treatments when additional water was added annually in April or June, but the trend indicated that the June water treatment may have a slight advantage. The supplemental water treatment yields, when water was applied in April every second year, were about as good as those obtained when water was added every year in April or June. The treatment where water was added every April and June had somewhat greater yields over only one supplemental watering. Yields were maximum on the optimum water treatment with the 320 lb N/acre.

Forage N content remained about the same at the low N rates and then increased as the N rate increased over 80 lb/acre in no supplemental water treatment. However, this trend generally became less as supplemental water increased. At the high supplemental water levels, no significant difference was noted in forage N content between fertilization levels. Percent N tended to decrease as supplemental water increased. Percentage N varied from about 1.15 to 2.15% on the western wheatgrass and from about 1.00 to 2.32% on the smooth brome.

A least-square analysis indicated that without supplemental water an increase of 100 lb N/acre increased the forage yields about 1,350 lb/acre. When supplemental water was added each spring, 100 lb N/acre increased forage yields about 1,920 lb/acre and, under the optimum supplemental water regime, 100lb N/acre increased forage yields about 2,300 lb/acre.

The least-squares analysis using all N and supplemental water treatments indicated that each lb/acre of N applied increased forage yields by about 19 lb/acre, and each inch of additional water increased the forage yields by about 50 lb/acre.

Fifteen years of runoff data from two watersheds located on Pierre shale soils indicated that a supply of supplemental water could be expected most years. The amount of water and the time that water was available varied greatly from year to year. The most reliable source of water, when considering both amount and consistency, was from snowmelt runoff. The availability of water during April, May, or June was about the same each month. When these 3 months were considered together, 80% of the time there was at least 0.10 inch, and 40% of the time there was 0.50 inch of runoff during one of the 3 months each year.

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