Effects of Nitrogen Source and Phosphorus on Crested Wheatgrass Growth and Water Use[1]

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Highlight

The effects of four nitrogen (N) sources upon crested wheatgrass growth were studied for five years at Mandan, North Dakota. The four sources—ammonium nitrate, ammonium sulfate, calcium nitrate, and urea—were applied annually at rates of up to 160 lb N/acre both with and without annual phosphorus (P) fertilization. Dry matter production of crested wheatgrass was increased by N and P fertilization in all years. Only in years of higher production did higher N rate, N source, or any interactions, influence yields. Average yields for the 5-year period were also increased by fertilization with P and with increasing rates of N—but were not influenced by N source. Responses to N fertilization increased by about 380 and 490 pounds for each acre-inch increase in water supply (above 5 inches) with and without P, respectively. In contrast, response to P fertilization was about 50 lb/acre-inch regardless of water supply. Dry matter production and response to N fertilization were both closely correlated with May precipitation ($r \geq 0.89$).

If the projected demand for livestock products is to be satisfied in future years (Hodgson, 1968), the productivity of grassland must be increased. One way of accomplishing this is by nitrogen fertilization. Recent technological improvements have reduced the cost of manufacturing nitrogen fertilizer. If these cost savings can be passed on to the consumer, major alterations in the cost/benefit ratios from nitrogen fertilization should result.

Previous research at Mandan, North Dakota has indicated that crested wheatgrass (*Agropyron desertorum* (Fisch. ex link) Schult.) responds very favorably to N fertilization (Lorenz and Rogler, 1962 and 1967; Smika et al., 1963). However, in all these trials only ammonium nitrate fertlizer was used, and only at rates of 80 lb N/acre or less. Little information is available on the relative performance of other N carriers under these conditions, or on higher N rates. Consequently, the following project was initiated to obtain information on the relative efficiencies of various N sources at several rates of annual application. If fertilizers are deleterious to the growth or stands of dryland grasses, such effects should be hastened and magnified by the use of higher rates.

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Experimental Methods

The effects of nitrogen carriers on crested wheatgrass production were studied in a field experiment from 1962 through 1966 at Mandan, North Dakota. The experiment was located in a crested wheatgrass pasture which was seeded in 1932 and grazed annually thereafter. Although a small amount of blue grama (*Bouteloua gracilis* (H. B. K.) Lag.) had invaded the area, the crested wheatgrass stand was reasonably uniform, but of low vigor. The soil was Eakin silt loam, one of the more productive chestnut soils of the region. This soil contained 0.243% N, 2.71% organic C, and 5.0 ppm $NaHCO_3$-soluble P in the 0- to 6-inch depth, with a saturated paste pH of 6.2. The experiment was located on the upper part of a low knoll and received no runoff water from other areas.

Experimental treatments consisted of a complete factorial arrangement of (1) annual application of four N carriers—ammonium nitrate, ammonium sulfate, calcium nitrate, and urea; (2) N rates of 0, 80 and 160 lb N/acre; and (3) P rates of 0 and 17.5 lb P/acre as 0–45–0 (35 lb P/acre in beginning year only). Treatments were completely randomized in each of three replications, with plot dimensions of 6×16 feet. Fertilizer materials were broadcast by hand in late March or early April each spring before any visual evidence of plant growth became apparent. Weeds were controlled with 2,4-D spray as necessary. Plant material was cut at the 1-inch height in July of each year (seed filled) from a 3×12 ft strip for measurements of dry matter production. Regrowth was generally negligible and was not harvested.

In 1962 soil water content was measured gravimetrically to the 5-ft depth on 0- and 160-N plots only. Thereafter, soil water content was measured on the same plots with a neutron probe to the depth of 4 feet only, since the 1962 data indicated that the fifth foot was dry (below wilting point) at all times. Soil water was measured at approximately monthly intervals from April through harvest in July.

Notes were taken annually on plant vigor, stands, and morphological appearance.

Results and Discussions

Dry Matter Production

Data on dry matter production for each treatment each year are presented in Table 1. In all years the application of either N or P fertilizers significantly increased dry weights in comparison to plots without added N or P. In years of high production (1962 and 1965) all variables and several interactions significantly altered yields. In the others years, however, the effects of neither N source, N rate (80 vs. 160 lb N), nor any interactions were statistically significant.

The five-year average yields (Table 1) were increased as N rate increased from 0 to 160 lb N/acre, and increased with P fertilization. Interactions between treatments or years were generally of little significance. The only case where N source produced significant yield differences was for the comparison of ammonium sulfate and urea at 160 lb N/acre (both without P). Ammonium sulfate was the only N source that produced a significantly

Table 1. Dry weights (lb/acre) of crested wheatgrass fertilized annually with various N sources and phosphorus.

		Year											
	N	1962		1963		1964		1965		1966		Avg.[1]	
Source	Rate	−P	+P	−P	+P	−P	+P	−P	+P	−P	+P	−P	+P
Check		1830	2340	1010	1400	900	1000	1590	1980	600	910	1190a	1530a
NH_4NO_3	80	4070	4590	2440	3300	2160	2780	4690	5590	1630	2480	3000b	3750cde
	160	5220	5760	2800	3440	2310	2790	5250	5610	1670	2120	3450bcd	3940de
$(NH_4)_2SO_4$	80	3620	3980	2520	2660	2370	2560	4770	5340	1710	1840	3000b	3280bc
	160	4730	5680	3380	3280	2620	2950	5830	6250	2240	2640	3760cde	4160e
$Ca(NO_3)_2$	80	4430	5550	3160	2890	2510	2750	4240	5370	2220	2040	3310bc	3720cde
	160	4980	6090	2880	3700	2150	2770	4500	5360	1610	2480	3220bc	4080e
Urea	80	4150	4330	2970	3220	2200	2840	4290	5150	1820	2040	3090b	3520bcd
	160	4420	4680	2560	3210	2040	2950	4670	6120	1550	2400	3050b	3870de
LSD(0.05)		500		320		420		690		670			

[1] Values followed by a common letter are not significantly different.

greater yield on the 160 lb N than at the 80 lb N rate, both with and without P. Several of the interactions between sources and rates barely missed being significant at the 5% level of probability.

The responses of crested wheatgrass dry weights to N fertilization were usually highest at the 160 lb N rate. However, exceptions to this statement were common for both calcium nitrate and urea when applied without P, but not with P. This effect of P upon N response was not of sufficient magnitude to produce significant differences between N source over the 5-year period, however.

The efficiency of N fertilization (increase in dry matter in pounds per pound N applied) was about 26 and 24 pounds per pound of N at the 80 lb N rate, with and without P respectively. At the 160 lb N rate, N efficiencies averaged 16 and 14 lb/lb N with and without P. N source had no marked effect upon N efficiencies. Efficiencies varied from 5.9 to 45.1 lb/lb N with the higher values being recorded in years of higher production.

Water Use

In a semiarid region it is usually logical to expect that variation in production from year to year can be largely attributed to a variation in moisture supply (Colville, et al., 1963; and Smika, et al., 1965). Such was the case in this experiment. However, both N and P fertilization influenced the relation between water availability and crested wheatgrass growth. These relationships are illustrated in Figure 1. In this figure, total dry matter production is plotted as a function of total water used, primarily for evapotranspiration, from early spring until harvest—as determined from soil moisture and precipitation data. Since the entire soil profile was dried to the approximate wilting point by, or shortly before, harvest each year, and since no leaching or runoff occurred, total water use and available water supply are practically synonymous. Also since all available water was used, treatment had no effect upon total water used. Data from 1962 are not included in Figure 1 because 1962 soil moisture data were collected by gravimetric means, whereas the neutron probe was used in later years. Because of the difficulty in obtaining accurate measurements of bulk density over a range of depths and moisture contents, conversion of gravimetric data to a volumetric basis is often difficult.

Phosphorus fertlization increased water use efficiency by about 50 pounds dry matter per acre-inch of water for all N treatments and moisture conditions. On the other hand, with N fertilization dry matter production per inch of water use

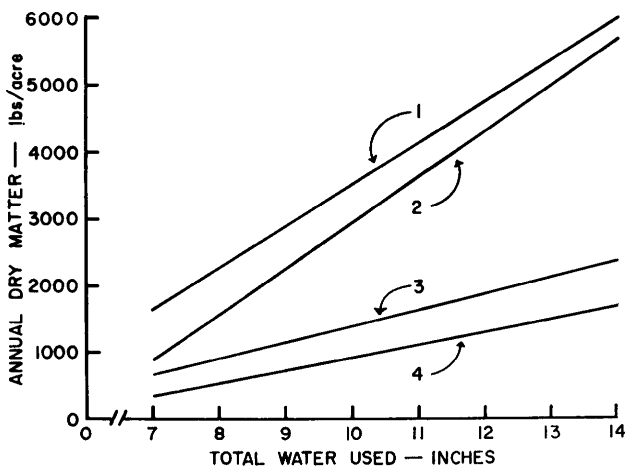

FIG. 1. Dry matter production of crested wheatgrass as a function of water use. (1) = N + P, Y = 628X − 2753, r = 0.96**; (2) = N only, Y = 680X − 3867, r = 0.96**; (3) P only, Y = 248X − 1089, r = 0.81**; and (4) = check, Y = 191X − 995, r = 0.99**.

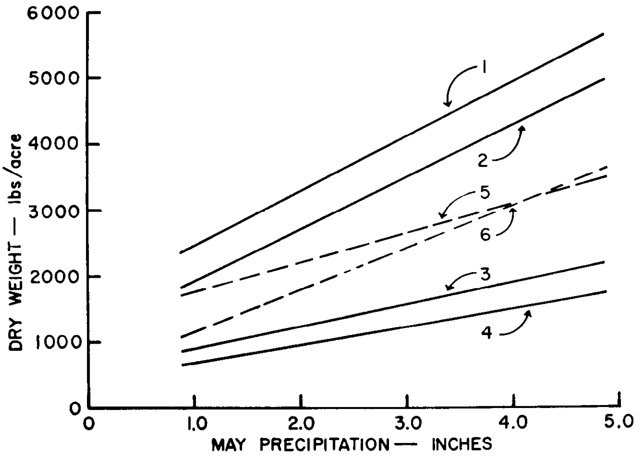

FIG. 2. Dry matter production and fertilizer N responses as influenced by May precipitation. (1) = annual production with N + P, Y = 814X + 1652, r = 0.97**; (2) = annual production with N only, Y = 769X + 1158, r = 0.97**; (3) = annual production with P only, Y = 322X + 581, r = 0.97**; (4) = annual production for check, Y = 258X + 437, r = 0.95**; (5) = N response with P, Y = 428X + 1337, r = 0.89*; and (6) = N response without P, Y = 624X + 527, r = 0.97**.

increased as water use increased. This increase in water use efficiency was approximately 380 and 490 pounds dry matter for each additional acre-inch of water use in excess of 5 inches, with and without P, respectively. Thus the effects of P fertilization were relatively independent of water supply, while the effects of N fertilization were related to water supply. N source had no appreciable effect upon this relationship. Smika et al. (1965) found a similar relationship for the effects of N on water use efficiency on native range.

Much of the variation in both crested wheatgrass production and response to N was closely correlated with May precipitation. Such relationships are illustrated by the regression lines in Figure 2. All correlation coefficients were statistically significant. With no May precipitation (X = 0), dry weights were about 35% of the means. Therefore, approximately 65% of the mean dry weight was dependent upon May precipitation. Again, the effects of P fertilization upon dry weights were rather independent of May precipitation, while response to N fertilization increased as May precipitation increased. About 800 pounds of dry matter could be expected for each inch of May rainfall when N was applied. All correlation coefficients relating either dry weight or yield response to N fertilization with May precipitation were 0.89 or greater. The relationships expressed in Figure 2 were not affected by N source. Soil moisture reserves in the spring had little influence on these relationships. Correlations between annual production and precipitation during other periods of the growing season were of much lower significance.

Table 2. Seasonal and May precipitation (inches) at Mandan, North Dakota, 1962–66.

Year	Precipitation			
	Seasonal[1]	May	A+M+J[2]	M/A+M+J (%)
1962	9.1	4.8	8.2	58.5
1963	9.4	2.9	9.9	29.3
1964	9.6	1.1	9.6	11.5
1965	11.0	4.7	11.4	41.2
1966	6.0	0.9	5.8	15.5
Ave.	9.0	2.9	9.0	32.2
40-year Ave.	–	2.2	7.3	30.2

[1] From initial spring sampling (early April) to harvest in early July.
[2] April, May, and June.

It may be fortuitous that the relationship between May precipitation and yield or yield response of crested wheatgrass to N fertilization was so high during these five years. Both May and seasonal precipitation for these five years averaged slightly above normal (Table 2). For both the 5-year and 40-year averages, May precipitation was slightly over 30% of the April–May–June total. For the years of study no relationship existed between May precipitation and seasonal or April–May–June precipitation. Likewise for the 40-year average, the correlation coefficient between May and April–May–June precipitation was only 0.50. Therefore, these data suggest that for this location May precipitation may be a fairly reliable indicator of crested wheatgrass growth and N response. Although some variation with location or years might occur, these data certainly support the common observations that spring rains are essential for grass production in semiarid regions.

Fertilizer N source had no apparent effect on crested wheatgrass stands. Good to excellent stands remained on all fertilized plots at the conclusion of five years of fertilization. After several years of low precipitation, rate of development of new tillers decreased while rate of senescense of old tillers increased, resulting in less vigorous stands. However, good recovery occurred with a more favorable year. Observations indicated that ammonium sources of N produced a much broader lamina than nitrate sources. Otherwise the prime effect of N fertilization on plant morphology was mainly through alteration of tiller number and size.

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