The Influence of Ammonium Nitrate on the Growth and Yield of Crested Wheatgrass on the Oregon High Desert

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SYNOPSIS

Spring yields of crested wheatgrass were more than doubled by application of 30 pounds per acre of N and were directly related to April and May temperatures but inversely related to the amount of fall and winter precipitation over a 4-year period. Annual yields were directly related to fertility rate, and to the amount of precipitation received in the preceding November 1 to June 1 period. Counting residual response, the 20 pounds per acre fertility rate returned 25 pounds of herbage per pound of N applied.

THE Oregon High Desert in southeastern Oregon has characteristics common to most of the 96 million acres of big sagebrush-bunchgrass range. In this semiarid region the supply of soil moisture is well recognized as the limiting factor in grass yields. Moisture for vegetative growth is limited by total amount and seasonal distribution of precipitation. Only in recent years has attention been directed to the influence of this winter pattern of precipitation and low total supply of moisture upon the release of nitrogen in available forms. This consideration of moisture-fertility balance has led to interest in nitrogen fertilization.

This paper presents the results of fertility trials on crested wheatgrass grown under semiarid climatic conditions.

REVIEW OF LITERATURE

Although information on the production of soil nitrate in semi-arid regions is limited, the requirements of nitrifying soil bacteria are fairly well established (6, 11). In eastern Oregon, with precipitation concentrated in the winter months, the soil is generally dry during the summer when temperatures are favorable for bacterial activity. Conversely, when soil moisture is favorable, soil temperature is often too low. It can be shown that soil moisture and temperatures optimum for bacterial activity coincide only for brief periods under these climatic conditions. These climatic conditions prompted Matthews and Coles (7) to conclude that in dryland areas of the intermountain regions nitrogen may be the limiting factor in continuous crop production.

Jacquot (5), reporting on a 4-year study of annual versus biennial cropping of wheat in the intermediate rainfall area (approximately 15 inches) of eastern Washington, concluded the following: "There is a critical balance between the available soil moisture and the amount of nitrogen needed to utilize the moisture effectively in the production of crops. Both are indispensable and neither will substitute for the other. . . . The efficiency of moisture utilization by crops grown annually or biennially is greatly influenced by the availability of nitrogen. The available soil moisture was utilized least efficiently without nitrogen application and the most efficient use of soil moisture occurred at the highest rate of nitrogen application."

Nitrogen fertilization increased the yield of crested wheatgrass in Wyoming, Montana, and South Dakota (2, 9, 10). At Nephi, Utah (3), which has a precipitation pattern similar to that at Squaw Butte, crested wheatgrass response to nitrogen was primarily greater vegetative growth early in the season. Heavy fertilization produced vegetative burning. It seems apparent that the limitation in moisture in the growing season is critical, not only directly but also indirectly, in terms of nitrification.

METHODS AND PROCEDURE

Squaw Butte range lies in southeastern Oregon at an elevation of 4,600 feet, and receives an average annual precipitation of 10 to 11 inches. Over half of this moisture is received in the winter months. In general, the soils are sandy-loam, of basaltic origin, and are underlaid with a caliche layer varying from 2 to 4 feet below the surface.

The study was conducted on an established stand of crested wheatgrass which had never been grazed or fertilized. The stand was uniform throughout and very few weeds or other grass species were present.

Ammonium nitrate at 0, 10, 20, 30, and 40 pounds of N per acre was applied in late fall with a plot fertilizer spreader. The treatments were randomly assigned to 15 by 15-foot plots arranged in a latin square design in each of the years 1953, 1954, and 1955.

Herbage samples were obtained from one-half of the plot area on June 1 and from the remaining half on August 1, at which time the grass was mature and the green color nearly all gone. Regrowth from the plots harvested on June 1 was also sampled August 1. Herbage samples were taken by hand clipping 48 square feet of the plot area. Second-, third-, and fourth-year yield effects were obtained.

Yield samples were oven-dried, adjusted to 12 percent moisture, and expressed in pounds per acre. Crude protein content in the herbage was determined in 1954, 1955, and 1956 by the Kjeldahl method.

Plaster of Paris moisture blocks were placed at depths of 6 and 15 inches below the soil surface in all plots in 1954 and 1955. A Bouyoucos available-soil-moisture meter was used in reading the blocks at weekly intervals during the growing season. Although the soil moisture meter was not calibrated to this soil, the information is valuable for qualitative interpretations.

Available soil nitrate was followed in the upper 6 inches of soil in 1954 and 1955, using a LaMotte field testing kit.

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[2] Range Conservationists, Crops Research Division, A.R.S., U.S.D.A.

[3] Agronomist, Crops Research Division, A.R.S., U.S.D.A.

Table 1.—Yield response of crested wheatgrass on June 1 to nitrogen fertilization expressed in terms of herbage yields, percent of unfertilized yields, and N efficiency.

Year and herbage response	Nitrogen rate per acre						
	0 lb. N	10 lb. N	20 lb. N	30 lb. N	40 lb. N	Average	LSD 5%
1953							
Herbage yields (lb./A. at 12% moisture)	185	226	250	325	356	288	73
Percent of unfertilized	100	122	135	176	192		
Gain per pound of N	—	4	4	5	4		
1954							
Herbage yields (lb./A. at 12% moisture)	414	589	802	894	887	717	197
Percent of unfertilized	100	142	194	216	214		
Gain per pound of N	—	18	19	16	12		
1955							
Herbage yields (lb./A. at 12% moisture)	212	317	443	516	489	395	62
Percent of unfertilized	100	150	209	243	231		
Gain per pound of N	—	11	12	10	8		
Averages							
Herbage yields (lb./A. at 12% moisture)	270	377	498	578	577		68
Percent of unfertilized	100	140	184	214	214		
Gain per pound of N	—	11	12	10	8		

RESULTS

Yields on June 1

First-year effects.—Years, nitrogen rates, and the year by nitrogen interaction were all highly significant sources of variation in spring yields.

Differences in spring yields (table 1) were closely related to spring temperatures. Average mean temperatures for the period April 1 to June 1 were 43, 48, and 42°F., respectively for 1953, 1954, and 1955. The average mean temperature in that period for the past 15 years was 48°F.

Mean yields were consistently increased with nitrogen up to 30 pounds per acre, beyond which no additional increase was noted.

Nitrogen efficiency (pounds of additional herbage gained per pound of N applied) was in direct proportion to the favorableness of the spring growing period as measured by the unfertilized yields (table 1). However, the response to nitrogen varied among years and was related to both spring temperatures and winter precipitation. This interaction is best shown when fertilized yields are expressed as a percentage of unfertilized yields.

With late fall fertilization, winter precipitation should determine the depth of nitrogen penetration into the soil and consequently the concentration of the nitrogen in the soil solution. Precipitation from November 1 to June 1 was 11.07, 8.47, and 5.28 inches, respectively, preceding the growing seasons of 1953, 1954, and 1955. The percentage of yield increase was inversely proportionate to "winter" precipitation. "Winter" precipitation is the precipitation which falls between November 1 and June 1 preceding the growing season. Therefore, both spring temperatures and "winter" precipitation influenced spring yields and account for the interaction (table 1). For comparison with other years, the average "winter" precipitation in the past 15 years was 7.50 inches.

The fertilized and unfertilized grass started growth on approximately the same date in spring; however, the rate of growth of the fertilized grass prior to June 1 greatly exceeded that of the unfertilized

Crude protein content in the herbage on June 1 was obtained only in 1955 for first-year effects and was 12.68, 12.73, 13.95, 15.91, and 16.70%, respectively, with 0, 10, 20, 30, and 40 pounds of N.

Regrowth on spring harvested plots occurred only in 1953. For the above rates of nitrogen the average yields of regrowth were, respectively, 546, 566, 627, 722, and 884 pounds of herbage per acre.

Differences in regrowth yields among nitrogen rates were highly significant in 1953. In that year regrowth was due to heavy rains in late May and early June which prolonged the growing season.

Second-year effects.—Second-year yield response to fertilization was inversely related to the amount of precipitation in the first year after fertilization. The high precipitation obtained in 1953 produced sufficient regrowth to use up nearly all the nitrogen applied so that there was no residual effect in 1954. Residual nitrogen significantly increased second-year herbage yields in 1955 and 1956. In 1955 residual yields were 240, 316, 359, 394, and 428 pounds per acre, respectively, for 0, 10, 20, 30, and 40 pounds of N per acre. In 1956 the yields from residual nitrogen for these rates were 626, 613, 811, 899, and 1,091 pounds per acre.

Yields on August 1

First-year effects.—Years, nitrogen rates, and the year by nitrogen interaction were all significant sources of variation in annual yields. However, the response varied among years (table 2) and was closely associated to "winter" precipitation between November 1 and June 1.

In 1953, germination and lush growth of cheatgrass brome *(Bromus tectorum)* occurred on plots fertilized at 20, 30, and 40 pounds of N and materially influenced annual yields. This occurrence of cheatgrass brome was due to the late spring rains and possible greater abundance of available soil nitrogen at those higher rates of nitrogen. Cheatgrass brome was not present on the plots in either of the other 2 years of this study.

Table 2.—Herbage yields of crested wheatgrass on August 1 in the first and second year following nitrogen fertilization in each of the years 1953, 1954, and 1955.

Year of fertilization and yield year	Crested wheatgrass yields (12% moisture) at:						
	0 lb. N/A	10 lb. N/A	20 lb. N/A	30 lb. N/A	40 lb. N/A	Average	LSD 5%
	lb./A	lb./A	lb./A	lb./A	lb./A	lb./A	
1953							
First year	1053	1043	1626	1551	1985	1452	257
Second year	640	568	578	616	565	593	NS
Total	1693	1611	2204	2167	2550		—
1954							
First year	707	803	920	1021	1093	909	251
Second year	438	473	475	512	498	479	NS
Total	1145	1276	1395	1533	1591		—
1955							
First year	373	476	506	520	452	465	NS
Second year	1364	1615	1972	2206	2409	1913	287
Total	1737	2091	2478	2726	2861		—
Averages							
First year	711	774	1017	1031	1176		118
Second year	814	885	1008	1111	1157		129
Total	1525	1659	2025	2142	2333		—
Percent of unfertilized yields	100	109	133	140	153		
Gain per pound of N		13	25	21	20		

The accelerated rate of growth of the fertilized grasses depleted soil moisture more rapidly than unfertilized grasses and consequently the fertilized grasses cured earlier. The manner of curing appeared to be that which occurs naturally and not an induced "nitrogen burning". In 1955 the increased rate of growth of fertilized grasses combined with the limited moisture supply resulted in a definite wilting of the leaves prior to maturity. Nitrogen fertilization increased the number of seed heads per plant, allowed normal seed maturation, and did not impair seed viability even in the driest year.

Crude protein content in the herbage was increased by fertilization in 1954 and 1955. For rates of 0, 10, 20, 30, and 40 pounds of nitrogen per acre the crude protein values were, respectively, 3.94, 3.96, 3.79, 4.03, and 4.29% in 1954 and 4.46, 5.63, 6.68, 8.14, and 9.18% in 1955.

Second-year effects.—Significant increases in annual yields (table 2) from nitrogen occurred only in those years which followed a near normal or dry season.

Since harvesting in the third year following fertilization has shown no further residual response in yield or crude protein content, the total apparent benefit due to nitrogen was derived in the first 2 years. By average for the first 2 years of each experiment, nitrogen efficiency has been the greatest at the 20-pound N level (table 2).

Protein content in the grasses in the second year following fertilization was not increased when either the first or the second year was adequately supplied with moisture. However, an increase in crude protein was obtained in 1955 in those grasses which had been fertilized at 30 and 40 pounds N per acre in 1954. Crude protein content in the grasses in 1955 was 4.79, 4.92, 4.72, 5.42, and 6.42%, respectively, for the 5 rates of nitrogen employed.

Soil Moisture, Nitrate, and Plant Nitrogen Relations

Available soil moisture.—Available soil moisture was depleted more rapidly by fertilized than by unfertilized grasses. However, fertilization increased the efficiency of soil moisture use (table 3). Figures 1 and 2 show available soil moisture at 6 and 15 inches below the soil surface

Table 3.—Relative use of water by crested wheatgrass in the first year following nitrogen application.

Year	Water use per pound of dry matter produced*				
	0 lb. N/A.	10 lb. N/A.	20 lb. N/A.	30 lb. N/A.	40 lb. N/A.
	lb.	lb.	lb.	lb.	lb.
1953	2,400	2,400	1,500	1,600	1,300
1954	2,800	2,400	2,100	1,900	1,800
1955	3,200	2,500	2,400	2,300	2,600
Mean	2,800	2,400	2,000	1,900	1,900

*The amounts of water are those received from November 1 to June 1 preceding each growing season and do not allow for variations in precipitation effectiveness, residual soil moisture, or evaporation losses.

Table 4.—Seasonal growth of crested wheatgrass made prior to June 1 in the first year following nitrogen fertilization in each of the years 1953, 1954, and 1955.

Year	Growth prior to June at:					
	0 lb.N/A	10 lb. N/A	20 lb. N/A	30 lb. N/A	40 lb. N/A	Mean
	%	%	%	%	%	%
1953	17	21	15	21	18	18
1954	58	73	87	88	81	77
1955	57	66	88	99	100	82
Mean	44	53	63	69	66	

during 1954. Available soil moisture in 1954 and 1955 was essentially depleted by the fertilized grasses on June 1.

Nitrogen fertilized grasses made a larger portion of their growth in the early part of the growing season than did unfertilized grasses. The percentage increases in yield due to fertilization was greater on June 1 than on August 1 (tables 1 and 2). Over the 3 years, 44% of the season's growth by unfertilized grasses was made prior to June 1 as compared with 69% for grasses receiving 30 pounds of N per acre (table 4). Cool spring temperatures and heavy June precipitation, as in 1953, contributed to proportionately less growth prior to June 1 and less effective responses to N in that period.

Available soil nitrate.—Soil nitrate values in the first year following fertilization are presented in table 5. There are two points of interest in table 5. First, on April 6,

Table 5.—Available soil nitrate in the upper 6 inches of soil under actively growing crested wheatgrass in the first year following nitrogen application in the fall of 1953 and 1954.

Year	Available soil nitrate in ppm. at				
	0 lb. N/A	10 lb. N/A	20 lb. N/A	30 lb. N/A	40 lb. N/A
1954					
May 12	1	8	4	6	12
June 7	1	2	3	2	4
July 5	2	2	3	5	6
July 22	1	4	3	3	6
Average	1	4	3	4	7
1955					
April 6	2	4	9	14	15
April 12	1	3	5	6	16
May 2	3	1	2	6	13
May 9	1	2	3	4	2
Average	2	2	5	8	12

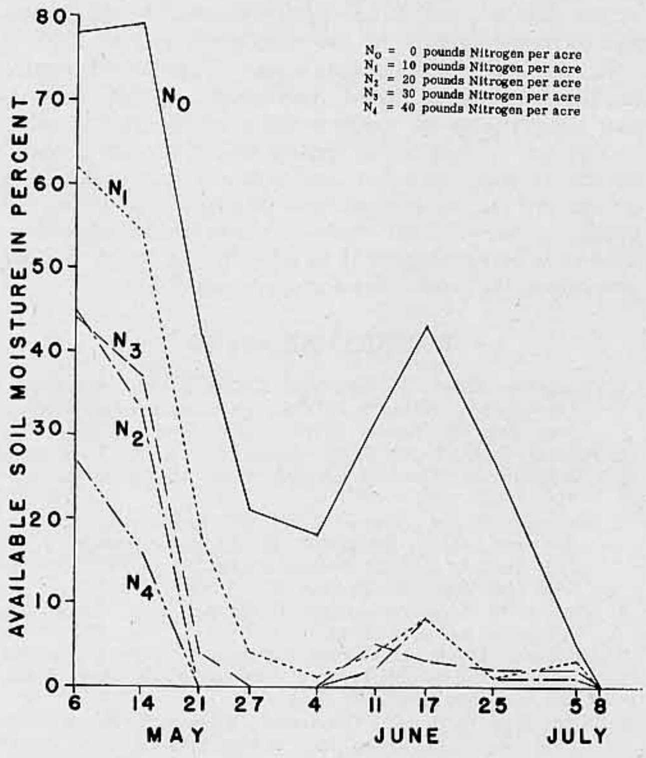

FIG. 1.—Available soil moisture at 6 inches below the soil surface under crested wheatgrass at 5 levels of nitrogen fertilization in 1953.

1955 the differences in soil nitrate levels among fertilization rates account for approximately all of the nitrogen applied the previous fall. This would have been impossible with heavier winter precipitation. Sampling in 1954 was not conducted early enough to produce similar results. Secondly, the grasses assimilated the nitrogen in the early stages of growth as reported by Miller and Amemiya (8). This is in accord with the advancement of physiological development. Apparently, unfertilized crested wheatgrass continuously assimilated nearly all the nitrogen produced in this soil.

Plant nitrogen.—Maximum recovery of the applied nitrogen occurred at the time of the June 1 harvest. Total average N recovery for all rates in the first 2 years of the 1955 experiment was 36% for the June 1 yields and 25% for the August 1 yields. For the 2 years of the 1954 experiment total average N recovery for all rates for August 1 yields was only 10%.

Table 6.—Nitrogen in crested wheatgrass herbage on June 1 and August 1, 1955 and the percent of N loss between those dates in the first year following nitrogen fertilization.

Rate of Nitrogen application	Nitrogen in herbage		Loss
	June 1	August 1	
lb./A	lb./A	lb./A	%
0	4.3	2.7	37
10	6.5	4.3	34
20	9.9	5.6	43
30	13.1	6.8	48
40	13.1	6.6	50

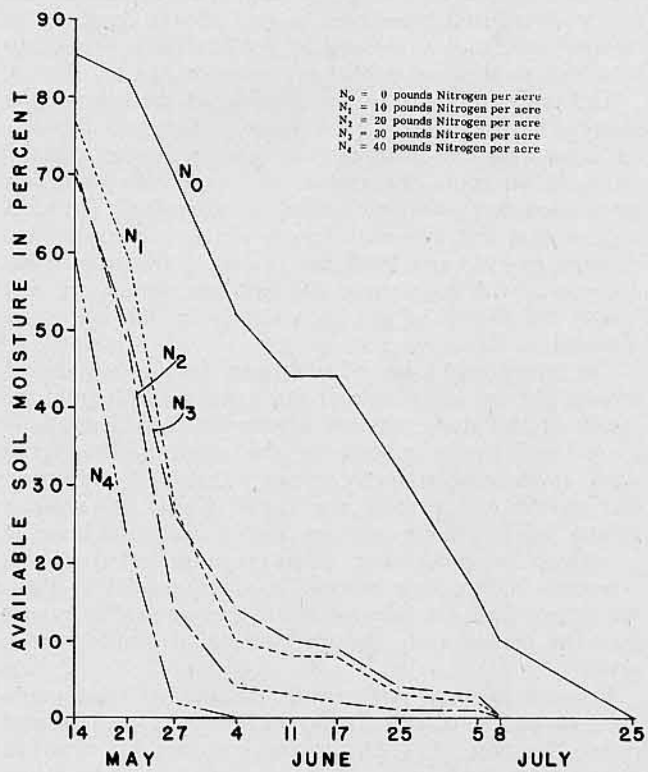

FIG. 2.—Available soil moisture at 15 inches below the soil surface under crested wheatgrass at 5 levels of nitrogen fertilization in 1953.

Recovery of N is low and varies among years, but of more concern is the loss of N which takes place in the grass after June 1 (table 6). The decrease in total nitrogen which occurred cannot be entirely attributed to an actual loss of the aerial portions of the grass. Losses from the dropping of seeds and leaves prior to August 1 were negligible. Losses in total nitrogen with advancing grass maturity have been reported elsewhere (1, 4, 8), and in South Africa (12) they were attributed to the translocation of N to the roots.

DISCUSSION

Semiarid soils are generally considered to be fertile soils with respect to mineral constituents; however, because of their low organic matter and limited opportunity for nitrate production they are deficient in nitrogen. Increased forage production can be obtained by correcting that deficiency through the use of nitrogen fertilizers.

Growth of crested wheatgrass prior to June 1 is rarely restricted by lack of moisture, but depletion of available soil nitrate with prevailing low temperatures may materially reduce spring growth. Continuation of growth after June 1 is more closely related to moisture supply; however, optimum production is contingent on the presence of available soil nitrate.

Moisture is and will continue to be a limiting factor in forage production in the sagebrush-bunchgrass range. Increased production must be accomplished within the limits of available moisture. In this respect, increases in moisture efficiency as induced by fertilization is one means by which an increase in forage production can be effected.

The study has also focused attention on the loss of total nitrogen in the herbage after June 1. Although this loss has been shown to occur in some grasses through translocation to the roots, the amount of loss in this study was great enough to warrant special consideration. The data suggest that the increased forage yields due to residual nitrogen in 1955 and 1956 may in part be due to nitrogen reserves in the roots from the previous season, as only minor differences in available nitrate in the soil were obtained in those years.

The economics of crested wheatgrass fertilization are not known, but can be considered to a limited extent from the results of this study. Crested wheatgrass is used primarily as an early-spring pasture in the sagebrush-bunchgrass areas. If managed properly, it can withstand heavy use in that period and permits the native grasses to attain a greater height prior to grazing. Such a practice is believed to increase the productivity of native range and contribute eventually to the improvement in range condition. Thus, the returns from the integrated native range may be greater than the returns from the seeded field of crested wheatgrass.

In years of short hay supply, the rancher must either purchase additional feed or turn cattle onto spring pastures early. The cost of a fertilization program can then be directly compared to the cost of purchasing and feeding hay. On the basis of a 2-year return the cost of producing a ton of early-spring crested wheatgrass fertilized at 20 pounds of N per acre would be approximately 24 dollars per ton when nitrogen is valued at 17 cents per pound. Under such circumstances, the use of nitrogen fertilizers to increase the spring production of crested wheatgrass may be viewed quite favorably.

SUMMARY

Yield and growth response of crested wheatgrass to various levels of ammonium nitrate in the Oregon High Desert were studied over a 4-year period. Total moisture received, spring temperatures, available soil moisture and nitrate, crude protein content in the herbage, 2 harvest dates, and field observations were utilized to evaluate the influence of nitrogen.

Nitrogen fertilization increased crested wheatgrass yields in all years. June 1 yields were in direct proportion to the average mean temperatures for April and May, but were inversely related to "winter" precipitation. The amount of "winter" precipitation influenced the concentration of nitrogen in the soil solution where it might be assimilated by early-active roots. Nitrogen at 30 pounds per acre doubled herbage yields by June 1 of each year.

August 1 yields of crested wheatgrass were directly proportional to the "winter" precipitation received. Crested wheatgrass yields in the second year following fertilization were increased only when the preceding year was limited in soil moisture. The highest efficiency of N was obtained at 20 pounds of N per acre. At this rate, 25 pounds of additional herbage was returned over a 2-year August 1 harvest period for each pound of N applied.

Fertilized grasses depleted soil moisture more rapidly, which caused an advancement in the growing season and shortened the green-feed period. Crested wheatgrass was not injured even in the driest year by nitrogen fertilization at the rates applied. Crude protein content in the grasses was increased only in the exceedingly dry year of 1955.

Results and practical implications of crested wheatgrass fertilization were discussed. The results provide information necessary to the understanding of the factors influencing the production of crested wheatgrass on semiarid ranges. It was concluded that nitrogen fertilization may benefit the grazing management program by reducing the number of seeded acres necessary where crested wheatgrass seeding is being considered to alleviate the spring grazing pressure on the sagebrush-bunchgrass range.

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