Nitrogen Fertilization of Northern Great Plains Rangelands[1]

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Research studies as well as the experience of individual ranch operators have shown that range land has a great potential for increased production. It is known that reseeding, weed and brush control, and proper management can do much to improve the range and increase the return per acre of land. A few recent studies on the use of fertilizers on native grasslands have indicated that here also may be a method of range improvement and of increasing the return per acre.

Unfortunately there is very little research information available on fertilization of native grass, especially in the Northern Great Plains region. Most of the studies have been with seeded grasses and results have been obtained only in terms of herbage yields. Results of these studies have shown, in general, that the response of seeded cool-season grasses to nitrogen in particular, even under low rainfall conditions, makes the use of this fertilizer economically feasible in many cases.

One of the few reports from the Great Plains region on the effect of nitrogen fertilizer on gains was made by McIlvain and Savage (1950). Their work at the U. S. Southern Great Plains Field Station, Woodward, Oklahoma, showed that ammonium nitrate applied to weeping lovegrass at 30 pounds of nitrogen per acre in 1947 and 53 pounds in 1948, increased grazing capacity 33 percent and gain of yearling steers per acre by 37 pounds.

[1]*Research investigations of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.*

Another experiment with fertilizers on native range in the Great Plains is being conducted in western South Dakota at the Range Field Station near Cottonwood. A progress report by Westin, Buntley and Brage (1955) for the 1952-54 period showed that good responses in forage yields were obtained from the application of 20, 40, and 80 pound rates of nitrogen per acre on pastures that had been grazed at heavy, moderate and light intensities. The greatest response was obtained on the heavily grazed pasture, where 80 pounds of nitrogen were applied per acre annually. This treatment produced 3,165 pounds more hay per acre over the 3-year period than the check plots. Their studies also showed that 80 pounds of nitrogen per acre applied once in three years produced more hay per unit of nitrogen than 80 pounds applied every year for three years. All rates of nitrogen produced residual effects for a period of three years. Marked increases were obtained in the percentage of protein from the higher rates of nitrogen.

Williams (1953) conducted a fertilizer experiment on upland prairie near Lincoln, Nebraska. He found the application of 60 pounds of nitrogen per acre raised the crude protein and phosphorus levels in most grasses, especially at the earlier stages of growth. Nitrogen-treated cool-season grasses were higher in crude protein at growth stages up to jointing time than were nitrogen-treated warm-season grasses at corresponding growth stages. The application of nitrogen fertilizer also resulted in greatly increased dry matter yields.

Climate, Soil and Vegetation

The climate of the area where the present study is located does not differ greatly from that of other sections of the Northern Great Plains. Temperatures reach extremes in both winter and summer, rainfall is limited, strong drying winds are common, and there are frequent drought periods.

Normally about half of the annual rainfall comes in May, June, and July, and the seasonal precipitation from April 1 to September 30 is about three-fourths of the annual. The annual rainfall, as shown in Table 1, averaged 17.91 inches during the period of the study. This compares with a 42-year average of 16.01 inches. During the period of study, 1952 was the only year when the lack of precipitation sharply limited plant growth. The most favorable year for growth was 1953.

The soil of the plots is classified as Williams silt loam. It is developed over calcareous glacial till and has a dark grayish-brown surface soil. Tests made prior to the initiation of the experiment showed the total nitrogen content of the soil in both a heavily and moderately grazed pasture, where the experiment was conducted, to be relatively high, being .257 and .250 percent in the surface six inches for the heavily and moderately grazed pasture, respectively.

Table 1. Annual and seasonal precipitation for the 1951-56 period at the Northern Great Plains Field Station, Mandan, North Dakota

Year	Precipitation	
	Annual total	Seasonal total (Apr.-Sept.)
	in.	in.
1951	20.31	16.65
1952	10.25	7.46
1953	21.76	16.56
1954	20.17	18.10
1955	18.33	16.24
1956	16.64	14.94
Average (1951-56)	17.91	14.99
Average (1915-56)	16.01	12.50

Under moderate grazing the vegetation in the area is quite typical of much of the Northern Great Plains. It is mixed prairie type. The dominant warm-season grass is blue grama (*Bouteloua gracilis*) and the dominant cool-season grass is western wheatgrass (*Agropyron smithii*). Needle-and-thread (*Stipa comata*) is another important cool-season species along with threadleaf sedge (*Carex filifolia*), a grass-like plant. A number of forbs are normally present in the vegetative cover.

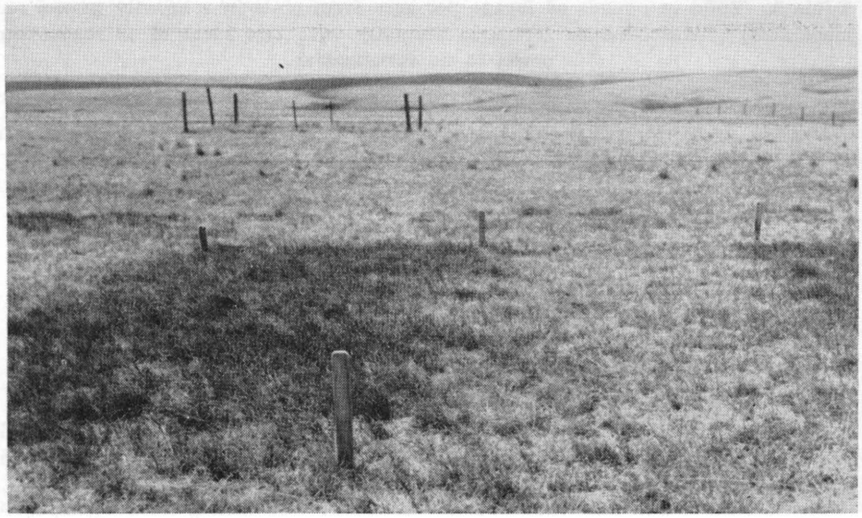

FIGURE 1. Fertilized and unfertilized plots of native grass in a moderately grazed pasture. The plot on the left shows the early growth and increase in amount of western wheatgrass on May 15, 1956, after six years of annual fertilization with 90 pounds of nitrogen per acre. The check plot on the right received no fertilizer.

Experimental Methods

The experiment was conducted on areas fenced off from grazing in 1951 in each of two pastures. One pasture had been heavily grazed for a period of 35 years immediately prior to the start of the experiment, and the other pasture moderately grazed for the same period. Nine plots, 6 by 20 feet in size, were established randomly in each of the enclosed areas. Three treatments with three replications were used. Plots in one treatment received no fertilizer and were used as checks. In another treatment, 30 pounds per acre of nitrogen were applied in the form of ammonium nitrate in the early spring the first year but in the late fall each year thereafter. The other treatment was a 90 pound per acre treatment applied in the same manner as the 30 pound treatment.

Observational notes were taken during the course of each season, and the forage harvested at one inch in height about the middle of August after the cessation of growth. Yields were calculated on the basis of 12 percent moisture in the forage. Separations were made of the forage from plots in the heavily grazed pasture to determine the amount contributed by various species. In addition to the fertilized plots in the heavily grazed pasture, an area was fenced off from grazing each year without further treatment, except annual harvest, in order to determine the natural recovery of the vegetation from an overgrazed condition. Soil moisture samples were taken to a depth of six feet by 1-foot increments in non-fertilized plots in both pastures and in the fertilized plots in the heavily grazed pasture in the spring and fall of each year. Crude protein determinations of the forage from the various treatments were made each year by the standard Kjeldahl method.

Results

At the initiation of the experiment in 1951, response to nitrogen by western wheatgrass and other cool-season species in the native mixture was almost immediate, as reflected in darker color and increased growth. This marked early response was evident every year thereafter (Fig. 1). Observational notes indicated that on the average there was sufficient growth on the fertilized plots to support grazing 10 days earlier than on the check plots.

Yields obtained during the course of the experiment are shown in Table 2. It is interesting to note that in the heavily grazed pasture, where the vegetation had changed from a typical mid-grass type to almost pure blue grama due to heavy grazing, yields were extremely low the first year for the check plots. The blue grama was also reduced in vigor due to close grazing. The application of 30 pounds of nitrogen per acre approximately doubled the yield the first year. Ninety pounds more than tripled it. Remnant western wheatgrass plants made a rapid recovery and accounted for most of the yield increase. In the moderately grazed pasture, where the vegetation was in excellent condition at the start of the experiment with a high percentage of western wheatgrass, the yields of the check plots were considerably higher. The percentage increase due to nitrogen application was not as high as in the heavily grazed pasture, but the total yields were greater. Since the vegetation was in a more vigorous condition at that time, yields naturally were more.

In 1952, when rainfall was much below normal, yields were extremely low in the moderately grazed pasture. Moisture shortage, as shown by moisture samples, was more pronounced because of the previous extraction of soil moisture by a deeper rooted, more vigorous grass cover. Soil moisture was actually higher at the deeper depths in the heavily grazed pasture, where a reduced root system had extracted less moisture previ-

Table 2. Yield in pounds of forage per acre from plots in a heavily grazed and moderately grazed pasture fertilized annually with two rates of nitrogen compared to no fertilization.

	Heavily grazed pasture			Moderately grazed pasture		
	Pounds nitrogen per acre			Pounds nitrogen per acre		
Year	0	30	90	0	30	90
1951	259	504	875	703	941	1218
1952	321	612	1158	243	345	544
1953	1247	2595	5062	944	2217	4341
1954	1172	1593	2334	674	1724	2086
1955	751	1350	2285	841	1414	2101
1956	739	1302	1915	533	1242	1754
Average	748	1326	2271	656	1314	2007

L.S.D. between treatment means for heavily grazed pasture:
at 5% level—381 pounds
at 1% level—630 pounds

L.S.D. between treatment means for moderately grazed pasture:
at 5% level—210 pounds
at 1% level—348 pounds

ous to the dry weather than that in the moderately grazed pasture. With the application of nitrogen, a more extensive root system developed which could tap the soil moisture at the deeper depths. Natural increase in vigor of the grass in the heavily grazed pasture resulted in increased yields over the previous year in spite of the extreme shortage of rainfall.

Precipitation was much above normal in 1953 and yields were extremely high in both pastures. The importance of moisture in relation to yield is shown by the fact that the check plots in the heavily grazed pasture yielded more than fertilized plots in previous years. Over a 4-fold increase in yield above the check plots was produced by the plots receiving 90 pounds of nitrogen. The extremely high yield was probably due partially to a residual effect of nitrogen from the preceding year, when growth was limited due to drought. Response to nitrogen continued to be marked from 1954 through 1956. The 6-year average shows that in both pastures, yields were approximately doubled by the annual application of 30 pounds of nitrogen per acre. Ninety pounds approximately tripled the yields.

The increases in pounds of hay per pound of nitrogen applied are shown in Table 3. On the basis of hay production, the data indicate a higher return per unit of nitrogen from the 30 pound rate of application than from the 90 pound rate. For hay production only, nitrogen fertilizer would be on the border line of being economical at present-day prices, since it would take an approximate increase of 20 pounds of hay per acre for each pound of nitrogen applied. Other factors which may be of greater economic importance than hay production must be considered in the determination of the possibilities for profitable use of nitrogen fertilizer on native range. Some of these factors will be considered in this paper.

One of the evident advantages of the use of nitrogen was the beneficial effect it had on the vegetation in the heavily grazed pasture. Yields in this pasture from plots isolated from grazing and harvested for hay every year but receiving no fertilizer are given in Table 4. There was a natural recovery in vigor and an increase in western wheatgrass, which was an indication of an improved range condition. Even so, two years of fertilization with 90 pounds of nitrogen each year did more to improve the range condition and to increase yields than six years of complete isolation from grazing.

Most of the increase in yield was due to the increased amount of western wheatgrass. In 1956, 83.5 percent of the herbage from the plots receiving 90 pounds of nitrogen in the heavily grazed pasture consisted of western wheatgrass, while only 57.5 percent of the herbage from plots protected from grazing six years without fertilization was western wheat. The herbage from plots protected from grazing only in 1956 contained just 9.4 percent western wheat. It should be pointed out that under the system of harvesting used, the basal cover or density was greatly reduced in the heavily fertilized plots. Blue grama, which is a short growing, high density species, was thinned out because of the shading effect and competition of the taller western wheatgrass. In this experiment, as in many others, there was a definite need for grazing trials to measure the total effects of fertilization. The removal of top growth of western wheatgrass throughout the season by grazing animals would have greatly altered the effects of shading and competition.

In addition to response to nitrogen in increased yields, protein

Table 3. Increase in pounds of hay per acre for each pound of nitrogen applied, from plots fertilized at two rates of nitrogen in a heavily grazed and moderately grazed pasture.

	Heavily grazed pasture		Moderately grazed pasture	
	Pounds of nitrogen per acre		Pounds of nitrogen per acre	
Year	30	90	30	90
1951	8.1	6.8	7.9	5.7
1952	9.7	9.3	3.4	3.3
1953	44.9	42.4	42.4	37.7
1954	14.0	12.9	35.0	15.7
1955	20.0	17.0	19.1	14.0
1956	18.8	13.1	21.5	13.6
Average	19.3	16.9	21.6	15.0

Table 4. Yield in pounds of hay per acre from plots isolated from grazing each year in a heavily grazed pasture.

Year	Number of years isolated from grazing: One	Two	Three	Four	Five	Six
1956	256	528	603	528	679	739
1955	248	690	524	677	751	—
1954	398	489	733	1172	—	—
1953	344	659	1243	—	—	—
1952	180	321	—	—	—	—
1951	259	—	—	—	—	—

content of the herbage was considerably higher for those plots receiving the high rates of application. Here again grazing tests were needed to determine whether increased protein in the herbage would have increased gains beyond those based strictly on amount of dry matter produced. Table 5 shows the percentage crude protein each year from 1952 through 1956 for the plots in both the heavily grazed and moderately grazed pastures. In some years the 30 pound application of nitrogen tended to decrease the percentage protein of the herbage below that from the check plots. This was probably the result of growth stimulation in the plants without sufficient nitrogen accumulation beyond the actual needs of the plants for growth. There evidently was a dilution effect on the nitrogen in the plants resulting in a lower percentage of protein.

Discussion and Conclusions

Many of the research studies that have been carried on indicate that range fertilization has a greater chance of successful application in the Northern Great Plains than in more southern regions of the Plains, or in many other areas in the west. The reason for this is that native grass in the northern Plains consists of a mixture of both cool- and warm-season grasses. The cool-season grasses show a marked early spring response to the application of nitrogen fertilizer, even on soils high in total nitrogen, because of the lack of available nitrogen from nitrification under the low soil temperatures that exist. Later on in the season, warm-season grasses will provide much of the forage needed for livestock use. Even though moisture is limited in the northern Plains, there is generally sufficient moisture in the early spring for plants to be able to take advantage of nitrogen that is applied artificially. Studies at Mandan have shown that, even after 32 years of heavy grazing, the total soil nitrogen under native grass has not been reduced below that in non-grazed areas or in moderately grazed pastures. Production, especially in the early part of the growing season, appears to be influenced primarily by available nitrogen and available soil moisture.

It has been demonstrated that the use of fertilizers can be economically profitable in the west on mountain meadows, sub-irrigated meadows, on irrigated pastures, and on seeded pastures of cool-season grasses. Full scale research would now seem justified on the problem of increased production of native range land. The meager information available is not overwhelming evidence in favor of the use of fertilizer, but it does indicate great possibilities. If the fertility level can be balanced with the supply of soil moisture, the efficiency of use of both moisture and fertilizer would be increased.

Nitrogen fertilizer can be used along with other range management methods as an effective tool in range improvement. Many of the present-day management methods have been designed to maintain the production of range land. Fertilizer use points up the possibilities of increased production. Because of the vast size of the Northern Plains, even a small increase in production per unit of area would amount to great economic value to the area as a whole. Many other advantages could well accrue from the use of commercial nitrogen, including a longer grazing period, better distribution of livestock over the range, and the maintenance of a better ecological complex of species.

Results of this study indicate a great potential for more efficient range production and increased returns per acre by the proper use of range fertilization in the Northern Great Plains, where the major portion of the land is in grass.

Summary

The effects on native range production from the annual application of two rates of nitrogen compared to no nitrogen on a heavily and moderately grazed pasture were studied for a period of six years at the U. S. Northern Great Plains Field Station.

On the heavily grazed pasture, 90 pounds of nitrogen per acre applied annually produced an

Table 5. Percentage crude protein of the herbage harvested from plots in a heavily grazed and moderately grazed pasture fertilized annually with two rates of nitrogen compared to no fertilization.

	Heavily grazed pasture			Moderately grazed pasture		
	Pounds nitrogen per acre			Pounds nitrogen per acre		
Year	0	30	90	0	30	90
1952	7.56	7.56	9.31	7.38	7.44	9.44
1953	6.25	6.31	7.19	6.50	6.44	9.06
1954	7.88	7.38	8.25	7.38	6.63	8.44
1955	7.44	6.75	9.19	7.00	6.56	8.06
1956	7.56	7.75	10.00	7.38	6.75	9.69
Average	7.34	7.15	8.79	7.13	6.76	8.94

average of 2271 pounds of dry forage per acre compared to 1326 and 748 pounds, respectively, for 30 pound and no nitrogen treatments. On the moderately grazed pasture, 90 pounds of nitrogen, 30 pounds of nitrogen, and no nitrogen produced 2007, 1314, and 656 pounds per acre, respectively.

The increase in yield resulting from nitrogen fertilization was due primarily to the increase in western wheatgrass. This grass showed a marked response because of the readily available nitrogen in the early spring, when low soil temperatures did not permit a rapid rate of natural nitrification, and because of its cool-season growth habits.

A greater return in pounds of hay produced per pound of nitrogen applied was obtained from the 30 pound rate than from the 90 pound rate.

Two years of fertilization of a heavily grazed pasture at the 90 pound rate of nitrogen did more to improve range condition and production than six years of complete isolation from grazing.

The crude protein level in the herbage was higher every year from the plots receiving 90 pounds of nitrogen than from the check plots but was lower in some years in the plots receiving 30 pounds of nitrogen because of a dilution effect.

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