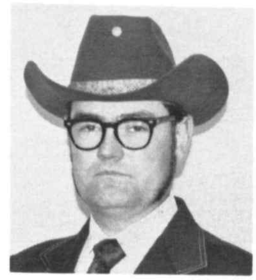
Part 1

Fertilization of Northern Great Plains Rangelands: A Review



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Editor's Note: Occasionally, we like to publish a review of the literature on a subject. This one on range fertilization is a good one for that. It's a little long, but it could not be shortened without leaving something out of importance, so, it will be in two parts.

The rancher today is being asked to produce more beef for less and to use less land to do it! Because of the greater returns from cash grain crops, much of our range is being replaced by cropland where it is possible to do so. Increased productivity of our remaining native range must support much of the increased demand for beef.

The potential for increased beef production from native range through the application of fertilizer is becoming more widely recognized. While a great deal of research has been done on this subject, the results are scattered throughout the literature and are not readily available to ranchers. This discussion will bring as much of this information together as possible.

Because of the scope of the subject, the information will be restricted as much as possible to an area defined as the Northern Great Plains. This area is roughly that which lies north of a line extending east and west through central Nebraska, and east of the Rocky Mountains. The eastern and northern borders are defined by a transition zone of climate, vegetation, and soil. This area includes most of North and South Dakota, northern Nebraska, portions of eastern Montana and Wyoming, and extends northwestward into Alberta to the vicinity of Edmonton.

Forage Production

Of the entire Great Plains area, the northern portion shows the greatest potential increase from fertilizer. This is partially due to a higher effective precipitation and partially to the greater number of cool-season grasses which constitute the native range. Although usable forage production is the most immediate, tangible benefit gained from fertilization, improvement of low-condition range is an important objective. Application of nitrogen (N) and phosphorus (P), along with better water-use efficiency, root development, and improved protein content, are less easily measured but of no less importance.

Rates of Fertilizer Application

Rogler and Lorenz (16) found that 30 lb of N per acre gave more production per pound of N than did 90 lb per acre. Other studies (10) (11) (16) (17) have also shown data which indicate that 30 to 40 lb per acre of N is more efficient than 80 to 90 lb. However, some studies within the Northern Great Plains have shown higher rates of N to give the best results. Nichols (13), in a 3-year study on western South Dakota ranges, found that 60 lb of nitrogen with or without herbicide application was the most efficient. In a study on heavily grazed native range in North Dakota, Smika et al. (20) found that 80 lb per acre gave more pounds of forage per pound of N than did 40 or 160 lb. The variability shown in these results is partially explained by the fact that these studies were conducted on different range sites or on similar range sites which had been subjected to different grazing pressure. On a range in fair to good condition with a large proportion of cool-season grasses, most results have shown 30 to 50 lb N per acre give the greatest increase in production per pound of fertilizer applied. Poor condition range or range with a large percentage of blue grama or other warm-season grass has been shown to respond better to 60 to 90 lb per acre of N. These recommendations are based on studies conducted over a

The solid line delineates the area described as the Northern Great Plains.

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number of years and are therefore averages and may not be reproducible in any given year. For example, in years of higher than normal precipitation, higher rates of nitrogen fertilizer may produce the most forage, while in years of low precipitation, only small increases in production may be obtained from fertilizer application.

Frequency of Fertilizer Application

In the above research, annual applications of nitrogen fertilizer were used. Power (15) suggests that larger amounts of N applied once may be more economical over a period of several years. His research has shown that at lower rates , there is no buildup of N within the soil. If large amounts of fertilizer are applied, what N is not used will remain within the root zone and be available the following season, thus allowing one application to last several years. Studies at the Swift Current Research Station in Canada have shown that over 355 lb per acre of N gave increased yields due to residual N as much as 8 years later. During this time, however, a needleandthread (*Stipa comata*)-blue grama (*Bouleloua gracilis*)-western wheatgrass (*Agropyron smithii*) range has been converted to one consisting primarily of western wheatgrass. (Kilcher and Leyshon personal communication). In research at Dickinson, N. Dak. Goetz (7) studied single application of 200, 300 and 400 lb N per acre. Seven years after application, yields from the 400 N plots were 18% higher than yield from unfertilized native mixed prairie. The 200 lb rate showed increases of 50 to 55% the first 2 years, but by the fourth year yields were slightly lower than those from the check treatment. The 300 N treatment lasted longer, still showing a yield increase of 14% over the check plots 5 years after application. Species composition data showed that blue grama had declined and needleandthread, prairie junegrass (*Koelaria cristata*), and western wheatgrass had increased. Power (15) also points out that further studies should be conducted on the effects of large applications of N on vegetation performance and on the rate of added N over a period of years under a variety of soil and climatic conditions. There is a possibility that under certain conditions high rates of N could produce nitrate toxicity, grass tetany, or other metabolic disorders.

In evaluating the results obtained from fertilizer application, several factors can be measured, the most common being increase in yield. Other important parameters are increased crude protein and total digestible nutrients (TDN). Of all these, however, animal gains are of the most interest to the rancher. While animal gains are the best overall measurement of a range's productivity (providing it is to be grazed), it is often not possible to graze a fertility study area. Therefore, many of the studies reviewed here did not include grazing and can only be reported as they were conducted.

Forage Quality

Crude Protein

Forage crude protein levels are increased by fertilizer application. Cosper, Thomas, and Alsayegh (3) found that forage crude protein percentage was significantly increased by the N application. In a study in Texas, Dee and Box (4) found that nitrogen fertilization in Texas increased the total protein content of warm-season grasses in late winter. Goetz (6) on four major range sites in western North Dakota found that application of N produced a general increase in the protein content of all species. The magnitude of the increase, however, varied greatly between species and sites. TDN is also a measure of the quality of range forage, and an increase can mean better gains later in the season. Rogler and Lorenz (17) at Mandan, North Dakota, found that the average TDN production was increased 88 and 146% for pastures receiving 40 and 80 lb of N per acre respectively.

Palatability

In addition to improving forage quality and quantity, fertilization can also improve the palatability of range plants to livestock. Fertilization with N can be used to improve the distribution of livestock. Cook (2) found that the utilization by cattle of plots treated with 40 lb of N exclusively or with phosphorus was significantly higher than on plots treated with only 20 lb of N. Studies in the Bighorn National Forest in Wyoming have shown that application of 75 lb of N increased forage utilization on areas normally only lightly grazed. (Smith and Lang 22).

Nitrogen fertilization can also increase utilization of some low palatability plants. Ryerson et al. (19) found that 200 lb N per acre increased utilization of a porcupine grass (*Stipa spartea* Var. *curtiseta*) community from approximately 50 to 90% or greater. Porcupine grass, as well as all other grass species, was completely utilized on the fertilized strips, while on the nonfertilized check strips porcupine grass was not grazed to any appreciable amount.

Besides altering animal distribution, application of N has been shown to eliminate uneven grazing. Application of N fertilizer on little bluestem (*Andropogon scoparius*)-dominated range increased the utilization by cattle near Mandan, North Dakota, (Russell J. Lorenz personal communication). Cook (2) found that heavier grazing resulted in less old plant growth the following year, which helped to reduce the number of "wolf" plants.

Root Growth and Water Use Efficiency

The effects of fertilization on root growth is sometimes overshadowed by our interest in aboveground plant production and its ultimate effect on the production of domestic livestock. While the final economic returns must be our major goal when dealing with fertilization of privately owned rangeland, the effect added nutrients have on the plant's ability to produce roots must not be overlooked. Continued moderate to heavy grazing can reduce rooting depth, which can cause greatly reduced production and higher plant mortality, especially during periods of drought. Lorenz and Rogler (9) studied root production under moderate and heavy grazing treatments. Results of this study show that the total root weights were nearly equal; however, the heavily grazed pasture had a greater percentage of the roots within the top 6 inches than did the moderately grazed one. The authors found that the addition of 30 and 90 lb N per acre significantly increased root volume over that of an unfertilized area within the same pasture. Data from this study also showed that on a heavily grazed plot a larger percent of this increased root production from additional N was in the lower root profile, thus minimizing the effect of the heavy grazing on root production below the 1-foot level.

Added root production has the effect of increasing the amount of soil water available to the plant. Water moves slowly through most grassland soils; therefore the more root volume a plant has, the more water that is readily available at any given time.

In addition to improving a plant's access to soil water, fertilization also has been shown to improve water use efficiency. Water use efficiency is merely the amount of water required by a plant to produce a given amount of forage. Research shows that with N fertilization greater water use efficiencies are possible. Smika et al. (21) found that with a total available water level of 18 inches an unfertilized range had produced less than 1,000 lb. of forage while the plots receiving 160 lb N per acre produced nearly 4,000 lb. of forage with the same amount of available moisture.

The fact that fertilization on our rangelands increases root production also shows up in a different way during dry years. During a drought, fertilized rangeland often does not produce significantly better than does unfertilized. In studies at the Dickinson, North Dakota Experiment Station during 1976, a year of lower than normal precipitation, fertilized crested wheatgrass (*Agropyron desertorum*) and native pastures demonstrated a much greater decline in production than did the unfertilized pastures (Nyren and Whitman 14). The unfertilized crested wheatgrass showed a slight increase over 1975 production levels. While no data were obtained on soil moisture levels it is possible that the increased vigor of the root system of the fertilized pastures had significantly reduced soil moisture reserves. Lacking the normal winter and spring recharge, these pastures had less soil moisture reserves than did the unfertilized pastures. The unfertilized pastures lacked root system volumes to extract as much moisture during the 1975 season. Other research at Dickinson tends to enforce this idea. Goetz (7) found that plots fertilized with 67 lb N per acre annually had less available soil moisture following the growing season than did plots receiving no fertilization. Fertilizer applied during dry years may not be used, but this added N will remain within the soil profile and be available for plant use when adequate soil moisture reserves improve.

(This article will be concluded in the next R. *At that time we will discuss effects of fertilization on grazing seasons, species composition, and improving overgrazed ranges. It will also carry a summary, along with a listing of the 23 pieces of cited literature).*

Soil Moisture and Grass Growth in Northern Nevada in a Drought Year

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Concern over possible drought promoted the monitoring of soil moisture in northern Nevada from March through June 1977. Moisture was measured by gypsum soil-moisture blocks buried in the soil at depths of 6, 12, and 24 inches. These blocks have essentially the same moisture content as the surrounding soil. The electrical resistance measured in the blocks can be converted to bars of tension, or the force with which water is retained by the soil. As the soil dries to a point near 15 bars of tension, plants are generally unable to extract water from the soil, and soil-moisture is termed "unavailable" to the plants. Under this condition, some plants permanently wilt, others continue to grow very slowly, and others go into dormancy and stop growing. Moisture held at ⅓ to 15 bars of tension is generally available for plant use.

Spring-soil-moisture directly affects spring and summer production of range forage in Nevada. The soil should have available moisture in the spring when temperatures are warm enough to permit rapid growth of plants. The availability of soil-moisture in the spring depends primarily on the amount of precipitation in the late fall and winter, the spring, or both. In winter, when evaporation and water use by plants are lowest because temperatures are low, dry soils are generally recharged with water from melting snows. Spring rains may provide additional recharge if they fall in sufficient quantity and at a rate slow enough to infiltrate the soil and percolate to the root zone.

Soil-moisture was monitored at 30 sites in 14 general areas from east to west across northern Nevada in 1977. The sites are on sagebrush/grass and cheatgrass ranges in the foothills and valleys and are past range research locations. Soil-moisture data from 1964 to 1969 and 1975 to 1976 for 22 of the sites in 11 areas were available for comparison with the 1977 data.

Precipitation varies greatly from year to year and from site to site within a particular year, so the availability of soil-moisture in spring and summer is quite variable. However, some general patterns of precipitation and soil-moisture availability were evident. The springs of 1964, 1965, 1967, and 1975 had from less than an inch to over 2 inches more precipitation than normal (U.S. Department of Commerce, 1964-69, 1975-77). Also, the winters preceding these springs generally had above-normal precipitation. Soil moisture in these years was available throughout the soil profile from March through June, and most sites had available moisture in some part of the profile in July. This availability pattern is representative of the wetter years, and would be expected to contribute to high forage and seed production because moisture is available for plant growth through July. The springs of 1966, 1968, and 1969 had precipitation ranging from an inch below normal to normal, and the winters preceding them were moderately dry (about 1.5 inches less than normal precipitation in 1966 and 1968) to moderately wet (about 1.5 inches more than normal precipitation in 1969). Generally, soil-moisture in these years was available throughout the soil profile from March through May and was available at depths below 12 inches in June. Moisture was unavailable throughout the profile in July. This pattern may be representative of dry to average years. In general, plant growth would be expected to end sooner in these years than in wetter years, and forage production from annual grasses such as cheatgrass would probably be lower than in wetter springs.

The spring of 1977 was preceded by an extremely dry winter in

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