Fertilization and Its Effect on Range Improvement in the Northern Great Plains

H. R. COSPER, J. R. THOMAS[1], AND A. Y. ALSAYEGH
Soil Scientists and Agricultural Research Technician, Soil and Water Research Division, Agricultural Research Service, U.S. Department of Agriculture, Newell, S.D.

Highlight

Application of nitrogen fertilizer to a deteriorated range site changed the botanical composition from predominantly forbs and shortgrass species to a western wheatgrass and shortgrass composition. Nitrogen fertilization increased both forage and crude protein yields.

---

[1] *Mr. Cosper is now a graduate student at the University of Nebraska, and Dr. Thomas is now at Weslaco, Texas.*

Research and practical experience indicate that much rangeland has a potential for greater forage production. Practices such as reseeding, control of undesirable species, proper management and mechanical treatments all aid in range improvement. Range pitting, for example, on the shortgrass plains of Wyoming (Barnes, 1952; Rauzi and Lang, 1956) increased carrying capacity and forage production.

Use of fertilizer on dryland ranges is also a practical means of increasing forage production in certain situations. However, some range fertilization studies have shown erratic or undesirable effects. Huffine and Elder (1960) in Oklahoma found that fertilized native pastures produced 2 to 5 times more weeds (by weight) than did unfertilized pastures. On the other hand, in southeastern Arizona blue grama responded consistently to fertilizer applications (Honnas et al., 1959). Similarly, results from a 6-year study in North Dakota showed that 2 years of fertilization, with 90 lb of nitrogen on a heavily grazed pasture, did more to improve range condition and production than did 6 years without grazing (Rogler and Lorenz, 1957). Studies in western South Dakota indicated that maximum forage production from utilizing runoff water could not be obtained without fertilization (Cosper and Thomas, 1961).

In the Northern Great Plains, forage yields from native ranges in poor to fair condition seldom exceed 600 lb/acre even in years of 15 inches or more precipitation. Little information is available on the effect of fertilizer on species composition and nutrient uptake on native rangeland. Generally, cool-season grasses responded to nitrogen fertilizer (Rogler and Lorenz, 1957). In order to evaluate potential forage production, in addition to other effects of fertilization, two native ranges in northeastern Wyoming were selected for study. The economics of rangeland fertilization was not investigated.

Experimental Area and Procedure

Site A was located approximately 11 miles north and site B, 6 miles east of Sundance, Wyoming. Due to the influence of the neighboring Black Hills, precipitation at the two sites varies somewhat from that recorded at Sundance (Table 1). Normally, 45% of the annual precipitation comes in April, May and June. Day temperatures in the summer very often reach 90 to 100F. Winter temperatures may go as low as minus 30F. Drouths are frequent. In 1961 lack of precipitation limited plant growth and forage yields were not taken.

The soils at the two locations were similar in that each developed from very fine sandy and silty parent materials weathered from fine-grained sandstones. At site A the surface 2 inches of soil was a very fine sandy loam with a pH of 6.8 to 7.0. At 2 to 9 inches the soil graded into a silty clay loam (35% clay) with a pH of 7.2. The soil at site B, from the surface to the 16-inch depth, was a silt loam with a pH of 8.0. Topography at both locations is gently sloping.

Table 1. Annual and seasonal (April 1 to June 30) precipitation in inches, 1957-1962, at Sundance, Wyoming.

Year	Annual	Seasonal
1957	24.59	13.12
1958	18.86	8.37
1959	18.10	8.48
1960	15.96	5.67
1961	17.91	4.84
1962	33.63	19.65
Mean	21.51	10.02
19-Year Mean	21.22	9.66

Native grass species at site A in 1958 accounted for 54.6% of the vegetation by weight and other plant species made up the remainder. Principal grass species present before the study was initiated were western wheatgrass (*Agropyron smithii* Rydb.), blue grama (*Bouteloua gracilis* H.B.K. Lag. x Steud.), buffalograss (*Buchloe dactyloides* [Nutt] Engelm.) and sandberg bluegrass (*Poa secunda* Presl.). Other principal species were horseweed (*Conyza canadensis* [L.] Cron.), fringed sagewort (*Artemisia frigida* Willd.), woolly plantain (*Plantago purshii* R. & S.), threadleaf sedge (*Carex filifolia* Nutt.), needleleaf sedge (*Carex eleocharis* Bailey), green sagewort (*Artemisia glauca* Pall.), and downy brome (*Bromus tectorum* L.). Numerous other species were represented but in relatively small amounts. Grass species at site B before the study began accounted for 91% of the vegetation by weight. In addition to the same grass species that were present at site A, a small amount of green needlegrass (*Stipa viridula* Tren.) was found at site B. Other species included sixweeks fescue (*Festuca octoflora* Walt.).

Three variables, nitrogen, phosphorus, and season of fertilizer application, were included in a factoral design with three replications at both sites A and B. Each fertilizer treatment was applied to an area 5 by 24 ft. Nitrogen as ammonium nitrate (33.5% N) was applied at rates of 0, 40, 80, and 160 lb/acre and phosphorus as superphosphate (43% P_2O_5) was applied at rates of 0, 80, and 100 lb/acre. The fertilizer was placed in bands 10 inches apart to a depth of 2 to 3 inches in the soil by means of small chisels. The nonfertilized treatments were also chiseled. The experimental sites were protected from grazing.

Fertilizer was applied at three seasons of the year, fall (October, 1957), spring (April, 1958), and summer (first week of June, 1958) at site A; and two seasons, spring (April, 1957) and summer (June, 1957) at site B. Fertilizer was applied only at the initiation of the study at each location.

The forage from 2 randomly selected areas (total of 28 ft^2) in each fertilizer treatment was clipped 1 inch above ground level late in June. The plant material was separated into 3 categories; intermediate grasses, short grasses, and other species which included nongrasses and summer annual grasses. Dry matter yields in each category were determined. Yields were measured in 1958 through 1960 and in 1962 at site A. At site B, yields were taken in 1957 and 1958.

Protein was determined by the A.O.A.C. method (1960). Plant phosphorus was determined by the methods of Bolin and Stamberg (1944) and Barton (1948).

Vegetative composition at each site was determined by the point frame method. The procedure was similar to that first described by Levy and Madden (1933). Points of contact were spaced 1 inch apart along a 2-foot frame. Two frames were counted per individual plot to determine vegetative composition and plant cover.

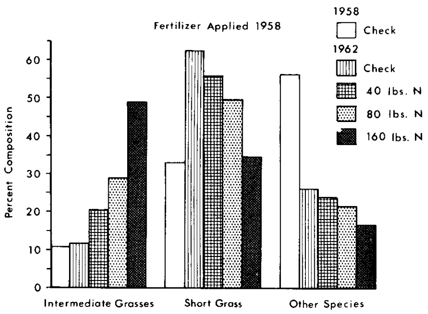

FIG. 1. Botanical composition of a deteriorated range fertilized in 1958. Averaged for all phosphorus rates and seasons of application.

Results and Discussion

Botannical Composition

Heavy grazing had deteriorated site A to such an extent that grasses made up only 43.7% of the total plant population, of which shortgrass and intermediate grasses comprised 33.0 and 10.7%, respectively. Five years of deferred grazing without fertilizer produced a marked change in botanical composition (Fig. 1). Vegetative composition in 1962 showed that shortgrass species, blue grama and buffalograss, had about doubled; intermediate species, mainly western wheatgrass, had remained approximately the same; and the other species had decreased from 56.0 to 25.9%.

Fertilizer applied in 1958 also produced botanical changes in 1962 (Fig. 1). Phosphorus had no significant effect on botanical composition. Point frame sampling showed that all nitrogen levels significantly increased the intermediate grasses but decreased shortgrass and other species. The 160-lb nitrogen application in combination with phosphorus increased the population of intermediate grasses in 1962 from 11.6% of total plant population for the check treatment (no nitrogen applied) to 48.3%. The corresponding nitrogen fertilizer treatments decreased shortgrass species composition from 62.3 to 34.5%, and other plant species from 25.9 to 16.7%, of the total plant population.

The differences in species composition due to season fertilizer was applied were small when measured in 1962. Fall-applied fertilizer slightly increased the intermediate grasses over that obtained from spring or summer applications.

Botanical composition at site B was not significantly altered by the fertilizer applications. This may reflect the short time over which measurements were taken (2 years) or the difference in species composition at sites A and B. Shortgrasses made up 80% of the total plant population at site B compared to 33% at site A.

Forage Production

Site A.—Total forage yields for the 4 years, (1958, 1959, 1960, and 1962) were affected significantly by both the time of year applied and rate of application of nitrogen and phosphorus fertilizer (Table 2). Summer application had the least effect on yields. Lack of moisture limited plant growth in 1959, 1960, and 1961.

In 1958 total forage production increased significantly with nitrogen applications and with phosphorus when applied with nitrogen. All of the yield response was due to the increased growth of other species (annuals and browse). Fertilizer application had no significant effect on growth of the intermediate or shortgrass species (Fig. 2). The significant yield response in 1959 was due mainly to residual nitrogen from the 160-lb nitrogen additions. The low amount of precipitation in 1959 restricted growth of the other species to a greater extent than that of the grasses. In response to the residual nitrogen from the 0-, 40-, 80-, and 160-lb nitrogen additions of 1958, the other species con-

Table 2. Dry matter forage yields (lb/acre) on a deteriorated native range (site A) as influenced by rate (lb/acre) and season of N and P fertilizer application (1958) and residual fertilizer (1959-1962).

Fertilizer applied in 1958		Fall applied				Spring applied				Summer applied			
N	P_2O_5	1958	1959	1960	1962	1958	1959	1960	1962	1958	1959	1960	1962
0	0	928d*	277d	374d	490d	945d	326d	547c	458d	744d	415cd	626bc	681d
40	0	1710d	443cd	543c	920c	1767d	522bcd	538c	827cd	1086d	364d	533c	863c
80	0	2570c	579bc	866a	1263b	2450c	662ab	697b	1081bc	1100d	634b	568bc	998c
160	0	3446b	646ab	818ab	1380b	2521c	859a	800ab	1514b	1468d	501bc	788b	1814a
0	80	762d	454cd	381d	477d	1099d	487bcd	481c	690cd	857d	466cd	382d	382d
40	80	1911d	459cd	469c	930c	2014c	546bc	658b	1047bc	1060d	499bcd	462cd	649d
80	80	3325b	534bcd	531c	1166bc	2281c	478cd	656b	1069bc	1381d	489bcd	824a	739c
160	80	2867c	812a	824a	2011a	4019b	700ab	872a	1605b	1633d	601bc	691b	1582b
0	160	963d	378d	466c	652d	1061d	388d	496c	482d	995d	324d	456cd	732cd
40	160	1404d	376d	523c	844c	2145c	482bcd	513c	927cd	1192d	449cd	660b	746cd
80	160	2895c	601bc	597bc	1053bc	3270b	494bcd	744b	1048bc	1592d	605bc	619bc	910c
160	160	5704a	827a	636bc	1746ab	3282b	733ab	722b	1702ab	1203d	698ab	686b	1501b

* Values in same year, column or row followed by the same letter not significantly different at 5% probability level by Duncan Multiple Range Test.

stituted 23.4, 25.9, 27.6, and 34.9%, respectively, of the total forage yield. In 1960 other species responded to a greater extent than the grasses to residual nitrogen. Other species made up 63.2, 62.0, 58.7, and 50.7% of the total yield in response to residual nitrogen from the 0-, 40-, 80-, and 160-lb nitrogen applications of 1958. The difference in response by grasses in 1959 and 1960 may be due to rainfall distribution.

Increased yields from residual N in 1962 were due to intermediate grasses (Fig. 2). These native grasses accounted for 46 and 62% of the total yield (by weight) of the nonfertilized and the previously fertilized (160 lb/acre N) forage, respectively. Shortgrass species such as buffalo and blue grama contributed 44 and 32% of the total yield at the same nitrogen additions, respectively.

Site B.—Applications of nitrogen and phosphorus to a predominantly shortgrass range significantly increased forage production. Forage yields for two seasons are presented in Table 3. Forage yields the first season increased as the rate of nitrogen application increased. The largest yield was obtained with the 160-lb nitrogen addition in combination with 80 lb of phosphorus. The greatest increase per pound of nitrogen applied, however, was from 40 lb.

In contrast to the initial plant species response on Site A, the increased yields at Site B were due to greater production by native grass species rather than by other species. Nonfertilized other species accounted for 45 and 9% of the total yield at Sites A and B, respectively. Following the application of 160 lb of nitrogen, the nongrass yields at Sites A and B constituted 88 and 19% of the total yield, respectively.

The time of fertilizer application significantly affected forage production (Table 3, Fig. 3). Spring applications (April, 1957) increased growth of other species

Table 3. Dry matter, total protein yields (lb/acre) and mean phosphorus content (%) of forage on a short grass range (site B) as affected by rate (lb/acre) and season of N and P application (1957) and residual fertilizer (1958).

Fertilizer applied in 1957 N	P_2O_5	Spring applied 1957	Spring applied 1958	Summer applied 1957	Summer applied 1958	Spring Crude prot.†	Spring Phosphorus	Summer Crude prot.	Summer Phosphorus
0	0	1345ghi*	669	1128hi	886	165	0.145	165	0.145
40	0	2205cd	1111	1390fg	960	274	.133	221	.127
80	0	2118cd	1198	1483fg	1019	324	.115	245	.118
160	0	2066cd	1013	1644ef	1240	337	.114	294	.124
0	80	1220hi	1098	1081hi	945	189	.156	175	.175
40	80	2401c	1519	1411fg	1214	337	.155	221	.167
80	80	3208a	1417	1581eg	1084	437	.158	264	.152
160	80	3157a	1278	2720b	1504	481	.164	458	.161
0	160	1372fgh	932	1027hi	750	203	.178	147	.176
40	160	1993d	1064	1570eg	1141	267	.167	248	.175
80	160	2201cd	1095	1809de	1035	320	.188	284	.161
160	160	2906b	1503	2215cd	1503	483	.211	459	.201

† L.S.D. 5% Crude protein—Fertilizer, 58 lb/acre; Season, 49 lb/acre.

* Values in same year, column or row followed by the same letter not significantly different at 5% probability level by Duncan Multiple Range Test.

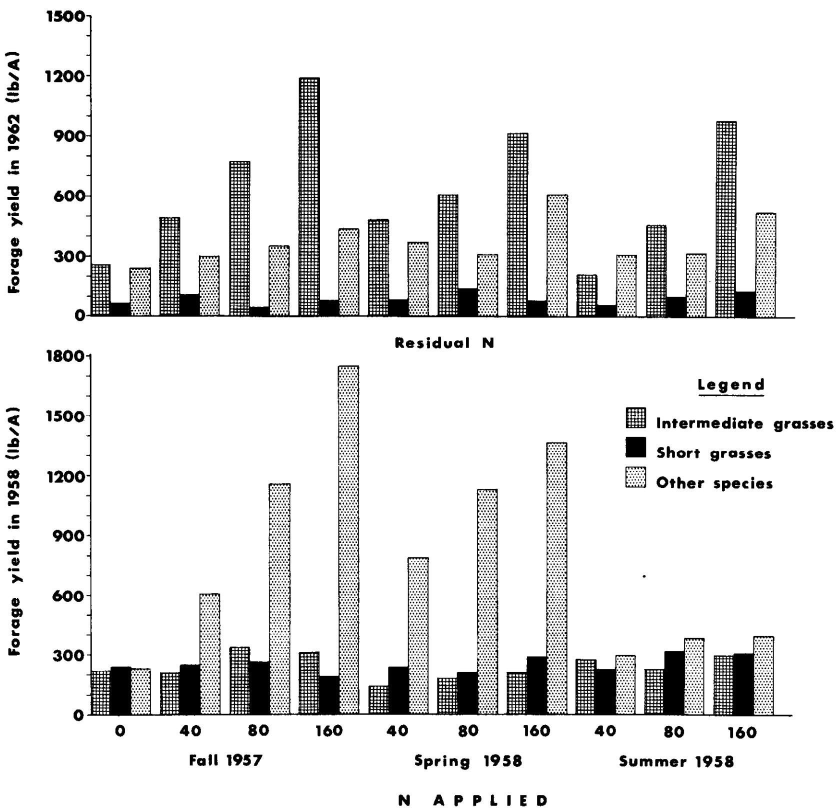

FIG. 2. Forage yields by species on a deteriorated range as affected by applied and residual nitrogen fertilizer.

Table 4. The effect of nitrogen fertilizer (applied in 1958) on the 1962 production and germination of western wheatgrass seed (site A).

Nitrogen lb/acre	Seed heads No./ft²	Weight g/head	Germ. %[1]
0	1.2	0.251	80
40	2.3	.248	—
80	5.3	.235	91
160	5.5	.237	91

[1]Standard germination — KNO_3 (0.2% solution) diurnal temperature 15 to 30C.

Table 5. Total protein yields (lb/acre) and mean phosphorus content (%) of forage on a deteriorated native range (site A) as influenced by rate (lb/acre) and season of N and P fertilizer application.

Fertilizer applied in 1958		Fall applied		Spring applied		Summer applied	
N	P_2O_5	Crude protein	Phosphorus	Crude protein	Phosphorus	Crude protein	Phosphorus
0	0	170	0.193	175	0.170	184	0.179
40	0	312	.183	310	.201	273	.186
80	0	476	.174	489	.167	286	.179
160	0	711	.180	589	.171	497	.189
0	80	160	.194	230	.200	165	.190
40	80	284	.188	347	.187	280	.200
80	80	471	.172	416	.178	352	.202
160	80	637	.181	749	.188	474	.194
0	160	198	.185	206	.217	203	.214
40	160	302	.192	317	.204	284	.202
80	160	483	.177	485	.197	386	.207
160	160	883	.188	719	.181	447	.220

L.S.D. 5% Crude protein—Fertilizer, 63 lb/acre; Season, 52 lb/acre.

and intermediate grasses more than summer (June, 1957) fertilizer additions. The shortgrass species were not affected by the time of fertilizer application.

A marked response by the different plants to fertilizer was noted. The application of 160 lb of nitrogen resulted in yield increases over the nonfertilized plants of 58, 129, and 199% by the shortgrasses, intermediate grasses (chiefly western wheatgrass and sandberg bluegrass), and other species, respectively. Eighty pounds of phosphorus increased the yields of other species, intermediate grasses, and shortgrasses by 71, 30, and 9%, respectively.

Forage yield response to residual fertilizer from the 1957 applications was obtained only in 1958. All fertilizer treatments produced substantially more forage than the nonfertilized treatment. However, differences in yields among fertilizer treatments were small and nonsignificant.

Seed production.—Nitrogen increased both plant vigor and seed production of western wheatgrass. Forty pounds of nitrogen applied at site A in 1958 nearly doubled the number of seed heads and amount of seed in 1962, while the residual nitrogen from the 80- and 160-lb applications resulted in four times more heads and seeds than on nonfertilized western wheatgrass (Table 4). The results are averaged for all phosphorus levels and times of fertilizer application. The weight of individual heads decreased as the number produced per unit area increased. Seed heads on nonfertilized grass were larger and heavier than those produced by fertilized grass. Standard seed germination tests showed a range of 80 to 91% viable seed, with perhaps a possible trend favoring seed from fertilized grass.

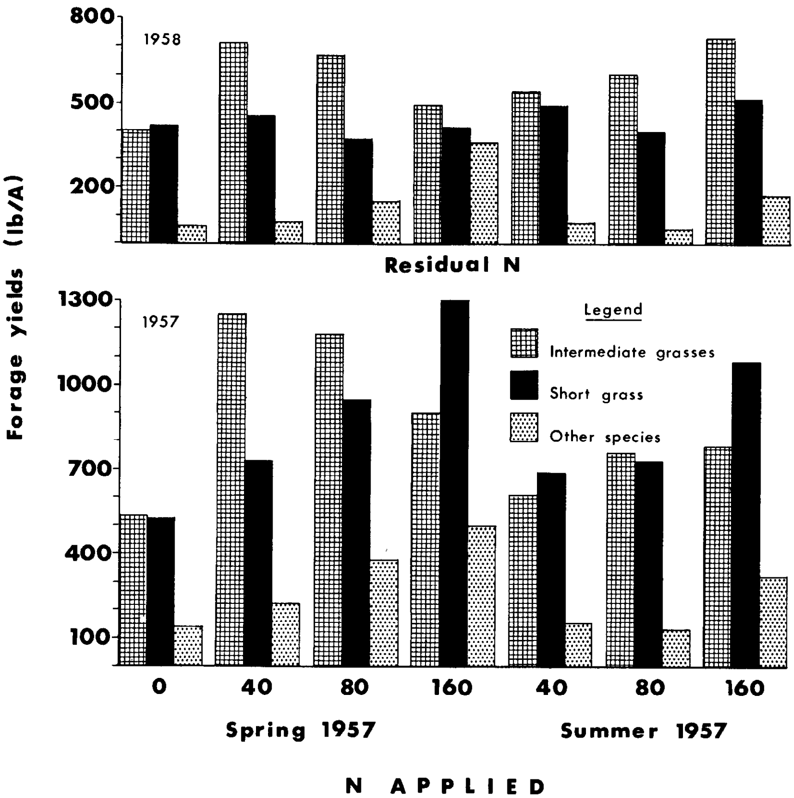

FIG. 3. Forage yields by species on a shortgrass range as affected by applied and residual nitrogen fertilizer.

Protein Content of Forage

Nitrogen fertilizer significantly increased the total protein yield at both sites (Tables 3 and 5). The relation between crude protein yields and rate of nitrogen application was linear up to the highest rate used, 160 lb/acre of nitrogen. The effect of nitrogen and the crude protein percentage was significant only in the first and second year.

Fall and spring fertilizer applications significantly increased crude protein yields above those obtained with a summer application. However, the percent of crude protein was generally higher in summer-fertilized forage. The mean crude protein content of forage at site A was 9.94, 10.26, and 10.65% for fall-, spring-, and summer-applied fertilizer, respectively.

The four-year average crude protein content of other species and grass species on site A was 9.50 and 8.75%, respectively. No differences were found between the protein percentages of grasses and other plant species at site B. The mean crude protein content of the forage was 9.50%.

Crude protein content of all grasses at both sites was below the minimum requirement for beef cattle except in the year 160 lb of nitrogen fertilizer was applied. An 800-lb beef animal requires 0.90 to 1.00 lb/day of digestible protein along with 17.1 lb of dry matter (Morrison, 1962). Nonfertilized grass at site A in 1958 supplied about 0.56 lb of digestible protein in the required amount of dry matter. The protein digestibility coefficient was estimated at 45% (Morrison, 1962). Grass species fertilized at the 160-lb nitrogen rate supplied 0.93 lb of digestible protein. The minimum protein requirement could be attained by increasing dry matter intake to 30.7, 24.8, and 21.4 lb/day for grass fertilized with 0, 40, and 80 lb of nitrogen, respectively.

Phosphorus Content of Forage

Phosphorus content of the forage was dependent on the application rate of nitrogen and phosphorus fertilizers and on the time of application. Phosphorus fertilizer significantly increased the phosphorus content of the forage at both sites (Tables 3 and 5). Forage at site A fertilized in the summer had a higher phosphorus content than fall- or spring-fertilized forage. However, the time of application had no effect on the phosphorus content at site B.

Botanical composition also influenced the overall phophorus content of the forage. Grass species at site B fertilized with 40, 80, and 160 lb of nitrogen contained 0.133, 0.139, and 0.135% phosphorus. Similar nitrogen addition to other species resulted in phosphorus concentrations of 0.174, 0.169, and 0.191%, respectively. Residual effects from the 160-lb phosphorus application at site A were measured in the third year.

The minimum dry matter requirement (17.1 lb/day) at site B would supply 0.019, 0.024, and 0.026 lb/day of phosphorus, respectively, from grass fertilized with 0, 80, and 160 lb of phosphorus. The daily phosphorus requirement for an 800-lb beef animal is 0.033 lb/day (Morrison, 1962). At the same phosphorus addition on site A, the minimum dry matter requirement would furnish 0.027, 0.029, and 0.032 lb of phosphorus, respectively, on a grass diet in 1958. Inclusion of other species would greatly increase the daily phosphorus intake.

Summary

The effects of nitrogen and phosphorus fertilization on botanical composition, forage yields, and chemical composition of forage from two native ranges in eastern Wyoming were investigated.

A single soil application of nitrogen fertilizer to a deteriorated range site changed the botanical composition from predominantly forbs and shortgrass species to a western wheatgrass and shortgrass composition. Nitrogen fertilizer applied to a similar soil on which shortgrass species represented 80% of the total vegetation did not alter botanical composition.

Nitrogen fertilization increased both forage production and crude protein yields at each location. The changes in forage yields were associated with botanical composition as well as the amount of nitrogen applied.

The crude protein percentage of the forage was significantly increased by the application of nitrogen fertilizer.

Phosphorus content in the forage increased with the addition of phosphorus fertilizer.

The relation between the protein and phosphorus content of the forage and the minimum requirements of these elements by range cattle are discussed briefly.

LITERATURE CITED

A. O. A. C. 1966. Official Methods of Analysis (9th Ed.). Association of Official Agricultural Chemists. Washington, D.C. 832 p.

Barnes, O. K. 1952. Pitting and other treatments on native range. Wyoming Agr. Exp. Sta. Bull. 318: 1-23.

Barten, C. J. 1948. Photometric analysis of phosphate rock. Anal. Chem. 20: 1068-1073.

Bolin, D. W., and O. E. Stamberg. 1944. Rapid digestion method for determination of phosphorus. Ind. Eng. Chem. Anal. Ed. 16: 345-346.

Cosper, H. R., and J. R. Thomas. 1961. Influence of supplemental runoff water and fertilizer on production and chemical composition of native forage. J. Range Manage. 14: 292-297.

Honnas, R. C., B. L. Branscomb, and R. R. Humphrey. 1959. Effect of range fertilization on growth of three southern Arizona grasses. J. Range Manage. 12:88-91.

Huffine, Wayne W., and W. C. Elder. 1960. Effect of fertilization on native pastures in Oklahoma. J. Range Manage. 13: 34-36.

Levy, E. B., and E. A Madden. 1933. The point method of pasture analysis. New Zealand J. Agr. 46: 267-279.

Morrison, Frank B. 1962. Feeds and Feeding, 23rd Edition. The Morrison Publishing Company, Ithaca, New York.

RAUZI, FRANK, AND R. L. LANG. 1956. Improving shortgrass range by pitting. Wyoming Agr. Exp. Sta. Bull. 344:1-11.

ROGLER, GEORGE A., AND RUSSELL J. LORENZ. 1957. Nitrogen fertilization of northern Great Plains rangelands. J. Range Manage. 10: 156-160.