# Response of Sub-Irrigated Meadow Vegetation to Application of Nitrogen and Phosphorus Fertilizer[1]

**J. S. RUSSELL, E. M. BROUSE, H. F. RHOADES, and D. F. BURZLAFF**

*Former Asst. Agronomist; Asst. Agron., retired; Prof. of Agron. deceased; and Assoc. Prof. of Agronomy. Nebr. Agr. Exp Sta. Lincoln*

### Highlight

**Combinations of nitrogen and phosphorus fertilizer gave greater yield increases than either element applied alone. Yield response and chemical composition of forage appeared to be a result of botanical composition changes in the meadow. Phosphorus fertilizer tagged with $P_{32}$ revealed that legumes used greater amounts of applied phosphorus than did grasses. Nitrogen fertilizer appeared to increase utilization of applied phosphorus by grasses.**

Meadow hay forms an important part of the livestock enterprise of the Nebraska Sandhills. Hay for winter feed is cut from meadows which lie between the sand ridges and on the bottomlands along streams and lakes. Tall prairie grasses grow in these areas. During the last half-century the botanical composition has changed as a result of the introduction of cultivated forage species.

Hay yields on the sub-irrigated meadows of the sandhills may be influenced by applications of nitrogen and phosphorus fertilizers (Brouse et al. 1953; 1954; Ehlers et al. 1952). There is also evidence to indicate that the nitrogen and phosphorus contents of the vegetation from these meadows are influenced by fertilization (Brouse et al. 1953; 1954). Based on the results obtained elsewhere it seems evident that nitrogen and mineral element percentages in the hay from the subirrigated meadows will be materially influenced by the stage of plant growth and by the species present (Beeson, 1941; Vandecaveye, 1941).

Thus, in evaluating the effects of fertilizer applications on meadow vegetation not only yield responses but changes in botanical composition of the sward and chemical composition of the forage plants with advance in season must be measured.

### Experimental Methods

An experiment was conducted during 1953 at two locations in Holt County Nebraska (referred to as Sites 1 and 2). The objective was to determine the influence of nitrogen and phosphorus fertilizers and time of harvesting on the yield and chemical composition of meadow hay. The experiment was planned in a randomized block design of 4 replications with 30 x 5 foot plots. Nitrogen as ammonium nitrate (33.5% N) at rates 0, 40 and 80 lb N/acre and phosphorus as treble-superphosphate (43% available $P_2O_5$) at rates of 0, 40, 80, and 160 lb $P_2O_5$/acre were applied in all combinations on April 1. Phosphorus at the 80 lb rate of $P_2O_5$ was tagged with $P_{32}$[2]. All fertilizer was applied with a Gandy spreader with the exception of the radioactive phosphorus. It was drilled at a depth of ¾ to 2 inches using a grain drill with a conveyor belt attachment.

Plant samples were obtained from Site 1 on June 16 and June 30 by clipping forage from an area 1 meter square at a height of 2 inches above ground. The entire sample from each plot was dried and weighed. At the final harvest on July 16 at Site 1 and July 17 at Site 2, strips 17.5 feet long and 3 feet wide were mowed through the center of the plot with a Jari Mower. Green weight of forage was obtained. Random samples of forage were taken from each plot for moisture determination and chemical analyses. All forage samples from plots receiving similar treatments were composited for chemical analyses except for the radioactive samples.

Species separations were made of samples from 4 treatments; check, 0-80-0, 40-80-0, 80-80-0. Each replication was sampled but in order to obtain sufficient plant material for analysis the replications were composited.

Total N was determined by a modified Gunning procedure. P, Ca, Mg, K and Na were determined after wet digestion of the samples with nitric and perchloric acids. Phosphorus was determined by the method of Sherman (1942). Cations were determined using a Beckman DU Flame Spectrophotometer with an oxy-hydrogen flame attachment. The amount of radioactive phosphorus in the plant material was determined by the briquet method of McKenzie and Dean (1950). Percentages of the plant constituents are expressed on an oven dry basis.

Vegetation on the check plots and on the non-fertilized area immediately adjacent to the plots was inventoried in early June using the point-quadrat method of Levy and Madden (1933).

*Characterization of Sites.* — The flora of both sites was characterized by a combination of warm-season and cool-season grasses, rushes, sedges, and introduced legumes. The main difference between Site 1 and Site 2 was found in the varying abundances of certain legumes. Red clover[3] was the only legume present

[1] *Contribution of the Nebraska Agricultural Experiment Station. Published with the approval of the Director as Paper No. 1659 Journal Series, Nebraska Agric. Exp. Sta.*

[2] *Acknowledgement is made to R. A. Olsen and F. E. Koehler who assisted in the application of $P_{32}$ and in final radioactivity assay.*

[3] *Scientific names of plants are listed in Table 1.*

to any extent at Site 1, whereas alsike clover was dominant at Site 2 (Table 1). There was also a higher percentage of little bluestem at Site 1 than at Site 2. This accounted, to some extent for the advance in maturity of the forage at time of harvest at Site 2 as compared to Site 1.

Properties of the soils in the Sandhill area have been reported by Russell and Rhoades (1956) to be related to the depth of water table below the surface. Analysis of the soil profiles (Table 2) showed that both sites were characterized by high organic matter percentages at the soil surface with decreasing amounts at increased depth of profile. This relationship affected total nitrogen, cation exchange capacity and total phosphorus. The direct correlation between organic matter and cation exchange capacity was shown by Burzlaff (1962). Differences were noted for pH and available phosphorus between the two sites.

When the fertilizer was applied in April the water table level was 15 inches below the surface at Site 1 and 17 inches below the surface at Site 2. At the time of final harvest in July, the ground water level on both sites was 36 inches below the surface.

**Table 1. Vegetation composition of experimental meadows expressed as percentage cover.**

| Species | Site 1 | Site 2 |
|---|---|---|
| *Trifolium pratense* | | |
| red clover | 7.4 | 3.6 |
| *Trifolium hybridum* | | |
| alsike clover | 0.0 | 10.4 |
| *Juncus* spp. rushes | 12.2 | 22.2 |
| *Carex* spp. sedges | 23.6 | 16.4 |
| *Poa pratensis* | | |
| Kentucky bluegrass | 17.6 | 21.6 |
| *Agrostis alba* | | |
| redtop | 1.1 | .1 |
| *Phleum pratense* | | |
| timothy | .5 | .3 |
| *Andropogon gerardi* | | |
| big bluestem | 7.5 | 7.3 |
| *Andropogon scoparius* | | |
| little bluestem | 6.9 | .1 |
| *Sorghastrum nutans* | | |
| indiangrass | 8.5 | 8.4 |
| Other grasses | 5.2 | 3.2 |
| Forbs | 1.5 | 4.2 |
| Total | 92.0 | 97.8 |

## Experimental Results and Discussion

*Yields of dry matter.*—Yields of dry matter were obtained at 3 stages of growth at Site 1 and at a final harvest at Site 2. Nitrogen fertilizer increased yields where phosphorus was applied but nitrogen fertilizer alone had relatively little effect on dry matter production (Fig. 1). Phosphorus fertilizer alone increased yields but the largest responses were obtained with the nitrogen-phos-

**Table 2. Characteristics of soil profiles from experimental areas.**[1]

| Depth, inches | Horizon | pH | Organic matter % | Nitrogen % | Cation ex. cap. me/100 gr. | Total p ppm | Available P ppm |
|---|---|---|---|---|---|---|---|
| *Site 1* | | | | | | | |
| 0- 2 | $A_0$ & $A_{11}$ | 8.1 | 13.7 | 0.62 | 21.8 | 668 | 4.4 |
| 2-10 | $A_{12}$ | 8.1 | 5.5 | 0.28 | 13.3 | 456 | 4.0 |
| 10-17 | $A_3$ | 7.7 | 1.7 | 0.09 | 8.1 | 198 | 3.3 |
| 17-25 | C | 7.3 | 0.1 | 0.01 | 3.0 | 43 | 1.4 |
| *Site 2* | | | | | | | |
| 0- 2 | $A_0$ & $A_{11}$ | 6.8 | 18.0 | 0.76 | 38.3 | 726 | 14.8 |
| 2- 5 | $A_{12}$ | 6.8 | 9.1 | 0.38 | 23.0 | 395 | 8.0 |
| 5-12 | $A_{13}$ | 6.6 | 1.1 | 0.05 | 9.1 | 89 | 2.5 |
| 12-16 | $A_3$ | 6.9 | 0.5 | 0.02 | 4.3 | 52 | 1.5 |
| 16-24 | C | 7.4 | 0.1 | 0.01 | 1.3 | 33 | 0.8 |

[1]These soils were classified as belonging to the Loup series.

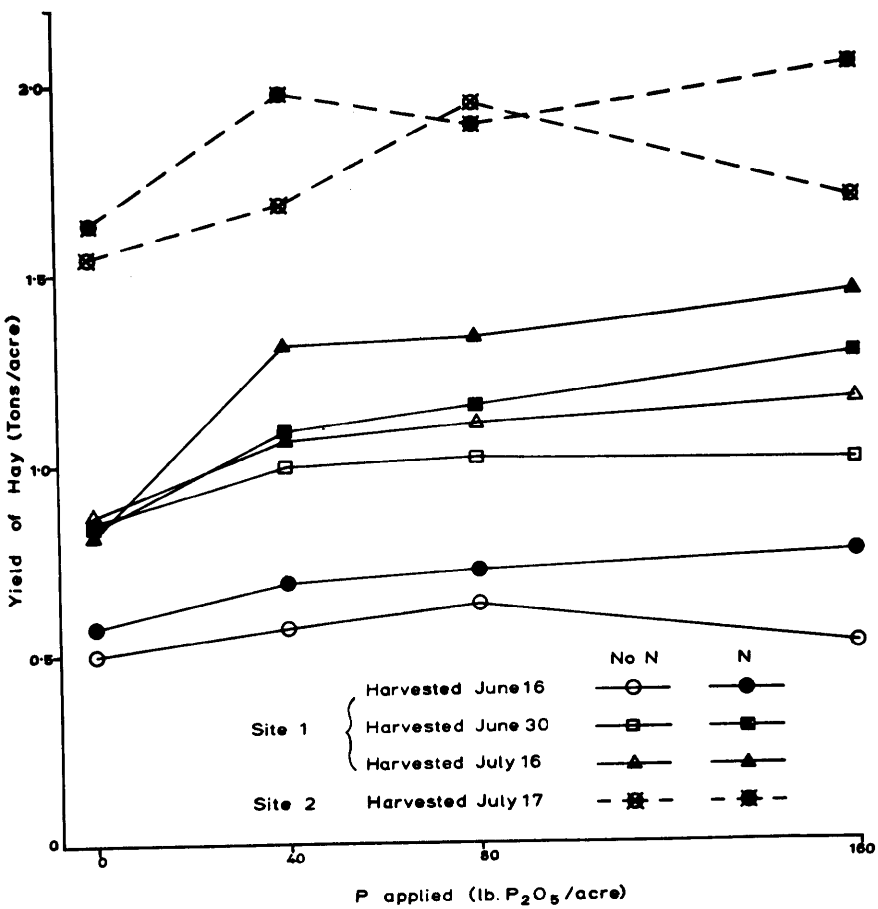


FIGURE 1. Yield of hay as influenced by fertilizer application. Values for N are the mean of 40 and 80 lb N/acre.

phorus combination. At Site 1 the effect of phosphorus fertilizer alone was much more noticeable at the third harvest than at the first harvest.

Changes in the vegetation composition as a result of fertilizer were observed at both sites. Nitrogen fertilizer alone caused a decrease in the amount of legume present. The stimulation of the grass which took place was insufficient to cause any significant increase in total yield. Phosphorus fertilizer alone caused a decided increase in the growth of legumes. When applied in combination nitrogen and phosphorus fertilizers appeared to stimulate both grasses and legumes causing significant increase in yield at both sites.

*Nitrogen Content of Forage.*— Nitrogen percentage of the forage from Site 1 declined from the first to the third harvest. Differences in nitrogen content due to fertilizer treatment were small. In particular the application of nitrogen fertilizer had little effect on the nitrogen content of forage from either site. However, phosphorus fertilizer resulted in an increase in the nitrogen content of forage at Site 2 (Fig. 2).

The efficiency of utilization of nitrogen fertilizer was low. Considering plots receiving nitrogen only, there was less nitrogen in the forage from treated plots than from the check plots at the final harvest at Site 1. At Site 2 there was a slight increase in the total nitrogen in the forage. Even so, the utilization of the nitrogen in an application of 40 lb of N/acre was only 4% and for 80 lb/acre utilization was 7%.

There was some increase in apparent utilization of nitrogen fertilizer when applied with phosphorus. At Site 1 utilization of nitrogen at rates of 40 lb and 80 lb N/acre was 26% and 20% respectively, when applied with phosphorus. Similarly, at Site 2 the utilization values were 38% and 20% for applications of 40 and 80 lb N/acre. However, where phosphorus was applied there was a considerable increase in the amount of legumes in the forage. It may be assumed that at least some of the additional nitrogen present in the forage resulted from nitrogen fixation by the legumes.

The effect of nitrogen and phosphorus fertilizer on the nitrogen content of individual species comprising the forage was examined (Table 3). These results show that changes in the nitrogen content of various species due to both nitrogen and phosphorus fertilizer were small. It seems probable therefore that the increase in nitrogen content of mixed vegetation at Site 2 was due to changes in botanical composition and particularly to the stimulation of legume growth as a result of phosphorus application.

*Phosphorus Content of Forage.*— At Site 1 there was a regular decrease in the phosphorus percentage

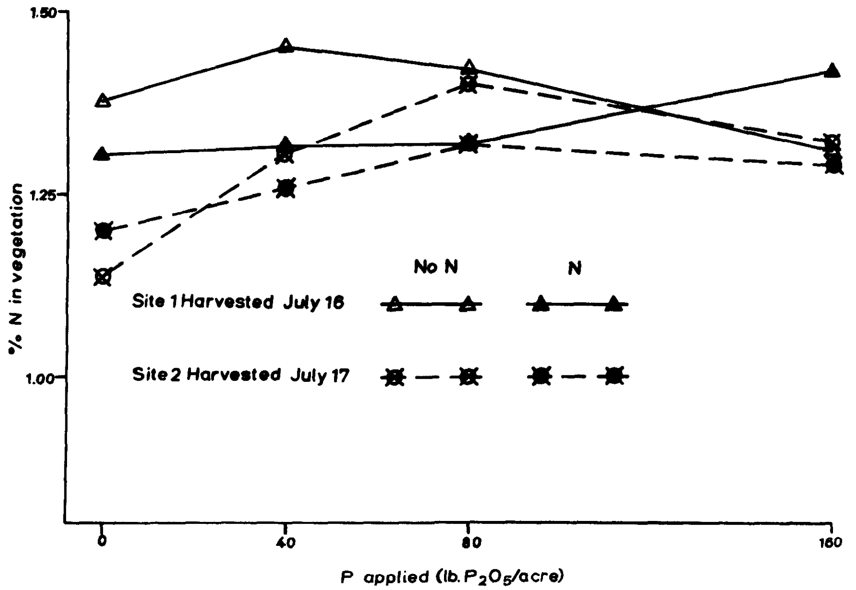


FIGURE 2. Nitrogen content of hay as influenced by fertilizer application. Values for N are the mean of 40 and 80 lb N/acre.

**Table 3. Nitrogen content of forage sampled from mixed vegetation, expressed as a percentage.**

| Species | None | Fertilizer Treatments 0+80+0 | 40+80+0 | 80+80+0 |
|---|---|---|---|---|
| *Site 1* | | | | |
| Red clover | 2.7 | 2.6 | 2.6 | 2.6 |
| Kentucky bluegrass | 1.2 | 1.2 | 1.2 | 1.2 |
| Indiangrass | 1.2 | 1.2 | 1.1 | 1.1 |
| Big bluestem | 1.2 | 1.2 | 1.2 | 1.2 |
| Little bluestem | 1.1 | 1.2 | 1.1 | 1.1 |
| Rushes | 1.1 | 1.0 | 1.1 | 1.1 |
| Sedges | 1.3 | 1.3 | 1.2 | 1.2 |
| Mixed vegetation | 1.4 | 1.4 | 1.3 | 1.4 |
| *Site 2* | | | | |
| Alsike clover | 2.3 | 2.2 | 2.2 | 2.1 |
| Timothy | 0.9 | 0.9 | 0.9 | 0.9 |
| Redtop | 0.9 | 0.9 | 0.9 | 0.8 |
| Mixed vegetation | 1.1 | 1.4 | 1.3 | 1.4 |

in the forage throughout the season (Fig. 3). Addition of phosphorus fertilizer at both sites caused large increases in the phosphorus percentage of the vegetation. These increases were directly related to the rate of phosphorus fertilizer applied. Addition of nitrogen fertilizer caused a decrease in the phosphorus percentage when applied alone or in combination with the lower rates of phosphorus fertilizer. Where applied in combination with the highest rate of phosphorus (160 lb $P_2O_5$/acre), however, nitrogen fertilizer caused a further increase in the phosphorus content of the vegetation. Average utilization of phosphorus fertilizer was 7% at Site 1 and 9% at Site 2.

Phosphorus fertilizer applied at 80 lb/acre $P_2O_5$ was tagged with $P_{32}$. This allowed a more comprehensive evaluation of utilization of the applied phosphorus. Phosphorus content of various species at the final harvest and the percentage derived from the applied fertilizer (Table 4) were calculated. Percentage of phosphorus derived from fertilizer in the mixed forage and the legume and grass portions for each harvest were also determined (Table 5).

Large differences in the utilization of fertilizer phosphorus were shown by the grasses and legumes in the mixed vegetation. Red clover in particular showed a higher utilization of fertilizer phosphorus with 75% phosphorus in plants fertilized with 0+80+0 being derived from this source. With alsike clover the respective value was 60%. Grasses were lower and showed a wide range from 56% for Kentucky bluegrass to 17% for big bluestem. Utilization of phosphorus fertilizer by the grasses was usually increased by addition of nitrogen fertilizer.

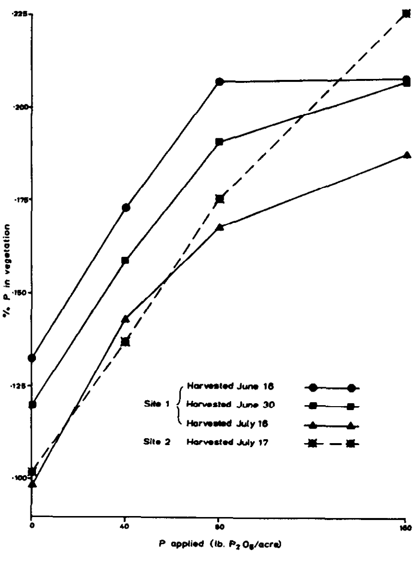


FIGURE 3. Phosphorus content of hay as influenced by application of phosphorus fertilizer. Values are the mean of 0, 40 and 80 lb N/acre.

**Table 4. Phosphorus content of forage sampled from mixed vegetation and percentage of phosphorus derived from fertilizer by treatments.**

| Species | None | Phosphorus in forage % 0+80+0 | 40+80+0 | 80+80+0 | Phosphorus in forage derived from fertilizer % 0+80+0 | 40+80+0 | 80+80+0 |
|---|---|---|---|---|---|---|---|
| *Site 1* | | | | | | | |
| Red clover | 0.17 | 0.19 | 0.19 | 0.20 | 75 | 69 | 66 |
| Kentucky bluegrass | 0.12 | 0.16 | 0.16 | 0.16 | 56 | 56 | 71 |
| Indiangrass | 0.11 | 0.18 | 0.15 | 0.15 | 39 | 31 | 39 |
| Big bluestem | 0.11 | 0.14 | 0.14 | 0.13 | 17 | 26 | 34 |
| Little bluestem | 0.09 | 0.13 | 0.14 | 0.12 | 29 | 34 | 44 |
| Rushes | 0.09 | 0.11 | 0.13 | 0.12 | 30 | 29 | 23 |
| Sedges | 0.15 | 0.16 | 0.16 | 0.15 | 26 | 15 | 31 |
| Mixed vegetation | 0.11 | 0.17 | 0.17 | 0.17 | 49 | 46 | 55 |
| *Site 2* | | | | | | | |
| Alsike clover | 0.19 | 0.19 | 0.18 | 0.18 | 60 | 47 | 44 |
| Timothy | 0.09 | 0.13 | 0.16 | 0.15 | 47 | 50 | 33 |
| Redtop | 0.09 | 0.14 | 0.17 | 0.14 | 28 | 46 | 33 |
| Mixed vegetation | 0.11 | 0.18 | 0.18 | 0.17 | 44 | 45 | 42 |

**Table 5. Percent phosphorus in the vegetation derived from applied phosphorus fertilizer, in relation time of cutting.**

| Fertilizer | Site 1 June 16 | Site 1 June 30 | Site 2 July 16 | Site 2 July 17 |
|---|---|---|---|---|
| *Mixed Forage* | | | | |
| 0+80+0 | 37 | 51 | 49 | 44 |
| 40+80+0 | 45 | 50 | 46 | 45 |
| 80+80+0 | 50 | 57 | 55 | 42 |
| Mean | 44 | 53 | 50 | 44 |
| *Grass Separations* | | | | |
| 0+80+0 | 34 | 44 | 29 | 31 |
| 40+80+0 | 39 | 47 | 28 | 42 |
| 80+80+0 | 39 | 56 | 35 | 41 |
| Mean | 37 | 49 | 31 | 38 |
| *Legume Separations* | | | | |
| 0+80+0 | 65 | 65 | 65 | 53 |
| 40+80+0 | 62 | 70 | 61 | 48 |
| 80+80+0 | 64 | 72 | 62 | 52 |
| Mean | 64 | 69 | 63 | 51 |

Some differences in the utilization of phosphorus at the two sites was observed. The final harvest at Site 1 revealed that 31% of the phosphorus in grasses and 63% in the legumes was derived from the fertilizer. Respective values of forage from Site 2 were 38% for the grasses and 51% for the legumes. A dominance of red clover at Site 1 and an appreciable higher available phosphorus content in the soil at Site 2 as compared to Site 1 may explain at least part of the difference in results obtained at the two locations.

*Cation Content of Forage.*—Changes in the cation content of forage throughout the season were small. The cation contents of different species from unfertilized plots are shown in Table 6. These data emphasize the relatively high content of calcium and magnesium in red and alsike clover and the low content of these cations in the mature grasses.

Certain trends were observed in cation content of forages as a result of the application of nitrogen and phosphorus fertilizer although differences were not significant. Nitrogen fertilizer decreased the calcium content of forage at all stages of growth (0.7% to 0.6% with 80 lb N/acre). Magnesium content was decreased slightly as was total cation content.

Phosphorus fertilizer tended to increase the calcium, magnesium and total cation content of the forage (.10%, .07%, 9 m.e./100 gr, respectively). Potassium content of forages was unaffected by either nitrogen or phosphorus fertilizer.

## Conclusions

It is important to fully understand the changes occurring in yield and chemical composition

**Table 6. Cation contents of different species from nonfertilized plots of two wet-meadow sites.**

| Species | Stage of growth | Cation percentages Ca | Mg | K | Na | Total cation content, m.e./100g |
|---|---|---|---|---|---|---|
| *Site 1, Harvested July 16* | | | | | | |
| Red clover | mid-bloom | 2.1 | 0.60 | 1.6 | 0.024 | 199 |
| Kentucky bluegrass | pre-boot | 0.6 | 0.24 | 1.2 | 0.013 | 82 |
| Indiangrass | mature | 0.4 | 0.18 | 1.2 | 0.004 | 63 |
| Big bluestem | pre-boot | 0.4 | 0.22 | 1.0 | 0.009 | 63 |
| Little bluestem | pre-boot | 0.4 | 0.16 | 1.1 | 0.004 | 62 |
| Rushes | mature | 0.4 | 0.20 | 1.3 | 0.005 | 70 |
| Sedges | pre-boot | 0.8 | 0.27 | 1.6 | 0.005 | 105 |
| Mixed vegetation | | 0.7 | 0.26 | 1.2 | 0.013 | 90 |
| *Site 2, Harvested July 17* | | | | | | |
| Alsike clover | past maturity | 1.5 | 0.52 | 1.2 | 0.010 | 148 |
| Timothy | mature | 0.1 | 0.09 | 1.0 | 0.004 | 41 |
| Redtop | mature | 0.2 | 0.14 | 1.1 | 0.006 | 47 |
| Mixed vegetation | | 0.6 | 0.26 | 1.1 | 0.005 | 79 |

of forage from hay meadows so that harvesting can be accomplished at the optimum time for maximum yields of the highest quality forage. Miller et al. (1955) in studies of high altitude meadows in Colorado found that dry weight of the plants continued to increase but nitrogen and phosphorus percentages declined with advance in maturity. Similar trends were found in this study of subirrigated meadows and it is evident that much delay in harvesting after early July could result in a loss of total nitrogen and phosphorus in the forage.

It appears that the diverse results that have been reported for yields of dry matter and chemical composition of the forage of fertilized meadows (Brouse et al., 1953; 1954) can be attributed to several factors. First, the botanical composition of meadows in the Nebraska Sandhills varies considerably. In particular the introduced forages red and alsike clover, timothy, and redtop show marked differences in composition percentages. Second, application of fertilizer results in changes in botanical composition. Nitrogen fertilizer stimulates the grass components and depresses the legume components of the sward. Phosphorus fertilizer stimulates the growth of legumes. Third, there is a tendency for the chemical composition of plants to undergo changes as a result of fertilizer application. In this study application of phosphorus fertilizer noticeably increased the phosphorus content of plants. Possibly the low initial phosphorus content of many plants found in this region materially contributes to this effect.

Fertilizer response will depend on the interaction of these factors and particularly on the important role of botanical composition of meadows.

## Summary

The yield and chemical composition of forage from two subirrigated meadows in the Nebraska Sandhills as influenced by the application of nitrogen and phosphorus fertilizers were studied.

Nitrogen and phosphorus fertilizer combinations gave the largest yield increases. Applications of phosphorus fertilizer alone gave smaller yield increases than did combinations of nitrogen and phosphorus. Nitrogen fertilizer alone did not give any increase in forage yield.

Sampling during the growing season showed that although yield increased, nitrogen and phosphorus percentages declined with advance in maturity. Calcium and magnesium percentages showed little change but potassium percentage after an initial rise also declined.

Phosphorus fertilizer was tagged with $P_{32}$ and utilization of applied phosphorus by the legumes was found to be considerably greater than by the grasses, although differences between grass species were also observed. There was some evidence that nitrogen fertilizer increased the utilization of applied phosphorus by the grasses.

Large increases in phosphorus content of mixed vegetation, when phosphorus fertilizer is applied, appear to be due to increases in the phosphorus content of individual species and also to the stimulation of legume growth.

Variation in the yield of dry matter and chemical composition of forage of subirrigated meadows in response to fertilization appears to be due to variations in original botanical composition and resultant changes in botanical composition of meadows and in the chemical composition of individual plants.

## LITERATURE CITED

Beeson, K. C. 1941. The mineral composition of crops with particular reference to the soil in which they were grown. USDA Misc. Pub. 369 164 p.

Brouse, E. M., P. L. Ehlers, and Glen Viehmeyer. 1953. Fertilizer experiments on native subirrigated meadows in Nebraska, 1952. Nebr. Agr. Exp. Sta. Outstate Testing Circ. 28. 10 p.

Brouse, E. M., P. L. Ehlers and Glenn Viehmeyer. 1954. Fertilizer experiments on native subirrigated meadows in Nebraska, 1953. Nebr. Agr. Exp. Sta. Outstate Testing Circ. 36. 20 p.

Burzlaff, D. F. 1962. A soil and vegetation inventory and analysis of three Nebraska Sandhills range sites. University of Nebraska Res. Bul. 206. 33 p.

EHLERS, P., GLENN VIEHMEYER, ROBERT RAMIG, AND E. M. BROUSE. 1952. Fertilization and improvement of native subirrigated meadows in Nebraska. Nebr. Agr. Exp. Sta. Circ. 92. 15 p.

LEVY, E. B., AND E. A. MADDEN. 1933. The point method of pasture analysis. N. Z. J. Agr. 46: 267-279.

MCKENZIE, A. J., AND L. A. DEAN. 1950. Measurement of $P_{32}$ in plant material by the use of briquets. Ind. and Eng. Chem. Anal. Ed. 22: 489-490.

MILLER, D. E., F. M. WILLHITE, AND H. K. ROUSE. 1955. High altitude meadows in Colorado; II. The effect of harvest date on yield and quality of hay. Agron. J. 47: 69-72.

RUSSELL, J. S. AND H. F. RHOADES. 1956. Water table as a factor in soil formation. Soil Sci. 82: 319-328.

SHERMAN, M. S. 1942. Colorimetric determination of phosphorus in soils. Ind. and Eng. Chem. Anal. Ed. 14: 182-185.

VANDECAVEYE, S. C. 1941. Effects of soil type and fertilizer treatment of the chemical composition of certain forage and small grain crops. Soil Sci. Soc. Amer. Proc. 5: 107-119.