# Seasonal Trends of Minerals and Proteins in Prairie Grasses

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EFFECTS of nitrogen and phosphorus fertilization on seasonal trends of minerals and protein in prairie grasses from virgin sod are valuable to agronomists in depicting certain soil-plant-animal relationships. Mineral and protein content of dominant grazing forages often reliably reflect soil characteristics. Analyses of calcium, phosphorus, and nitrogen, with certain restrictions, are widely used as a convenient alternative approach to more exacting but more expensive actual livestock assays. These constituents are often used for estimating the adequacy of mineral and protein for animal production.

Among the more comprehensive of the many reviews relating to minerals and protein in grazing forage are those of Theiler (1932 and 1941), Orr (1929), Watkins (1943), Stanley (1938), Vandecaveye (1940), Maynard (1941), and Beeson (1946). Beeson evaluates the present consensus of the various investigators in this field. Apparently, the important factors which tend to affect the nutritive content of grasses can be summarized as the inherent characteristics of the species, its stage of growth, the fertility of the soil, fertilizer applications, and the climate as it affects primarily the stage of growth, uptake of nutrients, weathering, and leaching of the tissues. Theiler's review is particularly devoted to the effect on animal performance of phosphorus deficiencies uncomplicated with various other nutritional deficiencies in natural grasslands of the world. His successors, Du Toit *et al* (1940), after extensive studies of the literature, nutrition balance studies, and the analysis of herbage samples from native grasslands, proposed levels of calcium, phosphorus, and protein required by cattle. United States authorities also have proposed well-accepted and widely used standards, however, for evaluating the nutritional qualities of the grasses in the present study, those of Du Toit in South Africa are used because of environmental similarities of natural grasslands.

The present study, concerned principally with the plant-animal relationship, reports the effects of nitrogen and phosphorus topdressings on the seasonal variation and differential concentration of calcium, phosphorus, and nitrogen in eight dominant grasses from a native prairie habitat near Lincoln, Nebraska. The general object was to relate quantitative variation of these plant constituents to differences in stage of maturity of the grasses and to a recommended nutritional standard for cattle on native grassland.

## Experimental Methods

An experimental plot 58 x 72.6 feet was established on a true prairie near Lincoln, Nebraska. The soil type at this location was Carrington silt loam on undulating to gently rolling upland prairie soil developed under approximately 28 inches average annual rainfall. The site was undisturbed by man except for any effects attributable to an annual autumnal mowing for hay (Clements, 1934). Three fertilizer treatments were applied to 1/200 acre plots (3 x 72.6 feet) in a randomized block design with four replications. These treatments consisted of topdressings of ammonium nitrate fertilizer, superphosphate, and an untreated check. The superphosphate, containing 43 per cent available phosphoric acid, was applied on February 15, 1947, at the rate of 80 pounds $P_2O_5$ per acre. The ammonium nitrate was applied on April 14, 1947, at the rate of 60 pounds of N per acre. Two-foot guard strips separated the individual treatments.

The common and scientific names of the species investigated are arranged below into two groups according to the season in which growth is most active (Hitchcock, 1951).

| *Common Name* | *Scientific Name* |
|---|---|
| *Cool-season Species* | |
| Junegrass | *Koeleria cristata* (L.) Pers. |
| Western wheatgrass | *Agropyron smithii* Rydb. |
| Needlegrass | *Stipa spartea* Trin. |
| *Warm-season Species* | |
| Prairie dropseed | *Sporobolus heterolepis* A. Gray |
| Little bluestem | *Andropogon scoparius* Michx. |
| Big bluestem | *Andropogon furcatus* Muhl. |
| Blue grama | *Bouteloua gracilis* (H. B.K.) Lag. |
| Side-oats grama | *Bouteloua curtipendula* (Michx.) Torr. |

In sampling, all plants were clipped about 1.5 inches above ground. With the exception of blue grama, samples for the first growth stage consisted of new vegetative material produced since dormancy. Samples for successive growth stages prior to and including jointing were made up of vegetation produced after the first clipping. Clippings at the early jointing growth stage removed the flowering culms from original sub-samples. Later growth from tillers in these subsamples, although available for animal consumption, was not sampled, consequently, all clippings at growth stages subsequent to the removal of the first flowering culms were taken from previously unclipped subsamples. This method of harvesting follows the nutritive levels of young growth from dormancy, vegetative regrowth through the time of early jointing, and mature growth subsequent to the removal of flowering culms. Hence it was possible to follow the maturation and weathering trend of original growth during the later season.

For estimating comparative yields resulting from fertilizer treatments, the total mixed vegetation in quadrats 2 x 6 feet was clipped at three dates during the growing season. Clippings in this incidence were taken from previously unclipped areas and hence consisted of the total year's growth up to the time of harvest.

A sample for analysis usually consisted of 200 to 300 grams of freshly clipped material. This was placed loosely in a large paper bag and dried in a ventilated oven at 100 degrees C. for about 24 hours. The oven-dry material was broken into small fragments and mixed. A representative portion of about 40 grams was obtained by quartering. This was ground in a Wiley mill to pass a one-millimeter sieve. For calcium and phosphorus determination, one-gram samples of the ground material were digested with a 1 to 1 mixture of concentrated nitric acid and 60 percent perchloric acid on a hot plate until colorless, then filtered to remove silica. Phosphorus content of an aliquot of the clear solution was determined by the method of Shelton and Harper (1940–41). Calcium was determined on a separate aliquot by the AOAC method (1945). Nitrogen was determined in separate one-gram samples by the

Kjeldahl-Gunning method, modified to include nitrate. All data reported are the average of four replications, calculated to a moisture-free basis. Percentage protein is expressed as percent total nitrogen times 6.25, and percentage phosphorus as the elemental form.

## Results

For convenient evaluation of the grasses in the present study, Du Toit's (1940) proposed requirements for an 800-pound beef steer consuming 16 pounds of dry matter per day are tabulated in Table 1. It is believed that greater meaning can be had from the analytical figures if the animal requirement is kept in mind.

TABLE 1

*Phosphorus and protein requirements for an 800-pound beef steer consuming 16 pounds dry matter per day*

| PHOSPHORUS IN PASTURAGE (PERCENT) | PROTEIN (6.25 N) IN PASTURAGE (PERCENT) | REMARKS |
|---|---|---|
| Under 0.11 | Under 5.0 | Below growth requirements |
| 0.11 to 0.14 | 5.0 to 7.0 | Limited growth |
| Over 0.14 | Over 7.0 | Sufficient for normal growth |

Limiting levels of calcium above the minimum requirement for growth are not given, but Du Toit concluded that pasturage containing a minimum of 0.14 percent calcium in the dry matter furnished the minimum requirement for an 800 pound beef steer consuming 16 pounds of dry matter per day. Younger animals may be expected to consume less than 16 pounds dry matter, and hence the nutritive constituents in the herbage should be higher for younger than for older animals. Similarly, in pregnant or lactating animals, amounts of phosphorus calcium, and protein should be superimposed on the requirements listed above or given in Table 1.

### *Crude Protein*

The data for the nutrient constituents of the grasses at varying growth stages at successive harvest dates are shown in Table 2. It may be observed that the crude protein of the native grasses ranged from 30.3 percent, in nitrogen-treated junegrass at the medium vegetative growth stage, to 1.8 percent in phosphorus-treated big bluestem harvested October 27. It may be further observed that 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. Cool-season grasses at earlier growth stages also showed greater differences in crude protein between treatments than warm-season grasses at corresponding growth stages. Moreover, cool-season species usually retained the increased crude protein at a more advanced growth stage, but such advantage was seldom apparent after the jointing growth stage, and not discernible in mature, cured, or seed-shattering material. Superphosphate generally produced no significant effect on protein content of any grass at any time, with the single exception of needlegrass sampled May 21.

### *Phosphorus Content*

Effects of fertilization and stage of growth on phosphorus content are given in Table 2. It may be observed that phosphorus in the grasses ranged from 0.51 percent in nitrogen-treated Junegrass at the medium vegetative growth stage to 0.09 percent in untreated little bluestem and prairie dropseed at the mature stage. As with protein content, the cool-season grasses were higher in phosphorus at growth stages up to jointing time than were warm-season grasses at corresponding growth stages. In many instances, fertilizer treatments increased the phosphorus content of the grasses. The differences in phosphorus content of fertilized and untreated grasses were greater in the earlier growth stages than in the later growth stages. In the majority of the cases, fertilization with ammonium nitrate produced greater increases in the phosphorus content of the grasses than did the application of superphosphate. The cool-season grasses at earlier growth showed greater increases in phosphorus content resulting from the fertilizer treatments than warm-season species at corresponding growth stages. Again, as with protein content, cool-season species retained this advantage in phosphorus content to a more advanced stage of growth; but differences were much less at the jointing stage, only slightly apparent at flowering, and were usually not discernible in mature or partly weathered material. As a rule, the phosphorus content of a grass was greatest in the earliest stage of growth and steadily became less as the plant developed and matured; but autumnal regrowth of western wheatgrass and needlegrass after a cutting for hay, and the regrowth of prairie dropseed after a previous cutting, showed an increase in phosphorus content in comparison to that of a preceding growth stage.

The nitrogen-treated vegetation was much darker in color and much more robust than the unfertilized or phosphated plots. This was especially true in the early part of the season, when the cool-season grasses were the principal components. Warm-season grasses responded less in color and growth to the application of nitrogenous fertilizer, but all species except big bluestem responded with increased phosphorus content at early vegetative growth stages.

Phosphorus fertilization produced a higher phosphorus content in both cool and warm-season grasses. This effect extended throughout all growth stages of the cool-season species, but was not always apparent in the late stages of warm-season grasses. Nevertheless, the warm-season grasses did show a delayed decrease as they matured. Irrespective of the treatment, they maintained higher phosphorus levels for a longer period of the year than the cool-season grasses. Thus the general downward trend of phosphorus content, as the plant developed, was similar to that of protein. This has been the observation of most investigators and in the present study was more clearly defined in cool-season than in warm-season species.

### *Calcium Content*

Calcium in the tissues of range grasses is generally not deficient. Such was the case in the present study. For convenience of presentation of data, tabulation of calcium content at varying growth stages as influenced by fertilization has been omitted. However, the calcium in the grasses ranged from 0.12 percent in untreated western wheatgrass at the late jointing stage to 0.48 percent in phosphorus-treated big bluestem at the early vegetative stage. In general, the calcium content was more erratic than phosphorus or protein content. Junegrass was the only species which seemed to show a consistent downward trend in calcium content at successive stages of development, but more than half of the species were lower in calcium content in the post-flowering stages than in earlier stages. Blue grama and prairie dropseed, which tended to maintain rather high phosphorus and protein contents for a longer period of the year, showed increases in calcium content in post-flowering growth.

At the two early harvests the calcium content of cool-season grasses from superphosphate plots was higher than that from the nonfertilized plots, but lower than the ammonium nitrate plots. The three

TABLE 2

*Effects of nitrogen and phosphorus fertilization on the protein and phosphorus content of native grasses at varying growth stages*

| SPECIES AND STAGE OF PLANT GROWTH | HARVEST DATES 1947 | EFFECT ON PROTEIN | | | EFFECT ON PHOSPHORUS | | |
|---|---|---|---|---|---|---|---|
| | | 60 lbs. nitrogen per acre | 80 lbs. $P_2O_5$ per acre | Untreated | 60 lbs. nitrogen per acre | 80 lbs. $P_2O_5$ per acre | Untreated |
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| *Cool-season species* | | | | | | | |
| *Junegrass* | | | | | | | |
| Early vegetative | 4/21 | 27.1‡ | 21.1 | 20.1 | 0.40‡ | 0.41‡ | 0.31 |
| Medium vegetative | 5/3 | 30.3‡ | 17.7 | 18.2 | 0.51‡ | 0.37‡ | 0.29 |
| Late jointing | 5/23 | 17.8‡ | 11.3 | 10.7 | 0.31† | 0.33‡ | 0.27 |
| Anthesis | 6/17 | 8.6† | 6.8 | 7.4 | 0.26 | 0.29† | 0.26 |
| Seed shattering | 8/12 | 4.1 | 4.3 | 3.5 | 0.12 | 0.14 | 0.11 |
| *Western wheatgrass* | | | | | | | |
| Early vegetative | 4/26 | 28.7‡ | 19.7 | 19.5 | 0.41‡ | 0.36 | 0.34 |
| Medium vegetative | 5/3 | 28.8‡ | 18.5 | 18.5 | 0.38‡ | 0.33‡ | 0.28 |
| Late jointing | 6/7 | 13.0‡ | 11.6 | 10.6 | 0.31 | 0.31 | 0.29 |
| Anthesis | 6/24 | 8.3† | 7.5 | 7.2 | 0.28† | 0.28† | 0.26 |
| Culms curing | 8/13 | 5.2 | 5.5 | 5.0 | 0.15 | 0.16 | 0.15 |
| Autumnal regrowth | 10/27 | —* | — | 18.0 | — | — | 0.21 |
| *Needlegrass* | | | | | | | |
| Early vegetative | 5/3 | 23.7‡ | 17.4 | 16.2 | 0.37‡ | 0.27† | 0.22 |
| Late vegetative | 5/21 | 18.0‡ | 13.2† | 11.5 | 0.27‡ | 0.22† | 0.20 |
| Late jointing | 6/7 | 12.9‡ | 9.8 | 8.4 | 0.23† | 0.20 | 0.19 |
| Early anthesis | 6/24 | 6.6 | 6.1 | 5.8 | 0.16 | 0.15 | 0.14 |
| Needles shattering | 8/15 | 5.6 | 6.2 | 6.3 | 0.11 | 0.15 | 0.10 |
| Autumnal regrowth | 10/27 | — | — | 10.5 | — | — | 0.18 |
| *Warm-season species* | | | | | | | |
| *Prairie dropseed* | | | | | | | |
| Early vegetative | 5/10 | 18.4‡ | 13.6 | 13.4 | 0.34† | 0.33 | 0.30 |
| Medium vegetative | 6/11 | 11.2† | 9.7 | 10.0 | 0.18 | 0.20 | 0.16 |
| Early jointing | 8/14 | 6.6 | 6.0 | 6.2 | 0.18 | 0.22 | 0.19 |
| Seed shattering | 9/13 | 6.5 | 5.0 | 6.1 | 0.25 | 0.22 | 0.26 |
| Increased maturity | 10/27 | 5.9 | 4.9 | 5.8 | 0.16 | 0.17 | 0.16 |
| Autumnal regrowth | 10/27 | — | — | 9.8 | — | — | 0.20 |
| *Little bluestem* | | | | | | | |
| Early vegetative | 5/23 | 15.7† | 13.5 | 13.7 | 0.28† | 0.27 | 0.24 |
| Late vegetative | 6/14 | 12.4† | 10.5 | 10.2 | 0.26† | 0.25 | 0.22 |
| Late jointing | 8/5 | 6.8 | 6.1 | 6.0 | 0.19† | 0.19† | 0.15 |
| Seed shattering | 9/13 | 5.2 | 3.9 | 4.0 | 0.17 | 0.16 | 0.14 |
| Mostly weathered | 10/27 | 2.3 | 2.1 | 2.5 | 0.09 | 0.10 | 0.09 |
| Autumnal regrowth | 10/27 | — | — | 3.4 | — | — | 0.14 |
| *Big bluestem* | | | | | | | |
| Early vegetative | 5/26 | 14.4 | 14.7 | 14.3 | 0.30 | 0.34† | 0.31 |
| Late vegetative | 6/15 | 11.1† | 9.3 | 9.8 | 0.25 | 0.22 | 0.20 |
| Late jointing | 7/28 | 7.3 | 6.8 | 5.8 | 0.18 | 0.23† | 0.18 |
| Early anthesis | 8/10 | 5.0 | 5.0 | 4.5 | 0.15 | 0.14 | 0.14 |
| Panicles shattering | 9/13 | 4.4 | 3.9 | 4.1 | 0.19 | 0.18 | 0.18 |
| Increased maturity | 10/27 | 2.0 | 1.8 | 2.0 | 0.12 | 0.12 | 0.14 |
| Autumnal regrowth | 10/27 | — | — | 9.0 | — | — | 0.25 |

TABLE 2—*Concluded*

| SPECIES AND STAGE OF PLANT GROWTH | HARVEST DATES 1947 | EFFECT ON PROTEIN | | | EFFECT ON PHOSPHORUS | | |
|---|---|---|---|---|---|---|---|
| | | 60 lbs. nitrogen per acre | 80 lbs. $P_2O_5$ per acre | Untreated | 60 lbs. nitrogen per acre | 80 lbs. $P_2O_5$ per acre | Untreated |
| | | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| *Warm-season species—Continued* | | | | | | | |
| *Blue grama* | | | | | | | |
| Early vegetative | 5/26 | 16.7† | 12.3 | 12.3 | 0.30† | 0.30† | 0.25 |
| Medium vegetative | 6/25 | 9.5† | 8.3 | 8.6 | 0.24 | 0.26 | 0.25 |
| First racemes exerted | 7/30 | 8.8 | 9.0 | 9.9 | 0.23 | 0.24 | 0.22 |
| Variable | 9/23 | 11.5 | 10.7 | 11.5 | 0.22 | 0.22 | 0.21 |
| *Side-oats grama* | | | | | | | |
| Late vegetative | 6/20 | 13.4‡ | 10.8 | 10.6 | 0.33‡ | 0.29‡ | 0.24 |
| Medium jointing | 7/17 | 7.2 | 7.8 | 7.4 | 0.25 | 0.29‡ | 0.24 |
| Anthesis | 7/28 | 5.7 | 5.5 | 5.9 | 0.20 | 0.22 | 0.18 |
| Variable, more mature | 8/14 | 4.5 | 4.4 | 4.6 | 0.19 | 0.22 | 0.18 |
| Variable, more mature | 9/23 | 3.8 | 3.6 | 3.6 | 0.19 | 0.17 | 0.18 |
| Mostly weathered | 10/27 | 2.8 | 2.8 | 2.9 | 0.11 | 0.12 | 0.09 |

* Vegetation not analyzed.
† Significant at .05 level.
‡ Significant over untreated at .01 level.

nitrogen-treated cool-season species were significantly higher in calcium content at the early vegetative stage than were the same species treated with superphosphate or left untreated. As a rule, the response of individual species to fertilizer treatment was less consistent as to calcium content than it was in regard to phosphorus and protein contents.

### *Nutrients in Mixed Herbage*

Yields and phosphorus, calcium and protein contents of mixed herbage are shown in Table 3. Probably the most striking observation is the great increase in yield resulting from the use of nitrogen fertilizer on the native vegetation. Ammonium nitrate treated plots yielded 4.5 times as much dry matter at the May harvest, three times as much when cut in June, and twice as much at the August cut, as the nonfertilized plots. The nitrogen treatment also produced significantly higher phosphorus and protein per-

TABLE 3

*Yield and composition of mixed herbage from fertilized plots on native grass prairie*

| SOIL TREATMENT | YIELD | PHOSPHORUS CONTENT | CALCIUM CONTENT | PROTEIN (6.25 N) CONTENT |
|---|---|---|---|---|
| *Lbs. per acre* | *Tons per acre* | *Percent* | *Percent* | *Percent* |
| *Sampled May 20, 1947* | | | | |
| None | 0.50 | 0.23 | 0.34 | 9.8 |
| 60 nitrogen | 2.28* | 0.29* | 0.30 | 15.4* |
| 80 $P_2O_5$ | 0.55 | 0.25 | 0.35 | 11.1 |
| *Sampled June 27, 1947* | | | | |
| None | 0.76 | 0.19 | 0.33 | 7.0 |
| 60 nitrogen | 2.38* | 0.26* | 0.27 | 8.1† |
| 80 $P_2O_5$ | 0.96 | 0.21 | 0.36 | 7.0 |
| *Sampled August 5, 1947* | | | | |
| None | 1.20 | 0.19 | 0.41 | 5.0 |
| 60 nitrogen | 2.64* | 0.24 | 0.43 | 5.1 |
| 80 $P_2O_5$ | 1.50 | 0.19 | 0.41 | 4.9 |

* Significant at .01 level, compared to untreated.
† Significant at .05 level.

centages in the May and June cuttings of hay.

Application of superphosphate produced approximately 25 percent apparent increases in yield of later cuttings, and a significant increase in phosphorus content of the first cutting of mixed herbage.

## Discussion

Clippings of the early vegetative stage of Junegrass were slightly lower in phosphorus and protein than those of the medium vegetative stage. Early growth of Junegrass produced after dormancy may have contained sufficient amounts of dormant material low in nutrients to influence the protein and phosphorus content. With the exception of this species, any grass sample composed of vegetation in a clearly defined growth stage was always higher in phosphorus and protein than a similar sample of the same species at a more mature stage. Accordingly, species such as blue grama seldom show clearly defined growth stages after early season growth. Blue grama may have young, flowering, and mature vegetation on the same plant at the same time. As a result, phosphorus and protein in such species and the general downward trend with advancing season are influenced in part by the proportions of material composing the sample. This observation is in general agreement with those of other workers and may indicate that a grass which remains in the vegetative stage of growth for a long period usually has a more desirable phosphorus and protein concentration than one with early culm formation. The last three growth stages of prairie dropseed illustrate such an effect.

For comparing the behavior of the species as a whole, particularly for satisfying the requirement of an 800 pound beef steer, it is difficult to designate an exact growth stage where phosphorus or crude protein had decided decreases. Late growth stages composed of mature and partly-weathered material with seeds shattered would be most striking from the viewpoint of physiological importance to the animal. It is near this growth stage that phosphorus concentration becomes insufficient for normal growth of an 800 pound beef steer considered to consume 16 pounds of dry matter per day. However, crude protein at the late growth stages would be of much greater importance since undernourishment in this constituent may immediately limit production or prevent it entirely. In contrast, low phosphorus levels in range grasses in late season apparently are not of immediate importance because reserves in the animal's body may sustain it over a rather lengthy period of inadequate intake without seriously affecting productive performance (Fraps and Fudge, 1940). Those stages of plant maturity when seeds or inflorescences or both began to shatter, and foliage began to cure or turn brownish-colored, were usually suboptimal in crude protein. Little bluestem, big bluestem, and sideoats grama were strikingly deficient in this constituent at the last growth stages after seeds began to shatter.

Many studies from various regions of the world have shown that certain areas produce native vegetation below the optimal nutritional requirements for cattle, but in other areas an adequate supply of constituents has been found. Calcium deficiencies in feeds under drylot condition have been found to cause disturbances in the health of animals (Eckles *et al.* 1932), but few range grasses have been found deficient in this element (Fudge and Fraps, 1944). Protein deficiencies often were found to be coexistent with phosphorus deficiencies.

Compared with analyses from investigations in other grasslands, the constituents in the present study were relatively high. However, blue grama was the only species investigated that contained both phosphorus and crude protein at levels sufficient for normal growth throughout the period of the study. Although not especially high above requirements adequate for normal growth in any of the constituents, blue grama retained the levels of its intermediary stages of growth for a relatively long period. In fact, there was a slight increase in protein at the time other prairie grasses were very low in concentration. Differences in the response of blue grama may have resulted from closer clipping, a practice that would include larger amounts of meristem tissue in the sample providing richer protein and phosphorus.

## Summary and Conclusions

1. Experimental plots were established on an area of upland true prairie near Lincoln, Nebraska, to study the effect of nitrogen and phosphorus fertilization on the phosphorus, calcium, and protein concentration in eight climax grasses at several successive stages of growth during 1947.

2. Samples of Junegrass, western wheatgrass, needlegrass, prairie dropseed, little bluestem, big bluestem, blue grama, and side-oats grama were harvested at dates ranging from April 21 to October 27. Samples represented as clearly as possible varying growth stages of advancing maturity between these dates.

3. Phosphorus content of grasses varied from 0.51 percent in nitrogen-treated Junegrass at the medium vegetative growth stage to 0.09 percent in unfertilized little bluestem and prairie dropseed at the mature and partly weathered stage.

4. Calcium content of grasses ranged from 0.48 percent in phosphorus-treated big bluestem at the early vegetative growth stage to 0.12 percent in unfertilized western wheatgrass at the late jointing stage.

5. Crude protein in the grasses varied from 30.3 percent in nitrogen-treated Junegrass at the medium vegetative growth stage to 1.8 percent in phosphorus-treated little bluestem harvested October 27.

6. Nitrogen-treated cool-season grasses were higher in phosphorus and protein at growth stages up to jointing time than warm-season grasses, irrespective of fertilization, at corresponding growth stages.

7. Calcium content of all species except Junegrass was inconsistent and erratic compared with the general downward trends observed with phosphorus and crude protein.

8. Nitrogen fertilization resulted in greatly increased growth of the cool-season grasses. Yield of mixed vegetation where these species were the principal components was increased fourfold.

9. It may be concluded from a consideration of the data obtained that an 800-pound beef steer whose sole ration consisted of 16 pounds daily of dry matter having the composition of that in this study would consume adequate phosphorus and calcium for normal growth. Protein might be a limiting factor for normal growth from early August until new growth was produced by favorable environmental conditions.

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## JOURNAL DEADLINES—1953

The following are the dates copy must be in Baltimore, Maryland for the next several issues:

| *Issue* | *Copy in Baltimore* |
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