A comparison of three sources of phosphorus

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Introduction

In Louisiana, particularly in the western part of the state where the production of livestock is becoming one of the important agricultural enterprises, the improvement and management of pastures are being given primary consideration. The soils of this area are low in nitrogen, calcium, and other bases, and are extremely low in phosphorus. These soils commonly support undesirable grasses and weeds which are able to thrive at a low fertility level. Most of these species are less palatable to livestock and yield less than the desirable species. These conditions result in lower carrying capacity of the pastures and higher cost of livestock production.

Studies have been made at the West Louisiana Experiment Station to determine what fertilization and liming practices are necessary for the establishment of improved pastures. In general, the results show that phosphorus is the limiting factor in pasture development. In addition to phosphate fertilization, liming is necessary to bring about a proper soil reaction, and in some cases other factors have to be taken into account. Therefore, a major step in pasture improvement is to apply sufficient available phosphorus for the growth of desirable pasture plants. In solving this problem, the question of what phosphate fertilizer will be the most efficient for this purpose becomes important.

The purpose of this investigation was to determine the relative efficiency of three sources of phosphate fertilizers in increasing the yield and improving the protein and mineral contents of forage from a mixture of rye grass, white clover, and Dallis grass.

Review of Literature

The effects of phosphate fertilization on the yield or production of pasture grasses and legumes have been studied in detail by a number of investigators. Fewer studies of the effects of applied phosphate on the chemical composition of pasture crops have been made.

The yield and chemical composition of pasture plants in general have been shown to vary greatly in relation to species, soil fertility, stage of plant maturity, and weather conditions. Most pasture plants contain a higher percentage of protein and minerals in the early growth stages. As the plants mature, the percentage of these constituents decreases and the quality of the forage progressively declines.

A number of experiments have been conducted by the Virginia Experiment Station in which superphosphate and rock phosphate were
The results of these experiments have been summarized by Rich and Lutz (33). Two phosphate materials were compared on an equal $P_2O_5$ basis. The data showed that most crops did not respond as well to rock phosphate as they did to superphosphate. However, the yields of all crops were relatively high without the use of any phosphate.

Woodhouse (42) summarized the data from North Carolina showing the value of rock phosphate in comparison with superphosphate. He concluded that rock phosphate was inferior to superphosphate when applied on an equal basis. Two to seven times as much phosphorus was required in the form of rock phosphate to give a response equal to that of superphosphate.

In three pasture experiments in Mississippi, Anthony (2) reported that rock phosphate applied at twice the rate of $P_2O_5$ as in superphosphate increased yields 47 per cent, compared with 68 per cent for superphosphate. Lyon (23) conducted a field test in New York on Dunkirk silty clay loam in which superphosphate applied at one-fourth the rate of $P_2O_5$ applied as rock phosphate produced as much increase in yield as rock phosphate.

Moores (28) summarized the results of a 3-year rotation for a 10-year period of an experiment in which superphosphate and rock phosphate were compared at several rates. An average of all crops showed that superphosphate was the more effective source on both limed and unlimed soils. Lime decreased the effectiveness of rock phosphate appreciably.

DeTurk (15) stated that free calcium carbonate may retard the intake of phosphorus from rock phosphate by plants which are not “strong feeders.” He did not recommend, however, that lime be omitted where rock phosphate is used. Legumes that are “strong feeders” on rock phosphate need lime, and as a result the advantage of using lime along with rock phosphate in a legume rotation may exceed any early reduction in the yield of non-legumes. It is evident that only enough lime should be added to satisfy the needs of the legumes.

Thorne (37) concluded that superphosphate proved to be a more effective as well as a more economical source of phosphorus than rock phosphate where freight rates are a relatively large part of the cost of the materials. He also stated, “Where a different outcome has resulted, it is usually found that one or both of the phosphate carriers have been used in such large quantities as to furnish more available phosphorus than the crops were able to utilize, thus making a comparative measurement of the effect of the two carriers impossible.” Since rock phosphate is cheaper per unit of $P_2O_5$ than superphosphate, it is often applied at two to four times the rate of $P_2O_5$ used for superphosphate.

Murdock and Seay (30), in experiments with red clover and wheat, found that the amount of available phosphorus from rock phosphate is increased by increasing the rate of application. About 3.5 to 4.0 times as much rock phosphate as superphosphate is needed to give equal yields
and plant phosphorus contents when the phosphorus sources are applied separately. Volk (40) found that the yields of oats and sorghum and the total calcium and phosphorus absorbed by the plants were much greater for superphosphate than for rock phosphate.

Long (22), in comparison of rock phosphate with triple superphosphate, found that the yield of red clover was only 75 per cent that obtained from triple superphosphate when rock phosphate was applied at 2.5 times the P₂O₅ equivalent of the triple superphosphate.

Neller and Lundy (31), in studies of the availability of residual phosphorus from superphosphate and rock phosphate, found that 40 per cent of the phosphorus in an oat crop was obtained from residual phosphorus of superphosphate applied at 100 pounds of P₂O₅ per acre. Pre-treatment with 300 pounds of P₂O₅ per acre resulted in more than 60 per cent uptake of phosphorus from residual phosphate. For oats in 1950, and for fescue in 1951, the uptake from residuals of finely ground rock phosphate at 640 pounds of P₂O₅ per acre was equal to that from superphosphate applied at 100 pounds of P₂O₅ per acre. The use of rock phosphate resulted in decreases in yields and in percentage of phosphorus in the crops, as compared with superphosphate.

McLean, Brown, and Hawkins (26), in comparative evaluation studies on rock and superphosphate, found that over long periods of time crops grown on soils receiving rock phosphate may eventually yield as well as those grown on soils receiving superphosphate. However, for short periods of time the crops treated with superphosphate definitely outyield those receiving rock phosphate as the only source of phosphorus.

Larson, Nelson, and Hunter (21) conducted field and laboratory studies on extremely deficient soils to determine the effects of different rates of superphosphate on yield and phosphorus composition of oats and alfalfa and to evaluate the residual effects of initial application of phosphorus over a number of years. Superphosphate was applied broadcast and disced into the soil in the spring of 1946 at rates of 0, 30, 60, 120, and 240 pounds of P₂O₅ per acre. The phosphate applications greatly increased the phosphorus content of the oats and alfalfa. By 1949, the 240-pound application of P₂O₅ was still responsible for large yield increases.

Cheaney, Weihing, and Ford (10) reported the first four years (1950-1953) of data from an experiment to determine the effects of various rates and frequencies of application of rock phosphate and superphosphate on the yield and chemical composition of pasture forage on a Lake Charles clay loam soil. The amounts of P₂O₅ in pounds per acre from each source and frequency of fall application of this amount were 30 pounds every year, 60 pounds every 2 years, 120 pounds every 4 years, 240 pounds every 8 years, and 480 pounds every 16 years. At the end of the fourth year, four yearly 30-pound applications and two 60-pound applications of P₂O₅ from superphosphate had equalled and surpassed the production from single applications of 120 and 240 pounds of P₂O₅ from
the same source. There appeared to be a similar trend with rock phosphate; however, the yearly 30-pound application had not proved very effective.

The chemical composition of pasture forage may be influenced by several factors. Existing data indicate that the most important causes of such differences are age of plant, species present, soil fertility, climatic conditions, and competition from other plants. It is well known that there are variations in the composition of plants at different stages of growth. Beeson (6) indicated that, in general, the nutritive elements attain maximum concentrations during the early life of the plant.

Daniel and Harper (13) found that nitrogen and phosphorus are high in the young plants and decrease toward maturity. The total calcium in the plants increases at first, then decreases at a slower rate than the phosphorus and nitrogen as the plant matures. Hart and Guilbert (19) of the California station reported that the protein, calcium, and phosphorus in range grasses decrease with maturity.

Fraps and Fudge (17) found that the phosphorus and protein contents decreased considerably and lime increased in most of the species as the plants passed from the early vegetative stage through blooming and maturity. The relative change in composition differed considerably, however, with different species. The average protein content ranged from 5.37 to 9.10 per cent in the early stage, from 3.89 to 7.20 per cent in the bloom stage, and from 3.64 to 7.30 per cent at maturity.

Armstrong (4) found that the herbage of a pasture varies botanically to a considerable extent during the season, the variation being determined largely by soil and weather. He also found that from the early part of June onward the percentage of nitrogen and phosphorus in the forage of a pasture gradually decreases, while the proportion of dry matter increases.

The relative production of pastures in terms of animal growth depends not alone on quantity of forage produced but also on quality. Vinall and Wilkins (39) stated that the application of fertilizer to Kentucky bluegrass caused significant increases in protein, calcium, and phosphorus. The application of phosphorus to the soil increased the phosphorus and calcium of both grass and white clover.

From a standpoint of nutritive value, the mineral content of forage crops is highly important. This is especially true with phosphorus, which for the country as a whole is more often than any other element a limiting factor in nutritional requirements for grazing livestock and for crop production.

Beeson (7) and Mitchell (27) pointed out that the most prevalent and widespread nutritional inadequacy among farm animals is phosphorus.

Crampton (11) stated that calcium and phosphorus contents of individual pasture species can be altered by fertilizer treatment. However, he believed that the nutritive value of the forage is not necessarily affected by such differences. Beeson (6) concluded that phosphorus ferti-
lizers can slightly increase the concentration of phosphorus in most species used for forage, particularly where the original phosphorus concentration in the plant is usually low. He pointed out that the phosphorus concentration in the plant, related to application of phosphates to the soil, depends to a large degree on the nature of the soil.

Singleton, Nelson, and Stanberry (35) found that the phosphorus content of alfalfa was increased by 79 per cent and the yield of hay by up to 50 per cent through the application of phosphate fertilizers at an average annual rate of 48 pounds of \( \text{P}_2\text{O}_5 \) per acre to phosphorus-deficient soils.

Alway and Nesom (1) concluded that, in farm practice, phosphorus fertilizers applied on phosphorus-deficient soils usually caused an appreciable increase in the protein content of alfalfa hay. They were able to show an increase of 1 per cent in crude protein as a result of phosphate fertilization in western Minnesota. This is almost double the increase in crude protein reported by Singleton, Nelson, and Stanberry (35), who conducted their trials on phosphorus-deficient soils.

Crampton and Findlayson (12) made extensive pasture trials. They concluded that some factor or factors other than quantitative differences in total protein, fiber, or minerals such as calcium and phosphorus, of the rations must cause differences in the nutritive value of pastures fertilized with lime and phosphate.

Maynard (24) stated that the deleterious effects of low phosphorus occur acutely where dry matter contains 0.12 per cent phosphorus or less. He considered that with forage as the sole feed for livestock during periods of maximum demands, such as growth or lactation, the phosphorus content of the forage should be at least 0.30 per cent.

A number of other investigators have considered that the minimum requirements of beef cattle may be met by a somewhat lower forage phosphorus content. Watkins (41) considered that forage with a phosphorus content of 0.113 per cent would have sufficient phosphorus to meet minimum requirements of beef cattle during the summer months. He stated that forage containing less than 0.113 per cent phosphorus was deficient for beef cattle. Forage containing 0.113 per cent to 0.151 per cent was considered to have a medium phosphorus content; and forage containing over 0.151 per cent was considered high in phosphorus from the standpoint of the nutrition of beef cattle. A forage phosphorus content of 0.093 per cent was considered the minimum winter requirement for beef breeding cows.

Black, Tash, Jones, and Kleberg (9) considered a forage phosphorus content of 0.13 per cent necessary to meet the minimum requirement for beef cattle. Savage and Heller (34) accepted the figure of 0.13 per cent forage phosphorus as the minimum requirement for beef cattle.

Davis (14) stated that in areas where phosphorus is supplied entirely by a pasture program, the minimum level of phosphorus in the forage should be between 0.17 and 0.20 per cent.
Beeson, Bolin, Hickman, and Johnson (8) found that rations containing from 0.11 to 0.15 per cent phosphorus were deficient for growing and fattening steer calves. A ration containing 0.18 per cent phosphorus was adequate to meet the requirements of fattening steers. Guilbert, Gerlaugh, and Madsen (18) also recommended higher phosphorus allowances for beef cattle. They considered that cows nursing calves should have a forage containing not less than 0.18 per cent phosphorus. This percentage in the ration will also be adequate for normal growth of heifers and steers except for those in the 400 to 600 pound weight range.

Davis (14) stated that the level of calcium in the forage below which a deficiency would be assumed must be somewhat arbitrary, inasmuch as beef cattle are less susceptible to a calcium deficiency condition than are dairy cattle in lactation. He concluded that levels below 0.20 per cent calcium on a dry weight basis are inadequate for milking cows, and 0.10 per cent calcium was considered as a minimum that will support even poor beef cattle husbandry.

Henderson and Weakley (20) found that for growing dairy animals the minimum requirements for calcium is 0.35 per cent and for phosphorus 0.20 per cent. They found that whenever conditions existed which enabled bluegrass and white clover to crowd out poverty grass and other undesirable herbage, the calcium and phosphorus contents were well above 0.35 and 0.20 per cent, respectively.

Experimental Procedure

A pasture mixture consisting of Louisiana S-1 white clover, common rye grass, and Dallis grass was grown for two years and used to determine the effects of various rates and times of application of rock phosphate, ordinary superphosphate, and triple superphosphate on the yield, chemical composition, and nutritive value of the forage. The pasture mixture was grown at the West Louisiana Experiment Station, DeRidder, Louisiana, on a Bowie very fine sandy loam. The topography of the experimental area varied from 2 to 3 per cent slope. Little bluestem (Andropogon scoparius), big bluestem (Andropogon gerardi), and broom sedge (Andropogon virginicus) were the common grasses growing on the area before the experimental mixture was established.

Soil samples were taken to a depth of six inches in the experimental area prior to the fertilization of the plots.

Soil analysis showed that this soil was low in available phosphorus (6 parts per million), available potassium (35 p.p.m.), available calcium (200 p.p.m.), and available magnesium (58 p.p.m.). The soil had a pH value of 5.9.

A seedbed was prepared in the fall of 1952 by plowing, discing, and leveling the area.

Four blocks, each consisting of 10 plots completely separated by alleyways, were established in a randomized block design. Each plot measured 10 feet by 60 feet.
Fertilizer treatments involved the use of 33.5 per cent ammonium nitrate, 20 per cent ordinary superphosphate, 45 per cent triple superphosphate, 33 per cent rock phosphate, and 60 per cent muriate of potash. Ammonium nitrate and muriate of potash were applied annually each fall to all plots, except to the check plot, at rates of 24 pounds of nitrogen and 96 pounds of K₂O per acre. Dolomitic limestone was applied before seeding in 1952 at the rate of 4,000 pounds per acre to all plots except the check plots and those receiving a treatment of rock phosphate as indicated below. The different phosphate treatments were as follows:

check (no fertilizer or lime)
15 pounds P₂O₅ per acre from triple superphosphate annually
30 pounds P₂O₅ per acre from triple superphosphate annually
60 pounds P₂O₅ per acre from triple superphosphate annually
120 pounds P₂O₅ per acre from triple superphosphate annually
300 pounds P₂O₅ per acre from triple superphosphate first year only
300 pounds P₂O₅ per acre from ordinary superphosphate first year only
300 pounds P₂O₅ per acre from rock phosphate first year only
600 pounds P₂O₅ per acre from rock phosphate first year only
600 pounds P₂O₅ per acre from rock phosphate first year only (no lime)

The lime was dropped from a fertilizer spreader onto the plots after seedbed preparation. The nitrogen, phosphate, and potash were then broadcast by hand on the plots, and the lime and mixed fertilizer were discied into the soil to a depth of approximately two inches.

Following the application of lime and fertilizers the plots were broadcast seeded with 5 pounds of Louisiana S-1 white clover and 25 pounds of common rye grass per acre. The area was then cultipacked to press the seed into the soil and to conserve moisture. A satisfactory stand of clover and grass was obtained in all the fertilized plots. In the check plots, the seed germinated and died within a short time. Dallis grass was broadcast seeded on the established sod at the rate of 10 pounds per acre in the spring of 1953. Again a successful stand was obtained in all plots except the check plot.

The forage harvested from the check plots, in all instances, consisted of native grasses and weeds. The entire area of each plot was clipped to a height of about two inches with a sickle type mower when there was enough growth to warrant harvesting to determine forage yields. Samples were taken from each replicated treatment at harvest to determine air-dry yields and chemical analysis. The samples were taken at random within each replication. An estimate was made of the percentage of grasses and legumes in the mixture at the time of sampling. The plants were placed in paper bags and allowed to air-dry. After the samples had been taken, the remainder of the vegetation was removed from the plots.

Air-dried plant material from the different replicates of the fertilizer
treatments was ground to 20-mesh fineness in a Wiley mill. The replicates were combined and chemical analyses were made on one composite sample for each fertilizer treatment. A portion of each composite sample was dried in a forced draft oven at 105° C. for 12 hours, after which it was removed and placed in a dessicator and allowed to cool. Between 1 and 2 grams of the dry plant material were weighed on an analytical balance, placed into 250 ml. beakers, and covered with ribbed beaker covers. The plant samples were wet-ashed with nitric and perchloric acids according to the method developed by Toth, Prince, Wallace, and Mikkelson (38). Fifteen milliliters of concentrated nitric acid were added to the samples, and they were allowed to digest for 12 hours without heating. The samples were then placed on a hot plate at low temperature and allowed to digest until the solution was straw-colored. The samples were then removed from the hot plate and allowed to cool. After the samples had cooled, 10 ml. of 70 per cent perchloric acid were added to each sample. The samples were then placed on a hot plate and were allowed to evaporate at low temperature to almost dryness. This procedure was repeated with 1:1 nitric-perchloric acid until a clear color appeared, indicating that all of the organic matter had been removed. The samples then contained the mineral elements and silica.

The mineral elements and silica were taken up in 10 ml. of 5 N hydrochloric acid and heated to almost boiling. Ten milliliters of hot distilled water were added and the samples were immediately filtered through a No. 42 Whatman filter paper into 100 ml. volumetric flask. The samples were washed several times with hot distilled water and allowed to cool before bringing up to volume.

The above solution, labeled “Solution A,” contained the calcium, phosphorus, magnesium, and potassium that were to be determined.

If exactly 1-gram samples of plant material had been used in the 100 ml. of “Solution A,” the dilution factor of the solution would have been 100. Since between 1 and 2 grams of the plant material were used, it was necessary to calculate a dilution factor for each sample in order to determine the per cent of each element in the solution. The dilution factors were calculated as follows:

\[
\text{Dilution factor (d.f.)} = \frac{100}{\text{Wt. of plant sample used}}
\]

The calcium, magnesium, and potassium contents of the plant material were determined by the use of a Beckman Model DU Flame Spectrophotometer. The instrument settings for determining these elements are given in Table 1.

Standard solutions for calibration were made up in 0.5 N hydrochloric acid and contained the following concentrations of calcium, magnesium, and potassium: calcium, 0, 50, 100, 150, 200, and 250 p.p.m.; magnesium, 0, 10, 20, 30, 40, and 50 p.p.m.; potassium, 0, 50, 100, 150, 200, 250, 300, and 400 p.p.m. The unknowns were aspirated through the
**TABLE 1.—Instrument settings for the Beckman Model DU Flame Spectrophotometer, for the determination of calcium, magnesium, and potassium**

<table>
<thead>
<tr>
<th></th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength, Mu</td>
<td>422.1</td>
<td>382.2</td>
<td>765</td>
</tr>
<tr>
<td>Slit width, mm</td>
<td>0.15</td>
<td>0.2</td>
<td>0.04</td>
</tr>
<tr>
<td>Load resistor</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fuel: C₂H₂, psi</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂, psi</td>
<td></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>O₂, psi</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Selector switch</td>
<td>0.1</td>
<td>Full</td>
<td>Off</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>2</td>
<td>Full</td>
<td>Off</td>
</tr>
<tr>
<td>Zero Suppression</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Phototube Blue</td>
<td>(Knob out)</td>
<td>Blue</td>
<td>Red (Knob in)</td>
</tr>
</tbody>
</table>

flame, and the values read were compared with a standard curve. The parts per million and per cent of each mineral element determined in the plant material were calculated as follows:

\[
p.p.m. \text{ Ca in plant} = \text{p.p.m. Ca in solution} \times \text{d.f.} \\
\%	ext{ Ca in plant} = \text{p.p.m. in plant} \times 0.001 \\
\]

Phosphorus was determined with the method developed by Dickman and Bray (16). One milliliter aliquots of the “Solution A” were transferred into 50 ml. volumetric flasks. After diluting the “Solution A” with approximately 35 ml. of distilled water, 10 ml. of 2.5 per cent ammonium molybdate solution in 10 N sulfuric acid and 5 ml. of dilute stannous chloride were added. The solution was made up to volume and agitated. A set of standards ranging from 0.1 to 0.5 p.p.m. phosphorus was prepared simultaneously. The color of each sample was allowed to develop for a minimum of 6 minutes and then the transmittency was read in a Fisher Electrophotometer using a 650 Mu filter. The amount of phosphorus present in the plant material was determined by reference to a standard curve.

The remainder of the composite air-dried samples were sent to the Feed and Fertilizer Laboratory of Louisiana Agricultural Experiment Station, where analyses were made according to the methods of the Association of Official Agricultural Chemists (5). The samples were analyzed for moisture, crude protein, ether extract or fat, nitrogen-free extract, fiber, and ash contents. The percentage of these constituents are reported on a moisture-free basis.

**Experimental Results and Discussion**

The results from the effects of different levels and sources of fertilizer phosphorus on the yield and chemical composition of the rye grass, Louisiana S-1 white clover, and Dallis grass pasture mixture are reported in Tables 2 through 7.

The forage yields for the two years 1953 and 1955 are given in Table 2 and are shown graphically in Figures 1, 2, and 3. The data for 1954
TABLE 2.—The effects of different sources and amounts of fertilizer phosphorus on the yield of a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass on a Bowie very fine sandy loam

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Harvests</th>
<th>1953</th>
<th>1955</th>
<th>Total 1953 and 1955</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>April</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>133</td>
<td>761</td>
<td>894</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,142</td>
<td>116</td>
<td>1,268</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1,275</td>
<td>917</td>
<td>2,192</td>
</tr>
<tr>
<td>15 lbs. P$_2$O$_5$/A. triple superphosphate annually</td>
<td>April</td>
<td>196</td>
<td>378</td>
<td>574</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>637</td>
<td>1,474</td>
<td>2,111</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,206</td>
<td>200</td>
<td>1,406</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,039</td>
<td>2,052</td>
<td>4,091</td>
</tr>
<tr>
<td>30 lbs. P$_2$O$_5$/A. triple superphosphate annually</td>
<td>April</td>
<td>370</td>
<td>655</td>
<td>1,025</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>708</td>
<td>2,102</td>
<td>2,810</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,119</td>
<td>244</td>
<td>1,363</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,197</td>
<td>3,001</td>
<td>5,198</td>
</tr>
<tr>
<td>60 lbs. P$_2$O$_5$/A. triple superphosphate annually</td>
<td>April</td>
<td>444</td>
<td>803</td>
<td>1,247</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>698</td>
<td>1,720</td>
<td>2,418</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,229</td>
<td>252</td>
<td>1,481</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,371</td>
<td>2,775</td>
<td>5,146</td>
</tr>
<tr>
<td>120 lbs. P$_2$O$_5$/A. triple superphosphate annually</td>
<td>April</td>
<td>378</td>
<td>1,861</td>
<td>2,239</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>1,032</td>
<td>2,283</td>
<td>3,315</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,238</td>
<td>319</td>
<td>1,557</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2,598</td>
<td>4,463</td>
<td>7,111</td>
</tr>
<tr>
<td>300 lbs. P$_2$O$_5$/A. triple superphosphate 1st year only</td>
<td>April</td>
<td>554</td>
<td>1,023</td>
<td>1,577</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>1,157</td>
<td>2,900</td>
<td>3,457</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,333</td>
<td>320</td>
<td>1,653</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3,044</td>
<td>3,643</td>
<td>6,687</td>
</tr>
<tr>
<td>300 lbs. P$_2$O$_5$/A. ordinary superphos. 1st year only</td>
<td>April</td>
<td>1,940</td>
<td>1,513</td>
<td>3,253</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>1,200</td>
<td>2,456</td>
<td>3,656</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,454</td>
<td>420</td>
<td>1,874</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4,594</td>
<td>4,189</td>
<td>8,783</td>
</tr>
<tr>
<td>300 lbs. P$_2$O$_5$/A. rock phosphate 1st year only</td>
<td>April</td>
<td>307</td>
<td>467</td>
<td>744</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>669</td>
<td>1,773</td>
<td>2,442</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,166</td>
<td>212</td>
<td>1,378</td>
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<tr>
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<td>Total</td>
<td>2,142</td>
<td>2,452</td>
<td>4,594</td>
</tr>
<tr>
<td>600 lbs. P$_2$O$_5$/A. rock phosphate 1st year only</td>
<td>April</td>
<td>568</td>
<td>804</td>
<td>1,372</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>1,040</td>
<td>2,192</td>
<td>3,232</td>
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<td>Sept.</td>
<td>1,302</td>
<td>340</td>
<td>1,642</td>
</tr>
<tr>
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<td>Total</td>
<td>2,910</td>
<td>3,386</td>
<td>6,296</td>
</tr>
<tr>
<td>600 lbs. P$_2$O$_5$/A. rock phos. 1st yr. only (no lime)</td>
<td>April</td>
<td>444</td>
<td>611</td>
<td>1,055</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>752</td>
<td>2,061</td>
<td>2,813</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>1,302</td>
<td>304</td>
<td>1,606</td>
</tr>
<tr>
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<td>Total</td>
<td>2,498</td>
<td>2,976</td>
<td>5,474</td>
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</table>

L.S.D. @ 5% level 1,161 880 1,861
L.S.D. @ 1% level 1,567 1,188 2,514
FIGURE 1.—The effects of the use of different sources and amounts of phosphorus on the yields from a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1953.

FIGURE 2.—The effects of the use of different sources and amounts of phosphorus on the yields from a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1955.
were omitted because of extremely low rainfall during most of the spring and summer seasons. The yields were low, and little differences were obtained among the different fertilizer treatments. The data reported for 1953 and 1955 were obtained under normal rainfall conditions.

Examination of the data in Table 2 shows that significant differences in dry matter production occurred among the different phosphate treatments. The differences are significant at both the 5 per cent and 1 per cent levels. In general, the dry matter production per acre increased as the amount of available \( \text{P}_2\text{O}_5 \) applied per acre was increased. It should be noted, however, that the rates of \( \text{P}_2\text{O}_5 \) are given in terms of total \( \text{P}_2\text{O}_5 \) applied per acre. The total \( \text{P}_2\text{O}_5 \) of ordinary and triple superphosphate is considered available; whereas in rock phosphate, only 10 per cent of the total \( \text{P}_2\text{O}_5 \) is considered available. In the case of the T.V.A. rock phosphate used in this experiment, 3 per cent of the material was available \( \text{P}_2\text{O}_5 \).

In 1953, the highest yield of dry matter obtained in the experiment was 4,594 pounds per acre from the application of 300 pounds of \( \text{P}_2\text{O}_5 \) from ordinary superphosphate (Table 2). The best yield of dry matter from rock phosphate was 2,910 pounds per acre from the application of 600 pounds of \( \text{P}_2\text{O}_5 \).

In 1955, the highest yield of dry matter was 4,436 pounds per acre from 120 pounds of \( \text{P}_2\text{O}_5 \) applied annually as triple superphosphate. A comparison of triple superphosphate and ordinary superphosphate at
the 300 pounds of $P_2O_5$ level shows that ordinary superphosphate gave a significantly higher total of dry matter per acre for the two-year period (Table 2). This significantly higher yield obtained from ordinary superphosphate may be attributed partly to the presence of sulphur in this source of phosphorus. However, in other phosphate studies at this station, no increase in yields was obtained from the use of sulphur with triple superphosphate.

The highest total yield of dry matter among the rock phosphate treatments was obtained from 600 pounds of $P_2O_5$ per acre. This yield was lower than the yield from the better superphosphate treatment, indicating that more rock phosphate was needed for maximum production. For the two years combined, the highest total yield, 8,783 pounds per acre, in the superphosphate series was produced by the application of 300 pounds of $P_2O_5$ per acre from ordinary superphosphate (Table 2).

Rock phosphate applied at the rate of 600 pounds of $P_2O_5$ per acre appears to be comparable to triple superphosphate applied at the rate of 300 pounds of $P_2O_5$ per acre for forage production. In other experiments, ordinary superphosphate has been found to be superior to triple superphosphate or rock phosphate for forage production on soils at DeRidder.

The data in Table 2 indicate that more than 60 pounds of $P_2O_5$ per acre applied annually from superphosphate is needed to maintain yields of forage under meadow conditions.

Data in Tables 3, 4, and 8 show that the crude protein content of the forage varied with the season and with botanical composition. Generally, the crude protein of the forage was higher in the spring and early summer when a relatively large percentage of the forage was composed of legumes. The crude protein content of the forage at the three sampling dates ranged from high values in the vicinity of 10 to 15 per cent in April and June to low values of about 5 to 6 per cent in September. The forage collected from the check plots, which consisted of native grasses, was low in crude protein content throughout the growing season.

Morrison (29) states that the protein requirements of a mature pregnant cow weighing 900 pounds will not be met when protein in forage falls below 6 per cent. For beef cows during the lactating period a forage protein requirement of 9 per cent is suggested. This requirement is based on a crude protein digestibility of 60 per cent, and consumption by the cow of 18 to 20 pounds of dry matter daily.

Guilbert, Gerlaugh and Madsen (18) state that 5 per cent digestible protein in the ration is adequate, except for heifers and steers weighing less than 800 pounds, bulls, and fattening cattle. If the protein in the forage is considered 60 per cent digestible, the crude protein content of the forage should be approximately 8.3 per cent in order to provide an allowance that would be generally adequate.

The data in Tables 3 and 4 show the crude protein content of the forage from all treatments, except from the check plots, to be approximately equal to or above the recommended minimum for beef cattle in
Fifteen pounds $P_2O_5$ per acre from concentrated superphosphate annually.

Thirty pounds $P_2O_5$ per acre from concentrated superphosphate annually.
Sixty pounds $P_2O_5$ per acre from concentrated superphosphate annually.

One hundred and twenty pounds $P_2O_5$ per acre from concentrated superphosphate annually.
Six hundred pounds $P_2O_5$ per acre from rock phosphate first year only.

Three hundred pounds $P_2O_5$ per acre from rock phosphate first year only.

Six hundred pounds $P_2O_5$ per acre from rock phosphate first year only.
Six hundred pounds $P_2O_3$ per acre from rock phosphate first year only (no lime).

April and June. By September, however, the crude protein content of the forage from all plots was well below the required minimum.

The production of crude protein per acre was greater as the available $P_2O_5$ applied per acre was increased (Figures 4, 5, and 6). The percentage of crude protein in the forage did not necessarily increase, as shown by data in Tables 3 and 4. This greater production of crude protein as the available $P_2O_3$ applied per acre was increased was due to greater yield of dry matter.

The percentage of fat and ash in the forage was generally higher in April and June than in September. The fiber content of the plants increased as the season advanced and plants reached maturity.

As a general measure of the nutritive value of a feed, digestion coefficients are used to compute the content of total digestible nutrients (T.D.N.). Although data on the total digestible nutrients are not available, certain speculations may be made. By referring to Tables 3 and 4, it is evident that the crude protein content of the forage was increased by fertilization. In general, the crude protein content was higher when a large percentage of the forage was composed of legumes.

An attempt was made to evaluate forage quality as characterized by a carbohydrate-protein ratio. This ratio was calculated as follows:

$$\frac{\% \text{ Nitrogen-free Extract} + \% \text{ Crude Fiber}}{\% \text{ Crude Protein}} = \text{Carbohydrate-protein Ratio}$$

The carbohydrate-protein ratios were narrower in the spring and summer, when the forage was relatively immature. The presence of
<table>
<thead>
<tr>
<th>Treatments</th>
<th>Harvests</th>
<th>Crude Protein</th>
<th>Fat</th>
<th>Fiber</th>
<th>Ash</th>
<th>N-free Extract</th>
<th>Carbo. Prot. Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>April</td>
<td>6.29</td>
<td>1.76</td>
<td>34.20</td>
<td>7.44</td>
<td>50.01</td>
<td>13.39</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>5.80</td>
<td>2.13</td>
<td>33.88</td>
<td>7.55</td>
<td>50.64</td>
<td>14.57</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A.</td>
<td>April</td>
<td>10.45</td>
<td>3.03</td>
<td>27.09</td>
<td>11.24</td>
<td>48.19</td>
<td>7.20</td>
</tr>
<tr>
<td>triple superphosphate annually</td>
<td>June</td>
<td>9.90</td>
<td>1.76</td>
<td>29.75</td>
<td>10.73</td>
<td>48.05</td>
<td>7.86</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>5.52</td>
<td>2.13</td>
<td>36.12</td>
<td>6.90</td>
<td>49.74</td>
<td>15.55</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A.</td>
<td>April</td>
<td>9.48</td>
<td>3.12</td>
<td>27.23</td>
<td>11.28</td>
<td>48.89</td>
<td>8.03</td>
</tr>
<tr>
<td>triple superphosphate annually</td>
<td>June</td>
<td>10.42</td>
<td>1.61</td>
<td>30.06</td>
<td>9.73</td>
<td>48.18</td>
<td>7.51</td>
</tr>
<tr>
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<td>Sept.</td>
<td>5.84</td>
<td>1.76</td>
<td>34.88</td>
<td>8.54</td>
<td>48.98</td>
<td>14.36</td>
</tr>
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<td>8.98</td>
<td>3.15</td>
<td>27.47</td>
<td>10.59</td>
<td>49.81</td>
<td>8.61</td>
</tr>
<tr>
<td>triple superphosphate annually</td>
<td>June</td>
<td>10.75</td>
<td>1.54</td>
<td>30.64</td>
<td>10.34</td>
<td>46.76</td>
<td>7.20</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>5.56</td>
<td>2.11</td>
<td>34.62</td>
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<td>49.07</td>
<td>15.05</td>
</tr>
<tr>
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<td>April</td>
<td>10.00</td>
<td>2.86</td>
<td>28.25</td>
<td>11.26</td>
<td>47.63</td>
<td>7.59</td>
</tr>
<tr>
<td>triple superphosphate annually</td>
<td>June</td>
<td>13.74</td>
<td>1.59</td>
<td>28.23</td>
<td>10.88</td>
<td>45.56</td>
<td>5.37</td>
</tr>
<tr>
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<td>1.64</td>
<td>36.16</td>
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<td>48.50</td>
<td>15.97</td>
</tr>
<tr>
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<td>April</td>
<td>9.01</td>
<td>2.93</td>
<td>28.60</td>
<td>12.33</td>
<td>47.13</td>
<td>8.41</td>
</tr>
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<td>June</td>
<td>11.81</td>
<td>1.59</td>
<td>28.86</td>
<td>11.01</td>
<td>46.73</td>
<td>6.40</td>
</tr>
<tr>
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<td>Sept.</td>
<td>5.07</td>
<td>1.58</td>
<td>36.47</td>
<td>8.02</td>
<td>48.86</td>
<td>16.83</td>
</tr>
<tr>
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<td>9.51</td>
<td>2.90</td>
<td>29.14</td>
<td>11.58</td>
<td>47.07</td>
<td>8.19</td>
</tr>
<tr>
<td>ordinary superphosphate 1st year only</td>
<td>June</td>
<td>14.89</td>
<td>1.56</td>
<td>28.10</td>
<td>11.93</td>
<td>43.52</td>
<td>4.81</td>
</tr>
<tr>
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<td>Sept.</td>
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<td>1.41</td>
<td>35.87</td>
<td>8.78</td>
<td>48.65</td>
<td>15.98</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
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<td>3.07</td>
<td>27.76</td>
<td>11.73</td>
<td>47.79</td>
<td>7.83</td>
</tr>
<tr>
<td>rock phosphate 1st year only</td>
<td>June</td>
<td>9.80</td>
<td>1.44</td>
<td>28.30</td>
<td>10.76</td>
<td>49.70</td>
<td>7.96</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
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<td>1.60</td>
<td>36.01</td>
<td>8.63</td>
<td>48.14</td>
<td>14.97</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
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<td>10.00</td>
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<td>27.70</td>
<td>11.84</td>
<td>47.34</td>
<td>7.50</td>
</tr>
<tr>
<td>rock phosphate 1st year only</td>
<td>June</td>
<td>12.01</td>
<td>1.51</td>
<td>28.37</td>
<td>11.10</td>
<td>47.10</td>
<td>6.28</td>
</tr>
<tr>
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<td>1.70</td>
<td>35.81</td>
<td>8.65</td>
<td>48.43</td>
<td>15.57</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
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<td>3.19</td>
<td>28.44</td>
<td>11.45</td>
<td>47.73</td>
<td>8.29</td>
</tr>
<tr>
<td>rock phosphate 1st year only</td>
<td>June</td>
<td>10.59</td>
<td>1.53</td>
<td>30.01</td>
<td>10.81</td>
<td>47.06</td>
<td>7.28</td>
</tr>
<tr>
<td>only (no lime)</td>
<td>Sept.</td>
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<td>1.80</td>
<td>35.62</td>
<td>8.25</td>
<td>48.91</td>
<td>15.60</td>
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<td>Treatments</td>
<td>Harvests</td>
<td>Composition of dry matter</td>
<td>Carbo. Prot. Ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crude</td>
<td>Protein</td>
<td>Fat</td>
<td>Fiber</td>
<td>Ash</td>
<td>N-free Extract</td>
</tr>
<tr>
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<td>April</td>
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<td>1.04</td>
<td>30.12</td>
<td>10.92</td>
<td>%</td>
<td>49.02</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>7.08</td>
<td>2.01</td>
<td>31.86</td>
<td>9.33</td>
<td>%</td>
<td>49.72</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>5.11</td>
<td>1.23</td>
<td>33.03</td>
<td>10.60</td>
<td>%</td>
<td>50.03</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A.</td>
<td>April</td>
<td>9.25</td>
<td>1.18</td>
<td>30.37</td>
<td>11.28</td>
<td>%</td>
<td>47.92</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>8.76</td>
<td>1.74</td>
<td>32.42</td>
<td>8.70</td>
<td>%</td>
<td>48.38</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>5.83</td>
<td>1.05</td>
<td>35.39</td>
<td>10.14</td>
<td>%</td>
<td>47.59</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A.</td>
<td>April</td>
<td>9.27</td>
<td>1.11</td>
<td>30.58</td>
<td>11.60</td>
<td>%</td>
<td>47.44</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>10.91</td>
<td>1.83</td>
<td>31.77</td>
<td>8.72</td>
<td>%</td>
<td>46.77</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
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<td>0.97</td>
<td>35.12</td>
<td>10.42</td>
<td>%</td>
<td>46.65</td>
</tr>
<tr>
<td>60 lbs. P₂O₅/A.</td>
<td>April</td>
<td>8.67</td>
<td>1.00</td>
<td>30.08</td>
<td>11.75</td>
<td>%</td>
<td>48.50</td>
</tr>
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<td>June</td>
<td>8.70</td>
<td>1.55</td>
<td>32.61</td>
<td>9.11</td>
<td>%</td>
<td>48.03</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>5.10</td>
<td>0.95</td>
<td>36.61</td>
<td>9.50</td>
<td>%</td>
<td>47.84</td>
</tr>
<tr>
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<td>April</td>
<td>11.05</td>
<td>0.93</td>
<td>31.32</td>
<td>12.18</td>
<td>%</td>
<td>41.54</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>8.12</td>
<td>1.22</td>
<td>36.65</td>
<td>8.32</td>
<td>%</td>
<td>45.69</td>
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<tr>
<td>annually</td>
<td>Sept.</td>
<td>5.83</td>
<td>1.02</td>
<td>35.39</td>
<td>9.71</td>
<td>%</td>
<td>48.05</td>
</tr>
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<td>April</td>
<td>10.21</td>
<td>1.09</td>
<td>32.08</td>
<td>11.81</td>
<td>%</td>
<td>44.81</td>
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<td>June</td>
<td>10.33</td>
<td>1.69</td>
<td>33.07</td>
<td>8.26</td>
<td>%</td>
<td>46.65</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>5.31</td>
<td>1.05</td>
<td>34.59</td>
<td>9.87</td>
<td>%</td>
<td>48.98</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>10.59</td>
<td>1.17</td>
<td>32.38</td>
<td>10.72</td>
<td>%</td>
<td>45.14</td>
</tr>
<tr>
<td>ordinary superphosphate</td>
<td>June</td>
<td>9.55</td>
<td>1.47</td>
<td>33.72</td>
<td>8.98</td>
<td>%</td>
<td>46.28</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>5.74</td>
<td>0.92</td>
<td>33.07</td>
<td>11.18</td>
<td>%</td>
<td>49.09</td>
</tr>
<tr>
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<td>8.82</td>
<td>1.04</td>
<td>30.41</td>
<td>11.20</td>
<td>%</td>
<td>48.53</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>9.88</td>
<td>1.82</td>
<td>32.14</td>
<td>8.57</td>
<td>%</td>
<td>47.59</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>6.03</td>
<td>1.07</td>
<td>33.74</td>
<td>10.89</td>
<td>%</td>
<td>48.27</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>9.20</td>
<td>1.13</td>
<td>30.17</td>
<td>11.68</td>
<td>%</td>
<td>47.82</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>10.38</td>
<td>1.76</td>
<td>33.54</td>
<td>9.03</td>
<td>%</td>
<td>45.29</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>6.54</td>
<td>1.03</td>
<td>32.83</td>
<td>11.52</td>
<td>%</td>
<td>48.08</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>9.27</td>
<td>1.20</td>
<td>31.53</td>
<td>11.24</td>
<td>%</td>
<td>46.76</td>
</tr>
<tr>
<td>rock phosphate first year only (no lime)</td>
<td>June</td>
<td>10.60</td>
<td>1.85</td>
<td>31.99</td>
<td>9.15</td>
<td>%</td>
<td>46.41</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>5.94</td>
<td>1.15</td>
<td>34.55</td>
<td>9.33</td>
<td>%</td>
<td>49.03</td>
</tr>
</tbody>
</table>
FIGURE 4.—The effects of the use of different sources and amounts of phosphorus on the production of crude protein in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1953.

FIGURE 5.—The effects of the use of different sources and amounts of phosphorus on the production of crude protein in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1955.
FIGURE 6.—The effects of the use of different sources and amounts of phosphorus on the production of crude protein in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1953 and 1955.

Legumes in the mixture also contributed to narrow ratios. Wide ratios were obtained in the fall, when the forage consisted of mature grasses. These wide ratios may be attributed to low protein and high fiber contents of the mature grasses. Maynard (25) states that as this ratio becomes wider, the digestibility of all nutrients tends to be lower. It is apparent from the data in Tables 3 and 4 that by September the forage from all plots was of poor quality.

The calcium, phosphorus, magnesium, and potassium contents of the forage harvested during different months for the two years are given in Tables 5 and 6, and a summary of the two years of data appears in Table 7.

The mineral contents of the forage for the different months differed greatly. The mineral contents of the forage from all treatments was generally higher in April and June than in September. The magnesium content of the forage varied less with season than did calcium, phosphorus, or potassium, which decreased in content with advance in season. This may be attributed to the stage of maturity and to changes in the botanical composition as shown in Table 8. The botanical composition of the clover-grass mixture showed abrupt changes with season. Thus, a considerable part of the chemical variation noted was assumed to be due to differences in the proportions of the several species, and their proportions were greatly influenced by the kind and amounts of fertilizer phosphate applied.
TABLE 5.—The effects of different sources and amounts of fertilizer phosphorus on the contents of magnesium, potassium, calcium, and phosphorus in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass on a Bowie very fine sandy loam, 1953

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Harvests</th>
<th>Composition of dry matter</th>
<th>Ca:P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mg</td>
<td>K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>No treatment</td>
<td>A—ril</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>0.18</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.19</td>
<td>0.76</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.36</td>
<td>2.92</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.27</td>
<td>2.10</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>0.22</td>
<td>1.33</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.37</td>
<td>2.77</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.29</td>
<td>2.20</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>0.25</td>
<td>1.11</td>
</tr>
<tr>
<td>60 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.34</td>
<td>2.73</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.29</td>
<td>2.14</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>0.27</td>
<td>1.19</td>
</tr>
<tr>
<td>120 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.35</td>
<td>2.88</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.35</td>
<td>2.23</td>
</tr>
<tr>
<td>annually</td>
<td>Sept.</td>
<td>0.26</td>
<td>1.46</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.31</td>
<td>2.35</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.32</td>
<td>2.00</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.30</td>
<td>1.76</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.29</td>
<td>2.47</td>
</tr>
<tr>
<td>ordinary superphosphate</td>
<td>June</td>
<td>0.36</td>
<td>2.05</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.29</td>
<td>1.75</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.37</td>
<td>2.83</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>0.31</td>
<td>1.84</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.27</td>
<td>1.34</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.40</td>
<td>2.74</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>0.34</td>
<td>2.01</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.29</td>
<td>1.44</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.31</td>
<td>2.77</td>
</tr>
<tr>
<td>rock phosphate 1st year only (no lime)</td>
<td>June</td>
<td>0.28</td>
<td>2.11</td>
</tr>
</tbody>
</table>

In 1953, the growth in early season was primarily rye grass and white clover. The amount of clover present in the plots was dependent on the amount of available P₂O₅ applied per acre as shown in Table 8. In the late summer and early fall the vegetation was predominantly Dallis grass in all of the fertilized plots.

The invasion of lespedeza into the plots where the lower rates of available phosphorus were applied was evident in the fall of 1954 and was pronounced in the spring and summer months of 1955, when it made
TABLE 6.—The effects of different sources and amounts of fertilizer phosphorus on the contents of magnesium, potassium, calcium, and phosphorus in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass on a Bowie very fine sandy loam, 1955

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Composition of dry matter</th>
<th>Ca:P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg</td>
<td>K</td>
</tr>
<tr>
<td>No treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.31</td>
<td>1.59</td>
</tr>
<tr>
<td>June</td>
<td>0.22</td>
<td>1.30</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.26</td>
<td>0.58</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A. triple superphosphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.29</td>
<td>2.29</td>
</tr>
<tr>
<td>June</td>
<td>0.29</td>
<td>1.33</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.26</td>
<td>0.80</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A. triple superphosphate annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.31</td>
<td>2.26</td>
</tr>
<tr>
<td>June</td>
<td>0.31</td>
<td>1.38</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.27</td>
<td>1.00</td>
</tr>
<tr>
<td>60 lbs. P₂O₅/A. triple superphosphate annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.38</td>
<td>2.21</td>
</tr>
<tr>
<td>June</td>
<td>0.32</td>
<td>1.59</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.25</td>
<td>0.86</td>
</tr>
<tr>
<td>120 lbs. P₂O₅/A. triple superphosphate annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.37</td>
<td>2.49</td>
</tr>
<tr>
<td>June</td>
<td>0.25</td>
<td>1.70</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.29</td>
<td>0.91</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A. triple superphosphate 1st year only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.35</td>
<td>2.41</td>
</tr>
<tr>
<td>June</td>
<td>0.30</td>
<td>1.38</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.27</td>
<td>0.82</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A. ordinary superphosphate 1st year only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.37</td>
<td>2.24</td>
</tr>
<tr>
<td>June</td>
<td>0.29</td>
<td>1.43</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.29</td>
<td>1.06</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A. rock phosphate 1st year only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.31</td>
<td>2.38</td>
</tr>
<tr>
<td>June</td>
<td>0.32</td>
<td>1.42</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.28</td>
<td>0.88</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A. rock phosphate 1st year only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.34</td>
<td>2.42</td>
</tr>
<tr>
<td>June</td>
<td>0.29</td>
<td>1.40</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.28</td>
<td>1.00</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A. rock phosphate 1st year only (no lime)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>0.30</td>
<td>2.32</td>
</tr>
<tr>
<td>June</td>
<td>0.27</td>
<td>1.50</td>
</tr>
<tr>
<td>Sept.</td>
<td>0.25</td>
<td>0.96</td>
</tr>
</tbody>
</table>

up as much as 60 per cent of the vegetative growth (Table 8). The occurrence of lespedeza in these plots may be attributed to the spreading of seed through animal droppings in the area prior to the establishing of the test in fall of 1952.

The data in Table 8 for 1955 also show that in plots where there was a relatively high percentage of white clover in the spring a small percentage of lespedeza was present in the summer and fall. This may be associated with a higher phosphorus requirement for white clover, and
TABLE 7.—The effects of different sources and amounts of fertilizer phosphorus on the contents of magnesium, potassium, calcium, and phosphorus in a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass on a Bowie very fine sandy loam (Mean of 1953 and 1955)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Harvests</th>
<th>Mg %</th>
<th>K %</th>
<th>Ca %</th>
<th>P %</th>
<th>Ca:P Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>April</td>
<td>0.31</td>
<td>1.59</td>
<td>0.74</td>
<td>0.08</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>0.25</td>
<td>1.11</td>
<td>0.69</td>
<td>0.07</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.23</td>
<td>0.67</td>
<td>0.40</td>
<td>0.06</td>
<td>6.7</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A. annually</td>
<td>April</td>
<td>0.33</td>
<td>2.61</td>
<td>0.94</td>
<td>0.15</td>
<td>6.3</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.28</td>
<td>1.72</td>
<td>0.63</td>
<td>0.13</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.24</td>
<td>1.07</td>
<td>0.36</td>
<td>0.06</td>
<td>6.0</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A. annually</td>
<td>April</td>
<td>0.36</td>
<td>2.52</td>
<td>0.99</td>
<td>0.16</td>
<td>6.2</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.30</td>
<td>1.79</td>
<td>0.69</td>
<td>0.16</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.26</td>
<td>1.06</td>
<td>0.36</td>
<td>0.09</td>
<td>4.0</td>
</tr>
<tr>
<td>60 lbs. P₂O₅/A. annually</td>
<td>April</td>
<td>0.36</td>
<td>2.47</td>
<td>0.97</td>
<td>0.21</td>
<td>4.6</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.31</td>
<td>1.87</td>
<td>0.66</td>
<td>0.22</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.26</td>
<td>1.03</td>
<td>0.36</td>
<td>0.08</td>
<td>4.5</td>
</tr>
<tr>
<td>120 lbs. P₂O₅/A. annually</td>
<td>April</td>
<td>0.36</td>
<td>2.69</td>
<td>1.06</td>
<td>0.27</td>
<td>3.9</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.30</td>
<td>1.97</td>
<td>0.65</td>
<td>0.23</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>0.28</td>
<td>1.19</td>
<td>0.41</td>
<td>0.11</td>
<td>3.7</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.33</td>
<td>2.38</td>
<td>1.01</td>
<td>0.26</td>
<td>3.9</td>
</tr>
<tr>
<td>triple superphosphate</td>
<td>June</td>
<td>0.31</td>
<td>1.69</td>
<td>0.67</td>
<td>0.19</td>
<td>3.5</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.29</td>
<td>1.29</td>
<td>0.42</td>
<td>0.11</td>
<td>3.8</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.33</td>
<td>2.36</td>
<td>0.97</td>
<td>0.25</td>
<td>3.9</td>
</tr>
<tr>
<td>ordinary superphosphate</td>
<td>June</td>
<td>0.33</td>
<td>1.74</td>
<td>0.76</td>
<td>0.19</td>
<td>4.0</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.29</td>
<td>1.41</td>
<td>0.46</td>
<td>0.11</td>
<td>4.2</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.34</td>
<td>2.61</td>
<td>0.76</td>
<td>0.15</td>
<td>5.1</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>0.32</td>
<td>1.63</td>
<td>0.65</td>
<td>0.12</td>
<td>5.4</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.28</td>
<td>1.11</td>
<td>0.37</td>
<td>0.08</td>
<td>4.6</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.37</td>
<td>2.58</td>
<td>1.01</td>
<td>0.17</td>
<td>5.9</td>
</tr>
<tr>
<td>rock phosphate</td>
<td>June</td>
<td>0.32</td>
<td>1.71</td>
<td>0.69</td>
<td>0.16</td>
<td>4.3</td>
</tr>
<tr>
<td>1st year only</td>
<td>Sept.</td>
<td>0.29</td>
<td>1.22</td>
<td>0.42</td>
<td>0.08</td>
<td>5.3</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A.</td>
<td>April</td>
<td>0.31</td>
<td>2.55</td>
<td>0.85</td>
<td>0.20</td>
<td>4.3</td>
</tr>
<tr>
<td>rock phosphate 1st year only (no lime)</td>
<td>June</td>
<td>0.28</td>
<td>1.81</td>
<td>0.73</td>
<td>0.19</td>
<td>3.8</td>
</tr>
</tbody>
</table>

with plant competition between the clover and lespedeza in the early spring.

The addition of phosphorus to the soil increased the phosphorus content of the forage at all the rates of phosphorus tested (Tables 5, 6, and 7). In general, the percentage of phosphorus in the forage increased as the rate of available P₂O₅ applied per acre was increased. However, in 1953, which was the first crop year, the application of more than 120 pounds of P₂O₅ per acre from superphosphate gave very small increases
### Table 8

The effects of different sources and amounts of fertilizer phosphorus on the botanical composition of a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass on a Bowie very fine sandy loam, 1953 and 1955

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1953</th>
<th>1955</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Harvests</td>
<td>Estimated Per Cent</td>
</tr>
<tr>
<td></td>
<td>Legumes</td>
<td>Grasses</td>
</tr>
<tr>
<td>No treatment</td>
<td>April</td>
<td>100*</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>100*</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100*</td>
</tr>
<tr>
<td>15 lbs. P₂O₅/A. triple superphosphate annually</td>
<td>April</td>
<td>5¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>20¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>30 lbs. P₂O₅/A. triple superphosphate annually</td>
<td>April</td>
<td>10¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>30¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>60 lbs. P₂O₅/A. triple superphosphate annually</td>
<td>April</td>
<td>10¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>30¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>120 lbs. P₂O₅/A. triple superphosphate annually</td>
<td>April</td>
<td>15¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>60¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A. ordinary superphosphate 1st year only</td>
<td>April</td>
<td>10¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>50¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>300 lbs. P₂O₅/A. rock phosphate 1st year only</td>
<td>April</td>
<td>15¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>80¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A. rock phosphate 1st year only</td>
<td>April</td>
<td>10¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>30¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
<tr>
<td>600 lbs. P₂O₅/A. rock phosphate 1st year only (no lime)</td>
<td>April</td>
<td>5¹</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>15¹</td>
</tr>
<tr>
<td></td>
<td>Sept.</td>
<td>100⁴</td>
</tr>
</tbody>
</table>

¹White Clover, ²Lespedeza, ³Rye grass, ⁴Dallis grass, ⁵Native grass

in the phosphorus content of the forage. The phosphorus content of the forage from the rock phosphate treatments was slightly higher when no lime was applied. The percentage of phosphorus in the forage from the application of 600 pounds of P₂O₅ per acre from rock phosphate, without lime, was approximately equal to that from 60 pounds of P₂O₅ per acre from triple superphosphate applied annually.

There were considerable differences in the phosphorus uptake per acre among the different phosphate treatments, as shown in Figures 7,
The phosphorus uptake per acre from 300 pounds of \( \text{P}_2\text{O}_5 \) applied as ordinary superphosphate was considerably higher than that from 300 pounds of \( \text{P}_2\text{O}_5 \) applied as triple superphosphate. However, the percentage of phosphorus in the forage was about the same. The higher uptake of phosphorus per acre from the ordinary superphosphate was due to a higher yield. By 1955, the differences in yield between these two treatments were considerably less, and the phosphorus uptake per acre for the two treatments was almost equal (Figure 8). The phosphorus uptake per acre from the annual application of 120 pounds of \( \text{P}_2\text{O}_5 \) per acre from triple superphosphate surpassed that of the initial application of 300 pounds of \( \text{P}_2\text{O}_5 \) per acre from triple or ordinary superphosphate the third year. However, the highest total phosphorus uptake for the two years was obtained from ordinary superphosphate (Figure 9). The total phosphorus uptake per acre from initial application of 600 pounds of \( \text{P}_2\text{O}_5 \) per acre from rock phosphate, with and without lime, was equal to that from triple superphosphate applied at the rate of 60 pounds of \( \text{P}_2\text{O}_5 \) annually.

The results of the chemical analysis (Tables 5, 6, and 7) show that the phosphorus content in the forage was low enough to become deficient for the proper nutrition of beef cattle by September. Phosphorus in the forage may be on the borderline of deficiency for a considerable period before this. The phosphorus content of the forage collected from the check plots, which consisted of native grasses, was considerably below the minimum requirements for beef cattle for all seasons.

On the basis of a minimum requirement of 0.13 per cent phosphorus in the forage (9, 34), it is apparent from the data in Table 7 that the phosphorus content in the forage during April and June from the fertilized plots is equal to or well above the minimum requirements for beef cattle, but not in September.

If the minimum phosphorus requirement of 0.18 per cent recommended by Guilbert, Gerlaugh, and Madsen (18) is used as a standard, the forage from all plots receiving less than 60 pounds of available \( \text{P}_2\text{O}_5 \) per acre annually is deficient in phosphorus for all seasons. It is apparent from the data that the phosphorus content in the forage from all fertilized plots will be nearing the critical levels before the end of the summer season.

The calcium content of the forage from all treatments (Tables 5, 6, and 7) was generally higher in the spring than in the summer or fall. However, the calcium content of the forage was relatively high throughout the growing season. Morrison (29) states that when legume hay or mixed hay containing considerable legumes forms any important part of the ration for cattle, sheep, or horses, they will ordinarily have an abundance of calcium. Even when no legume roughage is fed to these classes of livestock, there will usually be no deficiency of calcium unless the roughage is grown on soil very low in calcium.
FIGURE 7.—The effects of the use of different sources and amounts of phosphorus on the P$_2$O$_5$ taken up by a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1953.

FIGURE 8.—The effects of the use of different sources and amounts of phosphorus on the P$_2$O$_5$ taken up by a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1955.
FIGURE 9.—The effects of the use of different sources and amounts of phosphorus on P₂O₅, taken up by a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass, 1953 and 1955.

Most successful stockmen have at least a fair proportion of legume forage mixed with the total roughage available and are in that way supplying liberal amounts of calcium as naturally contained in the rations.

Examination of the data in Tables 5, 6, and 7 shows that the calcium content of forage from treatments receiving no lime was almost as high as in those treatments receiving lime. The data indicate that the native grasses growing on Bowie very fine sandy loam soil are relatively high in calcium, even though they are growing on soil of low calcium content and with pH 5.8. The application of lime to this soil is necessary to bring about proper soil reaction for the growth of white clover and grasses.

It is evident from these data that a phosphorus deficiency is more likely to occur than is a calcium deficiency.

It is known that calcium and phosphorus have definite relationships in animal nutrition. Calcium-phosphorus ratios in the ration as a whole have been found to be of importance. For the larger farm animals, suitable ratios vary from about 1 to 2.1 parts of calcium to each part of phosphorus. Ruminants have a greater tolerance for severely unbalanced calcium-phosphorus ratios, especially high calcium intakes, than have swine (29). While the desirable calcium-phosphorus ratio has been defined as one lying between 2:1 and 1:2, adequate nutrition is possible outside these limits. The optimum ratio varies somewhat according to the levels of these elements. With plenty of vitamin D in the ration, the
ratio becomes less important, and more efficient utilization is made of the amounts of the elements present (25). For example, rations having a calcium-phosphorus ratio as wide as 6.5:1 have been entirely satisfactory for raising dairy calves (29). Considering the ratios reported by Morrison and Maynard as ideal, it will be seen that the ratios obtained in this experiment are relatively wide. However, the ratios fall within the range of satisfactory limits.

The data in Tables 5, 6, and 7 show that the calcium-phosphorus ratios varied with treatment, botanical composition, and season. The mean calcium-phosphorus ratios for 1953 and 1955 were 4.47:1 and 5.45:1 respectively. The data show that wider calcium-phosphorus ratios were obtained when the forage consisted largely of grasses. This result appears to be due to a high calcium content associated with a low phosphorus content in the grasses and not to a greater prevalence of clover.

The mean percentage of calcium was about the same for the different fertilizer treatments, while the mean percentage of phosphorus increased as the rate of phosphorus application increased. This difference in the percentage of phosphorus is reflected in the narrow calcium-phosphorus ratios for the plots receiving the higher rates of phosphorus.

A highly significant positive correlation was found between yield and the amount of available $P_2O_5$ applied per acre in 4 of the 6 correlation values determined. Other correlations between the contents of the different mineral elements in the plant material were inconsistent.

**Summary and Conclusions**

A study has been made of the effects of three sources of phosphorus, applied at different rates and times, on the yield, chemical composition, and nutritive value of a mixture of rye grass, Louisiana S-1 white clover, and Dallis grass grown under field conditions.

Significant differences in the dry matter production were obtained among the different phosphate treatments.

The highest total yield of dry matter for two years (1953 and 1955) was 8,783 pounds per acre from the superphosphate series. This yield was obtained from the initial application of 300 pounds of $P_2O_5$ per acre applied in the fall of 1952.

The highest total yield of dry matter from the rock phosphate treatments was 6,246 pounds per acre. This yield was obtained from the initial application of 600 pounds of $P_2O_5$ per acre.

Rock phosphate applied at the rate of 600 pounds of $P_2O_5$ per acre appears to be comparable to triple superphosphate applied at the rate of 300 pounds of $P_2O_5$ per acre for forage production.

The annual application of 60 pounds of $P_2O_5$ per acre from triple superphosphate was not sufficient to maintain yields of forage under meadow conditions.

The crude protein content of the forage from all fertilized plots was
above the minimum animal requirements in the spring and early summer. The growth, largely grasses, in September did not contain enough crude protein to meet the nutritive requirements of beef cattle.

The calcium, phosphorus, magnesium, and potassium contents of the forage decreased with the advance of growing. The magnesium content of the forage varied less with season than did the other mineral elements.

In all instances the addition of phosphorus to the soil increased the phosphorus content of the forage. Only small increases in the phosphorus content of the forage were observed from additions above the 120 pounds of P₂O₅ level in 1953.

A comparison of triple superphosphate and ordinary superphosphate at the 300 pounds of P₂O₅ level shows that both sources supply phosphorus to the plants in approximately equal amounts. The residual effects from these two sources at this level appear to be equal at the end of the third year.

Phosphorus uptake was slightly greater from rock phosphate when no lime was applied. The percentage of phosphorus in the forage from the initial application of 600 pounds of P₂O₅ per acre from rock phosphate with no lime was approximately the same as that from 60 pounds of P₂O₅ per acre from triple superphosphate applied annually.

On the basis of an animal requirement of 0.13 per cent phosphorus in forage, the forage harvested from all fertilized treatments was equal to or above the minimum requirements for beef cattle in April and June, but the harvested forage was deficient in phosphorus from all treatments by September. On the basis of an 0.18 per cent phosphorus requirement in forage, the forage from the plots receiving less than 60 pounds per acre of available P₂O₅ was deficient in phosphorus throughout the season.

The calcium content of the forage, 0.30 per cent or more, appeared adequate from both limed and unlimed plots. Apparently a phosphorus deficiency is more apt to occur than is a calcium deficiency in the forage grown on this soil.

The calcium-phosphorus ratios were considerably wider than the optimum ratio of 2:1, but the ratios obtained fall within the range of tolerable limits.

A significant positive correlation was found between yield and the amount of available P₂O₅ applied per acre. Other correlations between the contents of the different mineral elements in the plant material were inconsistent.
Literature Cited


