THE EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZATION ON YIELD AND QUALITY OF BROMEGRASS <u>BROMUS INERMIS LEYSS</u>

by

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Loren Murphy
Major Professor

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

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To My Wife and Children

PATTY JEAN, SHALA LYNN AND SEAN JAY

this work is dedicated.

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INTRODUCTION

Smooth bromegrass (*Bromus inermis* Leyss.) can be one of the highest quality and most productive cool season grasses grown in northeast Kansas. Bromegrass is better adapted to this area of Kansas than most other seeded grasses. Northeast Kansas has one of the highest annual precipitations in Kansas, which occurs mainly in the spring and the fall. Along with this favorable rainfall distribution, the area has a relatively cool spring and fall. These reasons, coupled with the fact that much of this area has deep soils that are steeply rolling and subject to erosion when planted to row crops, make northeast Kansas a desirable area for the production of smooth brome. The majority of seeded pastures in this area are planted to bromegrass and when managed properly produce high quality pasture and hay.

One of the most important aspects of bromegrass management is a good fertilizer program. Bromegrass requires adequate quantities of nitrogen for maximum production, to maintain the stand and to enable the plants to compete with weedy grasses and broadleaf weeds native to the area. Possibly due to the fact that bromegrass is not a high value cash crop, there is little specific information available as to the effects of fertilizers on yield and quality of this potentially profitable crop in this area of Kansas.

In order to provide the needed information, an experiment was designed with the following objectives: (1) to determine the optimum levels of both nitrogen and phosphorus for bromegrass production in northeast Kansas; (2) to determine the effect of a wide range of nitrogen and phosphorus levels on yield and quality of bromegrass hay; and (3) to disseminate the information to farmers for use as a guide line in their management of bromegrass for higher profits.

LITERATURE REVIEW

Pastures are the cheapest source of nutrients for most forms of livestock. Serviss and Ahlgren (1955) state that our grasslands are the greatest undeveloped agricultural resource remaining and that an increased use of fertilizer can stimulate yields and improve nutrient content. They point out that there are a number of points to consider when selecting the proper forage; length of growing season, climate, soil fertility, topography and crops compared.

Using these criteria bromegrass is an excellent choice for northeast Kansas. Bromegrass has some other very desirable qualities for this region. It is very palatable, retains palatability and color longer, even though other seeded grasses will out-yield it slightly. It is drought-resistant, erosion-resistant, very winterhardy and responds vigorously to N fertilizer. Bromegrass is not only valuable for pasture but can also be utilized as hay or silage, Serviss and Ahlgren (1955).

Proper fertilization is one of the most important management practices in producing optimum yields and quality in bromegrass. Mott (1944) and MacLeod (1965) state that N is the first nutritional limiting factor for the growth of grasses in permanent pasture and has the greatest influence on yield. A number of investigators, Kennedy (1958), Raese and Decker (1966) and Carter and Ahlgren (1951) reported significant yield response of bromegrass to N fertilizer.

Specific growth responses to varying rates of N were recorded by Russell, Bourg, and Rhoades (1954). They observed that heavy applications of N fertilizer produce large increases in growth of bromegrass on N deficient soils in eastern Nebraska. They also noted N response in bromegrass in terms of weight, height and color of vegetation. Severe N deficiency symptoms, yellow color and the failure to produce seed stalks, were noted in the plants from the nonfertilized plots. On the other hand, bromegrass fertilized at the rate of 240 lb. N/A remained in a vegetative state with few seed stalks and a luxuriant growth of dark green foliage.

Anderson, Kernzin and Hide (1946) reporting on work done in Kansas, reported that seed and forage yields increased with increasing amounts of N up to 100 lbs. of N per acre. Beyond the 100 lb. rate, fertilizer became relatively less effective in stimulating yields and severe lodging occurred on seed plots. Ramage et al (1958) found that a 100 lb. N rate gave the greatest yield of dry matter. Dry matter yields assumed a typical diminishing returns response to increasing rates of N according to Carter and Scholl (1962). Since the response did not appear to have reached its maximum, they thought an additional increment of N over the 240 lbs. of N applied would have resulted in a further increase in yield.

This statement could be substantiated by work done by Laughlin (1962) in Alaska. He reported that each N increment up to 300 lbs. N/A resulted in increased bromegrass yields. Under the conditions of an experiment conducted by Raese & Decker (1966) they also found that bromegrass was more productive and competitive when fertilized with 300 lbs. N/A. However, maximum yields were obtained by Schmidt and Tenpas (1965) with rates as high as 500 lbs. N/A; the 1,000 lb/A rate reduced yields. Yield data reported by Lorenz, et al ., (1961) indicate some leveling off between the 160 lb. and 200 lb. rates of N at a low level of soil moisture.

Because N rates, necessary to produce maximum yields, vary so drastically, a review of factors effecting the response of bromegrass to N is necessary. Schmidt and Tenpas (1965) found that in the use of high rates of N, uniform rainfall distribution was a critical production factor. Although rainfall is an important factor in maximum yields, Lorenz, et al., (1961) stated that N fertilizer increased yields at all moisture levels. They reported that yields were doubled by the application of 40 lb. N/A and tripled by the application of 80 lbs. of N at a low moisture level. Their yield data indicate some leveling off between the 160 lb. and 200 lb. rates of N. According to Colville et al., (1963), the application of 120 lb/A N resulted in the most efficient use of rainfall. Each additional inch of precipitation produced 462.6 lbs. of forage at the 120 lb. application of N as contrasted to 52.2 lbs. without fertilizer. This means the bromegrass plants were 8.9 times more effective at the 120 lb. rate than where no fertilizer was applied.

Thomas and Osenbrug (1959) found that one inch of seasonal rainfall produced 86 lbs. of hay per acre on the checks treatment compared to 187 lbs. of hay per acre per inch of precipitation on the 255 lb. N treatment. Lorenz, et al., (1961) observed that N fertilizers increased yields at all levels of soil moisture regardless of whether the forage was harvested at hay stage or clipped frequently to simulate removal of the forage by grazing. Thomas (1961) came to a similar conclusion, that yields were highly related to rainfall at all fertility levels and that use of rainfall was improved by the application of N fertilizer. Temperature also plays a part in water use efficiency. Thomas and Osenbrug (1959) found that although large hay yields were generally obtained in years having high seasonal precipitation and low temperatures, in no case was seasonal precipitation significantly related to yield. However, low yields were associated with high seasonal temperatures.

While N increases yield through vigorous growth, it may have some adverse effects on stand persistence. Stands of orchardgrass and bromegrass were significantly reduced by high N according to Raese and Decker (1966). However, they point out that yields were increased with high N even though stand was reduced. Possible explanations for this could be an increase in tillers or a low pH and high Al in some cases. Paulsen and Smith (1968) reported that N fertilizer increased bromegrass yields by increasing the number of tillers and rapidity of regrowth after cutting. Eastin, Teel and Langston (1964), using six varieties of smooth bromegrass, found that the rank of variety yields coincides with the rank of variety tiller weights. Hertz (1959) noted that seedlings of bromegrass produced more rhizomes when kept free of weeds than when weeds were clipped or where a companion crop was used. The addition of fertilizer did not increase significantly the development of rhizomes. It would seem to follow that any practice which reduced weeds would be beneficial to stand. Although N does not seem to be directly related to stand persistence, it has been reported to reduce the weed problem; therefore, indirectly effecting favorably stand persistence.

Other factors that must be considered in relation to stand persistence and production are time of harvest and clipping height as affected by N fertilization. Raese and Decker (1966) observed that yields increased with maturity at harvest and the greatest stand persistence with least weed encroachment was obtained through harvest at the late bloom stage and especially in the case of bromegrass, late bloom was significantly better than earlier harvests.

Schmidt and Tempas (1965) and Wolf and Smith (1964) felt that cutting management was a more critical factor in stand reduction and maximum yield of bromegrass than N fertilization. The majority of investigators agree that early to late bloom is the optimum time to cut bromegrass. There seems to be a little more disagreement on clipping height. Van Riper and Owen (1964) reported that bromegrass yielded significantly more dry matter per acre than orchardgrass when cut at a 2-inch height, but not at the 5-inch height. Two-inch harvest height yielded more crude protein. Raese and Decker (1966) observed that the adverse effect of low stubble was most severe with high N and stands of bromegrass were significantly more persistent and dense when clipped at 3.5 inches rather than 1.5. Griffith and Teal (1965) observed that low clipping (2 inches) destroyed the collars of many leaf blades on N-fertilized grass. A greater leaf blade area remained as part of the stubble at the 4-inch cutting; permitting prompt recovery where N or soil moisture was not limiting. They reported, low clipping (2-inch stubble) caused stand reductions up to 57% at high N rates.

Sources of N have been investigated to some extent. Kennedy (1958) found no significant differences in the N carriers used in his experiment. Laughlin (1963) noted that ammonium nitrate, ammonium sulfate and calcium nitrate were equally effective as N sources but urea was seldom as effective. Anhydrous ammonia and calcium cyanamid were inferior to all other carriers. According to Burton (1952) nitrate of soda and ammonium nitrate produced hay containing significantly more protein than Uramon and cyanamid. There appears to be small differences in N sources; however, the majority of investigators use ammonium nitrate.

Effects of time of N application vary with location. Burton (1952) found that splitting the applications of nitrate of soda and ammonium nitrate in wet seasons significantly increased yields but had no effect in a season of average rainfall. Split N applications (half in the spring and half in early summer) produced higher second and third-cutting yields but no more dry matter for the entire season than did the same amount of N applied only in the spring according to Laughlin (1963). He reports that spring applications of N were generally superior to equal quantities applied in the fall. Johnson and Nichols (1969) observed that ammonium nitrate applied in the spring was more efficiently used than ammonium nitrate applied in the fall. Spring seems to be the most desirable time to apply nitrogen if only one annual application is desired.

Nitrogen has a very favorable effect on crude protein content of hay. Nitrogen percentages in the bromegrass forage have been reported to increase noticeably with increases in rate of N (Russell, et al., 1954). Nitrogen content is affected by a number of the same factors that effect yield. Watkins (1940) reported that nitrogen-fertilized plants and check plants at bloom stage were low in percentage of N and high in percentage of carbohydrates; however, the absolute amounts of both were highest in the N-fertilized plants. Laughlin (1953) also found that crude protein yields were markedly increased by N fertilizers. However, he noted that stage of maturity also affected crude protein yields which were highest when plants were harvested during the early flowering stage.

Thomas and Osenbrug (1959) observed that N applications increased crude protein content of the hay and total yield of protein significantly and that a high hay yield was associated with grass having a high protein content. For example, Colville, et al., (1963) observed that for maximum protein production in the forage, an application of 160 lbs. of N/A was close to optimum, but that forage production was not appreciably increased when fertilizer applications exceeded 120 lbs. of N/A.

Rate of N applied is important as is pointed out by Anderson, et al., (1946). They found that protein percentages in the fairly mature forage samples were not increased appreciably by amounts of N under 100 lbs/A, but rates of 140 and 200 lbs/A increased protein percentages os that yields of protein per acre continued to increase up to those rates of fertilization. Washke and Pennington (1956), using lower rates (100 lb/A and below) of N found that bromegrass yielded approximately equal amounts of protein per acre under conditions in Pennsylvania, regardless of N treatment or associated legume. Russell et al., (1954) reported crude protein contents when harvested for hay at the 240 lbs N/A rate to be as high as 15%, while Ramage et al., (1958) observed that the protein percentage of dry matter ranged from 12 to 20 as N application increased from 50 to 400 lbs.

Johnson and Nichols (1969) stated that N application can significantly increase the crude protein content of smooth brome but noted that seasonal weather also affected crude protein significantly. Percent crude protein measured at anthesis was significantly higher in the dry year 1966 than the wetter year 1967. Colville et al., (1963) also found that intermediate to high amounts of precipitation were associated with low percent protein. Dry seasons produced a low hay yield but were high in crude protein. In contrast to low crude protein percentages, maximum yields of crude protein were obtained from forage harvested during relatively wet seasons.

A balanced fertilizer, including 128 lbs. of N, produced 4.5 lbs. of protein for every pound of applied fertilizer N in a study conducted by Laughlin (1953). Studies reported by Reed et al., (1960) indicate that N fertilization of a soil will not guarantee constant percentages of amino acids in plants unless other elements required for plant growth are present in adequate amounts and balance to dispose of N by assimilation.

Phosphorus, while necessary for growth, does not have the dramatic effect on grass that N does. All species of grasses studies by Shoop et al., (1961) required applications of P for normal growth. Good growth of tall fescue was obtained with high rates of P on acid soils or with lower rates of P on limed soils. Anderson et al., (1946) tried applications of superphosphate alone and with N but reported that in no case did P give an appreciable response. No response to P was measured in bromegrass yields by Lorenz et al., (1961). They reported that three year average hay yields were 3.20 tons with, and 2.95 tons per acre without P. A comparison of year-by-year yields for these two treatments shows a tendency toward increased yields from the use of P but even in the third year, differences were not significant. They thought it is possible that over a longer period, the continued high production through the use of N would have in time resulted in a significant P response. Kennedy (1958) reported that application of P and K decreased yield without application of N; however, with N, yields were increased slightly. Laughlin (1964) found no significant yield increase resulted from P application in 1958. He states this reflects the high P content of the 1957 composite soil sample and possibly the extremely dry conditions after the first cutting. Each P increment in 1959 significantly increased the yield of both cuttings. The use of P produced a significant increase in the total hay yield but not in protein content of bromegrass according to Thomas and Osenbrug (1959). Read and Ashford (1968) observed a similar response in both bromegrass and reed canarygrass.

The time of P application was studied by Terman et al., (1960). They found that with only one initial application of P, yield usually became progressively poorer each year, as compared to yields with small annual top-dressings. Percent P in the herbage followed similar trends as for yields of hay. Phosphorus was consistently higher in herbage grown with applied P than with none. Laughlin (1964) reported that no significant difference in bromegrass yields could be attributed to fall and spring applications of either P or K with any clipping from 1958 through 1960.

Nitrogen and phosphorus fertilization has some effect on the content of P, K, Ca and Mg in plant material. Thomas (1961) states that N fertilization reduced the P content of bromegrass. Phosphorus content of the grass increased, however, with more rainfall, indicating that soil moisture conditions largely determine the uptake of soil phosphorus. He found that on P-deficient soils, the addition of P fertilizer, along with N, offset the depressive action of N on the P content of the grass. It is interesting to note that forage yields were directly related to the N content and inversely related to the P content of the grass at harvest.

Russell et al., (1954) found that there was a definite reduction in P percentage in bromegrass forage due to N fertilizers. Results contrary to this trend are reported by Terman et al., (1960). They observed that the percent P in the herbage followed trends similar to those of yields of hay. Phosphorus was consistently higher in herbage grown with applied P than with none. Holmes (1949) reported that there was a slight rise in P content after the second and third application of manure.

Russell et al., (1954) reported that K concentration was increased with increasing rates of N fertilizer and at the same time there was a tendency for Ca and Mg percentage of the forage to decrease. Nitrogen and potassium caused an increase in both P and K content of grasses but Ca and Mg showed a downward tendency according to Huvdsten et al., (1959). They found an interrelation of the cations and noted that the Ca content of grass also showed a distinct tendency to vary parallel with the N content. The variations, however, were much smaller than for K. The contents of Mg and P, on the other hand, was not markedly influenced by the dressings of N. Holmes (1949), on the other hand noted that the overall content of P and of protein in the treated grass leys was higher than in the control.

There appears to be more of an interaction between N and K than there is between N and P. Laughlin and Restad (1964) found K applications up to 33 lb/A significantly increased dry matter yield but produced relatively small increases at applications exceeding this rate. Each K increment increased the K content of the forage and also increased the sum of K, Mg and Ca cations. Ramage et al., (1958) showed that grasses heavily fertilized with N removed large amounts of K from the soil. MacLeod (1965) reported significant N-K interactions with grass species indicating that K fertilization facilitated the storage of carbohydrate reserves at high rates of N and that high rates of K without N fertilization were detrimental to the storage of carbohydrate reserves. The quantitative relationship between the uptake of anions and cations in plants according to Heidsten et al., (1959) is especially pronounced for NO_3^--N and K^+. With an ample supply, both of these ions are taken up in relatively large amounts. Teel (1962) noted the lack of association between N and true protein in K-deficient herbage.

The accumulation of excessive amounts of NO_3-N in forage plants can pose serious problems to animals, according to Murphy and Smith (1967).

They found that NO_3-N accumulations were directly related to rates of N fertilization. Less nitrate was present in the plants as they approached maturity. In their experiment, P treatments had little if any effect upon the NO_3-N content of bromegrass. Vanderlip and Pesek (1970) observed that in general, N, P, and K fertilizer applications early in the season increased the NO_3-N content. Later in the season only applied N had an effect on NO_3-N and that the content decreased sharply with time after application. Data presented by Carey et al., (1952) show a steady decline in total N concentration as the plants matured. There is little evidence to show that NO_3-N is a big problem in mature bromegrass; however, Kennedy (1958) reported at certain times in the season bromegrass occasionally reached or approached the 1 percent NO_5-N level.

Chemical analysis made over a period of 4 years by Fuelleman and Burlison (1941) show that a high protein and mineral content of bromegrass are apparently related to good animal gains. A number of chemical determinations have been made to measure the apparent value of bromegrass for livestock utilization. Protein percentage has been used extensively in this regard. However, many investigators such as Swift et al., (1950) have suggested that protein content alone is not sufficient. Swift and co-workers found a high degree of negative correlation between lignin and protein content and that this may have had more of an effect on total digestibility than protein itself. Ramage et al., (1958) studied the effect of N fertilization on ether extract and crude fiber of grasses. They found that N fertilization significantly increased protein content, had no effect on ether extract content and reduced crude fiber content.

One facet of using high rates of N and P fertilizers on bromegrass that has not been studied extensively is their effect on soil properties.

An excellent study by Owensby et al., (1968) points out some of the effects on soil chemical properties by continuous use of various rates of fertilizers over a 20 year period. A 200 lb. rate of N annually lowered the pH in the 0-6" soil layer from 5.9 to 4.7. In the 6-12" soil layer, soil pH was as low as 4.1 in some plots. Lime requirement was as high as 21,000 lb/A on some plots. Phosphorus application increased amounts of available P through the 36 inch soil layer sampled.

Unpublished data from the previous study shows that nitrate -N accumulated in the soil profile when N treatments were applied annually for 20 years. This occurred only at N rates higher than those producing maximum yields. Optimum yield was recorded at the 100 lb/A N rate; however, the 140 lbs N/A has been wett utilized by the bromegrass. Nitrate accumulations under the 200 lb/A N rate were significantly higher. The rates of N at which nitrate-N accumulated were higher than the optimum rates reported by Colville et al., (1963) for Nebraska.

MATERIALS AND METHODS

Seven experimental sites were established on selected areas in Jackson, Nemaha, Brown, Doniphan, Atchison, Jefferson and Franklin counties in northeastern Kansas. The experimental areas were located in established bromegrass pastures on soils that were steeply sloping or otherwise unsuitable for row crop farming.

A study involving a factorial, randomized complete block design with four replications, comparing rates of nitrogen and phosphorus was initiated in 1966. Experimental data were collected on the Franklin, Jackson, Doniphan and Nemaha county sites for three years. At the remaining three sites in Brown, Atchison and Jefferson counties, data were collected for only two years.

Individual plots were 6 feet wide by 20 feet long with a 10 foot alley between replications. Experimental areas were fenced to prevent livestock from grazing in the study area. All sites were located on cooperators' farms with the exception of the Franklin county site, which was located on the East Central Kansas Experimental Field.

Six rates of N varying from 0-250 lb/A in 50 lb. increments and three rates of P varying from 0-22 lb/A in 11 lb. increments were applied annually. Potassium was applied to all plots at the rate of 41 lb/A to insure that this nutrient would not be limiting.

Fertilizer materials used were ammonium nitrate, triple superphosphate and potassium chloride. All fertilizers were broadcast each year in late winter or early spring as soon as weather conditions permitted. A

5 foot Gandy applicator powered by a two-wheeled garden tractor was employed for the applications. The fall growth was removed each year in the early spring prior to application of that year's treatments. A composite soil sample was collected annually from selected plots prior to fertilization.

Bromegrass forage was harvested from individual plots with a small sicklebar mower. A sheet metal platform was fastened behind the sickle bar to catch the cut grass. The area harvested was 18 inches wide and 13 feet long cut from the center of each plot. Plots were harvested once a year at the bloom stage of plant maturity. After the plots were harvested, the entire experimental area was mowed to a uniform height of 4 inches and the hay removed. The forage was weighed in the field immediately after cutting and a sample of whole bromegrass plants collected from each plot. This sample was placed in a plastic bag sealed and placed on dry ice for transport to the laboratory. The samples were placed in a deep freeze until they could be weighed and oven dried at 60C for 72 hours at which time the dry weight was determined. The wet weight yield of the freshly cut grass was corrected to 12.5% moisture. The dry samples were ground through a Wiley mill using a 40 mesh screen in preparation for chemical analysis.

Nitrogen Analysis

One gram portions of the dried samples were weighed into Kjeldahl flasks and nitrogen determined by a modified Kjeldahl method (Jackson, 1965). One Kelpak No. 4 (10g K_2SO_4 and 1g HgO) was placed in each flask and 30 ml conc H_2SO_4 added. The flasks were placed on the Kjeldahl digestion apparatus and digested for 1 hour after the solution became clear. The flasks were cooled and 150 ml distilled H_2O added after which the flasks were allowed to cool again. Twenty-five ml 4% H_3BO_3 was then measured into 300 ml Erlenmeyer flasks and placed under the delivery tube of the Kjeldahl distillation unit. Ninety ml of 50% NaOH - 10% $Na_2S_2O_3$ solution were added carefully and quickly down the side of the Kjeldahl flask containing the digested solution. Two pieces of mossy Zn were added to the flask and immediately connected to the still. About 150 ml liquid was distilled into the Erlenmeyer flasks containing the boric acid solution. The ommonium borate solution was then titrated to the methyl purple end point with 0.0714 N H_2SO_4. Percent N was then calculated for each sample. Crude protein was calculated by multiplying the %N by a factor of 6.25.

Phosphorus and Potassium Analysis

Separate 0.5 g portions of the plant samples were weighed into 25 ml beakers and dry ashed in a muffle furnace at 200°C for 1 hour and at 500°C for 2 hours. The ash was dissolved in 0.1 N HCl solution, filtered through Whatman 42 paper and brought to 50 ml volume. Phosphorus was determined by the vanadate molybdate yellow method of Chapman and Pratt (1961). A 10 ml aliquot of the above solution was transferred to a 50 ml volumetric flask and 10 ml of the ammonium molybdate-ammonium vanadate reagent were added. The solution was mixed, diluted to volume and mixed again. After 30 minutes absorbance was read at 420 mu wavelength on a Beckman DB spectrophotometer. Another 5 ml aliquot of the 0.1 N HCl solution in which the ash was dissolved was transferred to a 50 ml volumetric and brought to volume. Potassium content was determined by flame spectrophotometry using a Coleman flame photometer. Calcium and Magnesium were determined by atomic absorption spectrophotometry using the Perkin-Elmer model 303 instrument. A 5:50 dilution was used and 10% La_2O_3 was added to the Ca samples to keep the Ca ions from forming complexes with P.

Plant Nitrate Analysis

Nitrate-Nitrogen (NO_3-N) was determined by the Alpha-naphthylamine-sulfamilie acid method. One gram samples of dry plant material were weighed into small beakers to which 20 ml of hot water were added and allowed to stand for 15 minutes, then filtered. One ml of plant extract was placed in test tubes and 9 ml of 20% acetic acid solution[1] and .8 gm of reacting powder[2] added. After shaking three times with 3 minute intervals, the test tube was placed in a colorimeter at a 520 mu wave length and compared with the standard curve (Bray 1945).

Crude Fiber and Crude Fat

The crude fat (ether extract) and crude fiber contents of the dry plant samples were determined by A.O.A.C. methods, 22.033 for fat and 22.038 for fiber (A.O.A.C., 1965).

Soil Analysis

All soil analysis were determined by the Soil Testing Laboratory of Kansas State University.

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[1]Two liters of glacial acetic acid, diluted to 10 liters with distilled water. 0.005 gm of copper sulfate is added and mixed thoroughly.

[2]a. 100 gm $BaSO_4$ (Dried at 110°C)
b. 10 gm $MnSO_4 \cdot H_2O$
c. 2 gm finely powdered zinc
d. 75 gm citric acid (powdered)
e. 4 gm sulfonilic acid
f. 2 gm alpha-naphthylamine

b, c, e and f are mixed separately with portions of the $BaSO_4$ and then all reagents mixed together and stored in a blackened bottle. Powder should be kept away from the sunlight.

RESULTS AND DISCUSSION

The data shown in (Figures 1-9) are regression values calculated from actual plot data. Each figure is followed by a corresponding table (1-9) showing the regression coefficients. Means of the actual plot data corresponding to (Fig. 1-9) are given in the Appendix (Tables XXV-XXXII). Analysis of Varience and means of N and P variables are included at the end of these tables.

Original soil data and soil types, classes and descriptions are found in (Table XVIII). All plot location headings in the tables were coded as follows:

Code	Location	Farm Cooperator
AT	Atchison county	Mr. Leonard Penning
BR	Brown county	Mr. Homer Jacobsen
DP	Doniphan county	Mr. Harold Rush
FR	Franklin county	E.C.K. Experimental Field
JA	Jackson county	Mr. J. C. Garman
JE	Jefferson county	Mr. Jim Varner
NM	Nemaha county	Mr. William Rempe

All plot sites were located in northeast Kansas counties with the exception of the Franklin county site which was located in the east central part of Kansas.

Effect of Nitrogen on Yield

Visual responses of the bromegrass plants due to nitrogen applications were obvious. Plots receiving no N showed severe N deficiency symptoms at all locations. The plants on these plots were very yellow in color, showed very little leaf growth and very few seed stalks were produced. Plants on the plots receiving the 50 lb/A rate of N, while visually better, were also chlorotic and a lack of plant vigor was evident. It was difficult to observe visual differences between plants receiving the 100 to 250 lb/A rates of N. The leaves in all plants were a dark green, growth of the foliage was lush and grew to a greater height than plants receiving lower rates of N. Increased height was a disadvantage in the 1967 and 1968 years of above average precipitation since many of the plants lodged severely on plots receiving the 150 to 250 lb/A N rates. This was especially true at locations where the highest hay yields were produced. These observations agree with those of Anderson et al., (1946), who noted that for seed production the 100 lb/A rate of N appears to be sufficient primarily because bromegrass plants receiving higher rates of N are subject to lodging under certain conditions. Broadleaf and grassy weeds were observed in the plots receiving no N in 1966 and weed infestation appeared to increase each succeeding season. Few weeds, if any, were observed in plots receiving the 100 lb/A rate of N or higher.

Nitrogen increased yields of bromegrass hay significantly in 1966, 1967 and 1968 at all locations (Fig. 1-3). Yields in 1966 (Fig. 1) were numerically much lower than yields in 1967 (Fig. 2) and 1968 (Fig. 3).

Precipitation records (Tables XIX-XXI) from official reporting stations in the northeast and east central Kansas areas show that precipitation received in 1966 was below normal. The northeast division was 11.43 inches below normal in 1966 and the east central division 12.31 inches below normal. The northeast division received 6.84 inches above normal precipitation amounts in 1967 and 3.14 inches above normal in 1968. The east central

Fig. 1 - Yield (T/A) of bromegrass hay (12.5% moisture) cut at bloom stage as affected by applications of nitrogen and phosphorus at seven locations (1966).

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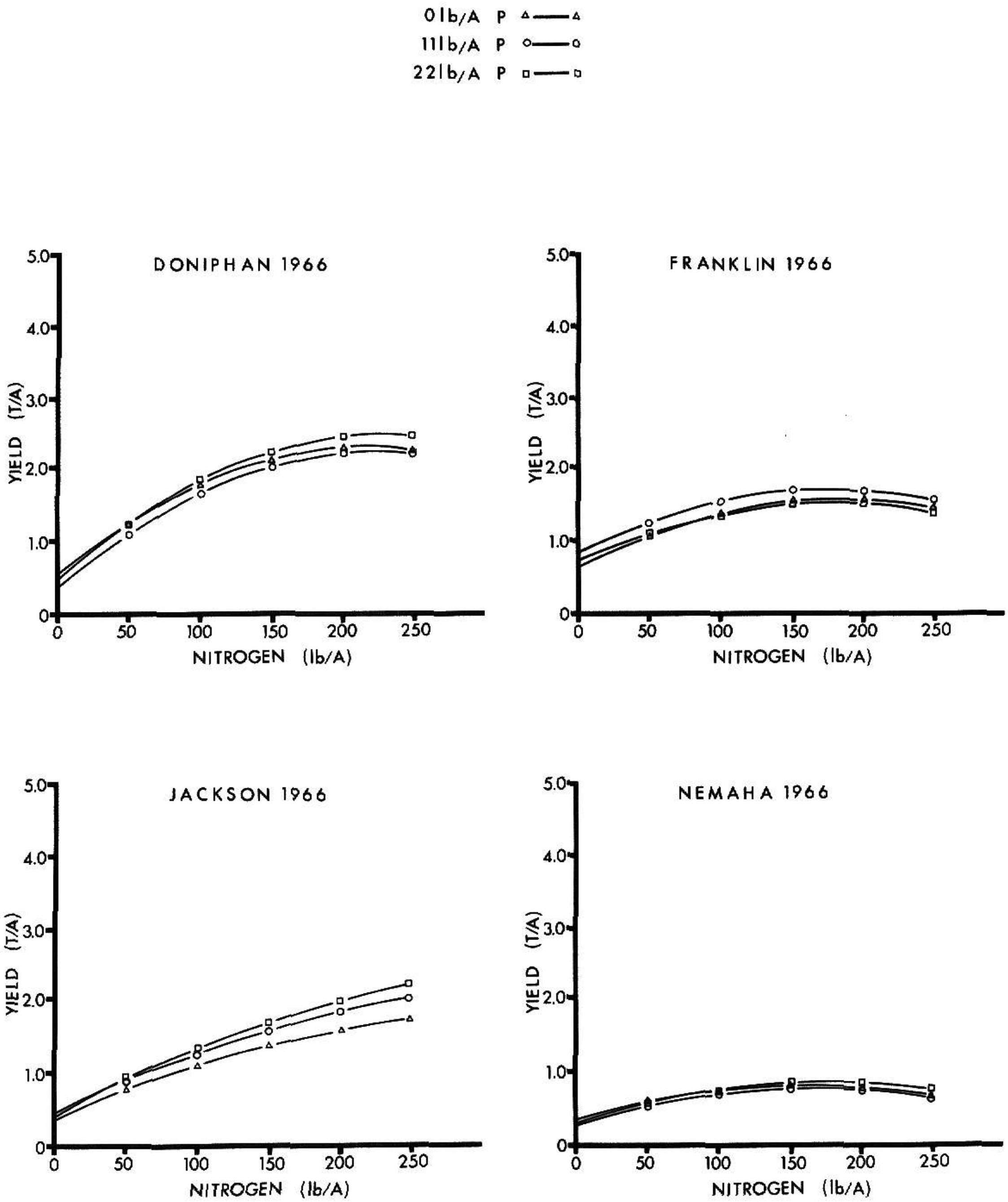

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1966
FRANKLIN 1966
JACKSON 1966
NEMAHA 1966
YIELD (T/A)
NITROGEN (lb/A)
0
1.0
2.0
3.0
4.0
5.0
0
50
100
150
200
250

Fig. 1 - (Continued)

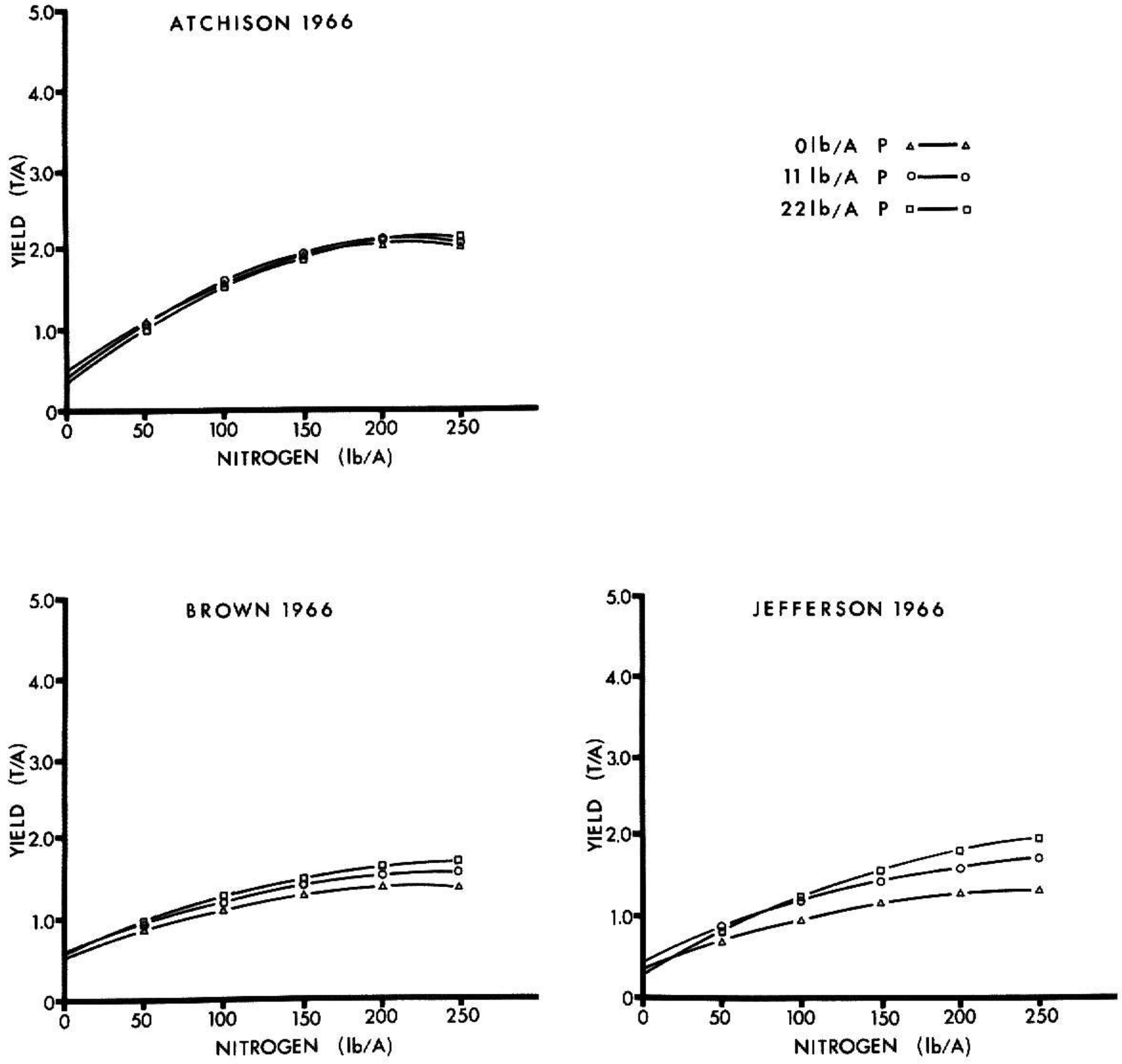

ATCHISON 1966
YIELD (T/A)
5.0
4.0
3.0
2.0
1.0
0
0
50
100
150
200
250
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
BROWN 1966
YIELD (T/A)
NITROGEN (lb/A)
JEFFERSON 1966
YIELD (T/A)
NITROGEN (lb/A)

Fig. 2 - Yield (T/A) of bromegrass hay (12.5% moisture) cut at bloom stage as affected by applications of nitrogen and phosphorus at seven locations (1967).

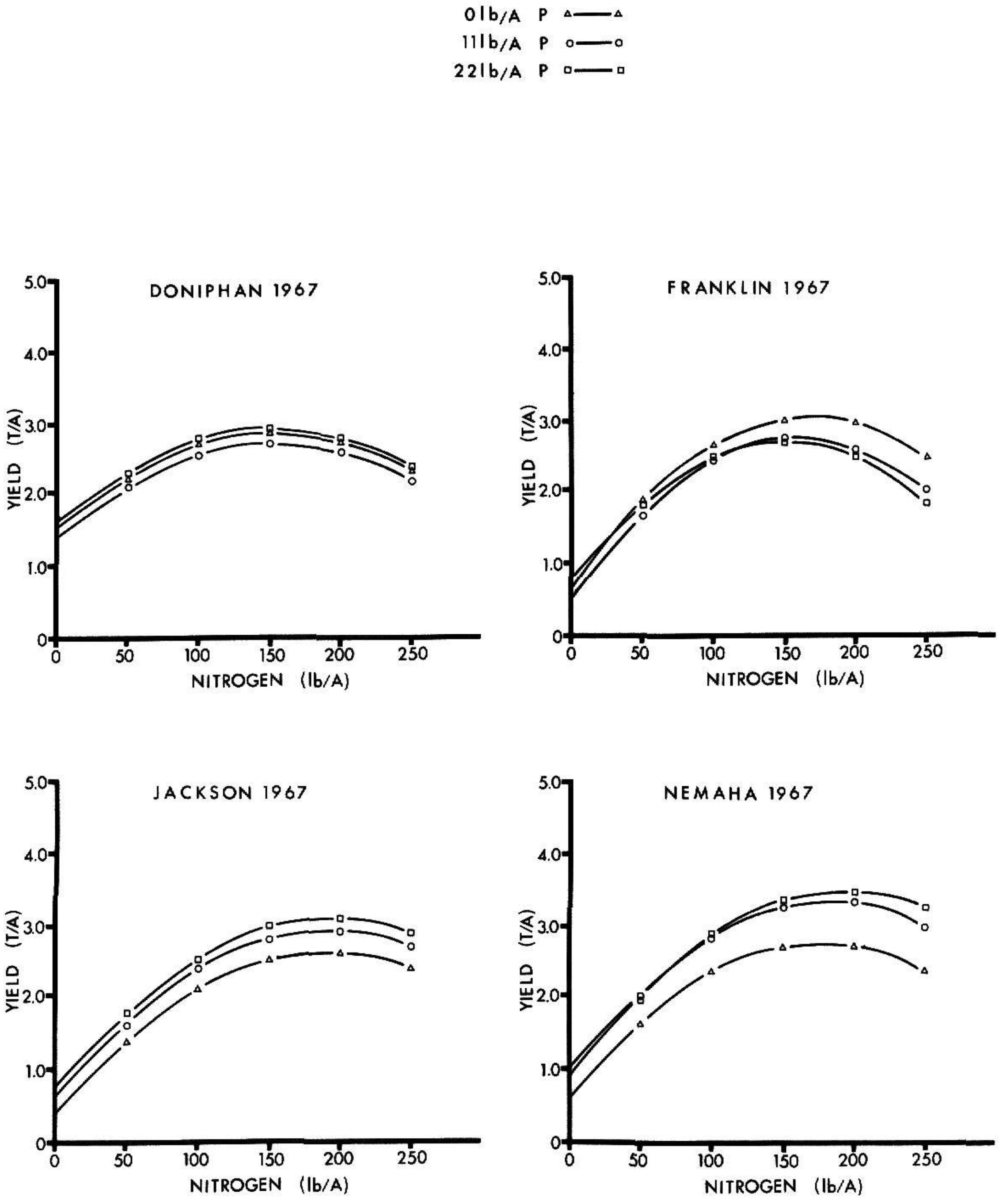

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1967
FRANKLIN 1967
JACKSON 1967
NEMAHA 1967
YIELD (T/A)
5.0
4.0
3.0
2.0
1.0
0
0
50
100
150
200
250
NITROGEN (lb/A)

Fig. 2 - (Continued)

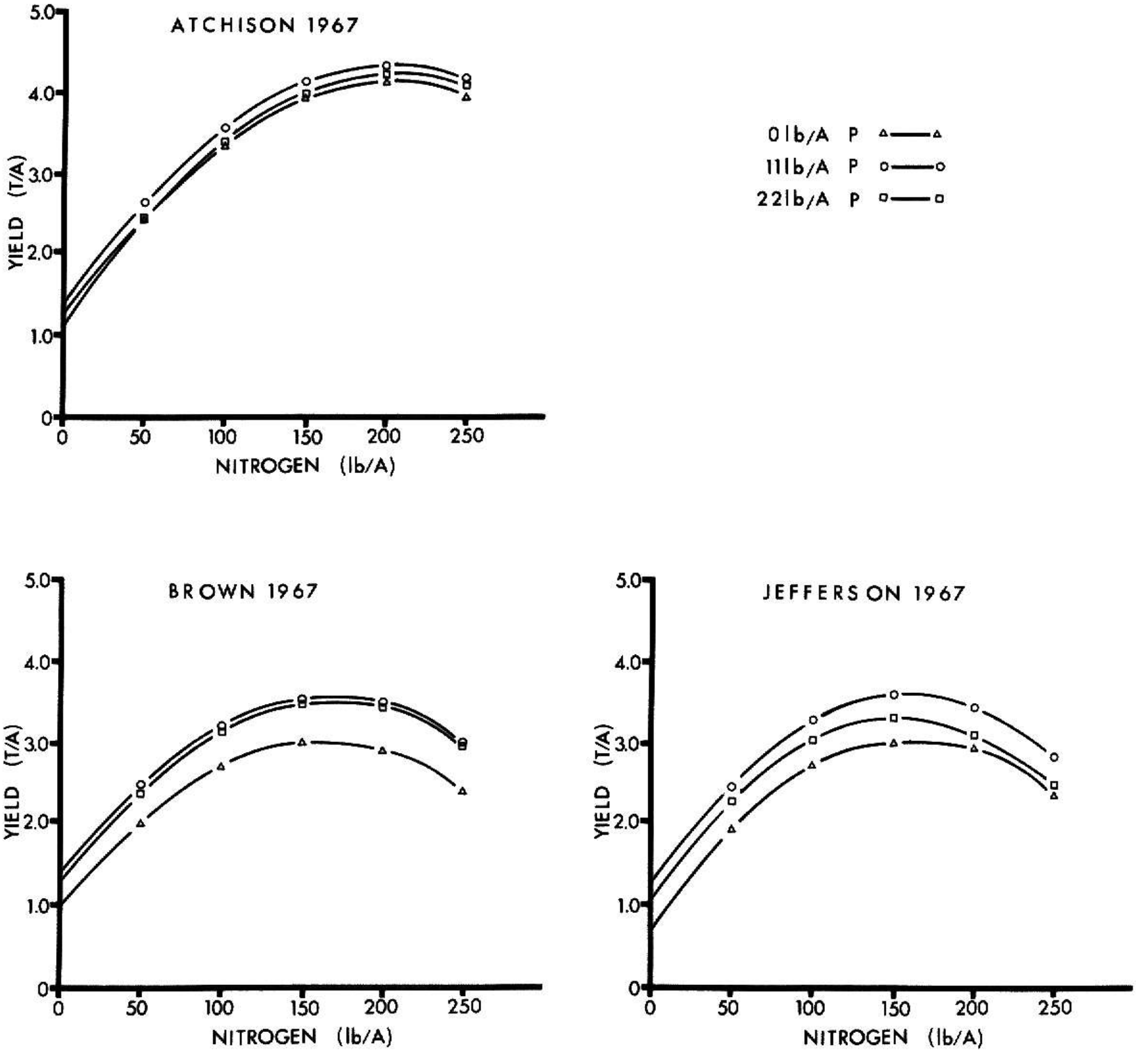
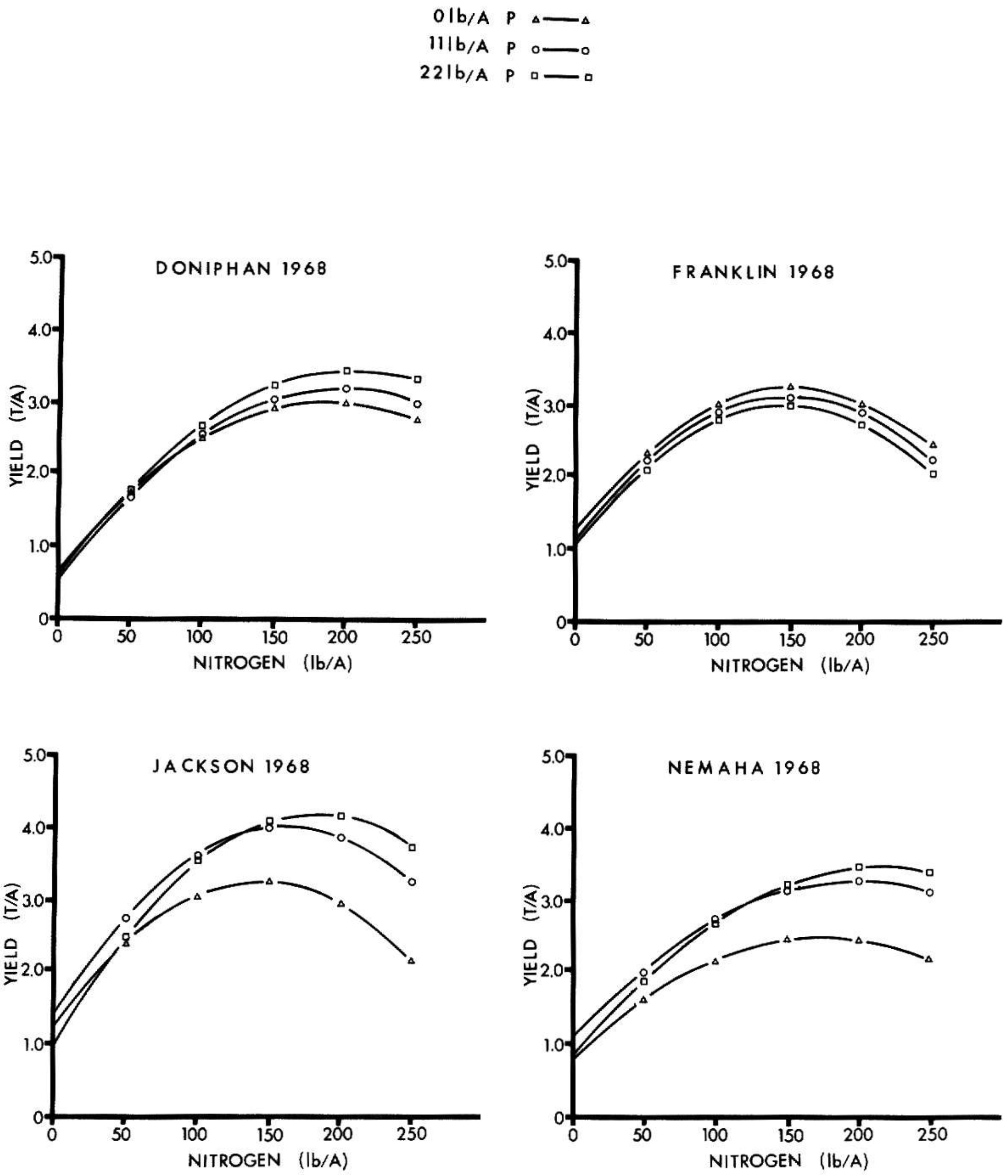

ATCHISON 1967
YIELD (T/A)
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
BROWN 1967
YIELD (T/A)
NITROGEN (lb/A)
JEFFERSON 1967
YIELD (T/A)
NITROGEN (lb/A)

Fig. 3 - Yield (T/A) of bromegrass hay (12.5% moisture) cut at bloom stage as affected by applications of nitrogen and phosphorus at four locations (1968).


0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1968
FRANKLIN 1968
JACKSON 1968
NEMAHA 1968
YIELD (T/A)
NITROGEN (lb/A)
0
1.0
2.0
3.0
4.0
5.0
0
50
100
150
200
250

division records show this area received 9.24 inches of precipitation above normal in 1967 and 1.33 inches above in 1968. Temperature records from the same stations (Tables XXII-XXIV) show that average temperatures were higher from May through July in 1966 than average temperatures for these months in 1967 or 1968.

Hay yields from plots receiving no N were low, as was expected from the observations. In 1966, (Fig. 1) yields from the plots receiving no N were approximately 0.5 ton per acre. Yields on these same plots in 1967 and 1968 (Fig. 2 and 3) were higher but were still low and seldom exceeded the 1.0 T/A yield level. Yields increased progressively with each increment increase in N. The maximum yield reached depended upon the interaction between rate of N, year and location.

The response of bromegrass hay yields to different rates of N in 1966 appeared to fall into four general groups, according to soil characteristics (Table XVIII) and location of the sites studied. Group 1: the Brown and Nemaha county sites located in the north central part of the northeast area, represent soils that are severely eroded, developed from glacial till or have a glacial till influence, high in clay and with a tendency to be droughty. The soils at these two sites tested very low in available soil P. Group 2: Jackson and Jefferson county sites located in the south central part of the northeast area, represent soils moderately eroded, also developed from glacial till, with clay loam to silty clay loam surface soils with high moisture holding capacity. The soils at these two sites also test very low in available soil P. Group 3: Atchison and Doniphan county sites, located in the northeast part of the northeast area, represent very productive soils developed in loess, with very deep silt loam top soils. The soils at these two sites tested medium in available soil P. Group 4: the Franklin county site, located in the center of the east central area of Kansas, represents soils with shallow top soils developed in loess with shale influence, a tight clay or clay pan subsoil with restricted moisture movement. This soil tested medium in available soil P.

Yield responses at the Nemaha and Brown county sites (Group 1) in 1966 (Fig. 1) to different rates of N were lower than the other sites. Yield increases were small with each 50 lb. increment in applied N. A maximum yield was reached around the 150 lb/A rate of N and the yield was reduced with the 250 lb/A N rate. The Jackson and Jefferson county sites (Group 2) showed a medium yield response to the N applications in 1966. However, yields at these two sites continued to increase with each 50 lb. increment increase in N and did not appear to have reached a maximum at the 250 lb/A rate of N. The Doniphan and Atchison county sites (Group 3) showed the largest yield increase to each 50 lb. increment increase in N of all the locations studied in 1966. Maximum yield was reached around the 200 lb/A rate of N and yield was reduced by the 250 lb. applications. Yield response at the Franklin county site (Group 4) showed a very gradual increase to the 150 lb/A rate, then leveled and dropped slightly at the 250 lb. rate. Yield differences at rates between 100 to 250 lb/A rates of N were very small.

Yield differences in 1967 (Fig. 2), a year of above average precipitation, were much greater than those recorded in 1966 (Fig. 1). Yields were also numerically much higher in 1967. Yield responses to N in 1967 were similar at all locations and did not fall into the groups described earlier. This would indicate that when precipitation is adequate, soil characteristics are not as much of a factor on yield response to N as they are in a dry year. Yields increased rapidly with each increment increase in N to 100 lbs/A, then assumed a slower rate of increase to a maximum around the 150 lb. rate. Yields then tended to level off or drop slightly at the 200 lb/A rate with the exception of Atchison county where the yield continued to increase even at the 200 lb. rate. The 250 lb/A N application reduced yields at all locations in 1967.

Three sites were discontinued in 1968 due to a number of factors. Four sites were continued in Doniphan, Franklin, Jackson and Nemaha counties. They were selected to represent each of the groups described earlier. Yield response to N in 1968 was similar to the response observed in 1967. There was a general trend toward a lower rate of N required to produce maximum yield with each consecutive year. In 1966 at most locations, maximum yield was reached around the 200 lb/A rate or higher. When the same N rates were applied in 1967, maximum yields were attained in the 150 to 200 lb. N/A range. These rates of N were applied again in 1968 and although the maximum yield was reached at similar N rates as in 1967, the yield differences between the 100 lb. N rate and the 150 lb. N rate were not as great as in the previous year. Yield reduction at the 250 lb/A rate of N also became more severe each consecutive year. This was especially true at sites which tested low in available P. Application of P at these sites moderated the adverse effect on yield from the yearly application of high rates of N. These data suggest that continuous yearly applications of rates of N above the 150 lb/A rate were not necessary for optimum bromegrass hay yield at these locations and can have a detrimental effect on yield. High rates of N can also have an adverse effect on soil properties as will be discussed later.

Table I - Multiple regression coefficients for yield as affected by different rates of nitrogen and phosphorus (1966).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	0.443	0.743**	-0.006	-0.083**	-0.005	0.008	0.671
Brown	0.524	0.358**	0.094	-0.037	-0.038	0.028	0.408
Doniphan	0.548	0.817**	-0.356	-0.095**	0.165	0.024	0.778
Franklin	1.643	0.499**	0.322*	-0.067**	-0.144	-0.014	0.647
Jackson	0.332	0.443**	0.144	-0.032**	-0.060	0.045*	0.880
Jefferson	0.327	0.413**	0.151	-0.042*	-0.079	0.071*	0.700
Nemaha	0.338	0.278**	-0.081	-0.041**	0.030	0.008	0.519

* N and P variables are coded as follows:

N		Code
0	=	0
50	=	1
100	=	2
150	=	3
200	=	4
250	=	5

P		Code
0	=	0
11	=	1
22	=	2

Table II - Multiple regression coefficients for yield as affected by different rates of nitrogen and phosphorus (1967).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	1.158	1.479**	0.353	-0.183**	-0.182	0.017	0.734
Brown	0.922	1.308**	0.722*	-0.201**	-0.288*	0.030	0.702
Doniphan	1.530	0.870**	-0.303	-0.143**	0.165	-0.003	0.435
Franklin	0.602	1.456**	-0.159	-0.216**	0.117	-0.078*	0.797
Jackson	0.367	1.189**	0.313	-0.157**	-0.070	0.022	0.870
Jefferson	0.623	1.527**	1.065**	-0.236**	-0.429**	-0.027	0.752
Nemaha	0.556	1.257**	0.619**	-0.178**	-0.228*	0.056	0.859

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

Table III - Multiple regression coefficients for yield as affected by different rates of nitrogen and phosphorus (1968)

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP^*$

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Doniphan	0.638	1.265**	-0.106	-0.167**	0.033	0.065	0.801
Franklin	1.220	1.334**	-0.059	-0.218**	0.005	-0.028	0.472
Jackson	1.217	1.418**	0.515	-0.246**	-0.326	0.188*	0.561
Nemaha	0.769	0.989**	0.644*	-0.140**	-0.313**	0.122**	0.811

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

Effect of Phosphorus on Yield

Response of bromegrass to P applications could not be observed visually and P deficiency symptoms were not apparent at any of the locations studied. Phosphorus applications did not have as much of an effect on yield as did N and responses were not as frequent nor as significant as those of N. However, adequate soil P or applied P appears to be necessary for producing maximum bromegrass yields and also can apparently increase nitrogen use efficiency in years of high production.

Yield response to P applications can be divided into the four soil groups according to soil characteristics and locations that were used in discussing yield response to N in 1966. The most important soil characteristic in the discussion of phosphorus appears to be the level of available phosphorus in the soils studied.

Soil analyses (Table XVIII) show that Brown, Nemaha (Group 1), Jackson and Jefferson (Group 2) county soils were very low in soil P. Yields were low at the Brown and Nemaha sites in 1966 (Fig. 1) and there was no significant response to P applications. The Jackson and Jefferson county sites which produced higher yields than the Brown or Nemaha sites showed a significant response to both rates of P applications in 1966 (Fig. 1). The yield difference at these two sites was greatest at the 250 lb/A rate of N and the high rate of P (22 lb/A). Both rates (11 and 22 lb/A) of P application increased yields at all rates of applied N. However, yield response was higher with the 22 lb/A P application. Phosphorus applications did not effect yield significantly at the Doniphan and Atchison county sites (Fig. 1) even though they produced the highest yields recorded in 1966. Soils at these two sites were higher in available soil P. The Franklin county site produced yields comparable to the

Jackson and Jefferson county sites but there was no significant response to P.

Yields were increased significantly by P applications at all four sites testing low in available soil P (Jackson, Nemaha, Jefferson and Brown) in 1967 (Fig. 2), a year of above average precipitation. Hay yields in 1967 were numerically higher at all locations, compared to the 1966 yields. Phosphorus applications increased yields at all N rates in 1967 at the Nemaha and Brown county sites. However, there was very little yield difference between the 11 lb/A rate of P and the 22 lb/A rate at these locations. The Jackson county site showed the high rate of P application to be the most effective. This was reversed at the Jefferson county site and the 11 lb/A rate of P produced higher yields. In fact, the 22 lb/A rate of P increased yields very little above N alone at the 200 and 250 pound per acre rate of N in Jefferson county. There was no significant increase in yield due to P treatments at the Doniphan and Atchison county sites again in 1967. Yield was significantly reduced by both rates of P application at the Franklin county site in 1967.

Three sites were discontinued in 1968 (Fig. 3) as was mentioned earlier. Phosphorus applications increased yields significantly at the Jackson county site (Group 2) again in 1968 when precipitation was above average. The 22 lb rate of P produced higher yields than the 11 lb rate at the higher rate of N application. Yield was also significantly increased by P application at the Nemaha county site (Group 1) in 1968. However, as was observed in 1967, there was very little difference between the 11 and the 22 lb/A rates of P. Phosphorus increased yield when high rates of N were applied, but the 22 lb/A rate was not significantly different than the 11 lb/A rate.

Phosphorus applications increased yield at the higher rates of N more in 1968 (Fig. 3) at the Doniphan county site (Group 3) than in previous years, however, the increase was not significant. Yield was reduced by P at the Franklin county site (Group 4) again in 1968 (Fig. 3) but the decrease was not significant. Each increment increase in P seemed to have a greater detrimental effect on yield at this location. A partial explanation for this could be that the Franklin county site is located farther south than the other six locations and is subject to higher temperatures and lower precipitation. However, an adequate explanation cannot be obtained from these data and the need for further study is indicated.

Accumulative results from these data show that phosphorus increases yields of bromegrass significantly on soils low in available P, generally when N was applied at rates of 100 lb/A and higher with the P treatments and when total yields were high. However, the yield curves for the P treated plots follow a similar pattern to those without P but at a higher numerical yield level. This would suggest that N is the dominant fertilizer factor in hay production in the general area and response of bromegrass to P is dependent on the supply of N. This suggestion is substantiated by the fact that the 11 lb/A P application annually appears to be sufficient at most locations when rates of N are below the 150 lb/A rate on sites which test low in available P. When higher rates of N are applied, the 22 lb/A rate of P produced numerically greater yields at most locations, however, seldom was the increase in yield significantly greater than when the 11 lb/A P rate was applied. The Jefferson county site in 1967 was the exception and the 11 lb/A P rate was significantly higher at the higher rates of N than the 22 lb/A rate.

Yields from sites testing medium in available soil P did not respond significantly to P applications, however, there is evidence from the 1968 data from the Doniphan county site (Fig. 3) that if high (200-250 lb/A) rates of N are applied annually, some P application may be necessary to maintain yields at a high level. It is therefore concluded from these data that the 11 lb/A rate of P was adequate at most sites to produce maximum yield and that the 22 lb/A rate was necessary to maintain yield at the high rates of N at sites testing low in available P. The 200-250 lb/A rates of N are probably not needed year after year.

Effects of Nitrogen and Phosphorus on Crude Protein Content

Nitrogen applications increased the percent crude protein content in bromegrass hay, especially at the 200-250 lb/A rates of N. In fact, N applications increased percent crude protein significantly at all locations in 1966, 1967 and 1968. Phosphorus applications on the other hand, did not effect crude protein significantly at any location in 1966, 1967 or 1968.

Crude protein percentages were numerically higher in 1966, (Fig. 4) a year of low yield and below normal precipitation, than in 1967 (Fig. 5) and 1968 (Fig. 6) when precipitation was above normal. Each increment increase in applied N produced a corresponding increase in percent crude protein in 1966 (Fig. 4) at all locations. There was a small increase in percent crude protein with each 50 pound increment increase up to 100 lb. N/A at the Doniphan, Franklin, Atchison, Brown and Jefferson county sites in 1966. However, each increment increase in N from 150 to 250 lb/A produced a much greater increase in percent crude protein. Crude protein means were near 15 percent at these locations with applications of 250 lb. N/A in 1966.

Percent crude protein means (Table XXVIII) from the Jackson county site in 1966 increased gradually from 11.5 percent on the control plots to 13.7 percent at the 250 lb. N rate. The Nemaha county location represented the other extreme in 1966 as crude protein means increased from 11.3 percent when no N was applied to 17.9 percent at the 250 pound N rate.

The 1967 (Fig. 5) and 1968 (Fig. 6) data indicate similar crude protein responses. Values were numerically lower than the 1966 levels and the curves followed a similar pattern at all locations in 1967 and 1968. In 1967 and 1968 rate of N had very little effect on crude protein content of bromegrass up to the 100 lb/A rate of N. Each 50 lb. increment in N application above the 100 lb. rate produced a corresponding increase in crude protein content.

A comparison of percent crude protein content (Figs. 4-6) with yield (Figs. 1-3) show that there is probably a correlation between percent crude protein and yield. When yield is increasing, percent crude protein content increases very little. However, once a maximum yield is reached, the crude protein content begins to increase at a faster rate. When yields decreased at the high rates of nitrogen (200-250 lb/A), crude protein percentages increased rapidly. This trend was observed to some extent at all locations. However, the most obvious locations which exemplified this pattern were Nemaha county in 1966 (Figs. 1 and 4) and Atchison county in 1967 (Figs. 2 and 5). Nemaha county yields in 1966 were the lowest recorded and percent crude protein the highest recorded. The Atchison county site in 1967 represented a reverse situation. As the yield increased to over 4 tons per acre, crude protein remained low, around 6 percent, and increased very little with increased N application. However, as the yield began to level off and drop at the high rates of N, percent crude protein increased. This would seem to suggest that percent crude protein content is not greatly affected by N application until maximum yield is reached or when hay yield is low.

Phosphorus had very little effect on percent crude protein at any location or in any year (Fig. 4-6). Crude protein response to P applications was erratic and appeared to follow no pattern.

Nitrogen applications increased protein yield (percent crude protein x dry weight yield) significantly at all locations in 1966 (Fig. 7), 1967 (Fig. 8) and 1968 (Fig. 9), as was expected since both dry weigh yield and percent crude protein were individually significant at all locations and years. Protein yield in 1966 (Fig. 7), a dry year, increased in almost a straight line function as rates of N increased. It appears from these data that dry weight yield is the dominant factor in protein yield. The Jackson and Jefferson (Group 2) county sites were the only two sites in 1966 (Fig. 7) which showed a significant response to P application in respect to both hay yield and protein yield. Phosphorus applications did not significantly increase percent crude protein at these locations. This is also shown at the Nemaha county site in 1966 (Fig. 7). Yield was low and percent crude protein was high; however, protein yield remained low. The dominant effect of dry weight yield on protein production per acre (protein yield) is further illustrated in 1967 (Fig. 8) and 1968 (Fig. 9) because these protein yield curves fit the hay yield pattern more closely than they do the crude protein curves. However, it should be pointed out that lbs. protein/A produced was numerically very little different at the various rates of N and P in 1966 (Fig. 7), 1967 (Fig. 8) and 1968 (Fig. 9).

Fig. 4 - Protein content (%) of bromegrass cut at bloom stage as affected by applications of nitrogen and phosphorus at seven locations (1966).

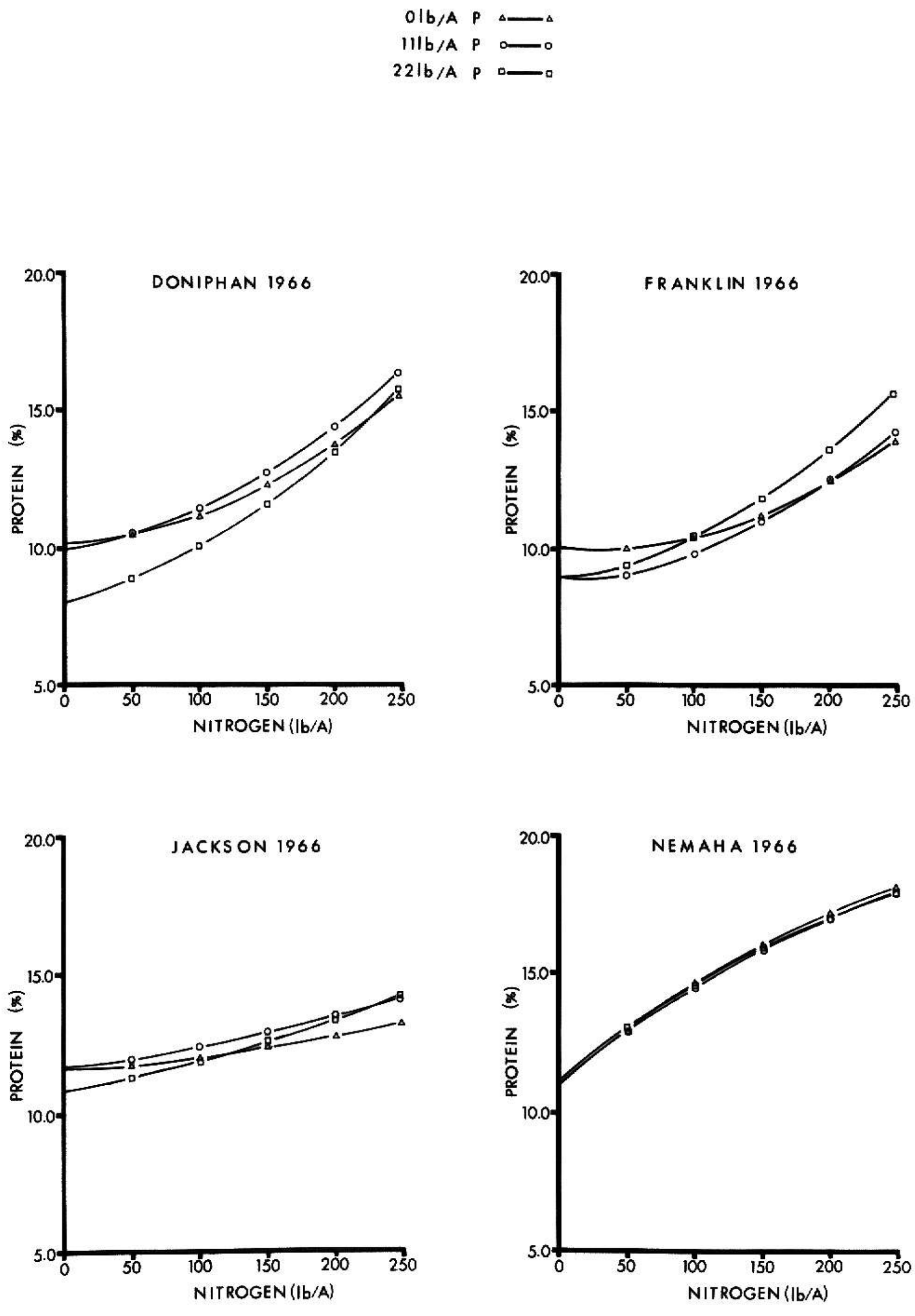

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1966
FRANKLIN 1966
JACKSON 1966
NEMAHA 1966
PROTEIN (%)
NITROGEN (lb/A)
20.0
15.0
10.0
5.0
0
50
100
150
200
250

Fig. 4 - (Continued)

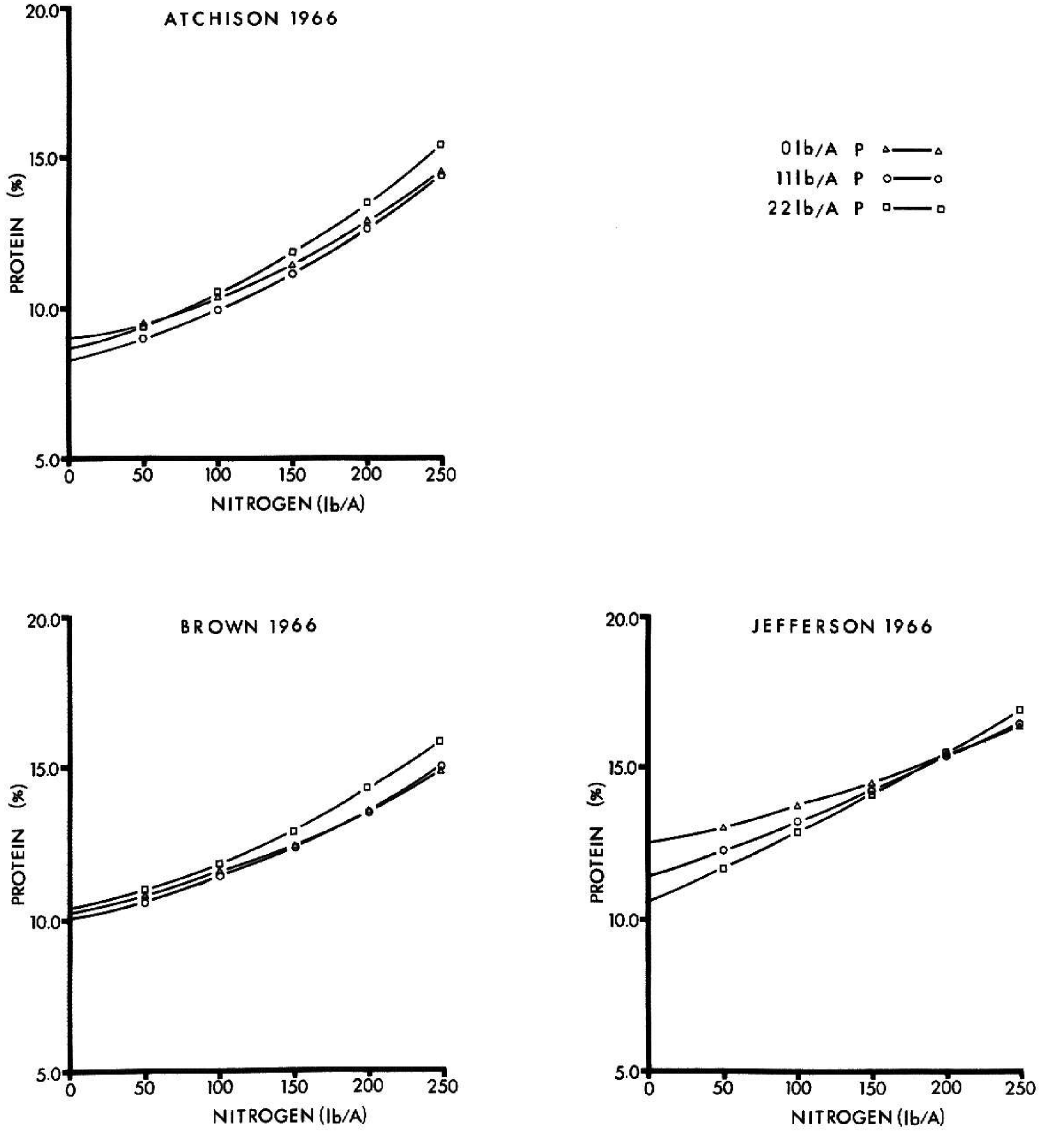

ATCHISON 1966
PROTEIN (%)
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
BROWN 1966
PROTEIN (%)
NITROGEN (lb/A)
JEFFERSON 1966
PROTEIN (%)
NITROGEN (lb/A)
20.0
15.0
10.0
5.0
0
50
100
150
200
250

Table IV - Multiple regression coefficients for protein content (%) as affected by different rates of nitrogen and phosphorus (1966)

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	9.015	0.355	-1.112	0.150	0.485	0.119	0.530
Brown	10.440	0.350	-0.710	0.106	0.308	0.116	0.339
Doniphan	10.156	0.134	0.389	0.191	-0.710	0.237	0.535
Franklin	10.083	-0.234	-1.825	0.205*	0.621	0.298	0.546
Jackson	11.692	0.131	0.455	0.038	-0.429	0.178	0.308
Jefferson	12.532	0.594	-1.269	0.038	0.167	0.234	0.338
Nemaha	11.020	2.022**	-0.048	-0.117	0.073	-0.038	0.530

*N and P variables are coded as follows:

N		Code
0	=	0
50	=	1
100	=	2
150	=	3
200	=	4
250	=	5

P		Code
0	=	0
11	=	1
22	=	2

Fig. 5 - Protein content (%) of bromegrass cut at bloom stage as affected by applications of nitrogen and phosphorus at seven locations (1967).

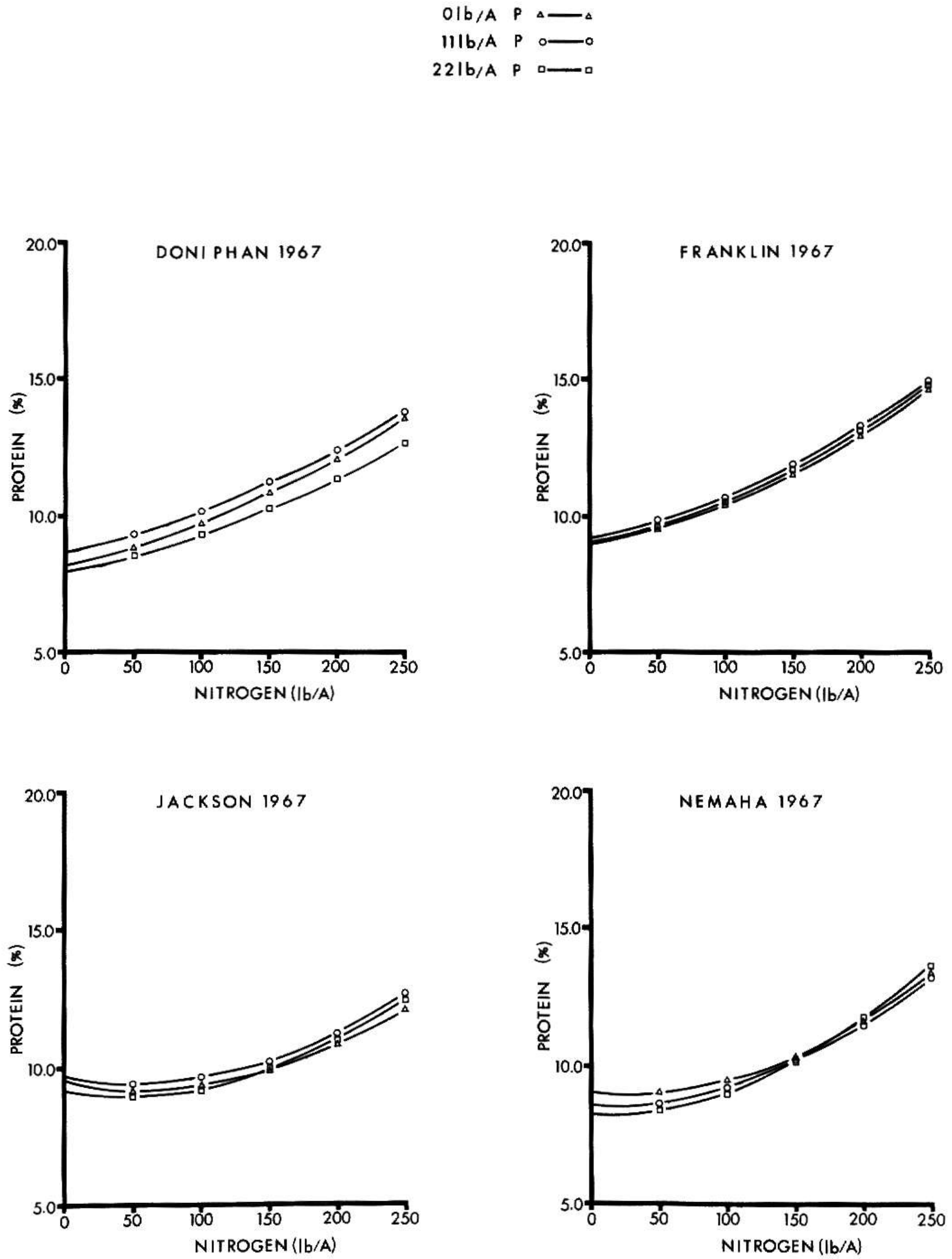

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1967
FRANKLIN 1967
JACKSON 1967
NEMAHA 1967
PROTEIN (%)
20.0
15.0
10.0
5.0
0
50
100
150
200
250
NITROGEN (lb/A)

Fig. 5 - (Continued)

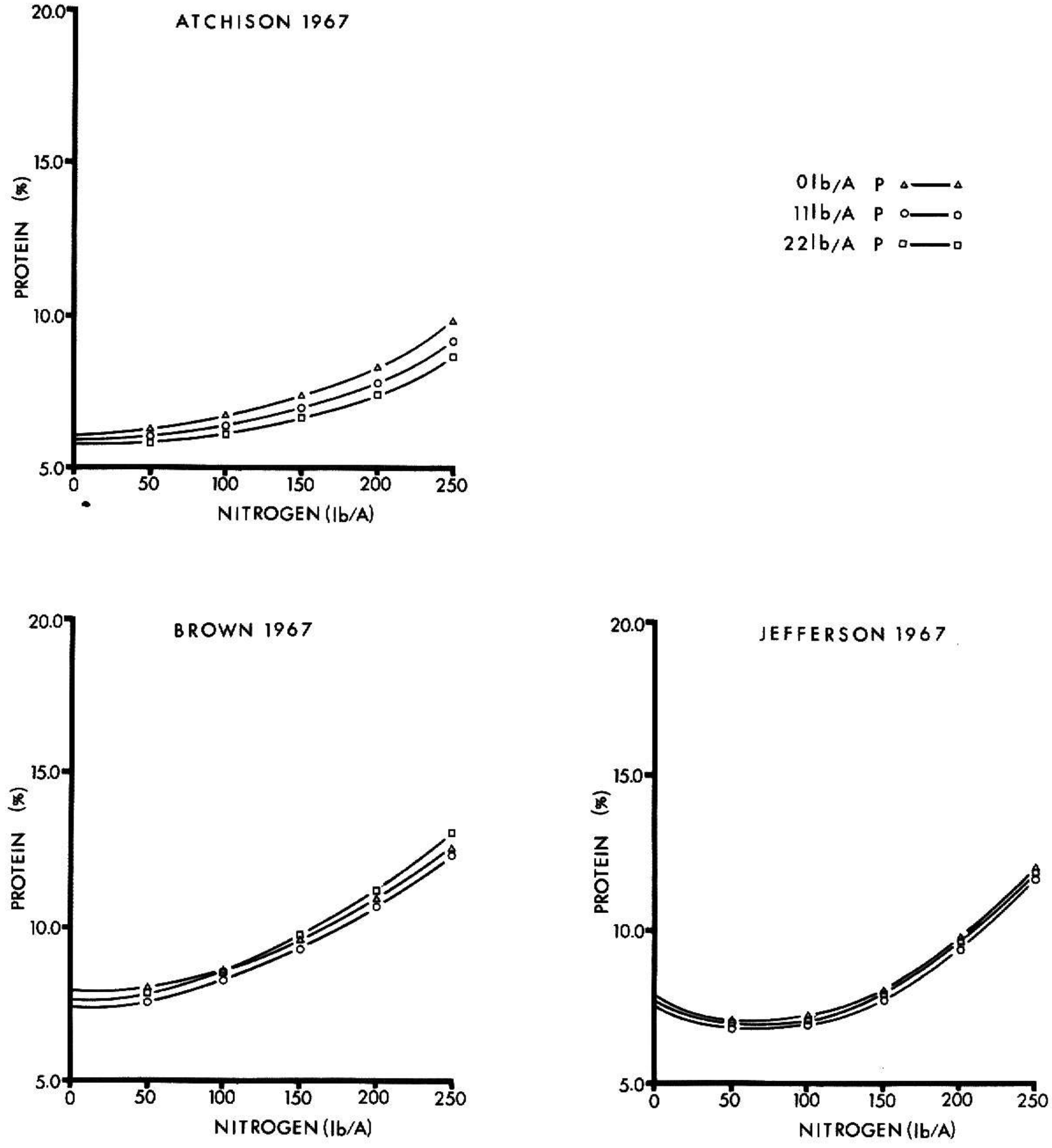

ATCHISON 1967
PROTEIN (%)
20.0
15.0
10.0
5.0
0
50
100
150
200
250
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
BROWN 1967
PROTEIN (%)
20.0
15.0
10.0
5.0
0
50
100
150
200
250
NITROGEN (lb/A)
JEFFERSON 1967
PROTEIN (%)
20.0
15.0
10.0
5.0
0
50
100
150
200
250
NITROGEN (lb/A)

Table V - Multiple regression coefficients for protein content(%) as affected by different rates of nitrogen and phosphorus (1967).

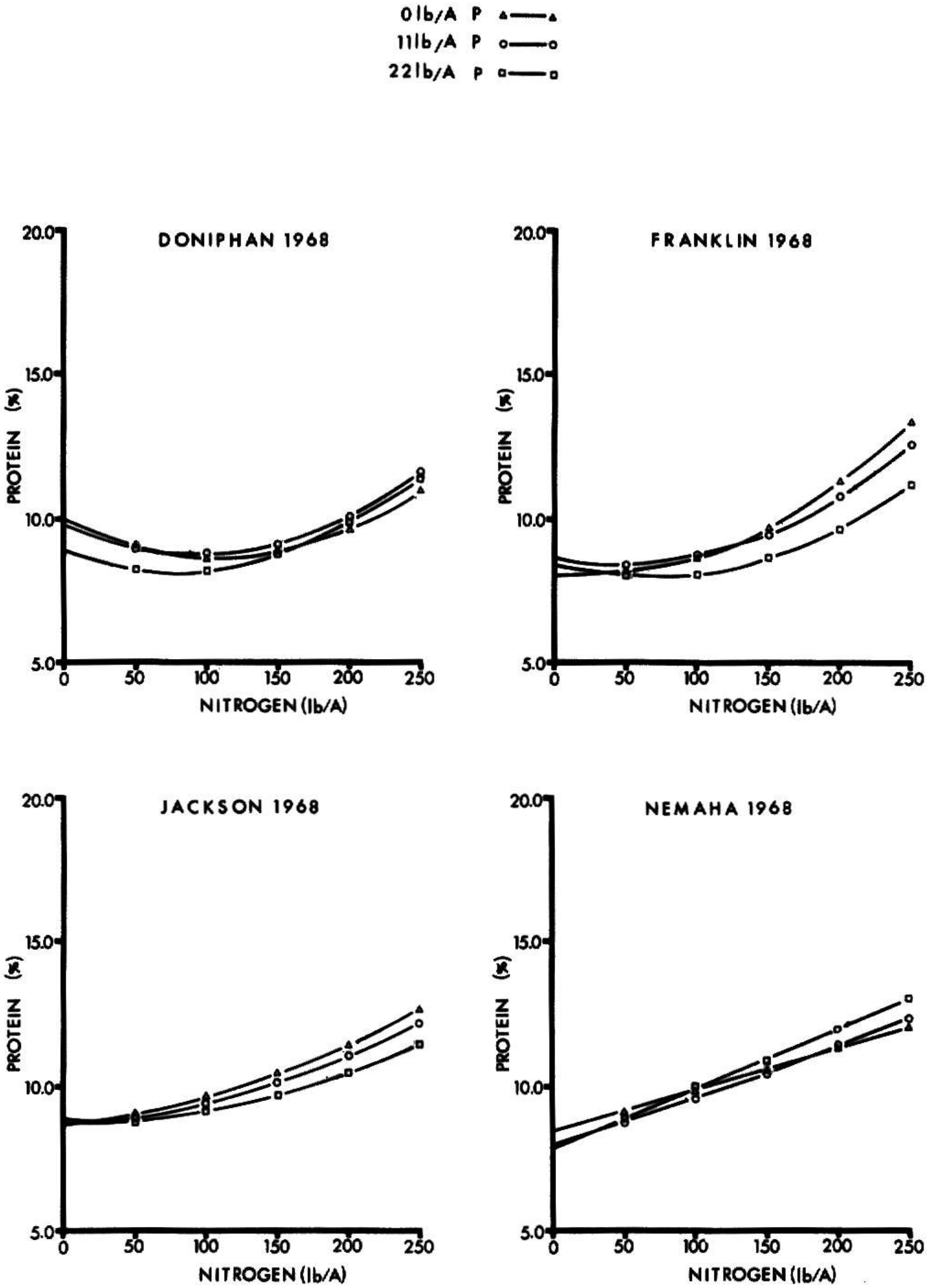
Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	6.099	-0.089	0.001	0.165*	-0.027	-0.100	0.416
Brown	7.975	-0.045	-0.945	0.192*	0.396	0.076	0.490
Doniphan	8.068	0.634	1.359	0.093	-0.694*	-0.091	0.659
Franklin	8.959	0.484	0.398	0.128	-0.210	0.032	0.696
Jackson	9.482	-0.454	0.404	0.197**	-0.296	0.065	0.568
Jefferson	7.807	-1.054**	-0.468	0.382**	0.178	0.010	0.608
Nemaha	9.079	-0.185	-0.615	0.210**	0.098	0.110	0.673

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

Fig. 6 - Protein content (%) of bromegrass cut at bloom stage as affected by applications of nitrogen and phosphorus at four locations (1968).



0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1968
FRANKLIN 1968
JACKSON 1968
NEMAHA 1968
PROTEIN (%)
20.0
15.0
10.0
5.0
0
50
100
150
200
250
NITROGEN (lb/A)

Table VI - Multiple regression coefficients for protein content(%) of bromegrass as affected by rates of nitrogen and phosphorus (1968).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Doniphan	9.986	-1.244**	0.122	0.289**	-0.342	0.168	0.434
Franklin	8.048	-0.179	0.846	0.246*	-0.323	0.251	0.299
Jackson	8.736	0.228	0.163	0.112	-0.062	0.128	0.458
Nemaha	8.555	0.625*	-0.744	0.017	0.223	0.162	0.656

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

Notable exceptions were Nemaha and Brown counties where hay yields were very low in 1966 and higher in 1967 and 1968. Nitrogen means were 232.4 lb/A in Nemaha county and 408.2 lb/A in Brown county at the 250 lb/A N application in 1966. These protein yield means, at this rate of N, increased to 700.2 and 677.3 lb/A in 1967 and 682.8 lb/A at the Nemaha site in 1968. The Doniphan county site, where yield was not greatly different from year to year, showed protein yield means at the 250 lb. N/A application to be 622.2 lbs. crude protein/A in 1966, 563.5 lb/A in 1967 and 600.6 lb/A in 1968. Therefore, it would appear that lb. protein/A produced each year at any given nitrogen or phosphorus treatment and location remained comparatively constant when yield was not extremely low, at all sites studied. One reason protein yield remained relatively constant in this study was because of the interaction between yield and percent crude protein. One seemed to compensate for the other, producing similar protein yields each year at any given fertilizer treatment.

Phosphorus applications appear to effect protein yield through its effect on percent crude protein content in the plant. Phosphorus application produced significant protein yield increases in all three years at the Jackson county site. Therefore, since P applications did not significantly increase percent crude protein in any year, but increased hay significantly all three years, it would seem P applications affect protein yield by increasing hay yields.

Effect of Nitrogen and Phosphorus Applications on Phosphorus Content of Bromegrass

Nitrogen significantly increased the P content of mature bromegrass only on the Atchison, Doniphan and Franklin county sites in 1966 (Table X).

Fig. 7 - Protein yield (% protein X dry weight yield) of bromegrass as affected by applications of nitrogen and phosphorus at seven locations (1966).

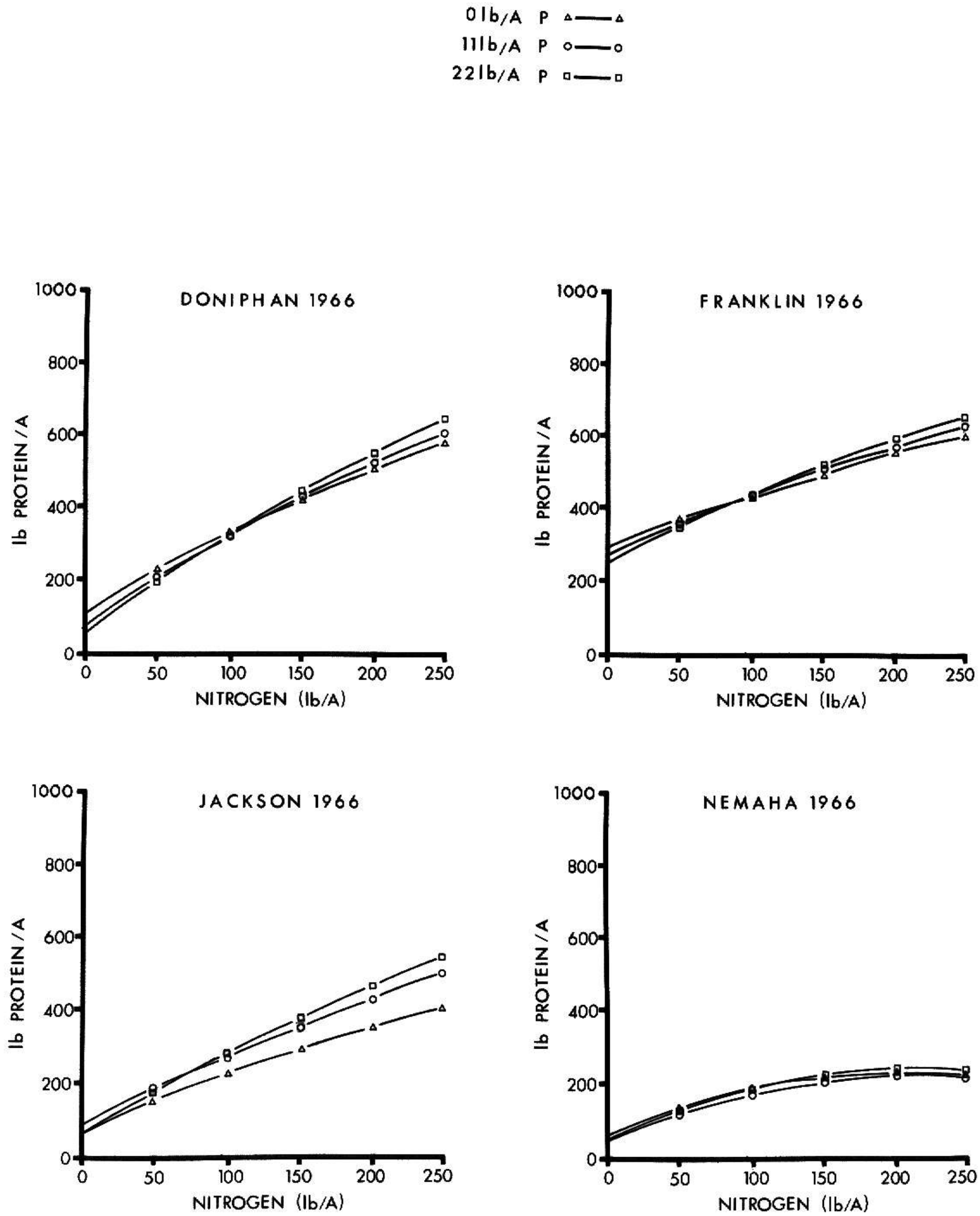

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1966
FRANKLIN 1966
JACKSON 1966
NEMAHA 1966
lb PROTEIN/A
NITROGEN (lb/A)
0
200
400
600
800
1000
0
50
100
150
200
250

Fig. 7 - (Continued)

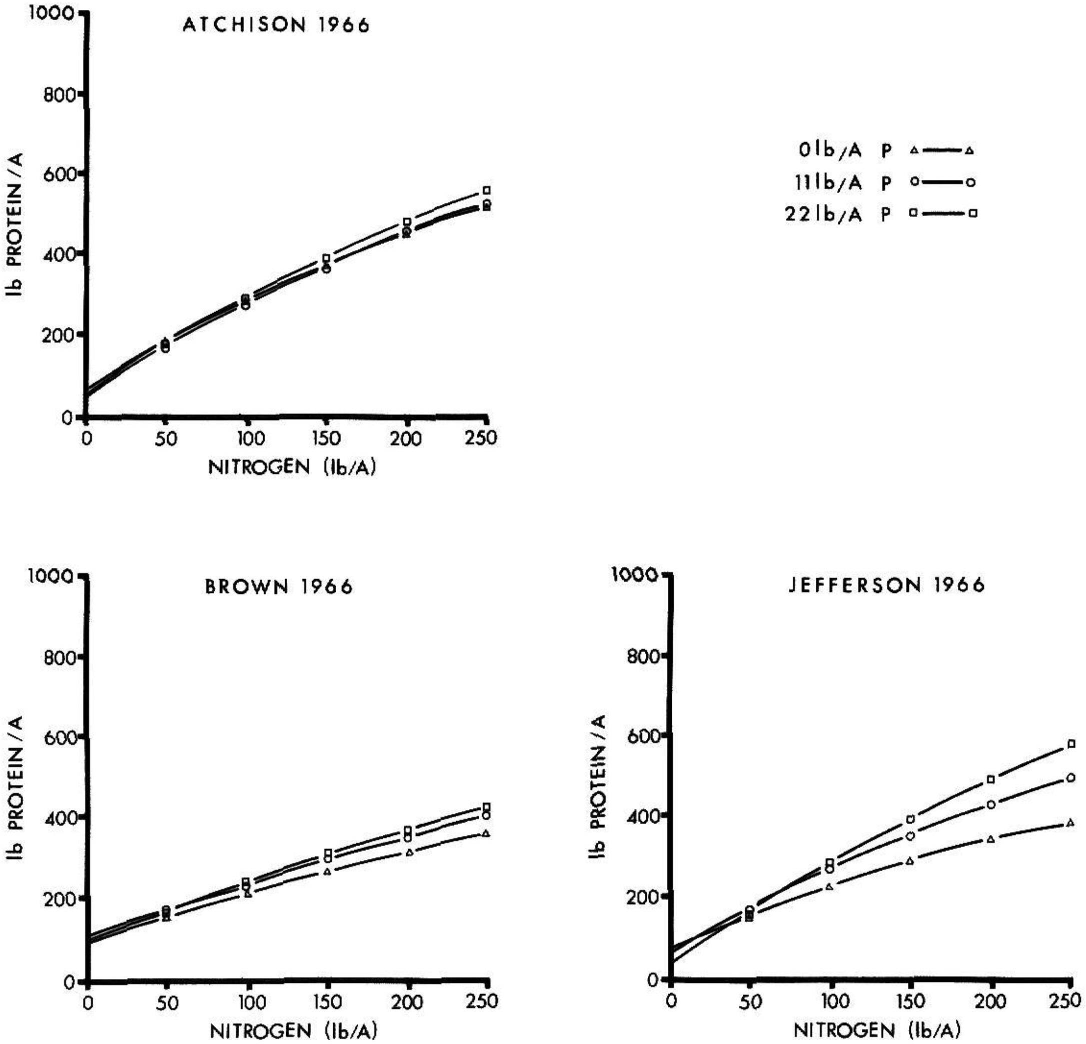

ATCHISON 1966
lb PROTEIN/A
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
BROWN 1966
lb PROTEIN/A
NITROGEN (lb/A)
JEFFERSON 1966
lb PROTEIN/A
NITROGEN (lb/A)

Table VII - Multiple regression coefficients for protein yield of bromegrass (% protein X dry weight yield) as affected by rates of nitrogen and phosphorus (1966).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	68.190	121.793**	-28.065	-6.210	9.562	5.768	0.791
Brown	91.469	63.421*	22.137	-1.784	-10.708	7.228	0.598
Doniphan	105.619	121.879**	-42.178	-5.344	7.312	12.796	0.865
Franklin	289.523	80.946**	-15.119	-3.661	-1.250	9.214	0.746
Jackson	67.908	85.208**	36.655	-3.256	-18.667	14.371**	0.898
Jefferson	72.156	88.273**	6.294	-5.073	-12.639	23.738**	0.857
Nemaha	64.448	81.191**	-25.655	-9.860**	9.292	3.078	0.631

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

Fig. 8 - Protein yield (% protein X dry weight yield) of bromegrass as affected by applications of nitrogen and phosphorus at seven locations (1967).

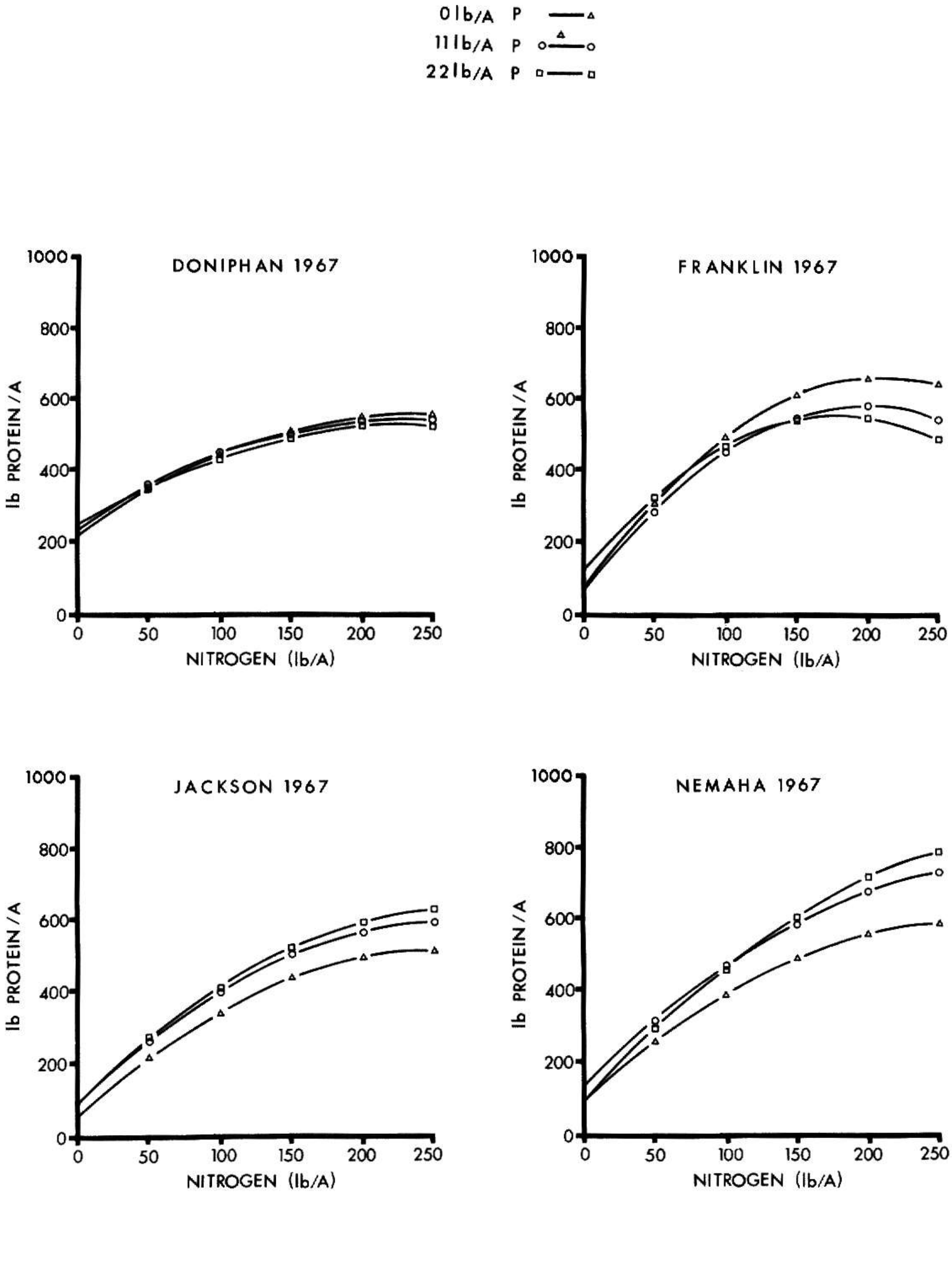

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1967
FRANKLIN 1967
JACKSON 1967
NEMAHA 1967
lb PROTEIN / A
NITROGEN (lb/A)
0
200
400
600
800
1000
0
50
100
150
200
250

Fig. 8 - (Continued)

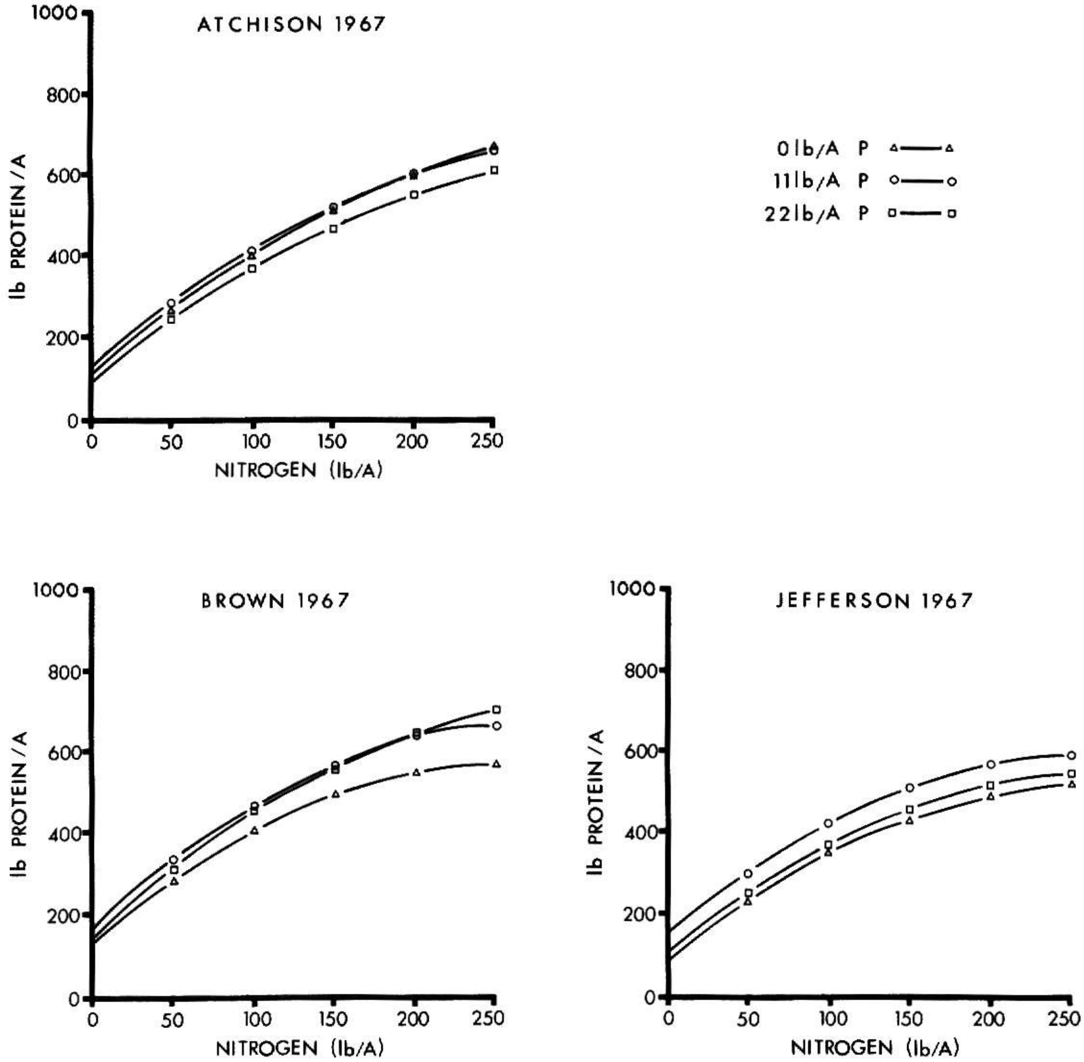

ATCHISON 1967
BROWN 1967
JEFFERSON 1967
lb PROTEIN/A
NITROGEN (lb/A)
0 lb/A P
11 lb/A P
22 lb/A P
0
200
400
600
800
1000
0
50
100
150
200
250

Table VIII - Multiple regression coefficients for protein yield of bromegrass (% protein X dry weight yield) as affected by applications of nitrogen and phosphorus (1967).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Atchison	113.797	166.598**	41.143	-10.996*	-24.812	-4.332	0.745
Brown	130.017	173.525**	76.976	-16.763**	-36.687	11.568	0.723
Doniphan	216.023	145.843**	9.113	-15.455**	-2.750	-2.928	0.603
Franklin	69.238	281.[illegible]5**	-30.541	-33.318**	26.270	-18.974**	0.863
Jackson	55.826	181.749**	63.535*	-17.962**	-21.833	7.935	0.920
Jefferson	84.214	163.586**	133.507*	-15.244**	-62.083*	0.719	0.734
Nemaha	94.832	181.905**	78.095	-16.837**	-39.708*	20.678**	0.898

*N and P variables are coded as follows:

N		Code
0	=	0
50	=	1
100	=	2
150	=	3
200	=	4
250	=	5

P		Code
0	=	0
11	=	1
22	=	2

Fig. 9 - Protein yield (% protein X dry weight yield) of bromegrass as affected by applications of nitrogen and phosphorus at four locations (1968).

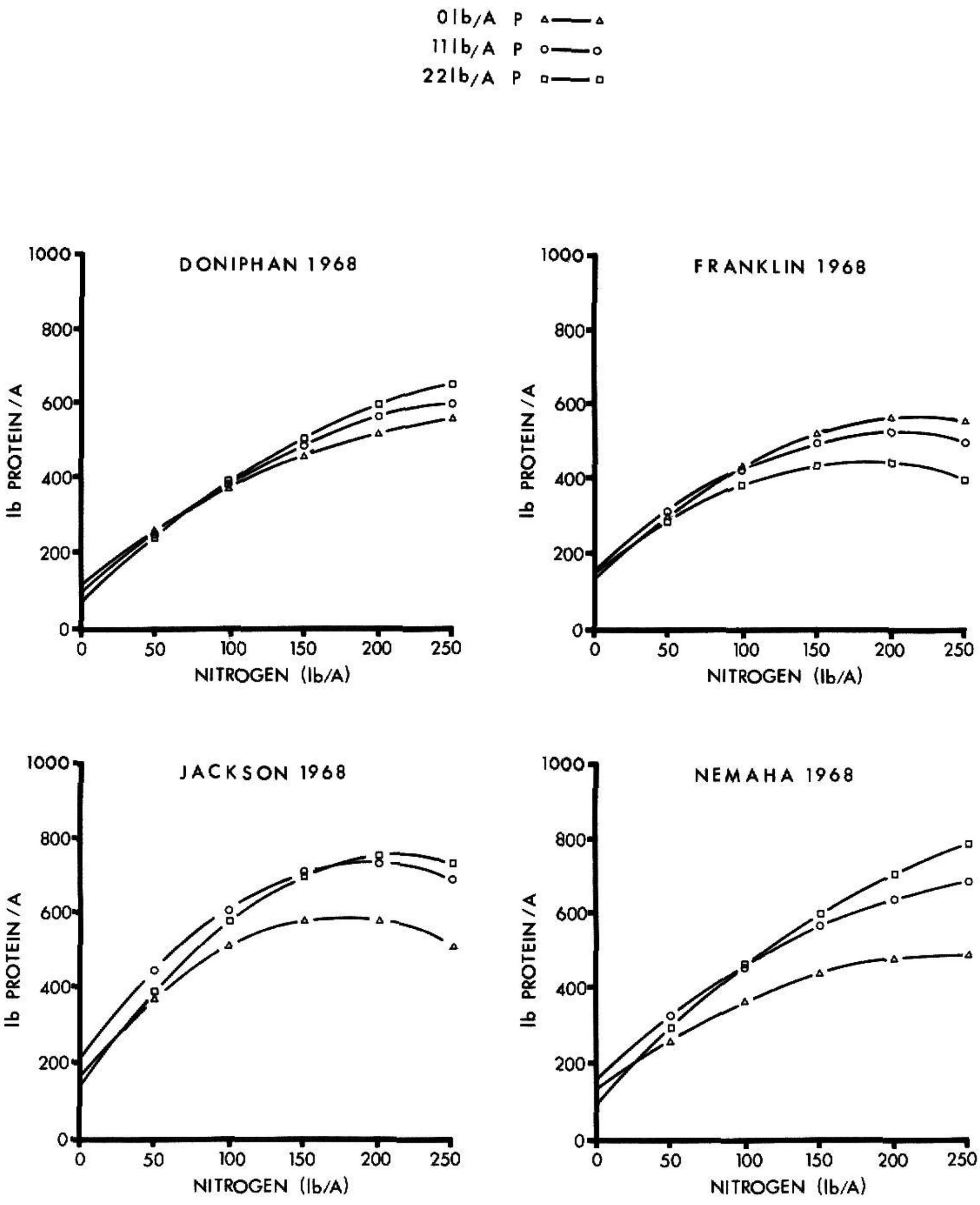

0 lb/A P
11 lb/A P
22 lb/A P
DONIPHAN 1968
FRANKLIN 1968
JACKSON 1968
NEMAHA 1968
lb PROTEIN/A
NITROGEN (lb/A)
0
200
400
600
800
1000
0
50
100
150
200
250

Table IX - Multiple regression coefficients for protein yield of bromegrass (% protein X dry weight yield) as affected by rates of nitrogen and phosphorus (1968).

Equation: $Y = a+b_1N+b_2P+b_3N^2+b_4P^2+b_5NP$*

Location	a	b_1N	b_2P	b_3N^2	b_4P^2	b_5NP	R^2
Doniphan	116.631	160.512**	-18.190	-14.863**	-3.479	16.167*	0.859
Franklin	123.225	202.791**	54.839	-22.936**	-21.958	-17.835	0.603
Jackson	160.442	244.687**	118.922	-34.949**	-67.458	25.914	0.591
Nemaha	132.469	148.947**	69.148	-15.386**	-44.520*	34.332**	0.850

*N and P variables are coded as follows:

N		Code	P		Code
0	=	0	0	=	0
50	=	1	11	=	1
100	=	2	22	=	2
150	=	3			
200	=	4			
250	=	5			

At the sites testing low in available soil P, Brown, Jackson, Jefferson and Nemaha, percent P increases due to N applications were not significant. Forage produced at all sites tested in 1967 and 1968 showed a significant increase in percent P due to N applications.

Phosphorus applications increased the P content significantly at all locations tested in 1966, 1967 and 1968 with the exception of the Jefferson county site in 1966. Although not significant, the general trend for P content to increase with each increment increase in applied P was also observed at this site. The four site groups could be divided into two groups: those on low P soils and those on medium P soils.

The P content of mature bromegrass harvested from the medium P sites contained consistently higher levels of P than the sites testing low in P. The P content did increase slightly on the low P soils in 1967 and 1968 but did not reach the P levels of the plants from the medium P soils. The mean P content of plants from the plots receiving no N (Table X) were relatively high. The P content of the plant tissue was reduced by the application of 50 lbs. of N/A and generally reached a maximum again somewhere between the 100 and 200 lb. rate of N. However, P content due to N applications within location varied little between the 50 and the 250 lb. rates of N.

These data would indicate that nitrogen affected the phosphorus content very little between the 50 and 250 lb. rates of N and when no nitrogen was applied, P content tended to be higher. This is apparently due to the dilution effect. Phosphorus applications increased the P content in the mature bromegrass plants. This increase in percent P content was greatest on sites low in available soil P and each increment of applied P produced a corresponding increase in P content of the plants at these sites.

Table X - Phosphorus content of bromegrass at the bloom stage. (Values are means of 4 replications)

Treatment lb/A		Locations 1966							Locations 1967			Locations 1968			
N	P	AT	BR	DP	FR	JA	JE*	NM	DP	FR	NM	DP	FR	JA	NM
		%P Means													
0	0	0.165	0.083	0.187	0.170	0.152	0.173	0.132	0.167	0.155	0.127	0.212	0.222	0.147	0.155
0	11	0.190	0.153	0.200	0.147	0.157	0.150	0.145	0.182	0.185	0.157	0.232	0.200	0.180	0.162
0	22	0.202	0.143	0.187	0.175	0.142	0.193	0.140	0.172	0.185	0.162	0.212	0.210	0.185	0.150
50	0	0.145	0.092	0.167	0.142	0.120	0.180	0.122	0.145	0.120	0.102	0.170	0.147	0.107	0.097
50	11	0.137	0.094	0.185	0.155	0.137	0.166	0.145	0.157	0.152	0.115	0.187	0.165	0.147	0.127
50	22	0.150	0.130	0.152	0.182	0.147	0.150	0.157	0.155	0.157	0.130	0.180	0.170	0.165	0.152
100	0	0.135	0.098	0.140	0.122	0.120	0.136	0.117	0.152	0.117	0.097	0.137	0.140	0.102	0.085
100	11	0.167	0.109	0.172	0.142	0.135	0.153	0.145	0.160	0.142	0.145	0.162	0.165	0.142	0.130
100	22	0.137	0.115	0.177	0.150	0.122*	0.173	0.175	0.172	0.165	0.142	0.175	0.187	0.165	0.170
150	0	0.140	0.127	0.137	0.150	0.140	0.160	0.132	0.160	0.125	0.090	0.130	0.155	0.097	0.080
150	11	0.130	0.097	0.165	0.147	0.127	0.160	0.160	0.187	0.132	0.140	0.160	0.177	0.157	0.125
150	22	0.180	0.117	0.182	0.190	0.140	0.160	0.137	0.195	0.180	0.162	0.182	0.182	0.165	0.142
200	0	0.125	0.087	0.157	0.130	0.097	0.146	0.142	0.160	0.100	0.107	0.135	0.150	0.102	0.090
200	11	0.137	0.101	0.192	0.150	0.142	0.143	0.112	0.195	0.160	0.130	0.167	0.180	0.145	0.102
200	22	0.175	0.136	0.180	0.175	0.165	0.170	0.170	0.192	0.187	0.182	0.165	0.157	0.157	0.165
250	0	0.132	0.122	0.145	0.140	0.122	0.130	0.117	0.182	0.127	0.125	0.132	0.155	0.100	0.085
250	11	0.167	0.108	0.170	0.155	0.130	0.163	0.142	0.212	0.157	0.142	0.162	0.155	0.112	0.110
250	22	0.142	0.129	0.142	0.162	0.152	0.170	0.152	0.187	0.190	0.180	0.175	0.180	0.155	0.140

Table X - Continued

Treatment lb/A N	P	1966 AT	1966 BR	1966 DP	1966 FR	1966 JA	1966 JE*	1966 NM	1967 DP	1967 FR	1967 NM	1968 DP	1968 FR	1968 JA	1968 NM
		% P by N Means													
0		0.185	0.127	0.192	0.164	0.150	0.172	0.139	0.174	0.175	0.149	0.219	0.211	0.171	0.142
50		0.144	0.106	0.168	0.160	0.135	0.166	0.142	0.152	0.143	0.116	0.179	0.161	0.140	0.126
100		0.146	0.108	0.163	0.138	0.126	0.154	0.146	0.162	0.142	0.128	0.158	0.164	0.137	0.128
150		0.150	0.114	0.162	0.162	0.136	0.160	0.143	0.181	0.146	0.131	0.158	0.172	0.140	0.116
200		0.145	0.108	0.177	0.152	0.135	0.153	0.142	0.182	0.149	0.140	0.156	0.162	0.135	0.119
250		0.147	0.120	0.169	0.152	0.135	0.154	0.138	0.194	0.158	0.149	0.157	0.163	0.122	0.112
L.S.D. 0.05		0.018	N.S.	0.019	0.014	N.S.	N.S.	N.S.	0.017	0.020	0.016	0.015	0.017	0.011	0.018
		% P by P Means													
	0	0.140	0.102	0.156	0.142	0.125	0.154	0.128	0.161	0.124	0.108	0.153	0.162	0.110	0.092
	11	0.155	0.111	0.181	0.150	0.138	0.156	0.142	0.182	0.155	0.138	0.179	0.174	0.148	0.126
	22	0.164	0.129	0.179	0.172	0.145	0.169	0.155	0.179	0.178	0.160	0.182	0.181	0.165	0.153
L.S.D. 0.05		0.013	0.018	0.013	0.010	0.015	N.S.	0.016	0.012	0.014	0.012	0.010	0.012	0.008	0.012

*Values are means of 3 replications

Increase in percent P due to P application was less at the medium soil P sites but still significant. P content in the bromegrass plants was numerically higher from soils medium in P as compared to the soils low in soil P.

Effect of N and P Applications on K, Ca and Mg20 Content of Mature Bromegrass

Four locations, Doniphan, Franklin, Jackson and Nemaha, were selected for analysis of K, Ca and Mg content of mature bromegrass in 1966 and 1968.

The potassium content was affected very little by N and P applications. Nitrogen increased the K content significantly in Doniphan county at the higher levels of application in 1966 (Table XI). This was the only location which showed a significant response in 1966. Potassium content was not changed significantly by application of P at any location studied in 1966. The K content was significantly lower than the control at all rates of N at the Franklin county location in 1968. Plant analysis shows that the Franklin county plots contained considerably less K than any other location analyzed. The K means at most locations was near 2.0 percent, however, means at the Franklin county site in 1968 were near the 1.6 percent K level. Potassium was applied to all plots at each location in 1966, 1967 and 1968 so that this element would not be limiting. These data would suggest that for some reason K may have been a limiting factor at the Franklin county site in 1968. Laughlin and Restad (1964) reported lower hay yields when concentrations of K in the plant material were at the 1.6 percent K level. All other sites showed little or no change in percent K due to N and P applications.

The Ca content of bromegrass was affected by N in a manner similar to that of P. The Ca content was highest in plant material from the plots receiving no N. Analysis of plant material indicated little change due to rate of N applied. The Doniphan, Franklin and Jackson county sites were significantly lower than the control in percent Ca content in 1966. The Ca content of the plants was significantly lowered by N applications at the Doniphan and Jackson county sites in 1968. The Nemaha site showed no significance either year. The Ca content was higher at the Nemaha site than any of the others analyzed. This may have been due to the fact that free lime was present in the soil profile at about 18 inches which made the pH high and more Ca available to the plants at this location. Phosphorus applications had no significant effect on percent Ca content of the plant material. A high Ca content in plant material at the Nemaha site was associated with a lower Mg content (Table XIII). The Mg content appeared to be affected very little by nitrogen and phosphorus applications.

Nitrate Nitrogen, Ether Extract and Crude Fiber Content of Bromegrass

The NO_3-N content of bromegrass hay at all locations in 1966 was very low (Table XIV). Nitrogen applications increased the NO_3-N content in plant material significantly at the Doniphan, Franklin, Jefferson and Nemaha sites in 1966. The relatively high NO_3-N means were recorded at the 250 lb/A rate of N application at all locations. However, the NO_3-N contents were considered to be modest even at the 250 lb. N rate. The highest NO_3-N means recorded were only 0.14 percent NO_3-N. These data would indicate that NO_3-N accumulation in bromegrass hay is not a problem even in a dry year like 1966, when concentrations could be expected to be high.

Table XI - Potassium content of bromegrass at the bloom stage (values are means of 4 replications)

Treatments lb/A N	P	Locations 1966 DP	FR	JA	NM	Locations 1968 DP	FR	JA	NM
		% K Means							
0	0	2.06	2.07	1.95	1.85	2.00	1.95	1.96	1.78
0	11	2.16	1.86	2.06	1.93	1.91	1.76	2.17	1.82
0	22	1.90	2.00	1.81	1.88	1.88	2.01	2.03	1.81
50	0	2.23	1.97	1.92	1.76	1.87	1.48	1.93	1.76
50	11	2.12	1.91	2.01	1.81	2.03	1.65	1.97	1.90
50	22	2.11	2.05	2.11	1.81	1.77	1.50	2.05	1.87
100	0	2.17	1.91	1.95	1.95	1.87	1.50	2.00	1.81
100	11	2.21	2.00	1.86	1.88	1.95	1.51	2.13	1.85
100	22	2.15	2.03	1.72	1.98	1.80	1.68	2.17	1.98
150	0	2.27	1.98	1.86	1.92	1.91	1.47	2.10	1.80
150	11	2.46	2.03	1.77	1.92	1.87	1.63	2.33	2.15
150	22	2.37	2.02	1.86	1.80	2.01	1.48	2.10	1.93
200	0	2.31	2.00	1.85	1.98	2.17	1.53	1.82	1.75
200	11	2.43	1.91	1.90	1.81	1.88	1.47	2.20	1.77
200	22	2.55	1.98	1.93	2.01	1.91	1.53	2.13	1.92
250	0	2.28	1.93	1.68	1.77	1.97	1.60	1.77	1.68
250	11	2.21	1.91	1.98	2.03	2.03	1.80	2.10	1.73
250	22	2.36	1.98	1.87	1.78	1.93	1.66	2.08	1.66
		% K by N Means							
0		2.042	1.979	1.942	1.892	1.933	1.908	2.058	1.808
50		2.158	1.979	2.017	1.796	1.896	1.546	1.988	1.846
100		2.179	1.983	1.846	1.942	1.875	1.567	2.104	1.883
150		2.371	2.017	1.833	1.883	1.933	1.533	2.179	1.962
200		2.433	1.967	1.896	1.936	1.992	1.517	2.054	1.817
250		2.288	1.946	1.850	1.867	1.983	1.688	1.988	1.696
L.S.D. 0.05		0.154	N.S.	N.S.	N.S.	N.S.	0.177	N.S.	0.156
		% K by P Means							
	0	2.225	1.981	1.871	1.875	1.969	1.592	1.933	1.767
	11	2.269	1.940	1.933	1.902	1.950	1.640	2.154	1.873
	22	2.242	2.014	1.888	1.881	1.888	1.648	2.097	1.867
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.099	N.S.

Table XII - Calcium content of bromegrass at the bloom stage. (Values are means of 4 replications)

Treatments lb/A N	P	1966 DP	1966 FR	1966 JA	1966 NM	1968 DP	1968 FR	1968 JA	1968 NM
		Locations 1966				Locations 1968			
		DP	FR	JA	NM	DP	FR	JA	NM
		% Ca Means							
0	0	0.417	0.355	0.387	0.672	0.415	0.460	0.377	0.612
0	11	0.402	0.332	0.447	0.637	0.457	0.287	0.547	0.610
0	22	0.312	0.377	0.367	0.720	0.382	0.335	0.470	0.607
50	0	0.332	0.320	0.307	0.575	0.335	0.285	0.417	0.560
50	11	0.317	0.307	0.367	0.525	0.320	0.222	0.392	0.492
50	22	0.332	0.305	0.395	0.425	0.310	0.430	0.447	0.470
100	0	0.265	0.272	0.340	0.470	0.297	0.302	0.502	0.450
100	11	0.280	0.300	0.297	0.437	0.297	0.335	0.457	0.517
100	22	0.272	0.345	0.272	0.475	0.295	0.430	0.432	0.540
150	0	0.285	0.345	0.297	0.657	0.287	0.355	0.305	0.450
150	11	0.290	0.342	0.282	0.430	0.305	0.365	0.465	0.490
150	22	0.290	0.322	0.325	0.535	0.302	0.342	0.407	0.490
200	0	0.290	0.297	0.277	0.447	0.312	0.467	0.417	0.462
200	11	0.362	0.352	0.305	0.487	0.342	0.430	0.432	0.507
200	22	0.307	0.342	0.327	0.665	0.290	0.352	0.372	0.485
250	0	0.287	0.340	0.342	0.602	0.305	0.415	0.325	0.410
250	11	0.295	0.377	0.315	0.572	0.327	0.402	0.305	0.490
250	22	0.300	0.360	0.312	0.500	0.305	0.365	0.370	0.480
		% Ca by N Means							
0		.378	.355	.401	.677	.418	.361	.465	.610
50		.323	.311	.357	.508	.322	.312	.419	.508
100		.272	.306	.303	.461	.297	.356	.464	.502
150		.288	.337	.302	.541	.298	.354	.392	.477
200		.322	.331	.303	.533	.315	.417	.408	.485
250		.294	.359	.323	.558	.312	.394	.333	.460
L.S.D. 0.05		.038	.034	.069	N.S.	.041	N.S.	.081	N.S.
		% Ca by P Means							
	0	.314	.322	.325	.571	.325	.381	.391	.491
	11	.324	.335	.336	.515	.342	.340	.433	.518
	22	.302	.342	.333	.553	.314	.376	.417	.512
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table XIII - Magnesium content of bromegrass at the bloom stage. (Values are means of 4 replications)

Treatments lb/A N	P	Locations 1966 DP	FR	JA	NM	Locations 1968 DP	FR	JA	NM
					% Mg Means				
0	0	0.107	0.107	0.107	0.082	0.110	0.107	0.100	0.075
0	11	0.102	0.097	0.122	0.095	0.120	0.080	0.107	0.082
0	22	0.095	0.107	0.100	0.082	0.092	0.087	0.102	0.070
50	0	0.085	0.097	0.095	0.072	0.092	0.080	0.095	0.065
50	11	0.085	0.090	0.097	0.077	0.090	0.065	0.092	0.075
50	22	0.075	0.097	0.105	0.082	0.087	0.070	0.100	0.072
100	0	0.075	0.090	0.100	0.085	0.082	0.087	0.087	0.070
100	11	0.080	0.095	0.092	0.077	0.082	0.087	0.097	0.072
100	22	0.080	0.107	0.087	0.090	0.085	0.110	0.097	0.085
150	0	0.087	0.112	0.092	0.087	0.085	0.110	0.095	0.065
150	11	0.090	0.110	0.095	0.087	0.092	0.102	0.110	0.075
150	22	0.082	0.115	0.102	0.077	0.085	0.110	0.092	0.087
200	0	0.092	0.100	0.087	0.090	0.097	0.127	0.090	0.067
200	11	0.107	0.127	0.102	0.077	0.095	0.147	0.102	0.075
200	22	0.097	0.125	0.102	0.095	0.092	0.102	0.100	0.090
250	0	0.092	0.120	0.105	0.087	0.090	0.135	0.090	0.070
250	11	0.092	0.127	0.102	0.100	0.102	0.152	0.092	0.075
250	22	0.100	0.145	0.102	0.097	0.085	0.112	0.105	0.097
					% Mg by N Means				
0		0.102	0.104	0.110	0.087	0.108	0.092	0.103	0.076
50		0.082	0.095	0.099	0.078	0.090	0.072	0.096	0.071
100		0.078	0.098	0.093	0.084	0.083	0.095	0.094	0.076
150		0.087	0.112	0.097	0.084	0.088	0.110	0.099	0.076
200		0.099	0.118	0.098	0.088	0.095	0.126	0.098	0.078
250		0.095	0.131	0.103	0.095	0.092	0.133	0.096	0.080
L.S.D. 0.05		0.011	0.009	N.S.	0.009	0.010	0.024	N.S.	N.S.
					% Mg by P Means				
	0	0.090	0.104	0.098	0.084	0.093	0.109	0.093	0.069
	11	0.093	0.108	0.102	0.086	0.097	0.106	0.100	0.076
	22	0.088	0.116	0.100	0.088	0.088	0.099	0.100	0.084
L.S.D. 0.05		N.S.	0.006	N.S.	N.S.	0.007	N.S.	0.006	0.007

Table XIV - Nitrate-nitrogen content of bromegrass at the bloom stage (1966). (Values are means of 4 replications)

Treatment lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		Locations						
		% NO_3 -N						
0	0	0.028	0.020	0.042	0.022	0.022	0.040	0.070
0	11	0.038	0.010	0.018	0.035	0.038	0.053	0.028
0	22	0.015	0.005	0.025	0.030	0.040	0.037	0.048
50	0	0.028	0.005	0.025	0.048	0.032	0.047	0.012
50	11	0.035	0.005	0.050	0.030	0.058	0.027	0.035
50	22	0.030	0.049	0.002	0.028	0.022	0.060	0.032
100	0	0.035	0.012	0.012	0.038	0.020	0.037	0.025
100	11	0.022	0.00	0.032	0.030	0.022	0.043	0.082
100	22	0.040	0.028	0.002	0.025	0.012	0.033	0.048
150	0	0.032	0.008	0.020	0.025	0.075	0.043	0.065
150	11	0.025	0.010	0.018	0.050	0.042	0.050	0.035
150	22	0.025	0.020	0.008	0.035	0.030	0.033	0.035
200	0	0.060	0.015	0.045	0.028	0.048	0.087	0.085
200	11	0.012	0.010	0.030	0.025	0.042	0.070	0.082
200	22	0.025	0.022	0.020	0.022	0.048	0.063	0.042
250	0	0.048	0.035	0.078	0.055	0.058	0.143	0.080
250	11	0.042	0.028	0.125	0.060	0.070	0.150	0.148
250	22	0.072	0.028	0.130	0.080	0.065	0.127	0.090
		% NO_3-N by N Means						
0		0.027	0.012	0.028	0.029	0.033	0.043	0.048
50		0.031	0.019	0.026	0.035	0.038	0.044	0.027
100		0.032	0.013	0.016	0.031	0.018	0.038	0.052
150		0.028	0.012	0.015	0.037	0.049	0.042	0.045
200		0.032	0.016	0.032	0.025	0.046	0.073	0.070
250		0.054	0.030	0.111	0.065	0.064	0.140	0.106
L.S.D. 0.05		N.S.	N.S.	0.024	0.023	N.S.	0.028	0.043
		% NO_3-N by P Means						
	0	0.038	0.016	0.037	0.036	0.042	0.066	0.056
	11	0.029	0.010	0.045	0.038	0.045	0.066	0.068
	22	0.034	0.025	0.031	0.037	0.036	0.059	0.049
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Values are means of 3 replications.

The only appreciable increase of NO_3-N occurred at the 200 to 250 lb. rates of N when yields were declining.

The Doniphan and Jackson county locations were selected in 1966 to study the effect of N and P applications on ether extract and percent crude fiber contents of the plants (Table XII). Fertilizer applications had no significant effect on the ether extract content in mature bromegrass. The crude fiber content of bromegrass was significantly lower in the control plots as compared to plots receiving N in both Doniphan and Jackson counties. There was very little difference in the fiber content in plants receiving the 50-250 lb. rates of N. At the Jackson county site, however, there was a slight increase in the crude fiber content with each increment increase in N. There was a significant decrease in percent crude fiber at the 11 lb. rate of P at the Doniphan county location. The Jackson county location showed a small decrease in percent crude fiber at the 11 lb/A rate of P but the level was not significantly different from the 0 or 22 lb. rate. These data show that varying N and P applications have very little effect on crude fiber and ether extract contents of mature bromegrass at the sites studied.

Effect of Nitrogen and Phosphorus Applications on Soils

Soil analysis from plots receiving annual applications of P and N for three years 1966-1968 indicate that some chemical properties of the soil changed. Jackson, Nemaha and Doniphan counties were selected for intensive soil studies. Soil samples were collected, by treatment from plots in Jackson county in 1966, 1967 and 1968, Nemaha county in 1966 and 1967, and in Doniphan county in 1967 and 1968.

Table XV - Ether extract and crude fiber content of bromegrass at the bloom stage (1966). (Values are means of 4 replications)

Treatment lb/A		Locations			
		DP	JA	DP	JA
N	P	% Ether Extract		% Crude Fiber	
0	0	3.07	2.51	29.56	30.82
0	11	2.75	2.76	30.22	29.56
0	22	2.38	2.45	32.21	31.24
50	0	2.58	2.46	31.56	31.57
50	11	2.77	2.52	30.80	31.90
50	22	2.16	2.57	34.73	31.18
100	0	2.30	2.58	33.07	30.42
100	11	2.39	2.51	32.53	31.61
100	22	2.06	2.19	33.55	32.81
150	0	2.14	2.52	34.02	32.53
150	11	2.48	2.33	32.85	32.00
150	22	2.49	2.31	33.15	32.86
200	0	2.60	2.08	32.72	32.40
200	11	2.99	2.58	31.23	32.12
200	22	2.53	2.46	33.09	32.90
250	0	2.48	2.44	33.38	33.18
250	11	2.57	2.27	32.15	32.90
250	22	2.71	2.70	32.63	32.00
		% Ether Extract by N Means		% Crude Fiber by N Means	
0		2.731	2.353	30.662	30.541
50		2.502	2.622	32.365	31.555
100		2.249	2.415	33.050	31.615
150		2.370	2.392	33.340	32.463
200		2.708	2.318	32.349	32.478
250		2.589	2.533	32.716	32.695
L.S.D. 0.05		N.S.	N.S.	1.676	1.329
		% Ether Extract by P Means		% Crude Fiber by P Means	
	0	2.530	2.382	32.384	31.828
	11	2.658	2.523	31.629	31.686
	22	2.388	2.412	33.227	32.168
L.S.D. 0.05		N.S.	N.S.	1.185	N.S.

These data indicate that annual applications of rates of N from 150 lb/A to 250 lb/A for three years tend to lower pH on these soils. There was very little change in pH the first two years of N application at the Doniphan and Jackson county sites. However, there was a noticable reduction in pH means at these two sites in 1968 (Table XVII), at the higher rates of N application. In Jackson county in 1968 there was a considerable reduction from pH 6.7 to pH 6.2 at the 250 lb/A N rate. The Nemaha county site which had a high original pH did not show this reduction in pH from N application. This might be expected since free lime was observed in the soil profile at the 18-24 inch depth which would indicate there may be high amounts of Ca present in this soil.

These experiments should be continued to acquire conclusive results. However, there is a definite indication that N applications at rates higher than those required to produce maximum yield can lower pH. These data would agree with Owensby, et al., (1968). When these investigators used rates similar to the rates used in this experiment but were applied continuously for 20 years, their data show pH was lowered to 4.7 on some plots. It would certainly be desirable to take soil samples periodically to check pH and NO_3-N accumulation in the soil profile if N rates of 120 lb/A or over are applied annually on established bromegrass stands in this northeast Kansas area.

These same soil samples were analyzed for available soil P. The Jackson county site showed that in 1967 and 1968 available soil P increased in the 0-6 inch soil samples with each increment increase in P applied (Table XVI). This increase in available soil P could not be observed in the 6-12 inch soil sample. Increase in available soil P was not as obvious at the 0-6 inch level at the Doniphan county site where the different rates of P were applied continuously for three years. The numerical values of available soil P in 1968 was much greater even when no P was applied. This may have been due to sampling error.

These data suggest that annual rates of P applications may increase available soil phosphorus in the 0-6 inch depth and that this apparent increase is greater in soils testing low in available soil P. Each increase in rate of P applied produced a corresponding increase in available soil P, especially after the third year of application. The greatest increase in available soil P was with the 22 lb/A rate of P application.

Table XVI - Available soil P(pp^2m) from experimental sites as affected by N-P treatments

Treatment lb/A		Locations															
		JA						NM				DP					
		Soil sample depth															
		0-6"			6-12"			0-6"		6-12"		0-6"		6-12"			
N	P	1966	1967	1968	1966	1967	1968	1966	1967	1966	1967	1967	1968	1967	1968		
		pp2m															
0	0	8	8	25	2	4	11	6	6	9	3	34	40	33	30		
0	11	3	10	31	4	4	14	2	7	1	4	30	37	26	22		
0	22	10	18	55	3	5	11	2	8	9	4	34	62	40	43		
50	0	7	11	26	2	5	13	6	6	3	3	32	39	32	46		
50	11	9	10	31	1	4	17	4	8	1	2	31	47	37	39		
50	22	6	19	50	3	5	13	4	12	6	4	30	47	43	32		
100	0	4	13	26	2	5	12	2	7	1	5	38	42	34	39		
100	11	11	11	38	2	4	14	2	5	1	4	31	50	30	39		
100	22	4	15	44	4	5	15	4	10	2	7	31	46	18	25		
150	0	3	6	28	2	3	11	5	6	11	3	48	48	51	35		
150	11	7	12	25	2	5	12	2	12	1	4	36	56	43	43		
150	22	7	19	37	5	8	15	3	7	2	4	28	54	33	34		
200	0	3	11	29	2	4	12	3	8	1	3	36	50	32	34		
200	11	3	19	28	1	6	11	6	7	4	3	45	49	31	33		
200	22	8	12	43	4	4	14	3	8	3	3	25	42	23	26		
250	0	12	8	28	2	5	12	3	7	3	4	32	40	30	26		
250	11	6	9	36	1	7	14	5	6	4	2	33	47	37	34		
250	22	8	16	42	2	5	14	2	8	3	2	36	48	27	25		
		Soil P(pp2m) by P Means															
	0	6	9	27	2	4	12	4	7	5	3	37	43	35	35		
	11	6	12	31	2	5	14	3	7	2	3	34	48	34	35		
	22	7	16	45	3	5	14	3	9	4	4	31	50	31	31		

Table XVII - Soil pH from experimental sites as affected by N-P treatments (soil sample depth 0-6")

Treatments lb/A N	P	JA 1966	JA 1967	JA 1968	NM 1966	NM 1967	DP 1967	DP 1968
		Soil pH						
0	0	6.8	6.6	6.8	7.8	7.2	6.2	5.9
0	11	6.9	6.8	6.6	6.9	7.2	6.2	6.2
0	22	6.6	6.7	6.6	8.0	7.4	6.2	6.1
50	0	7.0	6.8	6.9	7.7	7.4	6.3	6.0
50	11	6.8	6.6	6.3	8.0	7.3	6.2	6.0
50	22	6.7	6.7	6.3	7.3	7.0	6.2	5.9
100	0	7.1	6.9	6.8	7.4	7.4	6.1	6.0
100	11	6.9	6.6	6.6	7.4	7.4	6.2	5.9
100	22	6.2	6.6	6.1	6.8	7.1	6.3	6.0
150	0	6.6	6.5	6.2	8.0	7.2	6.2	5.8
150	11	6.0	6.7	6.5	7.2	6.9	6.1	5.9
150	22	6.8	6.5	6.5	7.2	7.4	6.2	5.7
200	0	6.8	6.6	6.4	7.5	7.5	6.1	5.6
200	11	7.0	6.7	6.5	8.0	7.4	6.0	5.8
200	22	6.9	6.5	6.2	7.2	7.5	6.1	5.7
250	0	6.9	6.5	6.2	7.2	7.2	6.2	5.7
250	11	6.8	6.8	6.3	7.8	7.4	6.1	5.8
250	22	7.0	6.8	6.1	7.6	7.4	6.0	5.8
		Soil pH by N Means						
0N		6.8	6.7	6.7	7.6	7.3	6.2	6.1
50N		6.8	6.7	6.5	7.7	7.2	6.2	6.0
100N		6.7	6.7	6.5	7.2	7.3	6.2	6.0
150N		6.5	6.6	6.4	7.5	7.2	6.2	5.8
200N		6.9	6.6	6.4	7.6	7.5	6.1	5.7
250N		6.9	6.7	6.2	7.4	7.3	6.1	5.8

Table XVIII - General Soil Information

Location	Soil Type	Land Class	Description
Atchison	Carrington Silt loam	IV	This is a deep, moderately steep (10%) soil, developed in loess. The top soil is a dark colored silt loam more than 12 inches thick. The subsoil is brown colored clay which moderately restricts moisture movement. This soil has a very severe erosion hazard. Cleared areas may return to brush.
Doniphan	Marshall silt loam	III	This is a deep sloping (5%) soil developed in loess. The topsoil is a dark colored silt loam more than 24 inches thick. The brownish colored silty clay loam subsoil does not restrict moisture movement and root development. This soil has a moderate erosion hazard.
Franklin	Woodson Silty Clay loam	III	This is a deep sloping (2%) soil developed in loess with a shale influence. The top soil is a dark colored silty clay loam more than 2 inches thick. The subsoil is brown colored tight clay or claypon which moderately restricts moisture movement. This soil has a moderate erosion hazard.
Brown	Grundy Silty clay loam	III	This is a deep and sloping (5%) soil developed in loess with glacial till influence. Erosion has removed most of the top soil. There is about 3 inches of dark colored silty clay loam topsoil remaining. The subsoil is a grayish-brown colored compact clay which moderately restricts moisture movement. This soil has a moderate erosion hazard.

Table XVIII - Continued

Location	Soil Type	Land Class	Description
Nemaha	Shelby clay loam	IV	This is a deep moderately steep (10%) soil developed in glacial till. The topsoil is dark colored clay about 12 inches thick. The subsoil is yellowish brown heavy clay loam or light clay. The movement of moisture and root development is not restricted. This soil has a severe erosion hazard.
Jefferson	Pawnee clay loam	IIIe	This is a deep, well-drained to moderately well-drained soil developed in glacial till. The surface layer is very dark brown clay loam 7 to 12 inches thick. The subsoil is a mottled, dark grayish brown, firm clay that moderately limits moisture movement. Permeability is slow and moisture holding capacity is high. Slope is approximately 5 percent. The erosion hazard is moderate.
Jackson	Shelby silty clay loam	III	This is a deep sloping (4%) soil developed in glacial till with loess influence. The topsoil is dark colored silty clay loam about 12 inches thick. The subsoil is yellowish brown heavy silty clay loam which does not restrict moisture movement and root development. The soil has a moderate erosion hazard.

Original Soil Test Information

Location	pH	%O.M	Available P	Available K
Atchison	6.2	2.3	14	300
Doniphan	6.2	1.8	16	365
Franklin	6.5	2.6	14	205
Brown	5.7	3.8	7	420
Nemaha	7.6	3.0	7	490
Jefferson	5.5	3.0	9	250
Jackson	6.5	3.4	8	500+

Table XIX - Climatological Data*
Total Precipitation 1966

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	.39	.16	.16	1.63	1.25	7.85	2.77	4.51	2.59	.92	.03	1.12	23.38
Blaine	.50	.79	.00	.84	.93	5.34	4.76	3.68	2.90	.71	.17	.77	21.39
Centralia	.91	.67	.30	1.38	2.54	5.61	3.13	4.23	3.18	.93	.07	.77	23.72
Holton	.66	.29	.35	1.67	1.52	8.05	2.89	4.79	1.60	.55	.10	.75	23.22
Horton	.89	.36	.25	1.47	2.84	11.89	3.33	4.24	2.48	.49	.06	.64	28.94
Leavenworth	.19	.62	.48	2.83	1.94	7.53	2.53	4.27	2.86	.58	.19	.89	24.91
Marysville	.32	.65	.11	.92	1.79	3.20	5.74	2.16	1.78	1.10	.05	.76	18.58
Oskaloosa	.03	.24	.10	2.07	2.80	11.25	3.58	3.52	2.55	.68	.18	1.00	28.00
Sabetha Lake	.79	.44	.21	1.23	1.57	3.60	3.47	3.59	3.16	.67	.21	.55	19.49
Troy	.37	.31	.14	.79	2.09	10.09	2.52	2.99	2.90	.81	.14	.81	23.96
East Central Kansas													
Garnett	.06	1.26	1.19	4.93	1.57	5.02	2.35	6.28	2.47	.85	.47	.93	27.38
Ottawa	.06	1.89	1.01	3.77	2.50	6.52	4.01	8.89-	2.65	.70	.43	1.02	33.45
Paola	.25	1.32	2.14	5.19	2.03	4.00	1.25	6.93	3.28	.81	.52	1.03	28.75

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

Table XX - Climatological Data*
Total Precipitation 1967

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	1.44	.03	.85	6.15	4.40	11.42	4.85	.55	5.21	6.13	.43	1.69	43.15
Blaine	.26	.19	2.41	3.64	3.16	10.00	3.12	1.94	5.58	3.90	.97	1.17	36.34
Centralia	.50	.28	2.33	3.81	2.47	13.58	4.17	2.49	3.72	4.21	.84	1.23	39.63
Holton	.92	.23	1.41	4.10	2.93	16.73	2.85	.92	6.58	6.10	.92	1.72	45.41
Horton	1.03	.24	.84	3.87	2.59	16.16	3.17	.81	3.01	5.18	.66	1.34	38.90
Leavenworth	2.03	.19	1.13	8.32	4.76	11.69	2.15	.22	4.48	7.34	.92	1.97	45.20
Marysville	.12	.34	1.25	3.59	2.19	9.26	1.51	1.54	4.03	3.31	.70	.69	28.53
Oskaloosa	1.40	.11	.82	6.23	4.65	16.95	3.57	1.33	4.95	6.95	.86	1.95	49.77
Sebetha Lake	.26	.29	1.83	3.55	5.06	9.66	2.93	1.67	4.36	4.99	.59	1.06	36.25
Troy	1.23	.22	.66	4.46	3.18	8.32	4.45	1.03	2.91	6.02	.36	1.77	34.61
East Central Kansas													
Garnett	2.68	.16	2.32	4.16	4.01	14.07	2.51	1.87	6.46	6.15	1.22	2.12	47.73
Ottawa	2.03	.29	2.60	5.61	5.41	10.42	4.72	.79	6.49	4.70	.95	1.79	45.80
Paola	1.75	.31	3.38	5.44	4.28	10.62	2.66	1.72	4.33	6.34	.89	1.26	41.98

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

Table XXI - Climatological Data*
Total Precipitation 1968

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	—	—	—	—	—	—	—	—	—	—	—	—	—
Blaine	.37	.48	T	2.47	3.32	2.60	7.87	8.45	1.05	4.94	1.70	1.63	34.88
Centralia	.51	.37	.13	2.38	3.79	3.76	10.08	5.33	2.44	4.95	2.10	1.56	37.40
Holton	.38	.20	.00	4.58	3.11	1.67	12.00	5.99	2.65	3.31	1.57	1.48	36.94
Horton	.27	.13	.06	4.00	2.53	2.11	8.52	9.71	2.44	6.34	1.29	1.35	38.75
Leavenworth	.35	1.24	.85	5.86	3.39	2.21	8.13	4.43	3.48	4.30	1.55	2.08	37.87
Marysville	.21	.47	.02	2.47	3.29	3.25	8.40	4.98	1.19	4.37	.95	1.67	31.27
Oskaloosa	.30	1.49	.51	5.15	3.27	4.41	10.00	7.64	3.10	4.80	1.69	1.90	44.26
Sebetha Lake	.37	.19	.09	2.22	3.85	2.71	12.63	3.76	1.14	4.35	2.18	1.84	35.33
Troy	.23	.07	.13	4.12	1.90	2.62	6.85	6.62	2.43	3.70	1.59	1.56	31.82
East Central Kansas													
Garnett	.45	.43	2.18	4.27	4.83	3.67	5.39	9.55	.94	3.39	5.26	3.49	43.85
Ottawa	.38	.40	.41	5.28	5.49	2.58	7.34	9.19	1.16	3.44	4.26	1.97	41.90
Paola	.38	.42	1.47	4.38	4.93	1.49	5.83	7.58	.86	3.79	3.85	2.09	37.07

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

Table XXII - Climatological Data*
Average Temperatures 1966

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	24.5	32.1	48.1	52.2	63.1	70.9	80.1	71.9	65.4	57.3	45.9	31.5	53.6
Blaine	21.4	27.7	44.2	49.3	62.3	71.5	80.5	71.9	64.4	56.5	41.9	29.1	51.7
Centralia	23.6	31.0	46.5	49.5	63.0	72.5	82.0	73.5	64.2	56.7	43.8	29.7	53.0
Holton	24.9	31.5	47.1	51.1	63.7	71.7	80.7	71.9	63.8	56.1	43.2	29.8	53.0
Horton	24.2	31.3	46.8	51.6	63.4	71.9	80.9	72.5	64.7	55.8	44.4	29.8	53.1
Leavenworth	25.4	32.4	48.1	52.0	62.9	71.9	81.0	72.0	65.2	57.0	46.9	31.7	53.9
Marysville	22.3	29.6	44.5	48.3	62.8	73.1	82.0	73.1	64.0	54.4	41.2	28.2	52.0
Oskaloosa	25.6	32.3	48.5	52.1	64.3	71.7	80.7	73.2	66.0	57.7	46.3	31.8	54.2
Sabetha Lake	22.4	30.2	45.9	50.1	62.9	71.6	81.0	72.0	63.5	56.7	43.9	29.2	52.5
Troy	23.9	31.8	47.8	51.9	63.8	71.6	80.0	71.9	64.5	57.5	45.6	31.3	53.5
East Central Kansas													
Garnett	29.1	34.1	51.8	55.0	66.2	74.1	82.9	74.4	67.4	58.6	49.9	35.7	56.6
Ottawa	28.0	32.5	49.0	53.7	64.4	73.1	82.3	73.7	66.3	57.2	48.4	33.5	55.2
Paola	27.6	32.7	49.7	53.5	64.2	72.8	82.5	73.5	65.5	56.3	48.1	33.7	55.0

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

Table XXIII - Climatological Data*
Average Temperatures 1967

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	30.1	31.6	47.1	57.3	61.6	71.3	74.8	—	65.0	56.2	43.7	—	—
Blaine	27.1	28.0	43.7	53.4	58.9	70.0	72.9	71.5	62.8	53.4	39.6	30.9	51.0
Centralia	28.6	32.2	45.6	56.7	60.2	71.7	74.9	73.1	64.8	55.2	40.6	31.7	52.9
Holton	29.6	31.6	46.6	57.1	59.9	71.3	73.6	72.3	63.3	56.8	41.9	32.8	53.1
Horton	29.1	31.0	46.7	58.6	60.7	71.9	74.4	72.9	65.0	55.6	40.6	32.5	53.3
Leavenworth	31.6	31.6	47.0	57.4	60.6	71.3	74.5	73.0	65.0	55.6	42.4	33.7	53.6
Marysville	27.1	30.2	43.8	54.9	59.4	71.0	74.6	72.6	63.8	54.1	39.6	31.2	51.9
Oskaloosa	31.6	32.[illegible]	48.0	58.7	61.4	71.6	74.7	73.3	65.2	56.3	43.0	34.0	54.2
Sebetha Lake	27.9	30.[illegible]	45.5	57.0	60.1	70.7	73.6	72.2	64.6	55.0	40.9	31.7	52.5
Troy	29.9	30.6	47.3	57.6	61.1	71.4	74.4	72.9	65.2	55.6	42.0	33.0	53.4
East Central Kansas													
Garnett	36.2	34.9	50.7	60.6	62.8	72.9	75.7	73.7	66.5	57.8	44.1	35.9	56.0
Ottawa	34.1	33.6	49.2	60.2	62.5	72.6	75.5	73.4	66.0	57.0	43.3	35.1	55.2
Paola	34.1	33.5	49.0	59.5	61.9	72.3	75.1	72.7	65.6	56.7	43.0	35.5	54.9

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

Table XXIV - Climatological Data*
Average Temperatures 1968

Station NE Kansas	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Atchison	25.7	31.8	49.2	55.8	60.2	—	76.6	—	66.7	58.2	40.9	28.0	—
Blaine	[illegible].9	28.5	44.7	52.7	58.4	71.5	76.9	73.4	65.3	55.8	38.6	25.9	51.3
Centralia	24.7	30.7	46.6	53.8	59.3	75.2	78.0	75.9	67.0	58.6	39.0	27.1	53.0
Holton	26.4	32.4	—	—	—	—	76.7	74.3	66.0	58.3	39.3	27.6	—
Horton	24.2	30.5	47.5	55.2	60.4	75.2	77.7	76.7	67.4	58.9	39.9	28.1	53.5
Leavenworth	26.5	31.7	48.4	55.4	60.9	75.1	76.8	74.5	67.2	58.7	—	—	—
Marysville	24.5	29.2	45.5	52.6	58.7	74.7	77.7	76.2	66.5	57.1	38.0	25.7	52.3
Oskaloosa	27.1	31.5	48.5	55.7	61.0	74.6	77.1	76.1	67.9	59.3	41.2	29.1	54.1
Sabetha Lake	24.0	30.1	47.5	54.4	59.3	74.0	76.8	75.3	66.5	58.9	38.9	26.9	52.7
Troy	25.3	30.2	47.3	55.3	59.5	74.4	76.3	75.0	66.0	58.4	39.8	27.4	52.9
East Central Kansas													
Garnett	30.5	33.1	49.5	57.6	62.3	76.3	77.5	76.2	68.8	59.9	42.5	31.0	55.4
Ottawa	29.1	33.0	48.5	56.3	61.8	75.1	78.0	76.2	68.4	59.8	41.6	31.0	54.9
Paola	29.1	32.3	48.3	55.9	61.4	75.3	78.2	76.0	68.0	59.1	41.8	30.4	54.7

*These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summarys of Kansas. Stations reported are in the general area of the experimental plots.

SUMMARY

Studies were conducted at six northeastern Kansas sites and one east central Kansas site on established bromegrass pastures to determine the effect of six N treatments 0 to 250 lb/A in 50 lb. increment increases and three P treatments 0 to 22 lb. P/A in 11 lb. increment increases, on yield and quality of bromegrass.

This field study confirms earlier findings that bromegrass yields are greatly increased by application of N on soils which are deficient in this nutrient. The initial applications of N treatments in 1966 produced yield increases up to the 200 to 250 lb/A rates of N applications even though precipitation received during this year was far below normal. However, numerical yields in 1966 were much lower than the succeeding years 1967 and 1968, when above normal precipitation was received. In 1967 and 1968 each increment increase in N produced numerically higher yield increases than in 1966; also, the rate required to reach maximum yield was less with each succeeding year of annual applications of N.

Therefore, it appears when soil N is extremely low, bromegrass responds to high initial rates of N. However, continuous annual applications of N tend to lower the rate of N required to produce maximum yields. After three years of annual N applications, the rate of N required to produce maximum yield was near the 150 lb/A rate. Higher rates of N not only lowered yield but there are indications from the soil analysis that soil pH can also be reduced by these higher rates. This would suggest that rates of 150 lb/A N and higher applied annually could not be

completely utilized by the bromegrass plants, and can be detrimental to yield and soil pH.

Analysis of these data show that the maximum rate of N that should be applied annually in this area of Kansas would be around 150 lbs. N/A per acre. However, the optimum recommended rate would appear to be nearer the 100 lb/A rate of N annually.

Phosphorus applications increased yields on soils testing low in available soil P but had very little effect on yields from soils testing medium to high in available soil P, with the exception of Franklin county. Applied P lowered yields at this site. The 22 lb/A rate of P reduced yield more severely than did the 11 lb/A application. There appears to be no simple explanation for this reduction in yield.

The highest yield response to P applications were associated with the higher rates of N. Locations which showed a yield response to P also showed that P tended to reduce somewhat the detrimental effect of high rates of N on yield. When higher rates of N were applied, the 22 lb/A rate of P was generally more effective in increasing yields. However, at the optimum rates of N application the 11 lb/A P application appears to be as effective as the 22 lb/A rate of P on soils low in P. Phosphorus application at either rate had very little effect on yield when soil P tested medium to high.

Although P applications did not increase yields to the same magnitude as N, and yield increases were not always significant, P applications were generally associated with high yields. Yields of over 4 tons per acre were recorded when N and P were applied in combination at the Jackson county site, a site testing low in soil P, in 1967. This suggests that some P should be applied if maximum yields are to be maintained. There was some indication at the Doniphan county site in 1968 that with continued use of high rates of N, P applications may be necessary even on soils testing higher in available soil P. These data show that the 11 lb/A rate of P was sufficient to produce optimum yields when recommended rates of N were applied. The soil analysis tends to confirm this also, since there was some indication that the 22 lb/A rate of P increased the available P content of some of the soils after three years of application. This suggests that all of the P applied was not being utilized by the bromegrass plants and that at the 22 lb/A rate it was accumulating in the soil. Therefore, it would seem that for annual application the 11 lb/A rate would be more desirable.

Nitrogen applications increased percent crude protein content in the bromegrass plant material, especially at the higher rates of N. This increase in percent crude protein was not obvious until after the rate of N required to produce maximum yield was reached. This increase in percent crude protein after maximum yield was not enough to offset the reduction in dry weight yield as far as total pounds of protein produced per acre were concerned. Therefore, it would seem that the more important factor is the effect of N applications on protein yield. Pounds of protein produced per acre increased with each increment increase in N; however, the increase in protein yield was much less after maximum dry weight yield was reached. The increase in percent crude protein at the higher N rates, therefore, may not be as beneficial to total protein production as it would appear. Although percent crude protein content at the optimum rates of N did not reach the maximum it would appear that the increase in percent crude protein by additional rates of N is not sufficient to recommend using higher rates of N to increase crude protein production in bromegrass.

Phosphorus applications had no significant effect on percent crude protein. However, in some instances P applications did have a significant effect of protein yield. This is probably due to the effect of P on dry weight yield rather than its effect on percent crude protein content. Phosphorus applications, on the other hand, did increase percent P content in the bromegrass plant material. Each increment increase in P applied generally produced a corresponding increase in percent P. Nitrogen application did not significantly increase percent P; however, at all locations tested in 1967 and 1968 percent P was significantly higher in the bromegrass samples when no N was applied. All other rates of N had very little effect on percent P in the plant material. Phosphorus applications increased percent P content and P yield. Nitrogen applications had very little effect on percent P in the plant material. Phosphorus applications increased percent P content and P yield. Nitrogen applications had very little effect on percent P; however, P yield was increased, apparently due to the increase in dry weight yield from applied N.

Nitrogen and phosphorus applications appear to have very little direct effect on percent K, percent Ca and percent Mg. However, there is an indication that N application may have an indirect effect on Ca and Mg since both Ca and Mg percentages tended to be higher when no N was applied compared to the other rates of N. Little difference in percent content of these minerals at the 50-250 lb/A N could be observed. There seems to be a close relationship between Ca and Mg. When percent Ca content was high as was the case in Nemaha county, percent Mg content was lowered.

Percent K content varied little with treatment or location with the exception of Franklin county where percent K content was near the deficient level at all rates of N above the check. There is no obvious explanation for this since the soil did not test low in available K and K applications were broadcast annually. This, along with the fact that P applications tended to reduce hay yield, would suggest further study at this location.

Nitrate-nitrogen content was not affected by P applications. Nitrogen applications, however, increased NO_3-N content at the 200 and 250 lb/A rates of N application. Nitrate-nitrogen in the mature bromegrass samples tested did not reach critical levels even with the high rates of N application. These data suggest that NO_3-N accumulation would not be a critical factor in mature bromegrass plants when optimum rates of N are applied.

Percent ether extract was not significantly effected by N or P applications. However, crude fiber content was significantly higher when N was applied compared to the check plot. Rates of N from 50 to 250 lbs. N/A did not affect crude fiber content significantly. The 22 lb/A P application increased crude fiber at the Doniphan county site.

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VITA

The author was born April 23, 1937 in Hays, Kansas. He grew up on an irrigated and dry land farm in northeast Scott County and graduated from Scott Community High School in 1955. The following year he enrolled with an athletic scholarship at Kansas State University. In 1968 he was selected to represent Kansas as an International Farm Youth Exchange delegate to Iran for six months. He went for Army training in 1960 and upon completion of the tour of active duty, returned to Kansas State University and completed his B.S. degree in Agronomy in 1962 at that University. He was married to Patty Jean Landon in the summer of 1962 and worked as an assistant to Dr. Lolyd Smith in soil fertility while his wife completed her degree in music at Kansas State University. He and his wife joined the Peace Corps in 1963 and worked with farmers in the highlands of Guatemala organizing farm cooperatives and giving general agricultural instruction in farm production methods. Upon returning to the United States in 1965, joined the staff at Kansas State University as a full time graduate assistant to study for his M.S. degree in soil fertility.

His achievements in High School were President of the Senior Class, National Honor Society and recipient of a one hundred dollar scholarship.

Presently, the author is a member of the American Society of Agronomy, Soil Science Society of America, Gamma Sigma Delta and employed as an Experiment Field Superintendent by the Kansas State University Agronomy Department.

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APPENDIX

Table XXV- Yield (T/A) of bromegrass hay (12.5% moisture) as affected by different rates of nitrogen and phosphorus (1966). (Values are means of 4 replications)

Treatment lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		Location T/A						
0	0	0.38	0.58	0.36	1.68	0.40	0.34	0.30
0	11	0.41	0.40	0.40	1.80	0.37	0.17	0.24
0	22	0.34	0.55	0.40	1.67	0.38	0.26	0.25
50	0	1.28	0.77	1.43	2.10	0.76	0.67	0.60
50	11	1.22	1.12	1.14	2.21	0.88	1.23	0.62
50	22	1.13	1.06	1.36	2.13	0.77	0.99	0.66
100	0	1.44	1.13	2.00	2.34	1.09	1.05	0.78
100	11	1.50	1.42	1.74	2.65	1.23	1.04	0.67
100	22	1.79	1.16	1.91	2.42	1.47	1.27	0.72
150	0	2.06	1.40	1.81	2.48	1.31	1.17	0.82
150	11	1.63	1.25	2.18	2.56	1.60	1.24	0.79
150	22	1.88	1.46	2.11	2.60	1.80	1.60	0.66
200	0	1.98	1.23	2.30	2.58	1.50	1.46	0.72
200	11	2.44	1.47	2.00	2.61	1.84	1.77	0.69
200	22	1.98	1.62	2.29	2.49	1.96	1.63	0.88
250	0	2.08	1.36	2.42	2.46	1.83	1.18	0.72
250	11	2.08	1.76	2.07	2.68	2.14	1.93	0.74
250	22	2.16	1.66	2.68	2.33	2.14	2.15	0.75
		Yield (T/A) by N Means						
0		.376	.508	.385	1.713	.382	.260	.263
50		1.209	.986	1.311	2.147	.802	.962	.625
100		1.577	1.173	1.885	2.472	1.262	1.119	.721
150		1.852	1.371	2.035	2.548	1.572	1.337	.758
200		2.134	1.439	2.196	2.559	1.764	1.619	.761
250		2.102	1.594	2.390	2.490	2.041	1.752	.735
L.S.D. 0.05		.260	.305	.287	.213	.161	.311	.142
		Yield (T/A) by P Means						
	0	1.535	1.078	1.720	2.274	1.148	.977	.654
	11	1.545	1.204	1.590	2.418	1.344	1.228	.624
	22	1.545	1.254	1.791	2.274	1.420	1.319	.653
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	.114	.220	N.S.

*Values are means of 3 replications.

Table XXVI - Yield (T/A) of bromegrass hay (12.5% moisture) as affected by different rates of nitrogen and phosphorus (1967). (Values are means of 4 replications)

Treatment lb/A N	P	Location AT	BR	DP	FR	JA	JE*	NM
					T/A			
0	0	1.22	1.06	1.17	.40	.48	.77	.75
0	11	1.31	.90	1.24	.47	.52	.63	.76
0	22	1.01	.94	1.20	.42	.46	.73	.61
50	0	2.51	2.28	2.69	2.09	1.46	1.83	1.61
50	11	2.50	2.55	2.34	2.10	1.82	3.31	2.39
50	22	2.63	2.80	2.94	2.12	1.85	2.89	2.26
100	0	3.48	2.62	2.95	2.87	2.01	2.88	2.09
100	11	3.56	3.76	2.92	2.65	2.50	3.50	2.82
100	22	3.75	3.52	3.07	2.42	2.87	2.93	3.16
150	0	3.56	2.81	2.32	2.68	2.32	2.88	2.58
150	11	4.00	3.50	2.15	2.52	2.70	3.11	3.47
150	22	3.72	3.02	2.23	2.87	3.01	3.33	3.28
200	0	4.66	2.54	2.58	2.47	2.55	2.66	2.86
200	11	4.30	3.09	2.53	2.41	2.70	3.63	2.96
200	22	4.41	3.58	2.51	2.35	3.14	2.73	3.49
250	0	3.63	2.80	2.42	3.03	2.57	2.62	2.51
250	11	4.66	3.38	2.34	1.98	2.94	2.88	3.18
250	22	3.89	2.92	2.68	1.93	2.77	2.72	3.24
		Yield (T/A) by N Means						
0		1.179	.968	1.201	.432	.486	.712	.708
50		2.547	2.542	2.654	2.105	1.709	2.676	2.086
100		3.599	3.302	2.982	2.648	2.458	3.102	2.690
150		3.762	3.108	2.318	2.689	2.674	3.104	3.113
200		4.455	3.072	2.538	2.409	2.798	3.008	3.102
250		4.059	3.035	2.480	2.315	2.759	2.743	2.979
L.S.D. 0.05		.514	.382	.344	.249	.250	.373	.289
		Yield (T/A) by P Means						
	0	3.177	2.353	2.398	2.258	1.898	2.274	2.067
	11	3.389	2.863	2.252	2.022	2.194	2.844	2.599
	22	3.236	2.797	2.437	2.20	2.350	2.554	2.674
L.S.D. 0.05		N.S.	.270	N.S.	.176	.177	.264	.204

*Values are means of 3 replications.

Table XXVII - Yield (T/A) of bromegrass hay (12.5% moisture) as affected by different rates of nitrogen and phosphorus (1968). (Values are means of 4 replications)

Treatment lb/A N	P	Location DP	FR	JA	NM
		T/A			
0	0	.59	.80	1.18	.62
0	11	.41	.90	.93	.89
0	22	.59	.87	1.01	.68
50	0	1.86	2.74	2.78	1.87
50	11	1.72	2.74	3.23	2.25
50	22	2.00	2.89	2.36	2.08
100	0	2.50	3.45	3.24	2.36
100	11	2.81	2.83	3.17	3.01
100	22	2.28	2.58	3.68	2.73
150	0	3.02	2.98	2.89	2.22
150	11	2.92	2.86	4.30	3.20
150	22	3.51	2.98	4.76	3.23
200	0	2.87	3.08	2.52	2.21
200	11	2.95	2.52	3.73	2.81
200	22	3.41	2.18	3.42	3.32
250	0	2.76	2.30	2.42	2.46
250	11	3.34	2.77	3.62	3.39
250	22	3.29	2.43	3.81	3.56
		Yield (T/A) by N Means			
	0	.528	.858	1.040	.732
	50	1.862	2.788	2.789	2.066
	100	2.532	2.955	3.365	2.702
	150	3.151	2.943	3.982	2.884
	200	3.078	2.592	3.222	2.781
	250	3.132	2.498	3.283	3.133
L.S.D. 0.05		.421	.558	.544	.326
		Yield (T/A) by P Means			
	0	2.269	2.560	2.505	1.956
	11	2.358	2.435	3.164	2.592
	22	2.514	2.322	3.171	2.602
L.S.D. 0.05		N.S.	N.S.	.385	.231

Table XXVIII - Crude protein content of bromegrass as affected by different rates of N and P (1966). (Values are means of 4 replications)

Treatment lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		% crude protein						
0	0	8.98	10.78	10.70	10.65	11.60	12.03	10.60
0	11	8.95	10.60	10.02	8.80	12.45	13.33	11.85
0	22	9.08	10.18	8.65	9.52	10.50	10.93	11.52
50	0	8.85	10.45	9.92	10.02	11.30	13.70	12.82
50	11	9.78	10.02	9.92	8.18	12.05	9.43	12.60
50	22	8.78	11.35	8.58	8.88	12.02	11.13	12.40
100	0	9.05	11.70	10.72	9.30	12.50	13.90	14.55
100	11	9.68	9.68	10.02	9.72	12.02	13.83	13.50
100	22	9.40	11.30	9.70	10.55	11.08	12.33	15.05
150	0	13.88	12.75	12.80	12.50	12.68	14.80	16.62
150	11	10.43	12.95	13.78	11.52	12.48	14.87	17.55
150	22	13.18	14.05	11.60	12.10	13.22	14.37	15.18
200	0	12.90	13.75	14.08	11.68	12.90	14.93	17.92
200	11	12.68	15.00	16.08	13.60	13.65	15.43	15.72
200	22	13.58	13.58	13.72	13.38	13.70	17.57	17.80
250	0	14.05	14.32	15.22	14.12	13.25	16.83	17.48
250	11	14.22	14.82	15.25	13.70	13.72	16.20	18.35
250	22	15.58	15.65	15.92	15.80	14.20	15.67	18.08
		% crude protein by N means						
0		9.000	10.517	9.792	9.658	11.517	12.100	11.325
50		9.133	10.608	9.475	9.025	11.792	11.422	12.608
100		9.375	10.892	10.150	9.858	11.867	13.356	14.367
150		12.492	13.250	12.725	12.042	12.792	14.678	16.450
200		13.050	14.108	14.625	12.883	13.642	15.978	17.150
250		14.617	14.933	15.467	14.542	13.725	16.233	17.967
L.S.D. 0.05		1.410	1.759	1.684	1.628	1.082	1.904	1.878
		% crude protein by P means						
	0	11.283	12.292	12.242	11.379	12.371	14.367	15.000
	11	10.954	12.179	12.512	10.920	12.842	13.850	14.929
	22	11.596	12.683	11.362	11.704	12.454	13.667	15.004
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Values are means of 3 replications.

Table XXIX - Crude protein content of bromegrass as affected by different rates of N and P (1967). (Values are means of 4 replications)

Treatment lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		% crude protein						
0	0	6.38	7.68	8.10	9.55	9.80	8.20	8.88
0	11	6.58	7.90	8.42	10.15	10.05	7.60	8.88
0	22	6.42	8.50	8.02	9.02	9.62	8.83	9.30
50	0	5.20	8.60	9.38	7.92	8.35	6.17	8.82
50	11	5.25	6.75	9.88	8.35	9.18	6.17	7.45
50	22	5.28	7.35	9.12	8.00	8.08	5.30	7.82
100	0	6.92	8.78	8.92	11.40	8.85	8.23	9.88
100	11	6.52	7.02	9.15	11.58	8.98	6.90	9.68
100	22	5.70	6.82	8.72	12.72	9.40	6.50	8.32
150	0	7.88	10.48	10.98	11.55	11.22	8.43	11.30
150	11	7.60	9.88	11.02	11.05	10.58	7.37	10.98
150	22	7.18	13.18	10.08	11.38	10.28	9.23	10.30
200	0	8.00	10.32	12.48	13.75	11.08	9.20	11.50
200	11	8.48	10.22	13.72	12.92	12.05	10.30	11.52
200	22	6.95	10.10	11.75	13.02	10.28	10.10	11.85
250	0	9.98	11.90	13.20	13.90	11.65	11.83	12.90
250	11	8.28	13.82	13.48	15.62	11.75	12.13	13.32
250	22	9.20	12.25	12.28	14.60	13.00	11.03	13.95
		% crude protein by N means						
0		6.458	8.025	8.183	9.575	9.825	8.211	9.017
50		5.252	7.567	9.458	8.092	8.533	5.878	8.033
100		6.383	7.542	8.933	11.900	9.075	7.211	9.292
150		7.550	11.175	10.692	11.325	10.692	8.344	10.858
200		7.808	10.217	12.650	13.233	11.133	9.867	11.625
250		9.150	12.658	12.983	14.471	12.133	11.667	13.392
L.S.D. 0.05		1.193	1.316	1.121	0.790	.690	1.376	.891
		% crude protein by P means						
	0	7.392	9.625	10.508	11.346	10.1[illegible]3	8.678	10.546
	11	7.117	9.267	10.946	11.612	10.429	8.411	10.304
	22	6.788	9.700	9.996	11.458	10.108	8.500	10.258
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Values are means of 3 replications.

Table XXX - Crude protein content of bromegrass as affected by different rates of N and P (1968). (Values are means of 4 replications)

Treatment lb/A N	P	Location DP	FR	JA	NM
		% Crude Protein			
0	0	9.60	10.48	9.02	8.28
0	11	10.38	8.12	9.65	8.92
0	22	9.12	9.25	9.42	7.95
50	0	9.72	6.90	8.05	8.98
50	11	8.78	6.50	7.88	8.55
50	22	7.58	6.05	8.22	8.62
100	0	8.32	7.92	9.48	9.70
100	11	7.60	8.22	8.80	9.50
100	22	8.20	9.82	9.30	9.68
150	0	8.78	9.30	11.90	10.85
150	11	9.35	9.32	11.18	10.78
150	22	9.32	10.18	9.50	11.05
200	0	9.88	11.30	11.65	12.35
200	11	11.05	13.88	11.58	10.68
200	22	10.00	9.35	10.28	12.58
250	0	10.85	13.22	11.88	11.48
250	11	11.20	12.45	11.58	12.50
250	22	11.22	12.38	11.85	13.02
		% crude protein by N means			
0		9.700	9.283	9.367	8.383
50		8.692	6.483	8.050	8.717
100		8.042	8.658	9.192	9.625
150		9.150	9.600	10.858	10.892
200		10.308	11.508	11.167	11.867
250		11.092	12.683	11.767	12.333
L.S.D. 0.05		0.946	1.470	1.021	.919
		% crude protein by P means			
	0	9.525	9.854	10.329	10.271
	11	9.725	9.700	10.108	10.154
	22	9.242	9.504	9.762	10.483
L.S.D. 0.05		N.S.	N.S.	N.S.	N.S.

Table XXXI - Protein yield (% crude protein x dry wt. yield) of bromegrass as affected by different rates of N and P (1966). (Values are means of 4 replications)

Treatment lb/A		Location						
N	P	AT	BR	DP	FR	JA	JE*	NM
		lbs. crude protein/A						
0	0	59.00	108.25	63.75	305.00	76.25	72.00	55.25
0	11	62.25	72.25	74.25	275.00	81.75	38.33	52.50
0	22	53.00	96.75	66.25	275.00	69.25	50.33	46.75
50	0	193.00	138.50	260.25	400.00	148.00	147.00	131.50
50	11	206.00	190.00	194.00	290.00	184.50	200.33	129.50
50	22	163.75	191.50	199.00	330.00	163.25	187.67	142.00
100	0	221.00	219.75	360.25	375.00	234.75	247.67	196.00
100	11	249.50	214.25	298.25	455.00	258.50	238.00	158.25
100	22	286.75	226.00	312.50	445.00	279.25	262.00	191.25
150	0	483.50	291.75	359.75	545.00	288.25	308.00	235.25
150	11	298.50	282.50	515.25	515.00	352.50	312.00	238.50
150	22	428.25	333.50	415.25	545.00	419.25	393.00	177.00
200	0	435.75	292.25	537.00	520.00	332.75	374.33	230.00
200	11	536.25	380.25	530.50	625.00	436.50	468.33	195.00
200	22	458.50	346.25	487.00	580.00	465.75	487.00	272.25
250	0	502.25	351.50	587.00	605.00	426.50	329.00	214.25
250	11	517.50	439.75	538.50	630.00	516.25	539.00	236.50
250	22	570.00	433.50	741.25	640.00	532.75	582.33	240.50
		lbs. crude protein/A by N means						
0		58.083	92.417	68.083	285.000	75.750	53.556	51.500
50		187.583	173.333	217.750	340.000	165.250	178.333	134.333
100		252.417	220.000	323.667	425.000	257.500	249.222	181.833
150		403.417	302.583	430.083	535.000	353.333	337.667	216.917
200		476.833	339.583	518.167	575.000	411.667	443.222	230.417
250		529.917	408.250	622.250	625.000	491.833	483.444	232.417
L.S.D. 0.05		60.032	69.211	54.357	61.418	39.965	69.120	41.831
		lbs. crude protein/A by P means						
	0	315.750	233.667	361.333	458.333	251.083	246.333	177.042
	11	311.667	263.167	358.458	465.000	305.000	299.333	168.375
	22	326.708	271.250	370.208	469.[illegible]	321.583	327.056	178.292
L.S.D. 0.05		N.S.	N.S.	N.S.	[illegible]	28.259	48.875	N.S.

*Values are a means of 3 replications.

Table XXXII - Protein yield (% crude protein x dry wt. yield) of bromegrass as affected by different rates of N and P (1967). (Values are means of 4 replications)

Treatment lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		lbs. crude protein/A						
0	0	134.50	141.75	165.75	67.50	78.75	110.33	116.50
0	11	137.25	124.75	178.75	83.25	91.25	87.67	118.00
0	22	112.50	140.00	164.50	66.50	78.00	114.67	100.25
50	0	224.00	340.75	441.00	291.50	213.00	202.00	244.00
50	11	232.25	300.75	407.00	307.00	289.75	362.67	310.75
50	22	243.00	356.25	468.00	297.50	258.25	267.67	304.75
100	0	443.75	410.00	455.00	573.75	311.00	415.67	354.50
100	11	415.75	458.50	467.00	528.75	392.00	428.67	480.00
100	22	373.00	423.75	467.50	535.25	471.50	332.33	461.50
150	0	489.75	517.75	447.75	542.00	453.25	423.67	510.25
150	11	533.00	607.00	413.00	487.50	495.75	403.33	665.00
150	22	468.25	669.25	397.25	570.50	540.75	536.33	589.50
200	0	654.00	465.75	563.75	595.75	492.00	425.67	580.75
200	11	630.75	561.25	607.50	547.25	569.75	663.00	596.00
200	22	515.50	639.00	516.75	536.25	571.75	475.00	727.00
250	0	631.00	585.00	560.50	734.25	525.25	543.33	565.50
250	11	661.00	824.00	554.75	540.75	604.00	614.67	742.25
250	22	633.00	623.00	575.25	493.50	629.50	528.33	793.00
		lbs. crude protein/A by N means						
0		128.083	135.500	169.667	72.42	82.667	104.222	111.583
50		233.083	332.583	438.667	29[illegible].67	253.667	277.444	286.500
100		410.833	430.750	463.167	54[illegible]92	391.500	392.222	432.000
150		497.000	598.000	419.333	53[illegible]3	496.583	454.444	588.250
200		600.083	555.333	562.667	559.75	544.500	521.222	634.583
250		641.667	677.333	563.500	589.50	586.250	561.111	700.250
L.S.D. 0.05		84.040	89.709	69.520	51.187	46.029	92.840	53.886
		lbs. crude protein/A by P means						
	0	429.500	410.167	438.958	467.46	345.542	353.444	395.250
	11	435.000	479.375	438.000	415.75	407.083	426.667	485.333
	22	390.875	475.208	431.542	416.58	424.958	375.722	496.000
L.S.D. 0.05		N.S.	N.S.	N.S.	36.195	32.547	N.S.	38.103

*Values are a means of 3 replications.

Table XXXIII - Protein yield (% crude protein x dry wt. yield) of bromegrass as affected by different rates of N and P (1968). (Values are means of 4 replications)

Treatment lb/A N	P	DP	FR	JA	NM
		Locations (lbs. crude protein/A)			
0	0	94.25	141.00	174.25	97.75
0	11	73.75	128.25	156.24	138.25
0	22	94.50	138.75	194.25	94.50
50	0	318.75	324.00	390.50	294.00
50	11	262.25	310.75	442.50	337.50
50	22	250.00	301.00	341.00	313.50
100	0	362.75	472.75	536.25	404.25
100	11	373.50	376.75	488.00	495.50
100	22	324.50	416.00	591.75	459.75
150	0	464.00	466.25	595.25	421.50
150	11	473.50	463.75	833.00	602.50
150	22	574.50	532.25	794.50	568.75
200	0	534.50	593.00	518.50	472.50
200	11	568.75	577.25	765.75	527.25
200	22	594.25	348.75	608.25	726.25
250	0	515.75	522.75	496.00	492.75
250	11	650.75	592.75	722.75	744.50
250	22	635.50	379.00	766.50	811.25
		lbs. crude protein/A by N means			
0		87.500	136.000	174.917	110.167
50		277.000	311.917	391.333	315.000
100		353.583	421.833	538.667	453.167
150		504.000	487.417	740.917	530.917
200		565.833	506.333	630.833	575.333
250		600.667	498.167	661.750	682.833
L.S.D. 0.05		63.302	89.620	106.896	66.224
		lb. crude protein/A by P means			
	0	381.667	419.958	451.792	363.792
	11	400.417	408.250	568.042	474.250
	22	412.208	352.625	549.375	495.667
L.S.D. 0.05		N.S.	N.S.	75.587	46.828

Table XXXIV - Phosphorus yield (% phorphorus x dry wt. yield) of bromegrass as affected by different rates of N and P (1966). (Values are means of 4 replications)

Treatments lb/A N	P	AT	BR	DP	FR	JA	JE*	NM
		Location lb/A						
0	0	1.12	1.09	1.12	4.95	.92	1.06	.68
0	11	1.36	1.02	1.46	4.60	1.16	.38	.64
0	22	1.18	1.39	1.23	5.10	.90	.91	.60
50	0	3.21	1.27	4.21	5.85	1.56	2.08	1.26
50	11	2.93	1.82	3.66	6.00	2.09	3.27	1.54
50	22	2.84	2.16	3.49	6.75	1.99	2.52	1.83
100	0	3.35	1.88	4.69	5.00	2.56	2.45	1.58
100	11	4.52	2.82	4.98	6.65	2.91	2.68	1.72
100	22	4.17	2.30	5.74	6.35	3.13	3.72	2.34
150	0	4.91	2.94	3.88	6.55	3.44	3.22	1.91
150	11	3.65	2.12	6.18	6.60	3.63	3.42	2.21
150	22	5.91	2.83	6.56	8.50	4.47	4.44	1.60
200	0	4.26	1.94	6.03	5.70	2.58	3.72	1.88
200	11	5.79	2.65	6.30	6.90	4.58	4.27	1.42
200	22	5.89	3.24	6.59	7.65	5.62	4.85	2.62
250	0	4.89	2.92	5.62	6.10	3.88	2.54	1.40
250	11	6.06	3.09	6.10	7.25	4.98	5.45	1.80
250	22	5.33	3.50	8.73	6.60	5.69	6.21	2.09
		lb/A P by N means						
0		1.221	1.166	1.271	4.883	0.994	0.786	0.639
50		2.996	1.750	3.788	6.200	1.880	2.622	1.542
100		4.012	2.331	5.136	6.000	2.765	2.952	1.882
150		4.824	2.628	5.539	7.217	3.848	3.692	1.906
200		5.313	2.611	6.305	6.750	4.261	4.277	1.976
250		5.427	3.169	6.815	6.650	4.847	4.733	1.764
L.S.D. 0.05		0.758	0.690	0.763	0.716	0.661	1.066	0.470
		lb/A P by P means						
	0	3.623	2.006	4.258	5.692	2.439	2.512	1.451
	11	4.051	2.252	4.779	6.333	3.224	3.244	1.556
	22	4.222	2.569	5.390	6.825	3.634	3.776	1.848
L.S.D. 0.05		N.S.	N.S.	0.540	0.507	0.468	0.754	N.S.

*Values are a means of 3 replications.

Table XXXV - Phosphorus yield (% phorphorus x dry wt. yield) of bromegrass as affected by different rates of N and P (1967). (Values are means of 4 replications)

Treatments lb/A N	P	DP	JA	NM
			Locations lb/A	
0	0	3.42	1.16	1.68
0	11	3.87	1.65	2.07
0	22	3.57	1.52	1.74
50	0	6.81	3.08	3.00
50	11	6.46	4.87	4.82
50	22	7.97	5.07	5.34
100	0	7.82	4.07	3.62
100	11	8.19	6.22	7.20
100	22	9.26	8.29	7.91
150	0	6.51	5.25	4.08
150	11	7.01	6.31	8.52
150	22	7.77	9.48	9.26
200	0	7.24	4.46	5.45
200	11	8.65	7.58	6.74
200	22	8.50	10.37	11.17
250	0	7.78	5.84	5.49
250	11	8.72	8.17	7.88
250	22	8.77	9.16	10.24
			lb/A P by N means	
0		3.619	1.444	1.828
50		7.078	4.341	4.386
100		8.424	6.193	6.239
150		7.099	7.012	7.288
200		8.129	7.473	7.785
250		8.423	7.725	7.870
L.S.D. 0.05		1.124	.986	.932
			lb/A P by P means	
	0	6.597	3.058	1.458
	11	7.150	5.512	2.480
	22	7.639	6.850	2.890
L.S.D. 0.05		.794	.777	.524

Table XXXVI - Phosphorus yield (% phorphorus x dry wt. yield) of bromegrass as affected by different rates of N and P (1968). (Values are means of 4 replications)

Treatments lb/A N	P	Locations DP	FR	JA	NM
				lb/A	
0	0	2.13	3.12	1.74	1.25
0	11	1.65	3.20	1.56	2.58
0	22	2.13	3.18	1.94	1.78
50	0	5.55	7.05	3.90	3.22
50	11	5.67	7.90	4.42	5.05
50	22	6.14	8.52	3.41	5.65
100	0	5.94	8.46	5.36	3.58
100	11	8.11	8.08	4.88	6.70
100	22	7.02	8.48	5.92	8.18
150	0	6.84	7.62	5.95	3.18
150	11	8.21	8.30	8.33	7.02
150	22	11.23	9.55	7.97	7.32
200	0	6.90	8.10	5.18	3.50
200	11	8.75	7.72	7.66	5.30
200	22	9.76	5.94	6.08	9.48
250	0	6.24	5.95	4.96	3.62
250	11	9.44	7.36	7.23	6.42
250	22	10.15	7.50	7.66	8.70
			lb/A P by N means		
0		1.970	3.168	1.749	1.867
50		5.788	7.824	3.913	4.642
100		7.024	8.337	5.387	6.150
150		8.760	8.489	7.409	5.842
200		8.471	7.253	6.308	6.092
250		8.610	6.937	6.617	6.250
L.S.D. 0.05		1.355	1.581	1.069	1.098
			lb/A P by P means		
	0	5.601	6.713	4.518	3.06
	11	6.971	7.094	5.680	5.51
	22	7.739	7.196	5.494	6.85
L.S.D. 0.05		.958	N.S.	.756	0.777

THE EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZATION ON YIELD AND QUALITY OF BROMEGRASS
BROMUS INERMIS LEYSS

by

CLIFFORD N. GRUVER

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AN ABSTRACT OF A THESIS

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Established bromegrass pasture response to different rates of nitrogen and phosphorus fertilizer applications in northeast Kansas was obvious when these two elements were deficient in the soil.

Nitrogen applications showed the greatest visual response. Yield increased numerically with N applications up to 150 to 200 lb/A and yield was generally depressed by the 250 lb/A application. The most rapid yield increase was between the 0 to the 100 lb/A rate. These trends in yield response to N were similar all three years of the study; however, the magnitude of yield was much lower when precipitation was below normal. Soil pH was lowered at some locations when 200 to 250 lb/A N was applied annually for three years. Therefore, the optimum rate of annual application of N appears to be between 100 and 150 lb/A.

Phosphorus applications increased yields on soils low in available soil P but had little effect on yield when soils tested medium to high in available P. Yield response to P was much greater in years of above normal precipitation and at the higher rates of N application when yields were high. The 22 lb/A rate of P increased yield when associated with the higher rates of N. However, when P is applied with the optimum rates of N, the 11 lb/A P rate is as effective as the 22 lb/A rate.

Percent crude protein was increased by N applications. The crude protein content increased rapidly after maximum dry weight yield was reached. P applications had little effect on percent crude protein.

Phosphorus concentrations in the plant material increased as each rate of P applied increased. N appeared to have little effect on P content.

Nitrate-Nitrogen concentration in the mature bromegrass plant material was low. However, when high rates of N were applied, nitrate-nitrogen content did increase.

Potassium, calcium and magnesium concentrations were affected little by either N or P applications. Higher concentrations of these nutrients were found in plant material from the control plots. When calcium concentrations were high magnesium concentrations tended to be low.