RESIDUAL FERTILIZER EFFECTS ON NATIVE GRASS AND WEEPING LOVEGRASS FORAGE PRODUCTION

By

DONALD EUGENE HUBBARD

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1977

RESIDUAL FERTILIZER EFFECTS ON NATIVE GRASS

AND WEEPING LOVEGRASS FORAGE PRODUCTION

Thesis Approved:

W E McMurphy
Thesis Adviser

Billy B. Tucker

Lavoy I. Croy

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express appreciation to my major adviser, Dr. Wilfred McMurphy, for his guidance and invaluable assistance throughout the course of this study. I also would like to express appreciation to my other committee members, Dr. Lavoy I. Croy and Dr. B. B. Tucker, for their help in the reading and editing that was required for the publication of this final manuscript.

To Dr. Robert Morrison I would like to give special thanks for his help in programming the statistical analysis portion of this study.

I would also like to recognize and express thanks to Stephen Molloy and Jim Haught for their assistance in the collection of data and also thank the others before them whose efforts also went into the accumulation of the final data.

Heartfelt appreciation goes to my wife, Janice, not only for her assistance in preparing this manuscript but especially for her understanding and support during the period of this study.

Special thanks goes to Pam Haught for her assistance in the typing of this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Despite the greater emphasis for food production, today's agricultural producer is caught in a precarious position. He is faced with annually inflating production costs on one hand, and depressed markets for most of his commodities on the other. With his margin for profit narrowing, the only means of ensuring economic survival is to make more efficient use of all production practices.

Chemical fertilizers are recognized as one of the means by which to efficiently provide the world's food and fiber needs. As fertilizers are applied in greater quanitites, it becomes apparent that new emphasis must be given to making full use of their residual effects for this represents an essential part of the economical use of fertilizers. It has been shown that due to residual carry-over, increases in the following year's crop are often sufficient to pay for the fertilizer applied to the current year's crop (Tisdale and Nelson, 1975).

Phosphorus is one of the most critical elements in the growth of field crops. This nutrient is somewhat unique among the major plant elements in that it is relatively non-mobile and remains within the upper root zones. Despite this, plant removal of P may be only 15-20% of the total amount applied. This is due in part to its tendancy to react with certain soil components forming relatively insoluble compounds which become unavailable to plants. To insure adequate P availability to future crops, soils having relatively small amounts of available P, but receiving annual P fertilization may have an accumlation of available P. This higher level, resulting from a carry-over effect, may last for many years. Maintenance of soil P can then be accomplished by periodic small applications. This system may represent the most efficient return of fertilizer dollar invested for some crops and conditions.

The objectives of this study were: 1) to evaluate the response from residual P on succeeding cropping seasons as measured by forage yields of four species of native and introduced grasses; and 2) to evaluate the effects of residual P on soil chemical components.

CHAPTER II

LITERATURE REVIEW

The deficiency of an immobile nutrient usually has its greatest effect on the earliest stages of growth. Phosphorus is no exception, for it is at this phase when reproductive primordia are developing (Tisdale and Nelson, 1975) which will set the stage for future seed production. The significance of this is reflected in data accumlated by Grunes (1959) in which 50 percent of the total P had been absorbed by the time the plant had reached 20% of its total growth.

Until recently it has generally been accepted that P actually stimulated early root proliferation. However, Power et al. (1963) and others have shown that top/root ratios generally increase with increased available P, suggesting early stimulation of top growth. In general, the importance of P in plant nutrition is its effect on rapid early growth which minimizes the effects of weeds, diseases and insects.

There are many physiological aspects of P nutrition, among these are that adequate P is associated with the quality of fruits, forages and grains. Phosphorus also plays an essential role in photosyntehsis, metabolism of fats and amino acids, and is critical in energy transfer processes.

In addition to playing an essential role in plant nutrition, P also favorably affects certain physical and chemical properties of soils. Lutz and Pinto (1965) published data showing that P applied as H_3PO_4 and

$CaH_4(PO_4)_2$ was effective in reducing the hardness of clay soils, particularly those with a higher content of montmorillonite. It was noted at the same time that the smaller applications gave the greatest effectiveness per increment of P applied. This effect on the soil's modulus of rupture was thought to have been indirectly related to the increase of negative charge on the soil particle.

Lutz et al. (1966) reported that the amount of water present in the soil could be increased by applying phosphate fertilizer. Associated with this, was also an increase in crop yield which was significant even eight years after initial application. This increased water holding capacity also was related to the increase of negative charge on the soil particles brought about by the addition of P.

Further studies by Lutz and Hague (1975) indicated that the rates of P up to 100 ppm had relatively little effect on the pH of clay soils. However, they did have an irregular effect of increasing the charge on the clay particles. It was concluded that nearly all of the P induced changes were beneficial to agricultural soils and most of the changes were produced at rates which were economically feasible.

It has been estimated that the average mineral soil contains about 2,000 pounds of P per acre (Anderson, 1970). While these levels of total P are comparatively low, of greater significance is the fact that most of the P is present in forms unavailable to plants.

Phosphorus absorption by plants requires the transfer of phosphate ions from the soil to the root zone of sorption. To accomplish this transfer, phosphate ions must be able to enter the soil solution. Evidence indicates that those phosphate ions in solution are exchangeable with those absorbed on both soil and root surfaces thus setting up an equilibrium type situation between surfaces. With absorption of P by the root, a true equilibrium is not established resulting in solution phase phosphates tending to migrate toward the root. This renewal of nutrients at the root sorption zone is a very important process and is dependent upon water movement and diffusion.

In situations involving low nutrient concentrations or immobile ions such as P, Marais and Wiersma (1975) determined that diffusion governed the rate of P movement in solution. This concept, rather than mass flow, had also been accepted by Mahtab et al. (1972) and Fox and Kamprath (1970).

The rate of diffusion of P ions to roots is slow. Olsen et al. (1962) found that after 10 days the only solution phase P movement that had occurred was within a distance of 1.3 mm of the root's surface.

Fox and Kamprath (1970) noted that the diffusion of P to plant roots was determined by P concentration in solution and the amount of solid phase P during depletion. Also related were mobility factors such as diffusion coefficient, and the soils buffering capacity related to clay content.

Since the rate of P renewal into solution should be at least as fast as the rate of plant removal, the ability of the soil to supply solution P is an important factor in evaluating its P status. Five Kentucky soils were studied by Ballaux and Peaslee (1975) with regard to the relationships of their P sorption and desorption. They concluded that an index could be made to catagorize soils according to their sorption-desorption characteristics. This index would be useful in making more accurate fertilizer recommendations. This could also conceiveably be used to recommend when to apply periodic small applications for the most effectiveness of the residual fertilizer P.

Lack of water severely reduces P availability in the soil by restricting the diffusion rate. Matocha et al. (1970) found evidence that the P diffusion coefficient could be maintained as field capacity decreased by increasing the rate of applied phosphorus. Comparing this work with that of Lutz et al. (1966) it would seem that maintaining favorable levels of P in the soil would be of benefit to crops during brief periods of drouth. This could be accomplished through increasing the amount of water present in the soil and at the same time increasing the diffusion coefficient.

As mentioned previously, the ability of a soil to maintain solution phase P was partially responsible for the degree of P diffusion. It has been shown that the lower P sorption capacity of sandy soils limits the soils capacity to renew the solution phase P. Soils of this nature require a higher degree of P saturation than clay soils (Woodruff and Kamprath, 1965; Fox and Kamprath, 1970). This agrees with the suggestion of Mahtab et al. (1972) that clay soils should show less tendency toward P deficiency during dry weather.

Olsen and Kemper (1968) indicated that the bulk of the P absorption takes place at new root hairs and that the volume of soil then at any one time supplying the plant with P is very small. Because of this, the plant is dependent upon continual new exploration to satisfy its P requirements. The amounts of P that must be present in the soil for maximum yields must be many times larger than the crop content. Soil strength and aeration are soil factors having a decided influence on the rate of root proliferation and ultimately the rate of nutrient uptake (Voorhees et al., 1975).

If the results demonstrated by Lutz and Hague (1975) are accurate, then the problem presented by increased soil strength can be somewhat overcome by maintenance of adequate residual soil P. Bray (1954) recognized the extension of root absorbing surfaces and rate of P entering into solution as being correlative processes which complement each other and largely determine the soil fertility requirements of a plant.

Tisdale and Rucker (1964) recognized seven environmental factors affecting crop response to phosphates. Two of these factors, soil texture and degree of phosphate saturation of the soil, have previously been discussed. Attention now will be given to four others: soil reaction, presence of hydrous oxides of iron and aluminum, soil temperature and soil moisture content.

Plants absorb P primarily in the form of primary and secondary orthophosphates. While P is present in insoluble organic forms, the majority of total P is present in relatively insoluable mineral compounds.

Soil pH has a strong influence on the reversion and eventual availability of fertilizer P. The presence of ions such as Ca and Mg in basic soils or Fe and Al in acidic soils combine with soluble phosphates forming an insoluble precipitate. The type and amount of fixation products formed will be somewhat dependent upon the soil pH and degree of P saturation.

To obtain maximum yields, a higher concentration of P is required in soils having a higher saturation of exchangeable Al. Neutralization of this exchangeable Al by liming reduces the amount of P required to obtain higher yields (Woodruff and Kamprath, 1965). Vaidyanathan and

Talibudeen (1968) found that field crops used labile P most efficiently at pH 6.6 and least efficiently at 4.5. For Walker et al. (1975), millet forage yield was unrelated to pH, but the P content was greater with higher soil pH levels. This behavior can have strong implications with regard to forage quality and animal nutrition. In this same study forage sorghum yield was increased 2,000 kg/ha when soil pH was increased 5.2 to 5.6.

The mechanism of fixation of phosphate by iron oxides was the subject of a study by Parfitt et al. (1975). Using infrared spectroscopic techniques, they were able to determine that two surface hydroxyl ions were replaced by one phosphate ion. Two of the oxygen atoms of the phosphate ion are in turn connected each to a different Fe ion. This linkage of phosphate by two bonds to different Fe ions results in the insolubility of the compound formed. It was felt that this same mechanism occurred between phosphates and hydroxyl Al.

In a study of residual P, Kamprath (1967) referred to the high P fixation capacities and inherently low levels of available P in red soils of warm humid regions. An example of a soil of this type was a clay soil used by Woodruff and Kamprath (1965) which exhibited a P adsorption maximum of 642 pounds of P per acre.

Phosphorus adsorption also increased with an increasing content of clay. However, Fox and Kamprath (1970) demonstrated that phosphate adsorption per gram of clay decreased with increasing clay content. This was due to decreased phosphate access to clay surface in the higher clay soils.

Temperature may affect plant growth by altering the availability and uptake of soil nutrients, and P is no exception. It has been demonstrated (Mack and Barber, 1960b) that higher soil temperatures prior to cropping increased P uptake and dry matter yield. In this study, fertilizer P was more effective at higher soil temperatures, and it was concluded that soil P availability would be less at lower soil termperatures. In a similar study, Power et al. (1963) found that by increasing the available soil P supply, the soil temperature range over which nearly maximum yield would occur could be widened. Maintaining a high available P supply could be a means of protecting crops against above or below optimum soil temperatures.

Mack and Barber (1960a) found evidence that the amount of P available to plants in the field was strongly related to combinations of soil temperature and soil water content, and that changing these conditions may sometimes contribute to a low correlation between soil tests and crop response. Their study indicated that the increase in P uptake and dry matter produced from P treatments was linearly related to soil moisture content.

Similar response was noted by Mahtab et al. (1972), and Matocha et al. (1970). Because of changes in diffusion coefficients, more P was needed by crops during periods of moisture stress than periods of adequate moisture. Furthermore, Marais and Wiersma (1975) found that in soybean plants, moisture stress broken by a single watering stimulated uptake to the extent that the plants contained almost as much P as those growing in soil that was continually moist.

The degree of the P saturation of a soil is of considerable importance in the fixation of added fertilizer P. Also, of importance is the extent to which plants can utilize those residual fixed forms. Since utilization of applied phosphorus is approximately 15-20% of the first year, considerable residual may accumulate.

Numerous studies (Kamprath, 1967; Brams, 1973; and Ridley and Tayakepisuthe, 1974) have demonstrated the effects of residual P lasting over a period of several years. In a comparison of the efficiencies of residual vs. applied P, Matocha et al. (1970) noted that there was an almost equal effect. With this evidence, it was concluded that P added initially was not irreversibly lost, but available in subsequent years and aided in maintaining the soil solution concentration. However, variation in the availability of residual P can occur and may be dependent upon several factors: the reaction product formed, the initial percent of P saturation, and the rate and source of P applied (Matocha et al., 1970).

The importance of the source of P applied with respect to both immediate and residual values was demonstrated by Mattingly and Widdowson (1963). In comparison of superphosphate and rock phosphate, the latter, containing less water soluble P, was of little value the first two years, but its value increased with time. After 3-4 years, the residues of the rock phosphate were almost equivalent to those of superphosphate.

One of the primary advantages of reaching a high level of residual soil P is that this level can be maintained by periodically applying relatively small applications of fertilizer P. This is particularly beneficial when dealing with crops such as annuals that are more responsive to P during early growth stages.

The practicality of following this practice was demonstrated by Kamprath (1967) where banding of small amounts of P improved the effectiveness of the residual. Small, frequent applications appear to supply the readily absorbable phosphate and as the root system developed, more use could be made of the residual phosphates.

If, however, the residual is sufficiently high within the soil as was the case with Brams (1973), application of fertilizer P may not elicit any yield increases. Under this situation, it was concluded that one of two soil conditions existed. Either residual P was adequate, or the applied soluble phosphorus was immobilized by Al, Fe or Ca. Most probably, both conditions existed to varying degrees.

With regard to the residual effects of applied P fertilizer, the method of application, drilled or broadcast, would have little bearing provided the fertilizer was eventually mixed with the soil (Ridley and Tayakepisuthe, 1974). Even though the drilled fertilizer would be the most effective the first year, the residual effects of either application method would become the same.

Most of this review has covered the role of residual P under conventional cropping systems. However, in the last decade or so, farmers have increasingly turned their attention to minimum tillage practices. Two of the primary reasons for this are fuel efficiency and soil conservation.

Soil erosion poses one of the greatest sources of loss of fertilizer nutrients. In a study of soil nutrient loss under five different soil cover conditions, Burwell et al. (1975) measured annual P losses ranging from 0.68 to 33.34 kg/ha. The greatest percentage of this loss occurred in sediment from a fallow soil condition. This was to be expected due to the location of P in the soil.

No-till methods have in some cases at least demonstrated that they are better suited to the buildup and maintenance of residual soil fertility than conventional methods. No-till has also been shown to improve the efficiency of applied P (Moschler and Martens, 1975; Moschler et al., 1975).

In a long term fertilizer program there are many advantages in building up soil fertility. On soils that have been heavily phosphated for several years, it should be possible to reduce the amount applied and allow plants to utilize the residual. Not only is the maintenance of high P levels important from a nutritional standpoint, but as research has indicated, other benefits may be derived.

Brams (1973) noted that sporadic fertilization during long cropping periods can maintain and possibly increase yields only if a residual pool of available soil P can be developed.

CHAPTER III

METHODS AND MATERIALS

Study Area

This study was initiated in June 1970 as a residual fertility investigation at the Agronomy Research Station, Perkins, Oklahoma.

The prevailing climate in this area is subhumid with hot, often dry summers, mild autumns, mild to cold winters and cool springs. The average length of the growing season is 210 days with an average annual temperature of 15.2 C. (USDA Weather Bureau, 1955).

The average annual rainfall is 35 inches (89 cm) with approximately 82% of that occurring between March and October. Precipitation and resultant soil moisture can vary tremendously from year to year in this area and this was the case throughout the duration of this study.

The soil on which the study was conducted was a Teller loam (Udic Argiustoll), with 1-3 percent slopes and slightly eroded. This soil is located in an area which is mantled with old alluvial and loessial sediments from the Cimmarron River. This soil then developed under the influence of such mixed grasses as little bluestem (*Andropogon scoparius* Michx), big bluestem (*Andropogon gerardi* Vitman), switchgrass (*Panicum virgatum* L.), indiangrass (*Sorghastrum nutans* L. Nash) and other lesser native species.

The A horizons are 13 inches in thickness and classified as a loam texture. The B horizons are a sandy loam and extend to 43 inches. The

C horizon is a sandy loam and is composed of old alluvial sediments.

The organic matter content of these soils is low to medium and decreases with depth. The cation exchange capacity in these soils is moderately low, being approximately 12 meg/100 grams of soil. Base saturation is dominated by Ca and maximum clay content ranges from 22 to 25 percent with the surface 7 inches containing 13.2% and silt and sand being approximately equally divided (Ford et al., 1976). Mineralogical estimations placed montmorillonite and illite at approximately 80% of the clay content and kaolinite at less than 10%. Total native P found in the surface 7 inches measured 138 ppm.

Previous Site Utilization

This study was initiated to investigate the residual effects of combinations of N and P fertilizers which had been applied in a previous study.

Stands of three native and one introduced grass species had been established in 1964. The experimental design being the same for both this and the previous study was a split plot with a factorial subplot arrangement in four replications. Whole plots were monocultures of the grass species 'Kaw' big bluestem, 'Caddo' switchgrass, indiangrass and weeping lovegrass [Eragrostis curvula (Shrad.) Ness]. Subplots were eight fertility treatments using N at 0, 45, 90, and 180 kg/ha in all combinations with P at 0 and 40 kg/ha randomized within each whole plot. Whole plots were 12.2 x 15.2 m, and subplots were 3 x 7.6 m.

Previous fertilizer applications, 1965 through 1969, had been broadcast in early April utilizing ammonium nitrate (33.5-0-0) and superphosphate (0-46-0). In March 1968, 85 kg of K/ha was uniformly applied to remedy apparent soil deficiencies.

Forage had been harvested about the last of June each year and regrowth, if sufficient, was also harvested after the first killing frost.

Annual controlled burning had been practiced each March to control cool season weedy species and remove any remaining old residue.

Present Treatment

In 1970, plots having previously received 45 and 90 kg of N/ha were fertilized twice at those same rates, thereby doubling the amounts they had previously received. However, the 180 kg N treated plots received no applications that year and was not harvested to permit stand recovery from drought death losses of the previous year. In April of 1970, a uniform application of 112 kg of K/ha (muriate of potash, 0-0-63) was applied and P was applied to those receiving 0, 45 and 90 kg of N/ha.

All plots received uniform applications of 90 kg of N/ha each spring from 1972 through 1976. These applications were made to maximize the potential of any residual P. A summary of the entire history of fertilizer applications is presented in Table 1.

Forage Production

Forage harvests of native grasses were made at the time of floral initiation which usually occurred about the first of July. A second harvest of summer regrowth was taken after a killing frost, except in 1972 and 1973 when lack of precipitation prevented sufficient regrowth. The physiological growth of weeping lovegrass did not follow that of the native species and consequently, harvests dates were different.

Table 1. History of fertilizer applications on the plots in kg/ha.

Year	0	45N	90N	180N
	N Treatment			
1965-1969	Yes	Yes	Yes	Yes
1970	Yes	90N	180N	None
1971	None	None	None	None
1972-1976	90N	90N	90N	90N
	P Treatment			
1965-1969	0 and 40	0 and 40	0 and 40	0 and 40
1970	0 and 40	0 and 40	0 and 40	None
1971-1976	None	None	None	None
	K Fertilizer			
1968	Uniform application of 85 kg K/ha to all plots.			
1970	Uniform application of 112 kg K/ha to all plots.			

Harvests were taken using a 0.9 m sickle-type mower adjusted to a clipping height of 5 cm. Clippings were taken from a 0.9 x 4.9 m area. Following harvests, plots were completely mowed and forage removed.

Forage moisture samples were oven dried and yields were reported in oven dry kg/ha.

Controlled burns were made in March each year primarily to control cool season weedy species. In spite of this, considerable stand deterioration was noted in certain plots, particularly those of indiangrass. Invading species were primarily lovegrass, annual three awn (*Aristida oligantha*) and various cool season annual bromes (*Bromus spp.*) Invasion of these and other species were not confined to any particular fertility treatment.

Soil Sampling

To monitor residual fertilizer levels and to compare with yield data, soil samples were taken from the 0-15 cm depth at the initiation of this study in 1970 and again in April 1973 and February 1976. Six samples were taken from each subplot and were composited to represent a single sample for that particular plot. Analyses were performed by Oklahoma State University soil testing laboratory.

Soil reaction was measured by mixing 1:1 paste of soil and distilled water. The pH was then measured using a glass-electrode meter. Buffer index was determined by SMP buffer procedure. Exchangeable K was determined using an atomic absorption spectrophotometer. Available P was extracted with Bray-1 extractant using a 20:1 solution to soil ratio.

CHAPTER IV

RESULTS AND DISCUSSION

Soil Test Study

The changes in soil fertility were monitored by sampling in 1970, 1973, and 1976. Beginning in 1971, all plots received a uniform application of 85 kg of K/ha in 1968 and 112 kg of K/ha in 1970.

Available Soil Phosphorus

The application of P with or without N in the years preceeding this study increased the available soil P level. The resulting highly significant build-up of residual soil P carried over throughout the six year duration of this investigation (Fig. 1). The absence of a trend toward decreasing available soil P indicated that either the P requirement of these forage species was relatively low, or a more sensitive test was required. From this it was apparent that the 40 kg of P/ha applied annually for six years prior to initiation of this study was substantially more than enough to maintain soil P levels and result in high residual levels. Neither N treatments nor species had a significant effect on soil P as may have been expected. However, in 1976 there was noted a significant species x P interaction (Fig. 2) occurring at the 40 kg P level. This suggested that weeping lovegrass and indiangrass either had significantly different yields or P requirements.

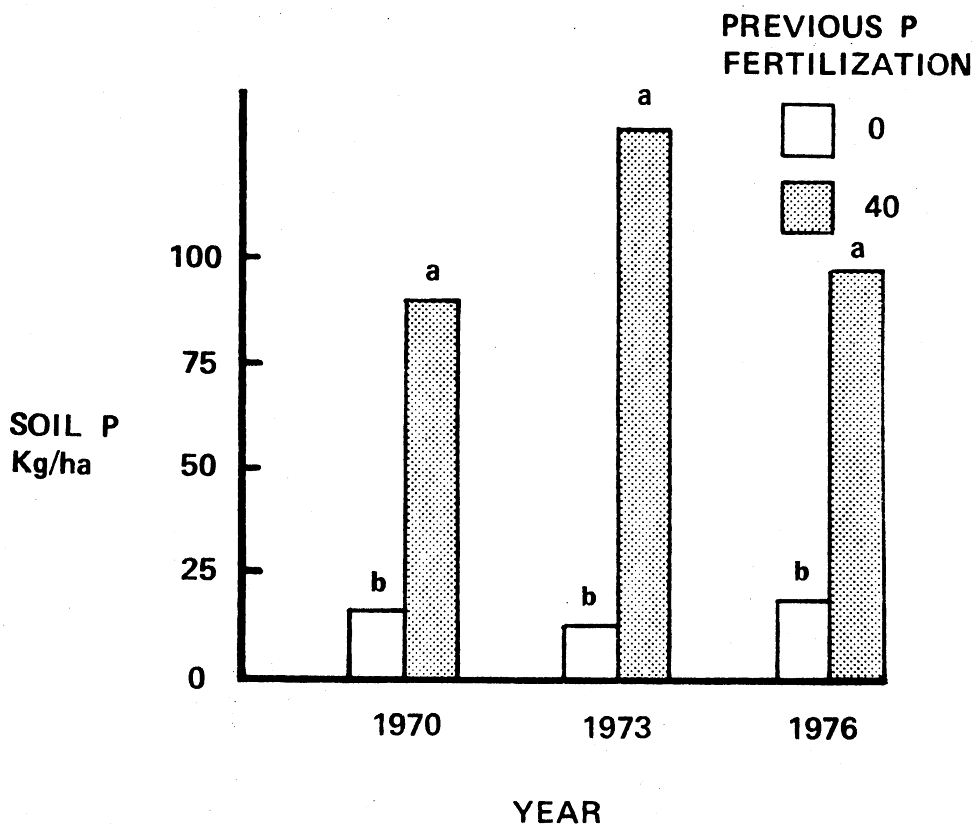

Figure 1. Available soil P as affected by previous P treatments. Means within a year having the same letter are not significantly different (P = 0.05).

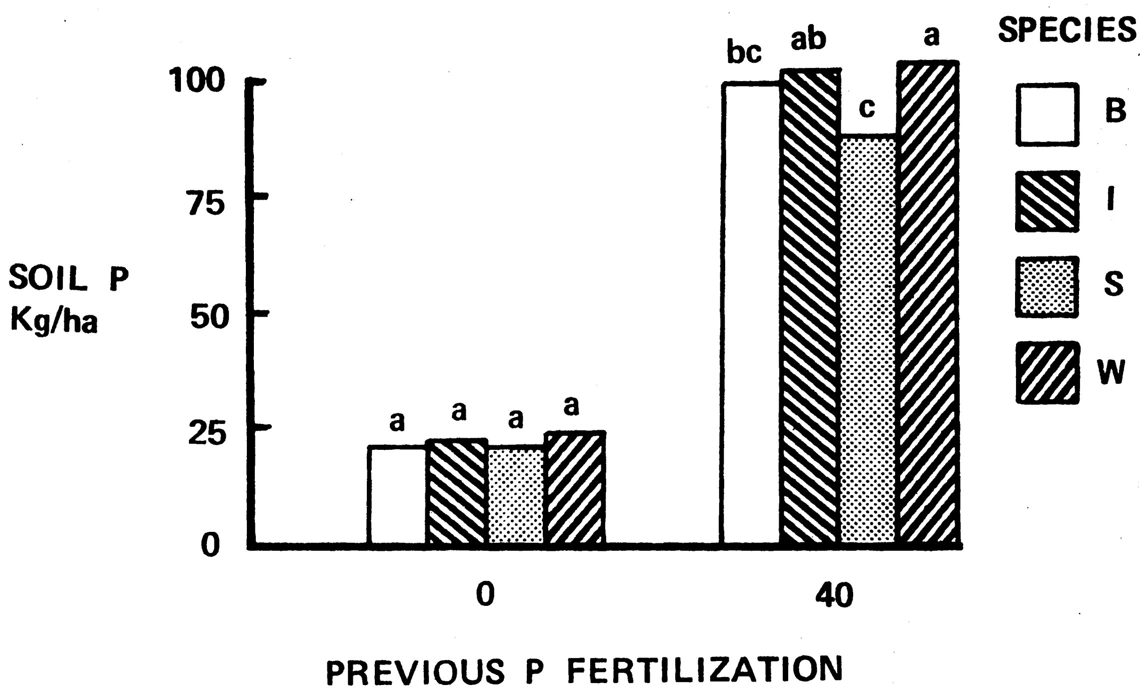

Figure 2. Available soil P in 1976 as affected by species and previous P treatments. Means within a P treatment having the same letter are not significantly different (P = 0.05).

Exchangeable Soil Potassium

Statistical analysis indicated both N and P fertilization had a significantly decreasing effect on exchangeable soil K (Fig. 3 and 4). These significant decreases in exchangeable K occurred with increased soil P and with each increasing level of N application. The exception to this was the nonsignificant difference noted with the 90 and 180 kg N treatments.

This result was evidently due to the increased forage production associated with increasing N and P levels. This same effect was seen in the previous study by McMurphy, et al. (1975). Mondart, et al. (1974), however, noted that P applied to bermudagrass (*Cynodon dactylon*) did not have a direct effect on the soils K status.

Soil pH

The acidifying nature of ammonium nitrate fertilizer was quite apparent in the reduction of soil pH with increasing levels of N fertilization (Fig. 5). After 1970 all plots received a uniform N application and soil pH was further reduced by 1976.

Species had a significant effect in that weeping lovegrass had a higher soil pH in 1970 and 1973 (Fig. 6). However, by 1976 no species difference in soil pH could be detected.

The P fertilization and the residual soil P had no effect on soil pH.

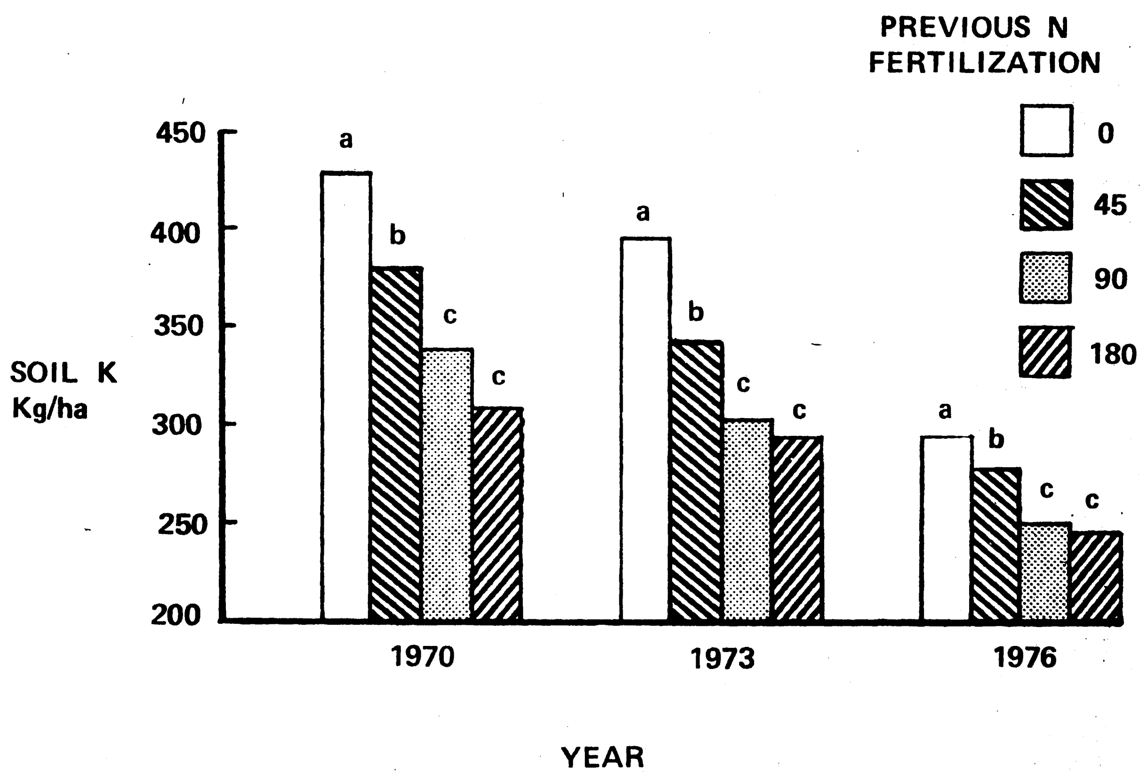

Figure 3. Available soil K as affected by previous N treatments. Means within a year having the same letter are not significantly different (P = 0.05).

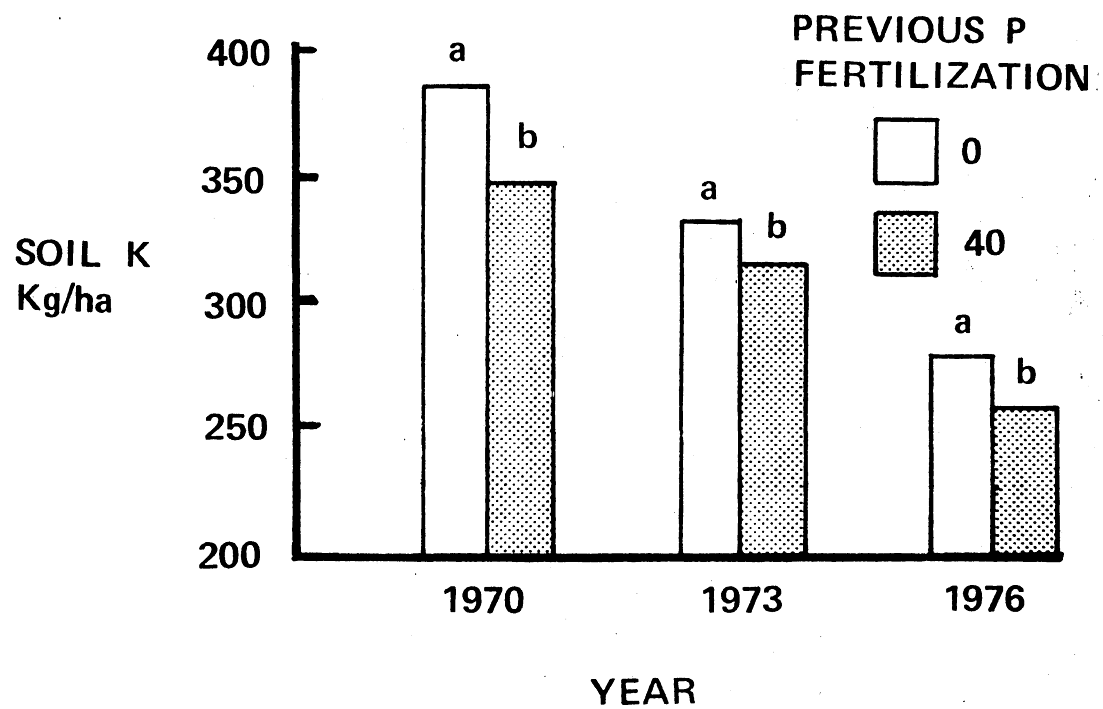

Figure 4. Available soil K as affected by previous P treatments. Means within a year having the same letter are not significantly different (P = 0.05).

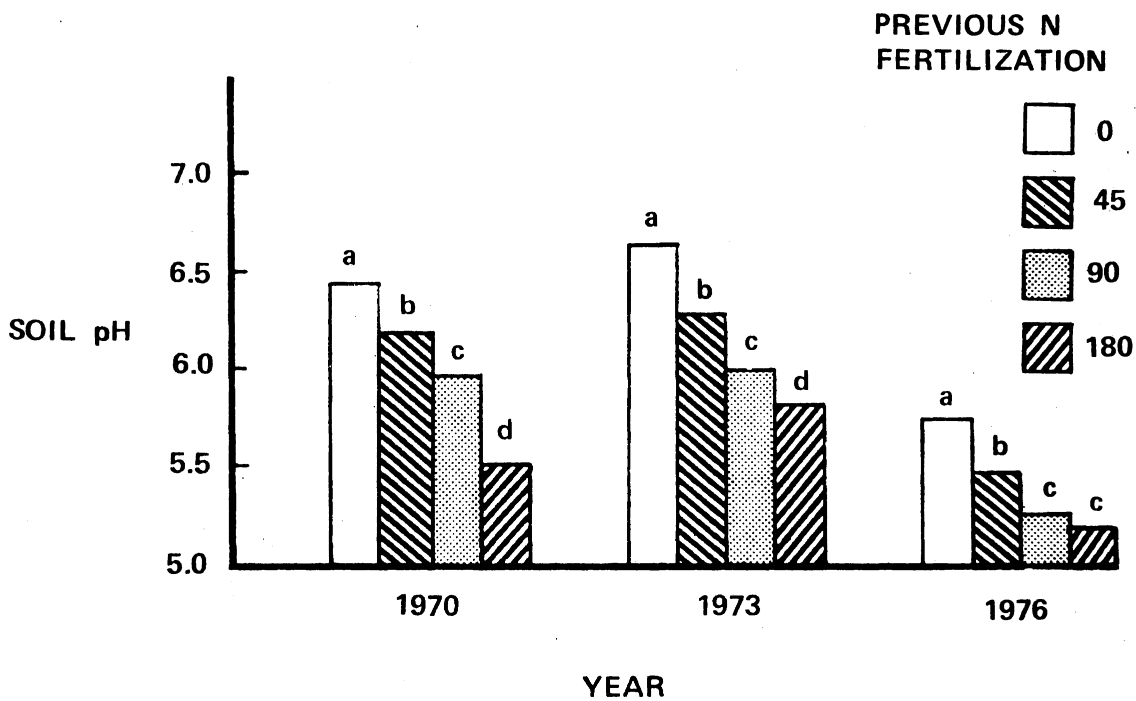

Figure 5. Soil pH as affected by N fertilization treatments (6 years) then a constant rate of 90 kg of N/ha for the last 6 years. Means within a year having the same letter are not significantly different (P = 0.05).

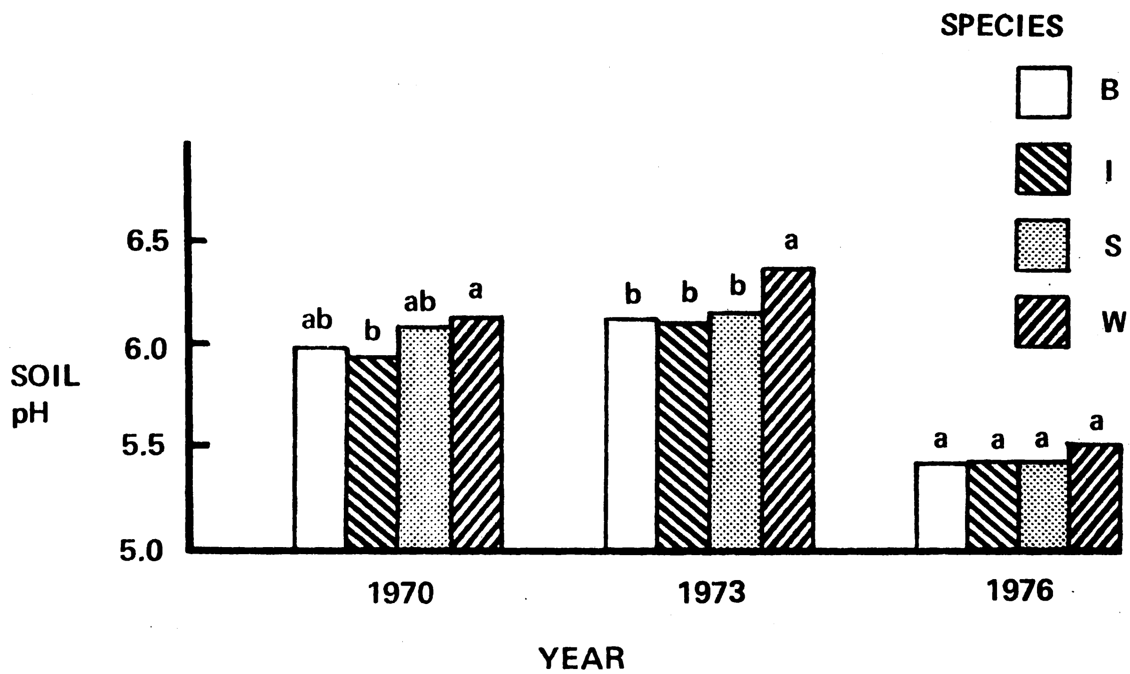

Figure 6. Soil pH as affected by grass species. Means within a year having the same letter are not significantly different (P = 0.05).

Forage Production

Mean hay yields of each species for all six years are presented in Table 3. Statistical analysis showed species yield differences were significant in each of the six years. There was no one species that consistently maintained the highest yield, but indiangrass was consistently maintained the highest yield, but indiangrass was consistently the lowest. Prior to termination of the previous study, it was noted that indiangrass stands were rapidly deteriorating and being invaded by cool season annual weedy species (McMurphy, et al. 1975). This condition persisted throughout this study and probably contributed to the lower overall yields of this species. While lovegrass plots remained a completely closed community, a few of the switchgrass and big bluestem plots had been invaded by individual lovegrass plants and some annuals. This invasion, however, was in no way as severe as that of the indiangrass, and these three species remained as a relatively closed plant community.

Wide fluctuations in precipitation occurred throughout this study (Table 2) despite the average overall precipitation being similar to that of the 30 year mean. Examination of annual forage yields by species and precipitation data indicated an apparent relationship between rainfall and yield each year (Table 3).

Effect of Previous Nitrogen Treatments

The effect of residual plus applied N significantly increased forage production in the years 1971 and 1972, but no residual effect was detected by 1973.

Table 2. Precipitation data (inches) for Agronomy Research Station, Perkins, Oklahoma.

Month	Year 1971	1972	1973	1974	1975	1976	6 Yr. Mean	Long Term 1/ Mean
	inches							
Jan.	1.32	.17	3.00	.45	2.70	0	1.27	1.53
Feb.	1.44	.32	.43	2.26	1.64	.51	1.10	1.46
March	0	1.72	7.83	2.66	3.24	1.82	2.88	2.20
April	2.09	2.42	2.61	3.13	1.70	5.14	2.85	3.16
May	2.35	2.38	3.68	6.28	9.72	2.95	4.56	5.09
June	3.21	2.47	1.48	5.35	4.19	.50	2.86	4.58
July	5.84	4.05	3.37	.78	4.05	1.54	3.27	3.45
Aug.	1.90	6.71	2.52	3.87	3.09	1.69	3.30	3.19
Sept.	7.68	1.86	6.69	6.29	1.34	1.67	4.25	3.81
Oct.	2.61	7.02	3.10	7.15	1.47	1.82	3.86	3.21
Nov.	.87	2.56	3.29	6.03	1.59	.22	2.43	1.90
Dec.	2.81	1.22	1.50	2.17	1.49	.21	1.56	1.42
Total	34.73	32.90	39.50	46.42	36.22	18.07	34.19	35.00

1/ 30 year mean from city of Perkins 1945-1975.

Table 3. Forage production by species for each year.

Species	Year					
	1971	1972	1973	1974	1975	1976
	kg/ha					
Big bluestem	4343a*	4187b	5106a	7698b	7375a	3636b
Weeping lovegrass	2549b	5343a	3926b	11254a	7996a	4809a
Switchgrass	4577a	3888b	4869a	7258bc	7397a	3285b
Indiangrass	2372b	2271c	3391b	6372c	5984b	2435c

*Means within a year followed by the same letter are not significantly different (P = 0.05).

It is noteworthy that the 180 N treatment received no N fertilizer in 1970 and the others had received twice the rate specified. The higher yield from the 90 N treatment is a reflection of the plots receiving the highest N fertilizer application in 1970 (Table 4).

The residual N effect lasted 2-3 years and was gone by 1973. Minor fluctuations in yield associated with previous N treatments were detected in 1974 and 1975, but by 1976 no difference in yield was associated with previous N treatment.

Effect of Residual Phosphorus

Phosphorus applied prior to 1971 continued to have a significantly beneficial effect on forage yields each year except 1971 (Table 5). In general, the response obtained from residual P initially was not as large as that from N, but the significant yield increase from P remained consistent each year. These findings disagree with those of Weeks and Miller (1948) in which yields were seen to progressively decrease following cessation of P applications.

Effect of Nitrogen and Phosphorus

A significant N x P interaction occurred only in 1971 (Fig. 7). The P treatment with the previously zero N level produced significantly more than the zero P treatment in this first year of uniform N applications.

Effect of Species and Nitrogen Treatment

Significant species x N interactions occurred in 1971, 1972 and 1974 (Fig. 8, 9 and 10).

In general, highest yields within a species were produced from the

Table 4. Forage production as affected by previous N fertilization treatments before 1971.

	Year					
Fertilizer N	1971	1972	1973	1974	1975	1976
			kg/ha			
000	1914d	3274c	4366a	8156a	7416a	3725a
045	2961c	3843b	4087a	7738b	6919b	3460a
090	4705a	4337a	4357a	8215a	7083ab	3437a
180	4260b	4235a	4483a	8474a	7334a	3543a

* Means within a year followed by the same letter are not significantly different (P = 0.05).

Table 5. Forage production as affected by previous P fertilization. Means of four species.

	Year					
Fertilizer P	1971	1972	1973	1974	1975	1976
	kg/ha					
00	3392a	3724b	3885b	7653b	6617b	3089b
40	3529a	4121a	4762a	8638a	7759a	3993a

* Means within a year followed by the same letter are not significantly different (P = 0.05).

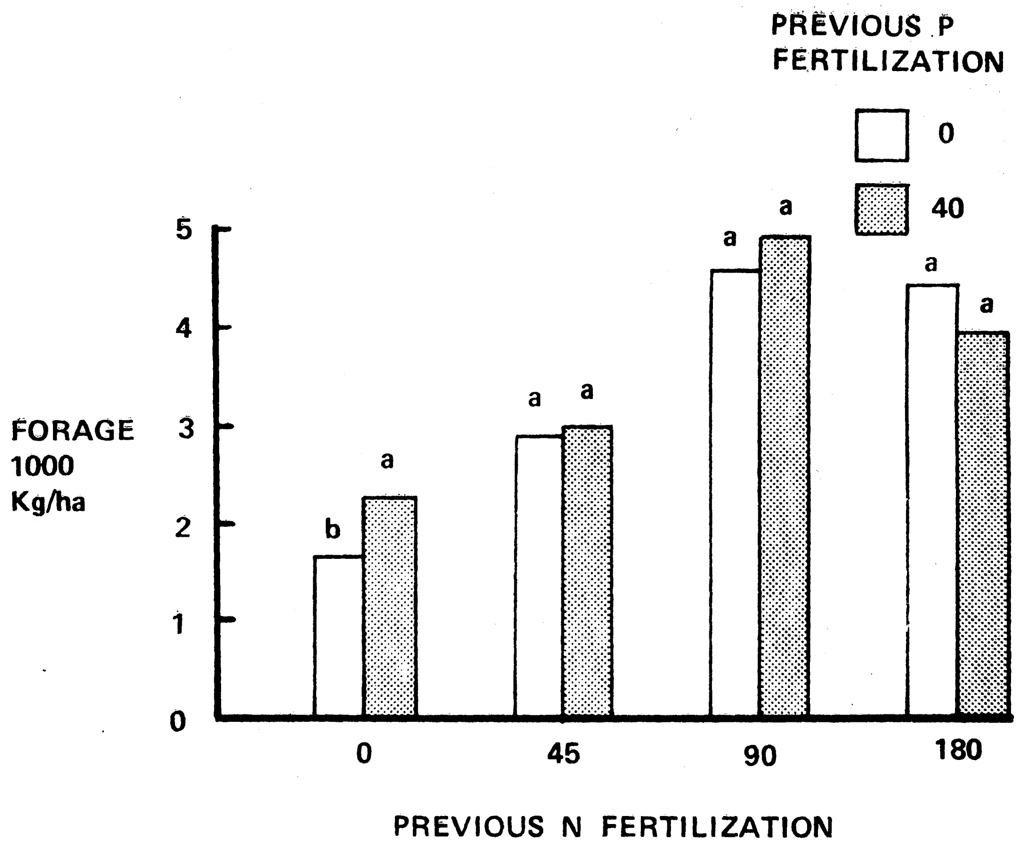

Figure 7. Forage production in 1971 as affected by previous N and P treatments. Means within a N treatment having the same letter are not significantly different (P = 0.05).

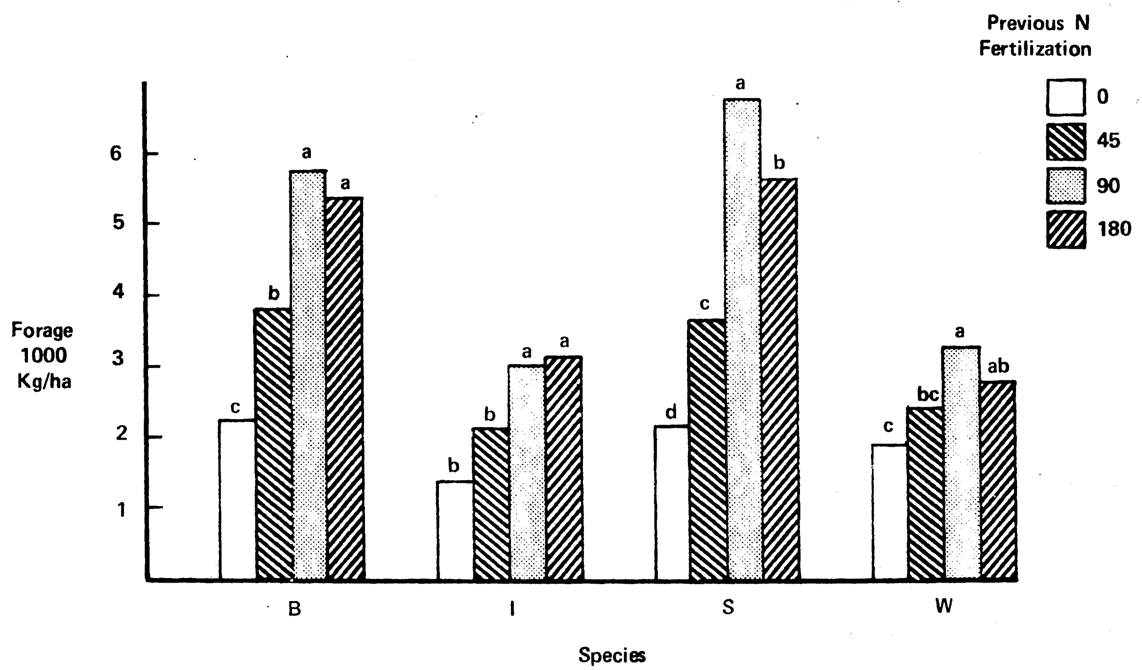

Figure 8. Forage production as affected by species and previous N treatment, 1971. Means within a species having the same letter are not significantly different ($p = 0.05$).

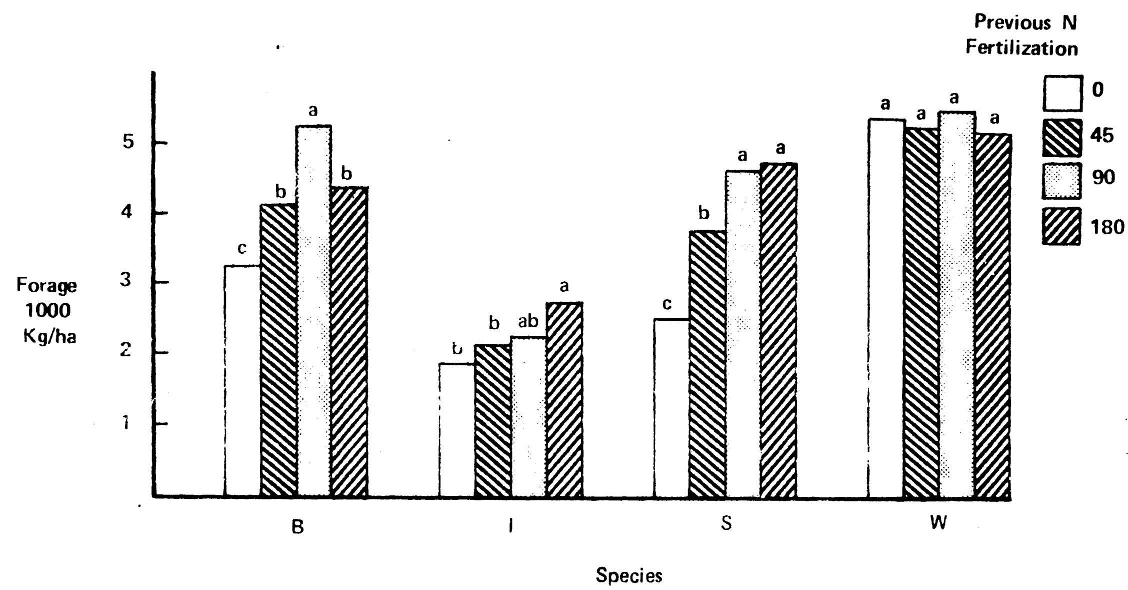

Figure 9. Forage production as affected by species and previous N treatment, 1972. Means within a species having the same letter are not significantly different (P = 0.05).

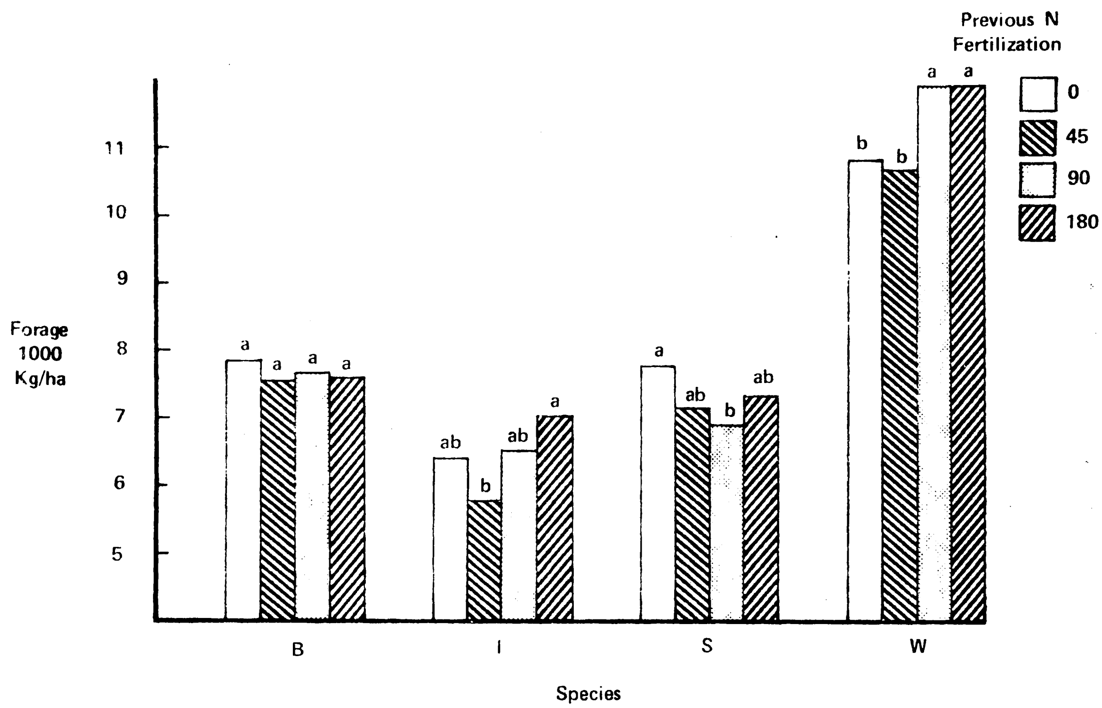

Figure 10. Forage production as affected by species and previous N treatment, 1974. Means within a species having the same letter are not significantly different (P = 0.05).

highest previous N fertilization. However, the magnitude of the response to residual N was greatest in big bluestem and switchgrass in 1971 (Fig. 8). The three native grasses had yield increases from residual N in 1972, but weeping lovegrass did not (Fig. 9). Thus, weeping lovegrass did not have any residual N response in the second season after the N fertilizer variables were stopped and the uniform N was applied.

Significant species x N still existed in 1974 (Fig. 10), however, the magnitude of the differences had become less and the order in which they occurred had changed.

Species x Phosphorus Interaction

In the majority of years big bluestem, switchgrass and indiangrass produced significant yield increases from residual phosphorus, but lovegrass had a significant response to residual phosphorus only in 1972 (Fig. 11, 12, 13 and 14). Weeping lovegrass forage production was less sensitive to low soil P, thus indicating that weeping lovegrass is capable of maintaining adequate production at a lower soil P than the other species.

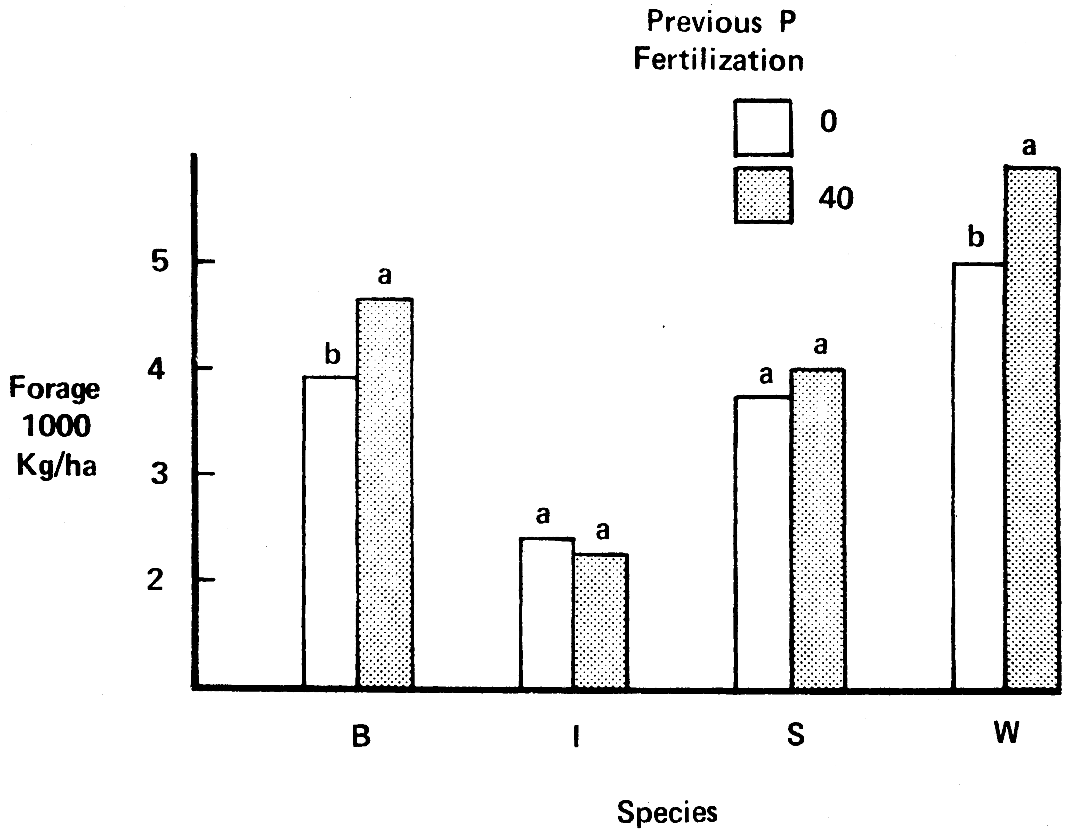

Figure 11. Forage production as affected by species and previous P treatment, 1972. Means within a species having the same letter are not significantly different (P = 0.05).

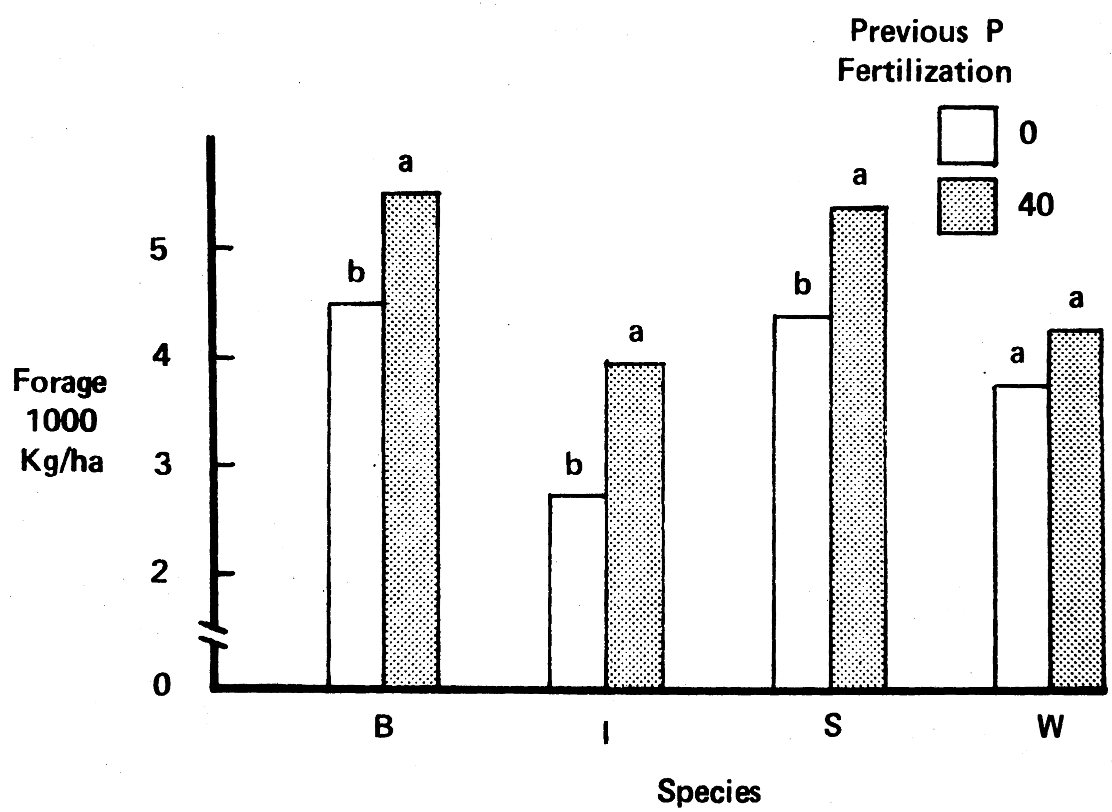

Figure 12. Forage production as affected by species and previous P treatment, 1973. Means within a species having the same letter are not significantly different.

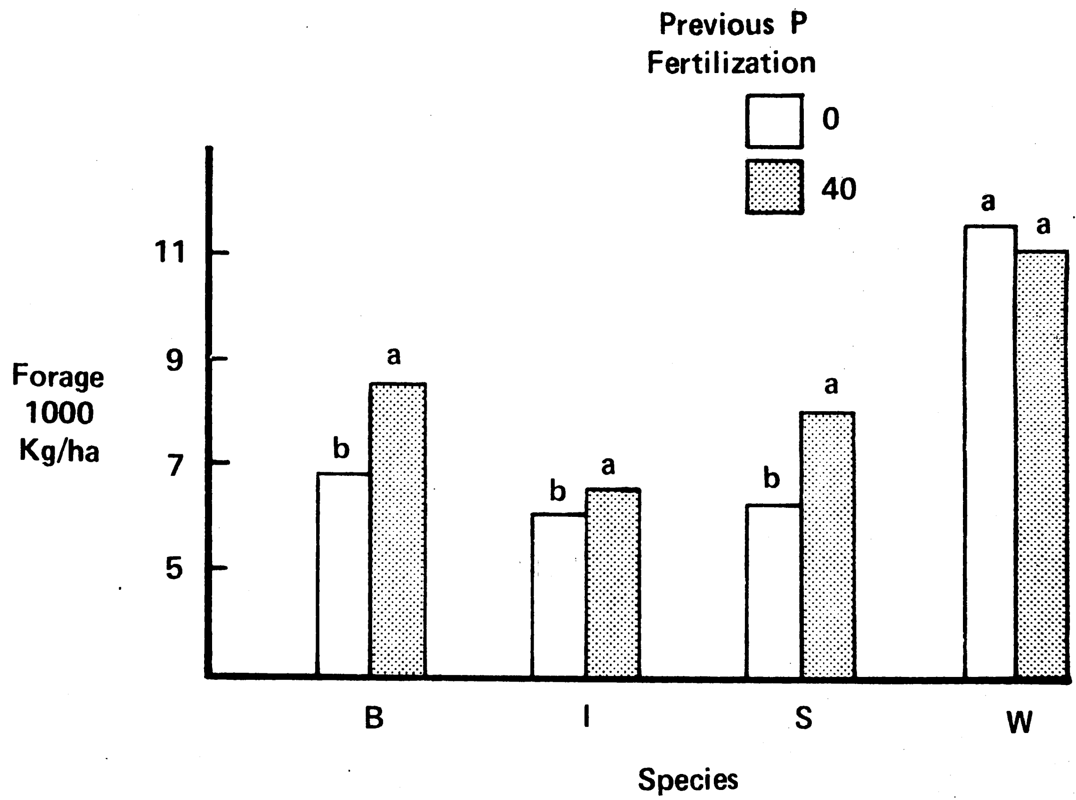

Figure 13. Forage production as affected by species and previous P treatment, 1974. Means within a species having the same letter are not significantly different (P = 0.05).

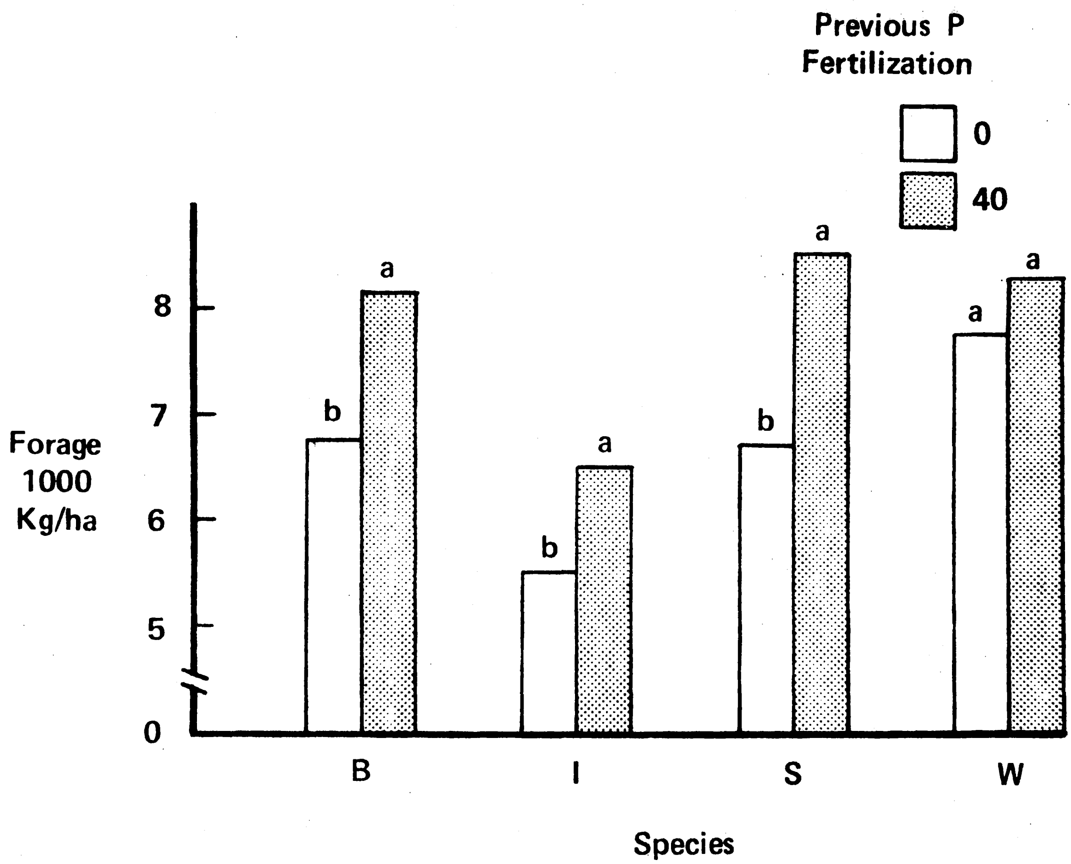

Figure 14. Forage production as affected by species and previous P treatment, 1975. Means within a species having the same letter are not significantly different (P = 0.05).

CHAPTER V

SUMMARY AND CONCLUSIONS

The residual effects of six continuous years of fertilization of three native and one introduced grass species were studied at the Perkins Agronomy Research Station, Perkins, Oklahoma. The four forage species included monocultures of big bluestem, switchgrass, indiangrass and weeping lovegrass. Annual forage yields and changes in soil chemical components were the factors used in measuring the effects of the N and P fertility treatments.

Soil Test Study

Throughout the duration of this study significant differences were seen in the chemical characteristics of the soil following the six years of differential fertilizer treatment. While soil pH was not affected by residual P, significant reductions were associated with each level of N that had been applied. It was also noted in 1970 and 1973 that species had an influencing effect which was demonstrated by the significantly higher pH levels associated with lovegrass.

The application of phosphate fertilizer was effective in increasing the available residual phosphate level. These residual phosphate levels remained essentially the same throughout the study.

Higher forage yields associated with either N treatments or more productive forage species were not seen to have any significant effect on soil P levels which suggest low P requirements for these species.

Exchangeable soil K was significantly reduced by applications of both N and P; however, no difference was noted in the effects of the 90 and 180 kg N treatments. Between 1970 and 1976 there was a noted trend toward the depletion of exchangeable K at all treatment levels suggesting a high K requirement with production stimulating inputs.

Forage Yield Study

Significant differences in forage yield as a result of previous N applications were obtained in four of the six years. In 1971 and 1972 residual from all previous N applications significantly increased yields over the zero N treatment. However, a comparison of yields after 1972 showed that yields obtained from the previously treated N plots were nonsignificant. In 1975 and 1976, the average yield in the zero N plots were higher than the average yields from plots having received N. The greatest total yield in each of the six years was not necessarily produced by the highest previous rate of N applied.

Within each species no significant differences in yields were seen between the 90 and 180 N treatments except in 1971 when switchgrass and in 1972 when big bluestem gave higher yield responses to residual from 90 kg N treatment.

Benefits from residual P alone increased yields in five out of six years.

The presence of high residual P as compared to low residual P produced significantly greater yields each year in big bluestem, indiangrass and switchgrass. Lovegrass exhibited a significant response to high residual P only in 1972.

The amount and distribution of rainfall may well have been an influencing factor in yield response.

While no one species consistantly yielded the most, indiangrass had the lowest average yields in each of the six years.

LITERATURE CITED

Anderson, W. B. 1970. Sources, levels, losses, and availability of mineral elements in soils. Southern Pasture and Forage Crop Imp. Conf. 27th (Athens, Ga.) 26-30.

Baker, J. M., and B. B. Tucker. 1973. Fertilizer recommendation guide. Okla. State Univ. Ext. Facts 2225.

Ballaux, J. C., and D. E. Peaselee. 1975. Relationships between sorption and desorption of phosphorus by soils. Soil Sci. Soc. Am. Proc. 39:275-278.

Brams, E. 1973. Residual soil phosphorus under sustained cropping in the humid tropics. Soil Sci. Soc. Am. Proc. 37:579-582.

Bray, R. H. 1954. A nutrient mobility concept of soil-plant relationships. Soil Sci. 78:9-22.

Burwell, R. E., D. R. Timmons, and R. F. Holt. 1975. Nutrient transport in surface runoff as influenced by soil cover and seasonal periods. Soil Sci. Soc. Am. Proc. 39:523-28.

Ford, J., E. Nance, and F. Gray. 1976. Modern detailed soil survey Perkins Research Station. Okla. Agric. Exp. Sta. Res. Rep. P-744.

Fox, R. L, and E. J. Kamprath. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils. Soil Sci. Soc. Am. Proc. 34:902-906.

Grunes, D. L. 1959. Effect of nitrogen on the availability of soil and fertilizer phosphorus to plants. Adv. Agron. 11:369-396.

Kamprath, E. J. 1967. Residual effect of large applications of phosphorous on high phosphorus fixing soils. Agron. J. 59:25-27.

Lutz, J. F., and R. A. Pinto. 1965. Effect of phosphorus on some physical properties of soils: I. Modulus of rupture. Soil Sci. Am. Proc. 29:458-460.

Lutz, J. F., R. A. Pinto, R. Garcia-Lagos, and H. G. Hilton. 1966. Effect of phosphorus on some physical properties of soils: II. Water retention. Soil Sci. Soc. Am. Proc. 30:433-437.

Lutz, J. F., and I. Hague. 1975. Effects of phosphorus on some physical and chemical properties of clays. Soil Sci. Soc. Am. Proc. 39:33-36.

Mack, A. R., and S. A. Barber. 1960a. Influence of temperature and moisture on soil phosphorus: I. Effect on soil phosphrous fractions. Soil Sci. Soc. Am. Proc. 24:381-385.

Mack, A. R., and S. A. Barber. 1960a. Influence of temperature and moisture on soil phosphorus: II. Effect prior to and during cropping on soil phosphorus availability for millet. Soil Sci. Soc. Am. Proc. 24:482-484.

Mahtab, S. K., A. R. Swoboda, C. L. Godfrey, and G. W. Thomas. 1972. Phosphorus diffusion in soils: II. The effect on phosphorus uptake by plants. Soil Sci. Soc. Am. Proc. 36:55-57.

Marais, J. N., and D. Wiersma. 1975. Phosphorus uptake by soybeans as influenced by moisture stress in the fertilized zone. Agron. J. 67:777-781.

Matocha, J. E., B. E. Conrad, L. Reyes, and G. W. Thomas. 1970. Residual value of phosphorus fertilizer on a calcareous soil. Agron. J. 62:572-574.

Mattingly, G. E. G., and F. V. Widdowson. 1963. Residual value of superphosphate and rock phosphate on an acid soil. J. Agric. Sci. 60:399-407.

McMurphy, W. E., C. E. Denman, and B. B. Tucker. 1975. Fertilization of native grass and weeping lovegrass. Agron. J. 67:233-236.

Mondart, Jr., C. L., H. E. Harris, R. H. Brupbacher, Jr., and J. E. Sedbury, Jr. 1974. Influence of annual applications of phosphorus on the yield and chemical composition of common bermudagrass and on the chemical composition of a bowie soil. La. Agric. Exp. Sta. Bul. 684.

Moschler, W. W., and D. C. Martens. 1975. Nitrogen, phosphorus and potassium requirements in no-tillage and conventionally tilled corn. Soil Sci. Soc. Am. Proc. 39:886-891.

Moschler, W. W., D. C. Martens, and G. M. Shear. 1975. Residual fertility in soil continuously field cropped to corn by conventional tillage and no-tillage methods. Agron. J. 67:45-48.

Olsen, S. R., W. D. Kemper, and R. D. Jackson. 1962. Phosphate diffusion to plant roots. Soil Sci. Soc. Am. Proc. 26:222-227.

Olsen, S. R., and W. D. Kemper. 1968. Movement of nutrients to plant roots. Adv. Agron. 20:91-151.

Parfitt, R. L., R. J. Atkinson, and R. St. C. Smart. 1975. The mechanism of phosphate fixation by iron oxides. Soil Sci. Soc. Am. Proc. 39:837-841.

Power, J. F., D. L. Grunes, W. O. Willis, and G. A. Reichman. 1963. Soil temperature and phosphorus effects upon barley growth. Agron. J. 55:389-392.

Ridley, A. O., and S. Tayakepisuthe. 1974. Residual effects of fertilizer phosphorus as measured by crop yields, phosphorus uptake, and soil analysis. Can. J. Soil Sci. 54:265-272.

Tisdale, S. L., and Nelson, W. L. 1975. Soil Fertility and Fertilizers. Macmillan publishing Co., Inc., New York.

Tisdale, S. L., and D. L. Rucker. 1974. Crop response to various phosphates. The Sulphur Ins. Tech. Bul. 9.

USDA Weather Bureau. 1955. Climatic Summary of the United States. U. S. Govt. Printing Office, Washington, D. C.

Vaidyanathan, L. V., and O. Talibudeen. 1968. Rate controlling process in the release of soil phosphate. J. Soil Sci. 19:342-353.

Voorhees, W. B., D. A. Farrell, and W. E. Larson. 1975. Soil strength and aeration effects on root elongation. Soil Sci. Soc. Am. Proc. 39:948-953.

Walker, M. E., W. H. Marchant, and W. J. Ethredge. 1975. Effects of soil pH on forage yield, and chemical composition of sorghum and millet. Agron. J. 67:191-193.

Weeks, M. E., and H. F. Miller. 1948. The residual effects of phosphates used on long-time field experiments. Soil Sci. Soc. Am. Proc. 13:102-107.

Woodruff, J. R., and E. J. Kamprath. 1965. Phosphorus adsorption maximum as measured by the Langmuir Isotherm and its relationship to phosphorus availability. Soil Sci. Soc. Am. Proc. 29:148-150.

APPENDIX

Table 6. Exchangeable soil K as affected by six annual N and P applications, 1965-1970. Means of four grass species.

Treatment		Year of Soil Sample		
N	P	1970	1973	1976
—— kg/ha ——		—— Exchangeable K kg/ha ——		
0	0	437a*	394a	304a
0	40	418ab	392a	288ab
45	0	404b	360b	289ab
45	40	363c	333c	256c
90	0	350cd	303d	269bc
90	40	324d	273e	229d
180	0	329d	296de	263c
180	40	296e	278e	231d

* Means within a year followed by the same letter are not significantly different (P = 0.05).

Table 7. The available soil P as affected by six annual N and P applications, 1965-1970. Means of four grass species.

Treatment N	Treatment P	Year of Soil Sample 1970	1973	1976
—— kg/ha ——		——— Extractable P kg/ha ———		
0	0	17c*	16b	20b
0	40	95a	136a	94a
45	0	19c	12b	18b
45	40	93ab	128a	99a
90	0	13c	12b	19b
90	40	81b	133a	103a
180	0	16c	13b	18b
180	40	89ab	127a	98a

* Means within a year followed by the same letter are not significantly different (P = 0.05).

Table 8. Soil pH as affected by six annual N and P applications, 1965-1970. Means of four grass species.

Treatment		Year of Soil Sample		
N	P	1970	1973	1976
—— kg/ha ——		—— Soil pH ——		
0	0	6.4a*	6.7a	5.7a
0	40	6.4a	6.6a	5.8a
45	0	6.2b	6.3b	5.5b
45	40	6.2b	6.3b	5.5b
90	0	5.9d	5.9cd	5.3c
90	40	6.0c	6.0c	5.3c
180	0	5.5e	5.8d	5.2d
180	40	5.5e	5.8d	5.2d

* Means within a year followed by the same letter are not significantly different (P = 0.05).

Table 9. Big bluestem forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year																
		1965			1966			1967			1968		1969			1970		
N	P	July	Dec.	Total	July	Dec.	Total	July	Dec.	Total	July	Total	July	Dec.	Total	July	Dec.	Total
0	0	7393	841	8235	4031	1106	5137	2456	889	3346	2835	2835	1698	781	2478	1058	783	1841
0	40	7123	965	8089	4220	1205	5426	2529	915	3444	2542	2542	1815	869	2684	936	691	1627
45	0	7454	1027	8481	4746	1614	6360	4380	1093	5474	5987	5987	4907	1016	5923	3123	2357	5480
45	40	6887	1042	7929	5115	2000	7115	5237	1322	6558	5941	5941	4751	1021	5773	3062	2210	5272
90	0	8237	1156	9393	5081	1881	6963	5125	1246	6371	6556	6556	5672	1126	6798	3379	2161	5542
90	40	7722	871	8593	4995	2918	7914	7774	1983	9758	8077	8077	6879	1019	7899	4430	3832	8262
180	0	7025	933	7957	4029	1952	5981	5242	1322	6564	5390	5390	4377	759	5135	None[1]	None	None
180	40	9295	1001	10296	4085	2705	6790	6930	1754	8684	6127	6127	5338	971	6310	"	"	"

1. Plots were not fertilzed or harvested in 1970 to permit recovery from plant death losses.

Table 10. Big bluestem forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year															
		1971			1972		1973		1974			1975			1976		
N	P	July	Dec.	Total	July	Total	July	Total	June	Dec.	Total	July	Dec.	Total	July	Dec.	Total
0	0	1642	422	2064	3600	3600	4307	4307	5860	1324	7184	4978	1035	6012	3114	493	3607
0	40	1958	419	2377	2840	2840	5590	5590	7111	1314	8425	7268	1327	8595	3602	567	4169
45	0	3086	585	3671	3579	3579	4482	4482	5756	1258	7014	5855	1091	6945	2502	356	2857
45	40	3168	773	3940	4668	4668	5130	5130	6678	1401	8079	6262	1169	7431	3409	402	3811
90	0	4510	773	5283	4096	4096	4462	4462	5265	1190	6455	5372	1223	6595	2705	211	2916
90	40	5718	857	6574	6112	6112	5804	5804	7550	1482	9033	6762	1136	7899	3905	475	4380
180	0	4464	859	5323	4007	4007	5158	5158	5918	1157	7075	5756	1500	7256	2857	399	3257
180	40	4510	1004	5514	4594	4594	5913	5913	6882	1439	8321	6948	1319	8267	3640	447	4088

Table 11. Indiangrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year																	
		1965			1966			1967			1968		1969			1970		
N	P	July	Dec.	Total	July	Dec.	Total	July	Dec.	Total	July	Total	July	Dec.	Total	July	Dec.	Total
0	0	7220	1260	8481	2148	691	2840	907	661	1568	559	559	709	839	1548	158	561	719
0	40	7648	1190	8837	2140	574	2715	681	482	1164	518	518	597	643	1240	675	579	1256
45	0	8516	1044	9560	3538	1268	4807	3259	1169	4428	2702	2702	3086	927	4013	2080	1711	3792
45	40	9086	1085	10171	3770	1098	4867	2875	1093	3974	3025	3025	2961	803	3765	2106	1511	3616
90	0	9930	1080	11011	4001	1695	5698	5025	1220	6246	3803	3803	3909	940	4851	2070	1759	3830
90	40	9447	1184	10631	4630	1504	6134	5908	915	6824	4884	4884	4771	729	5502	2864	2110	4974
180	0	9755	1034	10790	3719	2156	5875	6135	1627	7762	4556	4556	3777	775	4552	None1/	None	None
180	40	10227	1177	11405	4306	2420	6726	7983	1144	9127	4975	4975	3696	823	4520	"	"	"

1. Plots were not fertilized or harvested in 1970 to permit recovery from plant death losses.

Table 12. Indiangrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year															
		1971			1972		1973		1974			1975			1976		
N	P	July	Dec.	Total	July	Total	July	Total	June	Dec.	Total	July	Dec.	Total	July	Dec.	Total
0	0	582	463	1045	1996	1996	2619	2619	4589	1030	5618	5112	760	5873	2074	511	2585
0	40	1274	575	1848	1947	1947	4195	4195	5875	1218	7093	5908	920	6828	2207	590	2796
45	0	1426	524	1950	2207	2207	2885	2885	4635	875	5509	4540	808	5349	1744	516	2260
45	40	1510	651	2161	2146	2146	3452	3452	4980	1027	6007	5247	707	5954	2344	470	2814
90	0	2613	638	3252	2260	2260	2725	2725	4693	801	5494	4754	625	5379	1225	404	1630
90	40	2222	470	2692	2141	2141	4274	4274	6043	1215	7258	5499	877	6376	2113	305	2418
180	0	2397	699	3096	2639	2639	3076	3076	5628	1073	6701	4774	719	5494	1347	308	1655
180	40	2321	608	2929	2832	2832	3910	3910	6002	1289	7291	5641	981	6623	2697	628	3325

Table 13. Switchgrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year																
		1965			1966			1967			1968		1969			1970		
N	P	July	Dec.	Total	July	Dec.	Total	July	Dec.	Total	July	Total	July	Dec.	Total	July	Dec.	Total
0	0	12597	965	13563	3709	811	4520	1592	686	2278	1546	1546	1006	925	1931	368	551	920
0	40	12061	991	13052	3392	689	4081	1404	584	1987	1480	1480	1164	797	1962	821	783	1605
45	0	11387	1042	12429	5298	1342	6640	4853	915	5768	5055	5055	4728	1138	5867	2696	1754	4450
45	40	12826	1057	13884	5387	1396	6782	5380	839	6218	5550	5550	5687	983	6670	3039	2078	5117
90	0	11874	965	12840	5239	1881	7121	6576	1093	7670	7001	7001	6023	1088	7111	4422	2278	6701
90	40	12521	1121	13642	6419	1855	8275	7588	965	8554	7949	7949	6085	1222	7309	5009	2734	7743
180	0	12142	1113	13256	4902	2023	6925	7177	1450	8626	6572	6572	5313	1095	6409	None[1]	None	None
180	40	11816	1202	13020	5412	2995	8407	10027	1856	11882	7766	7766	7604	2036	9640	"	"	"

1. Plots were not fertilized or harvested in 1970 to permit recovery from plant death losses.

Table 14. Switchgrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year																
		1971			1972		1973		1974			1975			1976		
N	P	July	Dec.	Total	July	Total	July	Total	June	Dec.	Total	July	Dec.	Total	July	Dec.	Total
0	0	928	712	1640	2423	2423	4060	4060	5725	1042	6767	6262	1065	7327	2331	493	2824
0	40	1935	730	2664	2591	2591	5870	5870	7652	1159	8811	7357	1266	8623	3478	1009	4487
45	0	3221	580	3801	3735	3735	4365	4365	5575	948	6523	5420	816	6236	1843	699	2542
45	40	2769	615	3384	3760	3760	4652	4652	6490	1052	7543	6912	1309	8222	3623	719	4342
90	0	5438	900	6338	4782	4782	4411	4411	5120	864	5984	5013	1103	6117	2156	636	2791
90	40	6262	694	6956	4411	4411	5362	5362	6803	961	7764	6859	1063	7922	2725	628	3353
180	0	5705	1037	6742	4258	4258	4518	4518	5672	864	6536	5318	966	6284	1975	541	2517
180	40	4479	613	5092	5143	5143	5718	5718	7261	877	8138	7378	1068	8445	2906	519	3424

Table 15. Weeping lovegrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year														
		1965				1966				1967				1968		
N	P	June	Aug.	Dec.	Total	June	Aug.	Dec.	Total	June	Aug.	Dec.	Total	June	Aug.	Total
0	0	3887	2336	2156	8379	1378	1164	755	3297	490	953	636	2079	294	707	1001
0	40	4159	2679	2324	9163	1280	920	711	2913	534	1148	788	2470	394	770	1164
45	0	4634	3106	2242	9983	3031	2156	798	5985	2610	2326	813	5750	2492	963	3454
45	40	4897	3388	2436	10720	3427	2026	819	6271	2965	2542	813	6320	2636	951	3587
90	0	4835	3923	2646	11405	3757	2562	1164	7484	3440	3653	965	8059	3516	1182	4698
90	40	4886	4133	2735	11756	4129	2865	1250	8245	4510	3343	915	8768	4797	1200	5997
180	0	4945	3925	4372	13243	4037	3470	1640	9147	4312	4003	2186	10503	4159	1260	5420
180	40	5250	4360	4703	14313	4676	3287	1943	9906	4873	4426	2516	11816	4970	1358	6328

Table 16. Weeping lovegrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year													
		1969				1970				1971			1972		
N	P	June	Aug.	Dec.	Total	June	Aug.	Dec.	Total	July	Dec.	Total	June	Aug.	Total
0	0	322	577	935	1835	126	412	915	1455	974	717	1691	2850	2186	5036
0	40	76	637	867	1581	130	663	1040	1833	1154	831	1985	3376	2385	5761
45	0	2001	1324	1116	4442	2904	1833	2072	6811	1452	869	2321	2296	2585	4881
45	40	2135	1304	1039	4480	2710	1693	2505	6909	1584	877	2461	3613	2158	5771
90	0	3404	1990	1118	6514	3886	2545	3209	9641	2372	948	3320	2484	2623	5107
90	40	3869	1789	1400	7059	4453	2962	3354	10770	2352	875	3226	3399	2387	5786
180	0	3378	2018	2071	7469	None1/	None	None	None	1833	897	2730	2334	2641	4975
180	40	4418	2352	2326	9097	"	"	"	"	1601	1055	2656	3124	2306	5430

1. Plots were not fertilized or harvested in 1970 to permit recovery from plant death losses.

Table 17. Weeping lovegrass forage production (kg/ha) from forage fertility tests, Perkins.

Fertilizer		Year										
		1973		1974			1975			1976		
N	P	July	Total	June	Dec.	Total	July	Dec.	Total	May	Dec.	Total
0	0	4035	4035	8308	2357	10665	5967	1652	7619	3259	1200	4459
0	40	4256	4256	8313	2369	10683	6528	1919	8448	3562	1312	4873
45	0	3544	3544	8552	2423	10975	5573	1866	7439	2827	1294	4121
45	40	4182	4182	7863	2390	10253	5934	1843	7777	3671	1261	4932
90	0	3717	3717	9511	2573	12083	5705	2176	7881	3178	1490	4668
90	40	4101	4101	9137	2509	11646	6511	1988	8499	3961	1380	5341
180	0	3793	3793	9211	2652	11862	6010	2059	8069	3351	1386	4736
180	40	3778	3778	9302	2565	11867	6198	2039	8237	4004	1335	5339

VITA

Donald Eugene Hubbard - 2

Candidate for the Degree of

Master of Science

Thesis: RESIDUAL FERTILIZER EFFECTS ON NATIVE GRASS AND WEEPING LOVEGRASS FORAGE PRODUCTION

Major Field: Agronomy

Biographical:

Personal Data: Born October 9, 1946, at Oklahoma City, Oklahoma, the son of Donald and Jenell Hubbard.

Education: Graduate from Choctaw High School, Choctaw, Oklahoma in May, 1964; received the Bachelor of Science degree in Agronomy from Oklahoma State University in May, 1968. Attended numerous military schools including U.S. Army Aviation School. Completed the requirements for the Masters of Science degree at Oklahoma State University in December, 1977.

Professional Experience: Employed as farm laborer in summers of 63-65, and as a roughneck in the summer of 1966. Worked for the Department of Agronomy, Oklahoma State University summers of 1967 and 1968. Served as an officer and aviator in the U. S. Marine Corps, October, 1968 to February, 1974. Employed by the Soil Conservation Service USDA, March, 1974 to May, 1975. Employed as a Graduate Research Assistant for Oklahoma State University, June, 1975 to July, 1977 while concurrently being a member of the Oklahoma Army National Guard.

Professional Organizations: Society for Range Management.