COMPARATIVE PHOSPHORUS AVAILABILITY FROM SUPERPHOSPHATE WITH AND WITHOUT UREA AND AMMONIUM PHOSPHATE

By

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I INTRODUCTION

Availability of soil phosphorus for plant growth is of major importance in Oklahoma. Harper (13)[1] found that many soils in eastern Oklahoma are deficient to the extent that some crops cannot be grown profitably without the use of phosphate fertilizers.

Recent progress in fertilizer technology has resulted in the increased production and use of many relatively new types of phosphate fertilizers. A number of these fertilizers differ chemically and vary in their content of citrate and water-soluble phosphorus. There is need to determine the effectiveness of these various phosphatic materials for improved crop yield as affected by soil characteristics, rate of application and soil moisture conditions.

The purpose of this study was to compare relative phosphorus effectiveness and availability of ordinary superphosphate (20%) and ammonium phosphate (13-39-0) at various rates under both greenhouse and field conditions. Urea was used with the superphosphate as a source of nitrogen.

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[1] Figures in parenthesis refer to literature cited.

II REVIEW OF LITERATURE

Peterson, et al (25) reviewed and summarized the phosphate fertilizer investigations conducted in fifteen western states before 1950. Phosphate carriers were listed in the following order according to apparent efficiency in supplying phosphorus from the most to the least available: 1) ordinary superphosphate, concentrated superphosphate, mono-ammonium phosphate, and phosphoric acid; 2) calcium metaphosphate; 3) dicalcium phosphate; 4) tricalcium or fused phosphate; 5) phosphate rock or collodial phosphate. There were exceptions to this order under specified soil and cropping conditions. It was recognized that additional research is needed to determine the conditions under which these various fertilizer materials could be utilized most efficiently.

Fuller (11) and Schmehl, et al. (28) found the same order of effectiveness of these fertilizer materials as did Peterson, et al. (25). Schmehl, et al. (28) compared various phosphate fertilizers as equivalent to ordinary superphosphate. Results from their experiments at Colorado suggested that the more water soluble forms of phosphate may be preferred when the fertilizer is to be applied in bands. The more water soluble forms also appear to be best for low moisture conditions. In some cases, the moderately water soluble forms (when finely ground and then mixed with the soil) gave yield results similar or equal to very soluble forms.

In studies concerned with penetration of phosphate into the soil, Owens, et al. (23) found that water soluble phosphorus moved into the soil in 48 hours with the extent of phosphorus movement directly related to the water soluble phosphorus content. Phosphorus penetration studies in Virginia (17) indicated that movement into the soil was increased with higher rates of phosphorus applications, with greater water solubility and with decreases in particle size of the fertilizer material.

Speer, et al. (32) conducting experiments on Houston black clay, an alkaline soil with a pH of 8.1, found that phosphate availability was closely associated with water solubility.

Phosphatic fertilizer material used in experiments on limed acid soils planted to tobacco indicated a greater yield increase with the use of water soluble phosphates (35). Water soluble phosphates gave best results when placed in a band close to the seed. The largest uptake of fertilizer phosphorus occurred in the early stages of growth, while the root system was small (9) (33). As the roots grew deeper into the soil the amount of soil phosphorus had a greater influence on plant growth than fertilizer phosphorus.

Favorable effects of water soluble phosphates have been obtained with seedling vigor and stand establishment (12). Many effects of increased early growth were lost as the plant matured. However, with an early drought during the seedling stages, the plants fertilized with the more soluble phosphates were more vigorous apparently due to a better developed root system.

Garey (12) proposed that any form of phosphate incorporated into the soil will result in a reaction with the soil, establishing an equilibrium of some kind. Those plants, such as corn and oats, that need their phosphate before this equilibrium is reached would be expected to react best with the water soluble forms. Those plants, such as cotton and bermuda grass pastures, that require their phosphorus over a longer period of time will not be as influenced by the form of phosphate fertilizer applied.

Fixation of phosphorus at pH values of 7.0 and above were correlated with pH values and the fixing agent (20). Calcium is probably the predominate fixing agent in calcareous soils, due to formation of relatively insoluble dicalcium or tricalcium phosphates at high pH values. McGeorge (21) concluded that any applied phosphate to calcareous soils should be of the water soluble type, due to the high pH values. Two easily water soluble commercial fertilizers which give good yield results were superphosphate and ammonium phosphate. Ammonium phosphates were usually well adapted to alkaline or calcareous soils due to their high water solubility and nitrogen and phosphorus content (27).

Citrate soluble phosphates were found to be utilized most efficiently on acid soils when applied in a very small particle size and mixed throughly with the soil. Dicalcium phosphate gave approximately as high a total yield as the water soluble forms, although it was not as available in early stages of growth (34).

Phosphorus fertilization is complicated by soil, crop, and climatic factors. Fixation, immobilization, and mineralization of available phosphates are governed by soil characteristics and greatly influence the utilization efficiency of applied phosphorus fertilizers. Readily available forms become fixed over a period of time. The degree to which phosphorus is fixed depends partly on soil pH, and the kind and concentration of elements present in the soil (16).

The primary elements responsible for fixation below pH 6.0 appear to be iron and aluminum which form phosphate compounds. With pH values above 6.5 the fixation is dependent upon the presence of divalent bases, while at pH 6.0 the type of fixation will depend on the amount of reactive cations present since calcium, iron and aluminum have equal avidity at this level (22).

Coleman (5) conducted experiments on type and particle size of clays and found that montmorillonitic clays fixed more phosphorus than kaolinitic clays. The experiments conducted with fine and coarse particle sizes of both clays indicated a greater fixation with an increase in surface area. In another part of the experiment, the iron and aluminum oxides were removed from the clay particles. There was very little fixation on the clay particles after the iron and aluminum were removed, indicating a higher fixation due to iron and aluminum rather than type of clay.

Davis and Brewer (8) found that preliming an acid soil gave beneficial effects through influence of the increased pH and base saturation. Cook (6) found the increase of pH values on acid soils by liming increased the availability of natural soil phosphate by the formation of calcium and magnesium phosphate instead of iron and aluminum phosphates. McIntire and Hatcher (18) found that the formation of iron and aluminum phosphates continued in limed soils, but the rate of formation is greatly depressed. Optimum yields were obtained when the pH was increased to 6.5 to 7.0 (19). When phosphate fertilizers were applied with the lime they were found to be much more effective than when applied by themselves on naturally low pH soils (15).

The increase of base saturation, providing calcium and magnesium, increased plant growth and microbiological activity, and thus brought about an increase of available nitrogen in the soil (2).

III MATERIALS AND METHODS

Description of Soil Used in Field Experiment

The field experiment plots were located on a Port silty clay loam two miles north of Highway 51 and approximately 1000 feet east of Highway 86, west of Stillwater, Oklahoma on the NW$\frac{1}{4}$ of section 11, T 19N, R 1W.

This Port silty clay loam is a brown to dark reddish-brown non-calcareous soil over an alkaline to calcareous subsoil, occurring on a rarely to occasionally inundated flood plain. The top soil is about thirty inches in depth; having weak to medium sub-angular blocky structure with firm consistency. A buried soil horizon occurs at 18-30 inches depending on the sampled site.

Description of Soils Used in Greenhouse Experiments

Norge fine sandy loam, Grant loam and Zita clay loam were used in the greenhouse experiments.

The soil classified as Norge fine sandy loam was obtained from the post lot south of pastures III S, in SE$\frac{1}{4}$ of section 36, T 18N, R 2E on the Perkins experimental farm south of Stillwater, Oklahoma.

The Norge fine sandy loam was formed from freely drained reddish prairie soils developed in alkaline or calcareous old alluvium. This soil is found in areas transitional between the Norge silt loam deep phase areas and the Dougherty very fine sandy loam. It occurs mostly on the horticulture section and experimental pastures of the Perkins farm. The area has a convex surface sloping to the east and west with a gradient of 1 to 3 percent. A detailed description of the soil profile characteristics of this soil is presented in the soil survey of the Perkins Experiment farm.

Grant loam was obtained from the SE$\frac{1}{4}$ of section 16; T 26N, R 11W, between watershed two and three at the Wheatland Experiment Station, Cherokee, Oklahoma.

This soil appears to develop mainly in alluvium. The A horizon appears to be 16 inches in depth with a nearly structureless layer from 0-8 inches and moderate, medium granular structure from 8 to 16 inches: non-calcareous in all layers with excellent physical properties below the 8 inch plow zone. Slope is weak concave with an approximate gradient of 2.5 percent and has been terraced. A detailed description of the soil profile characteristics of this soil is presented in the detailed soil survey of the Wheatland Experiment Station at Cherokee, Oklahoma.

Zita clay loam was obtained approximately 1120 feet west and 360 feet north of the southeast corner of section 36; T 2N, R 13E, from the Cimarron base line at the Panhandle A. and M. farm, Goodwell, Oklahoma.

This soil occurs on a very slightly convex site which has a gradient of about one percent. The A_1 layer ranges from 12 to 16 inches. The plowed portion is dark brown or dark grayish-brown. This zone has compound coarse prismatic and moderate, medium granular structure. This soil occurs in the Oklahoma and Texas panhandles, and was developed on highly calcareous, silty earths that are probably aeolian, but have a higher clay content than most loess. A detailed description of the soil profile characteristics of this soil is presented in the detailed soil survey of the Panhandle A. and M. farm, Goodwell, Oklahoma.[1]

Results of some physical and chemical analyses of the field and greenhouse soils are listed in Table I. Mechanical analyses were determined by the Bouyoucos (3) hydrometer method. The moisture equivalents for the greenhouse soils were measured by the procedure outlined by Briggs and Shantz (4). Exchange capacity and exchangeable potassium were determined by methods presented by A.O.A.C. (1), using neutral normal ammonium acetate as an extracting agent. The glass-electrode method outlined by Peech and English (24) was used in determining pH. Organic matter was determined by a method proposed by Schollenberger (29). Percent nitrogen in each soil was determined by Piper's (26) method. Determinations were made for easily soluble phosphorus by a method presented by Harper (14).

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[1] Soil descriptions furnished by H. M. Galloway, Soil Scientist (Cooperative Soil Conservation Service and Agronomy Department, Oklahoma State University)

TABLE I. SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOILS USED IN THE FIELD AND GREENHOUSE EXPERIMENTS.

	Field Experiment	Greenhouse Experiments		
	Port silty clay loam	Norge fine sandy loam	Grant loam	Zita clay loam
Texture				
Percent sand	18.0	82.0	34.0	28.0
Percent silt	56.0	14.0	50.0	42.0
Percent clay	26.0	4.0	16.0	30.0
Moisture equivalent of greenhouse soils		4.0	12.0	22.1
Cation exchange capacity (Meq./100 gms.)	13.40	2.00	7.23	18.86
pH	6.2	7.1	5.8	7.4
Percent organic matter	2.59	.76	.96	2.34
Percent nitrogen	.110	.025	.078	.137
Easily soluble phosphorus (lbs./acre)	14.50	53.0	140.0	154.0
Exchangeable potassium (lbs./acre)	300.0	250.0	460.0	760.0

Field Experimental Procedure

Lahoma sudan was grown on Port silty clay loam to compare rates of superphosphate (20%), with and without urea (45% N), and ammonium phosphate (13-39-0) under field conditions. These materials were compared with and without potassium fertilization. The area was limed with two tons of lime per acre disked into the surface prior to applying the various fertilizer treatments of the experiment.

The experiment was arranged in a split plot arrangement with three replications. Potassium fertilization was used for the main plot treatment. Seven additional fertility treatments were included as sub plot treatments. All fertility treatments are listed in detail in Table II. Each individual plot was twenty-five feet in length and ten feet in width. The fertilizer materials were placed in bands two inches below the soil surface one foot apart extending the length of the plots. The Lahoma sudan was planted June 6, 1956 with a Planet Jr. seeder approximately one inch below the soil surface and directly over the fertilizer material. Two rows twenty feet in length were harvested for yield data September 10, 1956. Only one cutting was obtained due to drought. The sudan grass was harvested in the late boot stage.

Greenhouse Experimental Procedure

The greenhouse experiments were separated into three studies. In the first study seven fertility treatments were replicated three times

TABLE II. FERTILITY TREATMENTS, RATES AND FERTILIZER MATERIALS USED IN THE FIELD EXPERIMENT, LAKE CARL BLACKWELL SUBSTATION, PORT SILTY CLAY LOAM, STILLWATER, 1956.

Treatment	Lbs. per acre 1/	Fertilizer Material
Check	0-0-0	No fertilizer
P_1	0-40-0	Superphosphate (20% P_2O_5)
N_1P_1	13.3-40-0	Urea (45% N) + Superphosphate (20% P_2O_5)
AP_1	13.3-40-0	Ammonium phosphate (13-39-0)
P_2	0-80-0	Superphosphate (20% P_2O_5)
N_2P_2	26.6-80-0	Urea (45% N) + Superphosphate (20% P_2O_5)
AP_2	26.6-80-0	Ammonium phosphate (13-39-0)
K_1	0-0-40	Muriate of Potash (60% K_2O)
P_1K_1	0-40-40	Superphosphate (20% P_2O_5) + Muriate of Potash (60% K_2O)
$N_1P_1K_1$	13.3-40-40	Urea (45% N) + Superphosphate (20% P_2O_5) + Muriate of Potash (60% K_2O)
AP_1K_1	13.3-40-40	Ammonium phosphate (13-39-0) + Muriate of Potash (60% K_2O)
P_2K_2	0-80-80	Superphosphate (20% P_2O_5) + Muriate of Potash (60% K_2O)
$N_2P_2K_2$	26.6-80-80	Urea (45% N) + Superphosphate (20% P_2O_5) + Muriate of Potash (60% K_2O)
AP_2K_2	26.6-80-80	Ammonium phosphate (13-39-0) + Muriate of Potash (60% K_2O)

1/ Rate figures represent pounds per acre of N, P_2O_5 and K_2O respectively.

at two moisture levels with and without potassium on one soil, Norge fine sandy loam. Details of the soil fertility treatments and moisture levels are presented in Table III.

Ten kilograms of Norge fine sandy loam, screened to pass a .25 inch screen, were portioned into weighed two gallon glazed earthenware pots. A lime application of 3200 pounds $CaCO_3$ and 800 pounds $MgCO_3$ per acre was applied and throughly mixed with the soil. The fertilizer materials were then placed in a circular band one and one-half inches below the soil surface approximately one inch from the pot wall. The granulated superphosphate (20% P_2O_5) and ammonium phosphate (13-39-0) were screened to obtain uniform granular materials ranging from .050 to .073 inches in diameter. The potassium treatment common to half of each moisture level was 100 pounds K_2O per acre applied as KCl (C.P.). The soil moisture equivalent was determined and the weight of the soil at its specified moisture content plus the weight of the pot were recorded for each individual pot. The soil was then brought up to its specific moisture level and planted to Redlan grain sorghum (7) (Sorghum vulgare Pres.) October 1, 1956, one-half inch above and one inch in from the fertilizer band. The above ground portions of the plants were harvested when the first heads appeared December 8, 1956.

Individual pots were maintained at their respective moisture levels throughout the experiment by placing them on scales and bringing them up to designated weight with distilled water.

Grant loam and Zita clay loam were the soils used in the second study in the greenhouse. Both of these soils were screened to pass a .25 inch screen. Eight kilograms of the Grant loam was portioned into forty-two weighed glazed pots. Six kilograms of the Zita clay loam

TABLE III. FERTILITY TREATMENTS AND MOISTURE LEVELS USED IN THE GREENHOUSE EXPERIMENTS.

Fertility Treatments

Treatment	Lbs. per acre [1/]	Fertilizer Material
Check	0-0-0	No Fertilizer
P_1	0-75-0	Superphosphate (20% P_2O_5)
P_2	0-150-0	Superphosphate (20% P_2O_5)
N_1P_1	25-75-0	Urea (45% N) Superphosphate (20% P_2O_5)
N_2P_2	50-150-0	Urea (45% N) Superphosphate (20% P_2O_5)
AP_1	25-75-0	Ammonium phosphate (13-39-0)
AP_2	50-150-0	Ammonium phosphate (13-39-0)
K	0-0-100	KCl (C.P.) (60% K_2O)

1/ Rate figures are in equivalent pounds per acre of N, P_2O_5, and K_2O respectively.

Soil Moisture Levels

Low	.5 moisture equivalent
High	1.5 moisture equivalent

was portioned into the same number of pots giving approximately the same volume of soil per pot as the Grant loam.

Superphosphate (20% P_2O_5) and ammonium phosphate (13-39-0) were screened to obtain uniform granular materials ranging from .050 to .073 inches in diameter. The fertilizer materials were placed in a band one inch from the pot wall and one and one-half inches below the soil surface. Soil moisture equivalents were determined for each soil and the weight of the soil at its specific moisture content plus the weight of each individual pot were recorded.

The soils were then brought up to their specific moisture content and planted to Redlan grain sorghum. Seed was placed one-half inch above and one inch in from the fertilizer material. The Grant loam was planted January 28, 1957 and the Zita clay loam was planted February 4, 1957. The above ground portions of the plants were harvested April 8, 1957.

The moisture level of the individual pots of the high moisture level series were maintained by placing on scales and bringing up to their specific recorded weight with distilled water. The individual pots of the low moisture series were initially brought up to one moisture equivalent with distilled water for germination and early growth of the sorghum plants. The plants were then allowed to use up the moisture until wilting. Additional water was then added and the soil was brought up to one moisture equivalent level. This process was repeated until the plants were harvested. The fertility treatments and soil moisture levels used with these two soils are listed in Table III. The potassium treatment was not applied to these soils.

The third study of the greenhouse experiments was designed to determine the residual effects of the fertility treatments listed in Table III. In this experiment after the first crop was harvested from the Grant loam and Zita clay loam, another crop of Redlan grain sorghum was planted April 4, 1957. The two soils were maintained at the high moisture level throughout the study. The plants were harvested June 3, 1957 for yield and composition data.

The plants of the field and greenhouse experiments were harvested, oven dried at 65^{o} C and then weighed for yield data. After the yield data were obtained, the three replications of each treatment were composited and ground for chemical analyses. Chemical analyses were run to determine total nitrogen, phosphorus and potassium of the plant material. Nitrogen was determined by the Kjeldahl method outlined by Piper (26). Samples were digested for phosphorus and potassium analyses and phosphorus determined by a method outlined by Shelton (30). The potassium was determined with a Perkin-Elmer Flame Photometer.

Statistical Analyses

Forage yields were analyzed statistically. Analysis of variance for significant differences and coefficients of variations were determined by methods outlined by Snedecor (31). A multiple range test proposed by Duncan (10) was used as an aid in interpreting the data when significant values were obtained by the analysis of variance.

IV RESULTS AND DISCUSSIONS

Field Experiment

Yields from the field plots of Lahoma sudan grass with a statistical analysis of the yield data are reported in Table IV. Extreme dry weather conditions during the summer of 1956 undoubtedly restricted plant growth and possible response to fertilizer treatments. Lowest yields of 1491.0 lbs. per acre were obtained from the P_1 treated plots. Highest yields of 2591.7 lbs. per acre were obtained from the AP_1K_1 treatment. In general, those plots which received the potassium application outyielded those plots receiving the same fertility treatment without potassium. There was no statistical significant difference in yield from fertility treatments as indicated by the analysis of variance.

The percent nitrogen, phosphorus and potassium found in the Lahoma sudan grass grown in the field experiment are shown in Table V. Nitrogen percentages of samples from plots that received the potassium treatment were slightly higher than plots not receiving potassium. The percentages of phosphorus of samples from potassium treated plots were also higher than samples from plots having corresponding soil fertility treatment without potassium. The potassium percentages of these samples did not follow this trend and sample plots receiving the potassium treatment were not in every case higher than the corresponding samples from plots not fertilized with potassium.

TABLE IV. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF LAHOMA SUDAN GRASS FORAGE, FIELD EXPERIMENT, LAKE CARL BLACKWELL SUBSTATION, PORT SILTY CLAY LOAM, STILLWATER, 1956.

Treatment [1/]	Lbs. per acre Replications I	II	III	Av.	Treatment	Lbs. per acre Replications I	II	III	Av.
Check	1675	1595	1658	1642.7	K_1	1895	1044	1922	1620.3
P_1	1108	1981	1384	1491.0	P_1K_1	1994	1900	1761	1885.0
P_2	1686	1547	1346	1526.3	P_2K_2	2517	1686	2531	2244.7
N_1P_1	1845	2370	2329	2181.3	$N_1P_1K_1$	1785	2080	3435	2433.3
N_2P_2	2392	2653	1965	2336.7	$N_2P_2K_2$	2425	2006	2485	2305.3
AP_1	1540	2114	1259	1637.7	AP_1K_1	2344	3622	1809	2591.7
AP_2	2389	2015	1605	2003.0	AP_2K_2	1552	1864	2812	2076.0

[1/] See Table II for details of treatments. Each figure represents calculated yields from a sample area two rows, twenty feet long, within each field plot.

Analysis of Variance

Source	df	SS	MS	F
Main Plots				
Potassium	1	1,170,938	1,170,938	n.s.
Replications	2	74,725	37,362.2	n.s.
Main plots error	2	1,135,417	567,708.5	
Main plots C.V. = 37.69%				
Sub Plots				
Treatments	6	2,753,752	441,678.5	n.s.
Potassium x treatment	6	1,307,290	218,267.5	n.s.
Sub plots error	24	5,623,759	234,702.1	
Sub plots C.V. = 24.23%				

TABLE V. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF LAHOMA SUDAN FORAGE, FIELD EXPERIMENT, LAKE CARL BLACKWELL SUBSTATION, PORT SILTY CLAY LOAM, STILLWATER, 1956 [1/]

Percent Total Nitrogen

Treatments	% Nitrogen	Treatments	% Nitrogen
Check	1.36	K_1	1.46
P_1	1.06	P_1K_1	1.74
P_2	1.37	P_2K_2	1.39
N_1P_1	1.42	$N_1P_1K_1$	1.66
N_2P_2	1.64	$N_2P_2K_2$	1.66
AP_1	1.47	AP_1K_1	1.60
AP_2	1.33	AP_2K_2	1.58
Av.	1.38		1.48
S.D.*	.175		.121

Percent Total Phosphorus

Treatments	% Phosphorus	Treatments	% Phosphorus
Check	.170	K_1	.193
P_1	.183	P_1K_1	.193
P_2	.160	P_2K_2	.177
N_1P_1	.170	$N_1P_1K_1$	.171
N_2P_2	.181	$N_2P_2K_2$	.204
AP_1	.168	AP_1K_1	.181
AP_2	.168	AP_2K_2	.193
Av.	.171		.188
S.D.*	.080		.114

Percent Total Potassium

Treatments	% Potassium	Treatments	% Potassium
Check	1.56	K_1	1.44
P_1	1.38	P_1K_1	1.64
P_2	1.62	P_2K_2	1.46
N_1P_1	1.52	$N_1P_1K_1$	1.56
N_2P_2	1.18	$N_2P_2K_2$	1.46
AP_1	1.72	AP_1K_1	1.86
AP_2	1.50	AP_2K_2	1.62
Av.	1.50		1.58
S.D.*	.175		.148

* S.D. = Standard Deviation

[1/] See Table II for details of treatments. Each figure is the mean of duplicate chemical analyses on composite samples obtained by combining plant materials from three replications.

Greenhouse Experiments

There were three studies included in the greenhouse experiments. Yield data from the first study, conducted on Norge fine sandy loam, are reported in Table VI. Potassium, in general, increased yields slightly over the same treatments without the potassium application at both moisture levels. Yields of Redlan grain sorghum grown on soil maintained at the high moisture level were considerably higher than yields from the soil maintained at the low moisture level.

Yields from fertility treatments in the low moisture level did not appear to consistently follow any particular order. More variation was noted in yield from the various fertility treatments maintained at the high moisture level. Differences in yield as affected by fertility treatments were significant at the 1% level as indicated in Table VII. A multiple range test was conducted at the 1% level on the overall means of the fertility treatments indicated significance between the highest yielding treatment mean, N_2P_2, and the check, P_2 and AP_1 treatment yields. The check and P_2 yields were also significantly lower than the AP_2 yields.

The percent nitrogen, phosphorus and potassium found in Redlan grain sorghum grown on Norge fine sandy loam are reported in Table VIII. Nitrogen percentages, in general, appeared to be highest from samples taken from the low moisture level without the potassium addition. The percent nitrogen of samples from the high moisture level was consistently lower than the percent nitrogen from samples with corresponding fertility treatments at the low moisture level.

The phosphorus percentage, however, was higher from samples at the high moisture level than from samples from corresponding fertility

TABLE VI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON YIELD OF REDLAN GRAIN SORGHUM FORAGE, GREENHOUSE EXPERIMENT, NORGE FINE SANDY LOAM, STILLWATER, 1956.

Low Moisture Level

Treatment 1/	Without Potassium: Replications gms. per pot I	II	III	Av.	With Potassium: Replications gms. per pot I	II	III	Av.
Check	3.9	4.1	4.3	4.10	5.8	5.2	4.5	5.17
P_1	6.0	5.0	5.0	5.33	5.2	5.1	4.8	5.03
P_2	3.5	3.7	4.9	4.03	5.0	4.8	4.5	4.77
N_1P_1	4.8	4.9	4.6	4.77	5.5	5.4	5.7	5.53
N_2P_2	5.4	4.7	5.0	5.03	3.9	4.6	5.2	4.57
AP_1	4.1	4.6	4.4	4.37	4.5	4.7	4.2	4.47
AP_2	3.7	4.8	3.2	3.90	4.3	4.0	4.2	4.17

High Moisture Level

Treatment 1/	Without Potassium: Replications gms. per pot I	II	III	Av.	With Potassium: Replications gms. per pot I	II	III	Av.
Check	11.2	12.7	12.7	12.20	10.7	9.8	11.0	10.50
P_1	12.1	12.3	12.3	12.23	11.9	12.6	13.2	12.57
P_2	9.8	10.3	12.8	10.97	13.2	13.8	10.8	12.60
N_1P_1	13.7	11.8	12.7	12.73	14.3	13.2	13.8	13.77
N_2P_2	16.3	13.1	14.8	14.73	13.3	18.0	15.5	15.60
AP_1	11.9	13.4	11.8	12.37	13.8	11.9	12.8	12.83
AP_2	15.0	13.7	14.0	14.23	19.3	15.3	13.9	16.17

1/ See Table III for details of treatments. Each figure represents grams oven dry forage per pot.

TABLE VII. STATISTICAL ANALYSES OF YIELD OF REDLAN GRAIN SORGHUM AS AFFECTED BY VARIOUS SOIL FERTILITY TREATMENTS, GREENHOUSE EXPERIMENTS, NORGE FINE SANDY LOAM, STILLWATER, 1956. 1/

Analyses of Variance

Source	df	SS	MS	F
Main Plots				
Moisture levels-potassium combination	3	1504.09	501.36	
Replications	2	.63	.31	
Main plots error	6	2.79	.46	
Sub Plots				
Treatments	6	40.40	6.73	5.96**
Treatments x moisture levels-potassium combination	18	67.02	3.72	3.29**
Sub plots error	48	54.37	1.13	
Sub plots C.V. = 11.94%				

** Significant at the 1% level.

Multiple Range Test 2/

sm = .307 N_2 = 48

Ck	P_2	AP_1	P_1	N_1P_1	AP_2	N_2P_2
7.99	8.09	8.51	8.72	9.20	9.62	9.98
			———	———	———	———
		———	———	———	———	
———	———	———	———	———		

1/ See Table VI for individual pot yields.

2/ See Table III for details of treatments. Each figure is the mean of three replications at each moisture level with two potassium levels. Any means not underscored with the same line are significantly different at the 1% level.

TABLE VIII. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF REDLAN GRAIN SORGHUM FORAGE, GREENHOUSE EXPERIMENT, NORGE FINE SANDY LOAM, STILLWATER, 1956 1/

Percent Total Nitrogen

Treatment	Low Moisture		High Moisture	
	Without Potassium	With Potassium	Without Potassium	With Potassium
Check	1.83	1.61	1.55	1.33
P_1	1.58	1.34	1.39	1.20
P_2	1.67	1.72	1.34	1.64
N_1P_1	1.69	1.67	1.68	1.39
N_2P_2	2.07	2.19	1.58	1.67
AP_1	2.04	1.69	1.55	1.60
AP_2	2.16	2.28	1.61	1.79
Av.	1.86	1.79	1.53	1.52
S.D.*	.227	.325	.118	.207

Percent Total Phosphorus

Treatment	Low Moisture		High Moisture	
	Without Potassium	With Potassium	Without Potassium	With Potassium
Check	.180	.196	.248	.248
P_1	.192	.192	.252	.212
P_2	.224	.212	.268	.276
N_1P_1	.236	.184	.268	.216
N_2P_2	.252	.184	.300	.256
AP_1	.224	.208	.280	.228
AP_2	.240	.196	.284	.260
Av.	.221	.196	.271	.242
S.D.*	.024	.0101	.017	.023

Percent Total Potassium

Treatment	Low Moisture		High Moisture	
	Without Potassium	With Potassium	Without Potassium	With Potassium
Check	4.56	4.20	2.94	3.00
P_1	3.84	3.96	2.64	2.64
P_2	4.32	4.32	2.88	2.88
N_1P_1	3.18	4.32	3.06	2.64
N_2P_2	4.56	3.60	3.42	2.88
AP_1	3.48	4.20	3.06	2.52
AP_2	3.30	3.42	2.88	3.18
Av.	3.89	4.00	2.98	2.82
S.D.*	.578	.354	.234	.227

*S.D. = Standard Deviation

1/ See Table III for details of treatment. Each figure is the mean of duplicate analyses on composite samples obtained by combining plant materials from three replications.

treatments at the low moisture level. In most cases the phosphorus percentage was highest when the higher rate of fertilizer phosphorus was applied.

The percent potassium of samples grown at the low moisture level was higher than from plants grown at the high moisture level. However, the percent potassium did not appear to follow any particular order within either of the moisture levels.

Yield data from the Grant loam portion of the second study are reported in Table IX. Yields from the soil maintained at the high moisture level are considerably higher than from soil maintained at the low moisture level.

Soil fertilized with superphosphate alone applied at the low rate (P_1) gave higher yields than the check treatment at both soil moisture levels. Lower yields than check were obtained with superphosphate alone applied at the high rate (P_2). Addition of nitrogen with phosphate increased yields at both moisture levels.

Lowest yields were obtained with the P_2 fertility treatment at each moisture level. Highest yields were obtained with the N_1P_1 fertility treatment at the low moisture level and the N_2P_2 fertility treatment at the high moisture level.

The analysis of variance table indicated significant differences at the 1% level and the multiple range test was used with these data. The AP_2, N_2P_2, and N_1P_1 fertility treatments gave the highest yields, but these yields were not significantly different from each other. The AP_1 fertility treatment was intermediate, while the Check, P_1, and P_2 fertility treatments produced the lowest yields with no significant difference among the three.

TABLE IX. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON YIELD OF REDLAN GRAIN SORGHUM FORAGE, GREENHOUSE EXPERIMENT, GRANT LOAM, STILLWATER, 1957.

Treat-ments 1/	Low Moisture Replications gms. per pot I	II	III	Av.	High Moisture Replications gms. per pot I	II	III	Av.
Check	11.4	12.4	12.0	11.93	18.7	18.0	19.0	18.57
P_1	12.6	12.9	11.9	12.47	19.8	19.6	19.3	19.57
P_2	10.7	10.8	11.1	10.87	17.3	17.2	18.2	17.57
N_1P_1	17.5	19.1	16.6	17.73	30.1	35.7	31.1	32.30
N_2P_2	16.2	14.7	15.7	15.53	33.9	31.3	34.1	33.10
AP_1	13.6	15.5	14.0	14.37	27.0	29.0	28.0	28.00
AP_2	17.4	14.5	16.4	16.10	32.6	32.2	34.1	32.97

1/ See Table III for details of treatments. Each figure represents grams oven dry forage per pot.

Analysis of Variance

Source	df	SS	MS	F
Main Plots				
Moisture	1	1,478.59	1,478.59	
Replications	2	.62	.31	
Main plots error	2	1.33	.66	
Sub Plots				
Treatments	6	825.53	137.58	87.08**
Moisture x treatment	6	217.05	36.18	22.90**
Sub plots error	24	37.88	1.58	
C.V. = 6.27%				

** Significant at the 1% level.

Multiple Range Test 2/

sm = .513 N_2 = 24

P_2	Ck	P_1	AP_1	N_2P_2	AP_2	N_1P_1
14.22	15.25	16.01	21.18	24.32	24.53	25.02

(24.32, 24.53 and 25.02 are underscored by the same line.)

2/ See Table III for details of treatments. Any means not underscored by the same line are significantly different at the 1% level. Each figure represents the mean of three replications at each moisture level.

The percent nitrogen, phosphorus, and potassium content of Redlan grain sorghum grown on Grant loam are reported in Table X. Higher nitrogen percentage was found in the forage grown at the low moisture level than at the high moisture level with the same fertility treatment. The percent nitrogen was higher when the higher rate of nitrogen and phosphate was applied. Percent phosphorus did not follow any particular order according to moisture level, but the higher fertility rate gave higher phosphorus percentages in most cases. Percent potassium was highest at the low moisture level, but fertility treatments did not appear to consistently influence potassium content.

Yield data from the Zita clay loam portion of the second study are reported in Table XI. Yields from soil maintained at the high moisture level are much higher than from soil maintained at the low moisture level. In soil maintained at the low moisture level, all fertility treatments are higher than check, but follow no order as to fertility rate. Ammonium phosphate gave the highest yields at the low moisture level. The fertility treatments at the high moisture level all gave higher yields than the check, the highest fertility rate gave the highest yields. The fertilizer nitrogen did not appear to increase yields. No statistical significance was evident in the analysis of variance of yield data as affected by fertility treatments. Percent nitrogen, phosphorus and potassium content are reported in Table X.

The percent nitrogen was highest in forage grown at the low moisture level. Fertility treatments did not appear to influence the nitrogen content at the low moisture level. The nitrogen percentage was increased at the high moisture level with the addition of nitrogen in the fertilizer application. In most cases, the percent of phosphorus

TABLE X. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF REDLAN GRAIN SORGHUM FORAGE, GREENHOUSE EXPERIMENT, GRANT LOAM AND ZITA CLAY LOAM, STILLWATER, 1957.

Total Nitrogen Percent 1/

	Grant Loam		Zita Clay Loam	
Treatment 2/	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	.79	.57	1.70	1.14
P_1	.76	.63	2.06	.98
P_2	.90	.52	1.95	1.14
N_1P_1	.97	.70	2.08	1.47
N_2P_2	1.53	.72	2.07	1.57
AP_1	1.05	.61	2.00	1.42
AP_2	1.55	.81	2.05	1.45
Av.	1.08	.65	1.99	1.31
S.D.*	.330	.099	.125	.221

Total Phosphorus Percent 1/

	Grant Loam		Zita Clay Loam	
Treatment 2/	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	.152	.125	.200	.168
P_1	.162	.155	.175	.178
P_2	.153	.175	.220	.200
N_1P_1	.120	.140	.243	.198
N_2P_2	.156	.178	.205	.195
AP_1	.150	.152	.238	.180
AP_2	.230	.223	.210	.245
Av.	.161	.164	.213	.195
S.D.*	.034	.032	.023	.025

Total Potassium Percent 1/

	Grant Loam		Zita Clay Loam	
Treatment 2/	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	3.10	2.80	3.56	3.14
P_1	3.22	2.98	3.42	2.90
P_2	2.86	2.72	3.24	2.98
N_1P_1	3.02	2.86	3.30	2.90
N_2P_2	3.20	2.72	3.38	3.32
AP_1	3.10	2.64	3.24	3.04
AP_2	3.36	2.72	3.30	2.92
Av.	3.12	2.78	3.35	3.03
S.D.*	.159	.111	.112	.156

* S.D. = Standard Deviation

1/ Each figure is the mean of duplicate analysis on composite samples obtained by combining plant materials from three replications.

2/ See Table III for details of treatments.

TABLE XI. EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON YIELD OF REDLAN GRAIN SORGHUM FORAGE, GREENHOUSE EXPERIMENT, ZITA CLAY LOAM, STILLWATER, 1957.

Treat-ments 1/	Low Moisture Replications gms. per pot				High Moisture Replications gms. per pot			
	I	II	III	Av.	I	II	III	Av.
Check	7.4	6.3	7.3	7.00	17.9	22.0	16.3	18.73
P_1	8.0	8.0	8.9	8.30	19.3	31.6	24.6	21.83
P_2	7.9	9.5	8.8	8.73	22.2	25.0	20.8	22.67
N_1P_1	8.1	8.3	9.4	8.60	16.8	21.8	24.2	20.93
N_2P_2	8.8	9.7	7.0	8.50	20.5	21.0	22.0	21.17
AP_1	10.7	9.0	9.9	9.87	18.3	24.2	20.5	21.00
AP_2	9.1	11.3	8.9	9.77	20.3	25.1	22.4	22.60

1/ See Table III for details of treatments. Each figure represents grams oven dry forage per pot.

Analysis of Variance

Source	df	SS	MS	F
Main Plots				
Moisture levels	1	1,665.72	1,665.72	
Replications	2	27.19	13.60	
Main plots error	2	20.02	10.01	
Sub Plots				
Treatments	6	40.28	6.71	n.s.
Moisture levels x treatments	6	8.52	1.42	n.s.
Sub plots error	24	64.70	2.70	
C. V. = 10.95%				

was highest at the low moisture level, but there was no definite order due to moisture level or fertility treatments.

Potassium percentage was highest in the forage grown at the low moisture level. The higher fertility rate increased the percent of potassium in the plants to some extent, but check treatments were usually highest at each moisture level.

The yields and statistical analyses of forage grown to check residual effects of fertility treatments and moisture levels on Grant loam are reported in Table XII.

Highest yields were obtained from the soil that had been maintained at the low moisture level during the second greenhouse study. Yields were higher in most cases within each moisture level when a nitrogen fertilizer had been applied.

There were significant differences among fertility treatments at the 1% level as indicated in the analysis of variance. A multiple range test was conducted and the AP_2 fertility treatment yield was found to be significantly higher than yields from the P_2, check, and P_1 fertility treatments. Yields from the P_2 and check treatments were significantly lower than yields from the N_1P_1, AP_1 and N_2P_2 treatments.

Percent nitrogen, phosphorus and potassium content of Redlan grain sorghum forage grown on Grant loam to compare residual effects of soil fertility treatments and moisture levels are reported in Table XIII.

The percent nitrogen is slightly higher in forage grown in soil that had previously been maintained at the high moisture level. There was no particular order followed in percent nitrogen content of the forage due to fertility treatment at either moisture level. The percent

TABLE XII. RESIDUAL EFFECTS FROM VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON YIELD OF REDLAN GRAIN SORGHUM, GRANT LOAM, GREENHOUSE EXPERIMENT, STILLWATER, 1957.

Treat- ments 1/	Low Moisture Replications gms. per pot				High Moisture Replications gms. per pot			
	I	II	III	Av.	I	II	III	Av.
Check	8.3	7.7	6.0	7.33	4.8	3.7	4.2	4.23
P_1	7.8	7.3	7.1	7.40	5.7	7.3	6.7	6.57
P_2	7.8	7.7	6.6	7.13	4.4	4.6	4.1	4.37
N_1P_1	10.0	6.8	9.4	8.73	4.7	6.4	6.4	5.83
N_2P_2	11.2	12.8	11.6	11.87	6.8	5.5	4.9	5.73
AP_1	9.4	8.7	8.8	8.97	6.8	5.5	4.9	5.73
AP_2	10.7	11.0	11.2	10.97	6.7	5.5	6.4	6.20

1/ See Table III for details of treatments. Each figure represents grams oven dry forage per pot.

Analysis of Variance

Source	df	SS	MS	F
Main Plots				
Moisture levels	1	130.02	130.02	
Replications	2	.89	.45	
Main plots error	2	.31	.15	
Sub Plots				
Treatments	6	44.44	7.41	10.15**
Moisture levels x treatments	6	33.50	5.58	7.64**
Sub plots error	24	17.46	.73	
C.V. = 11.94%				

** Significant at the 1% level.

Multiple Range Test 2/
sm = .347 N_2 = 24

P_2	Ck	P_1	N_1P_1	AP_1	N_2P_2	AP_2
5.75	5.78	6.98	7.28	7.35	8.35	8.58

2/ See Table III for details of treatments. Any means not underscored by the same line are significantly different at the 1% level. Each figure represents the mean of three replications at each moisture level.

TABLE XIII. RESIDUAL EFFECTS FROM VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON PERCENT NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF REDLAN GRAIN SORGHUM, GRANT LOAM AND ZITA CLAY LOAM, GREENHOUSE EXPERIMENT, STILLWATER, 1957. 1/

Percent Total Nitrogen

	Grant Loam		Zita Clay Loam	
Treat-ments 2/	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	.76	.78	1.07	.86
P_1	.76	.84	.95	.87
P_2	.76	.77	.97	.87
N_1P_1	.75	.79	1.17	.89
N_2P_2	.72	.70	1.11	1.02
AP_1	.73	.77	1.04	.88
AP_2	.65	.74	1.14	1.05
Av.	.73	.77	1.06	.92
S.D.*	.040	.041	.083	.079

Percent Total Phosphorus

	Grant Loam		Zita Clay Loam	
Treat-ments	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	.121	.137	.096	.083
P_1	.153	.158	.102	.116
P_2	.151	.157	.114	.118
N_1P_1	.132	.153	.105	.111
N_2P_2	.120	.160	.102	.105
AP_1	.133	.150	.114	.119
AP_2	.104	.153	.117	.127
Av.	.131	.153	.107	.111
S.D.*	.017	.007	.007	.013

Percent Total Potassium

	Grant Loam		Zita Clay Loam	
Treat-ments	Low Moisture	High Moisture	Low Moisture	High Moisture
Check	3.12	2.92	3.08	2.92
P_1	3.24	2.92	3.08	3.12
P_2	3.08	2.88	3.16	3.04
N_1P_1	3.16	3.24	3.32	2.92
N_2P_2	2.76	2.84	3.00	3.12
AP_1	3.24	3.24	3.28	3.00
AP_2	2.72	2.84	3.08	3.08
Av.	3.04	2.98	3.14	3.03
S.D.*	.216	.177	.116	.084

*S.D.= Standard Deviation

1/ See Table III for details of treatments and moisture levels. Each figure represents the mean of duplicate analyses on composite samples obtained by combining plant materials from three replications.

phosphorus of the forage was highest from plants grown on soil that had been maintained at the high moisture level. Usually phosphorus percent was higher in plants that had been fertilized with phosphorus than the check treatment at each moisture level.

The potassium percent in the forage was highest in the forage from soil that had been maintained at the low moisture level. Within each moisture level the potassium percent of the forage was highest when grown on soil that had been fertilized with the higher rate of phosphate.

Yield and statistical analyses data are reported in Table XIV for forage grown on Zita clay loam to compare residual effects of moisture levels and soil fertility treatments. In most cases, forage grown in soil that had previously been maintained at the low moisture level produced the higher yields. Those fertility treatments that had nitrogen included usually produced the higher yields.

Significant differences among fertility treatments were found at the 1% level in the analysis of variance. A multiple range test was conducted and yields from the N_1P_1, AP_2 and N_2P_2 treatments were found to be significantly higher than the check yield at the 1% level.

Percent nitrogen, phosphorus and potassium found in Redlan grain sorghum forage grown on Zita clay loam to compare residual effects of soil fertility treatments and moisture levels are reported in Table XIII. Percent nitrogen of the forage grown on soil that had previously been maintained at the low moisture level was highest. Usually the nitrogen percent was higher when nitrogen had been included in the soil fertility treatment.

The percent phosphorus of the forage was, in general, highest

TABLE XIV. RESIDUAL EFFECTS FROM VARIOUS SOIL FERTILITY TREATMENTS AND MOISTURE LEVELS ON YIELD OF REDLAN GRAIN SORGHUM FORAGE, ZITA CLAY LOAM, GREENHOUSE EXPERIMENT, STILLWATER, 1957.

Treat-ments 1/	Low Moisture Replications gms. per pot I	II	III	Av.	High Moisture Replications gms. per pot I	II	III	Av.
Check	19.6	15.6	20.0	18.40	12.4	16.2	13.3	13.97
P_1	22.2	19.5	17.7	19.80	13.7	14.2	14.9	14.27
P_2	19.5	17.1	19.2	18.60	17.0	16.0	15.8	16.27
N_1P_1	21.5	18.1	16.8	18.80	19.6	19.5	18.6	19.23
N_2P_2	22.9	21.2	22.0	22.03	17.1	17.5	16.5	17.03
AP_1	17.9	19.1	21.6	19.50	19.0	16.0	17.4	17.47
AP_2	23.1	19.0	23.3	21.80	17.7	16.3	15.7	16.57

1/ See Table III for details of treatments. Each figure represents grams oven dry forage per pot.

Analysis of Variance

Source	df	SS	MS	F
Main Plots				
Moisture levels	1	125.15	125.15	
Replications	2	11.54	5.77	
Main plots error	2	11.41	5.71	
Sub Plots				
Treatments	6	56.88	9.48	4.39**
Treatments x moisture levels	6	43.69	7.28	3.37*
Sub plots error	24	51.87	2.16	
C.V. = 8.11%				

* Significant at the 5% level.
** Significant at the 1% level.

Multiple Range Test 2/
sm = .60 N_2 = 24

Ck	P_1	P_2	AP_1	N_1P_1	AP_2	N_2P_2
16.18	17.03	17.43	18.00	19.02	19.18	19.53

(A single line underscores 17.03 through 19.53.)

2/ See Table III for details of treatments. Each figure represents the mean of three replication of both moisture levels. Any means not underscored by the same line are significantly different at the 1% level.

when the soil had previously been maintained at the high moisture level with the higher fertility rates. Forage grown in soil that had previously been maintained at the low moisture level usually had the higher percent potassium. Potassium percentage was apparently not consistently affected by previous soil fertility treatment.

V SUMMARY AND CONCLUSIONS

The objective of these field and greenhouse experiments was to compare phosphate availability from superphosphate (29% P_2O_5) with and without urea (45% N), and ammonium phosphate (13-39-0).

The field experiment was conducted on a Port silty clay loam at the Lake Carl Blackwell substation. Lahoma sudan grass was grown on fourteen soil fertility treatments. Potassium was applied in half of these fertility treatments. Extreme dry weather conditions restricted plant yield response from these soil fertility treatments.

Results and conclusions from the field experiment may be summarized as follows:

1. Slightly higher yields were obtained in most cases from plots having potassium included in the soil fertility treatment.
2. Highest yield results were obtained from the 13.3-40-40 (ammonium phosphate + KCl) treatment with 13.3-40-40 (superphosphate + urea + KCl) next high. Lowest yields were obtained from the 0-40-0 (superphosphate) treatment.
3. Percent nitrogen and phosphorus were somewhat higher in the plants receiving potassium in the soil fertility treatment. Percentage of potassium, however, did not appear to follow any particular trend as to fertilizer treatment.

Redlan grain sorghum was grown in three greenhouse studies. In the first study, seven soil fertility treatments were applied to Norge fine sandy loam at two moisture levels. Potassium was applied in one-half of all treatments at each moisture level for a split treatment. In the second study, seven fertility treatments were applied to Grant loam and Zita clay loam with all treatments maintained at two moisture levels. Residual effects of the seven soil fertility treatments and two moisture levels used in the second study were compared in the third study. The Grant loam and Zita clay loam were maintained at the high moisture level throughout the third study.

Results and conclusions from the three greenhouse studies are summarized as follows:

1. The forage yields from soils maintained at the high moisture level were considerably greater than those from soils maintained at the low moisture level in the first two studies.
2. The forage yields from both soils maintained at the low moisture level in the second study produced the higher yields in the third study.
3. Response from different fertility treatments was more pronounced when soils were maintained at the high moisture level.
4. Potassium applications to the Norge fine sandy loam, in general, increased yields over the corresponding soil fertility treatment without potassium.
5. Yields from the check and superphosphate soil fertility treatments were consistently lower than the superphosphate plus urea and ammonium phosphate fertility treatments.
6. The higher fertility rates generally produced higher yields.
7. Percent nitrogen was generally higher in forage grown at the low moisture level than on the corresponding fertility treatment at the high moisture level. Percentage of nitrogen was higher at

each moisture level when nitrogen was applied in the fertilizer material.

8. Phosphorus percentage was generally higher in forage grown at the high moisture level. No particular order was followed due to fertility treatments, however, when potassium was added in the first study the percent phosphorus was increased over the no potassium treatment.

9. Percent potassium was highest in forage grown at the low moisture level. No particular order was followed in percent potassium due to fertility treatments.

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VII APPENDIX

Figure 1. Effect of the low moisture level and of various soil fertility treatments on growth of Redlan grain sorghum at 10 weeks, Norge fine sandy loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table VI for yield data)

Figure 2. Effect of the high moisture level and various soil fertility treatments on growth of Redlan grain sorghum, at 10 weeks, Norge fine sandy loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table VI for yield data)

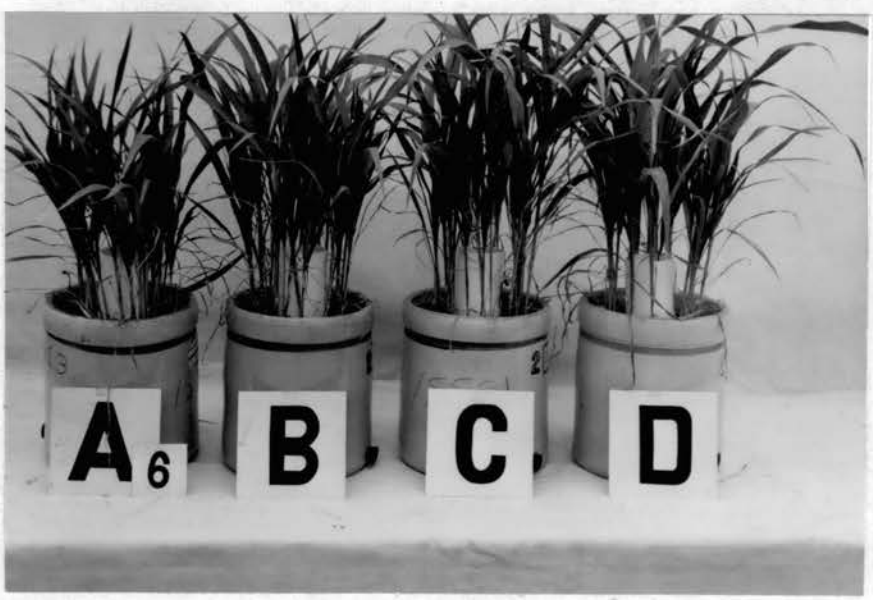

Figure 3. Effect of the low soil moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 8 weeks, Grant loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table IX for yield data)

Figure 4. Effect of the high moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 8 weeks, Grant Loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table IX for yield data)

Figure 5. Effect of the high moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 7 weeks, Zita clay loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XI for yield data)

Figure 6. Effect of the low moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 7 weeks, Zita clay loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XI for yield data)

Figure 7. Residual effect from the low moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 6 weeks, Grant loam. (A) Check, (B), P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XII for yield data)

Figure 8. Residual effect from the high moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 6 weeks, Grant loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XII for yield data)

Figure 9. Residual effect from the high moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 6 weeks, Zita clay loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XIV for yield data)

Figure 10. Residual effect from the low moisture level and various soil fertility treatments on growth of Redlan grain sorghum at 6 weeks, Zita clay loam. (A) Check, (B) P_2, (C) N_2P_2, (D) AP_2. (See Table III for treatment details and Table XIV for yield data)

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