# ALFALFA YIELD AND COMPOSITION AS AFFECTED BY SOIL CALCIUM, MAGNESIUM AND POTASSIUM AT THREE PHOSPHORUS LEVELS

By

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# INTRODUCTION

Alfalfa (Medicago sativa L.) is considered one of the most important perennial forage legumes in the United States because of its high productivity and nutritional value. Its importance in Oklahoma is reflected with an increasing acreage within the state. In 1965, alfalfa occupied 577,000 acres of land and yielded in excess of 1,298,000 tons of forage (17)[/1].

Alfalfa has a rather wide range of adaptation to soil types with deep, well drained, medium-textured soils being the most desirable. However, different responses to management and fertility practices are frequently encountered on various soils in different climatic regions within the state.

The Oklahoma Agricultural Experiment Station initiated a soil fertility research study in 1955 to determine the fertility requirements of alfalfa on representative soil types of Central and Eastern Oklahoma. The objective of this greenhouse experiment was to determine yield responses and chemical composition of alfalfa to fertilization with various Ca-Mg-K ratios at different phosphorus levels.

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/1 Numbers in parenthesis refer to Literature Cited.

## LITERATURE REVIEW

Alfalfa has a high requirement for available plant food nutrients. Although alfalfa is tolerant of a rather wide range of soil conditions, its fertilizer requirements for high production and stand longevity differ greatly between various locations (7).

In a study on the effects of lime and soil acidity on the growth of alfalfa, Maschler et al. (11) reported lime has proved to be indispensable to yield and longevity. Total yield ranged from .25 to 8.0 tons per acre and stand survival at the end of the third cutting year varied from 0 to 95%.

By using radio-calcium, Schmehl et al. (21, 22) studied the influence of soil acidity on the absorption of calcium by alfalfa. They reported the rate of absorption of calcium by alfalfa was markedly reduced in the presence of aluminum ions in the nutrient media and a lesser reduction was observed in the presence of hydrogen and manganese ions. They concluded that the low calcium content in plants grown on acid soils may result from an antagonistic effect of aluminum, manganese and hydrogen ions on the absorption of calcium ions rather than a low supply of calcium in the soil. Similar results were obtained by Fried and Peech (5, 18) who found that the addition of gypsum increased the calcium content of the soil solution, but failed to increase calcium content or growth of alfalfa. Additions of gypsum greatly increased the amount of Al and Mn in solution.

Liming of alfalfa to optimum pH levels is closely related to yield. Moser (12) showed that calcium supplied at low pH values was a more important growth factor than pH. His results indicated that calcium supplied in increasing increments gradually increased in the plant, reaching the maximum where 10 m.e. of calcium were applied at a pH of 6.0 to 6.5 In studying the influence of soil acidity on the activity of the calcium present, Albrecht and Schroeder (1) reported that a greater activity of the calcium in the soil occurred when a significant amount of hydrogen was present than in a neutral soil.

Woodhouse (27), in North Carolina, concluded that the time and method of application were more important than the application rate of lime. Best results were obtained by mixing the lime in the plow layer before planting. A high level of calcium depressed the uptake of magnesium and potassium. Nelson and MacGregor (16) reported no difference in fall and spring applied fertilizers on yield, composition and stand longevity of alfalfa. In studying the effects on alfalfa yield and composition with different times and rates of lime and phosphorus applications, Singh and Seatz (24) obtained highest yields when the highest rates of both lime and phosphorus were applied at planting.

Scanlan (20), working with inoculation of soybeans, found that increased nodulation was not caused by altering pH, but was caused by supplying calcium to the infecting organism.

Alfalfa is a heavy user of potassium. This element is often the first limiting plant growth factor on sandy or acid soils. Gerwig and Ahlgren (6) found potassium was the most important factor in maintaining high yields and persistence of an alfalfa stand. In 1953, their results indicated that plants receiving potash showed significantly higher yields at the 1% level.

Woodhouse (27) found that applications of potassium aided in stand maintenance of alfalfa and decreased the number of weeds as compared to alfalfa stands receiving no potash.

Peech and Bradfield (18) stated that potassium uptake was affected appreciably by calcium, whereas potassium suppressed the uptake of both calcium and magnesium. Similarly, Bear (2) found that when large amounts of potassium were available to plants, the uptake of calcium and magnesium was greatly reduced. Murphy (13) found that soils containing less than 60 ppm. of exchangeable potassium generally responded to potassium fertilization if other factors were favorable for plant growth. According to Chandler et al. (4), a profitable yield response usually resulted from potassium fertilization when the potassium content of alfalfa was less than 1.25 percent at the early bloom stage.

Available soil phosphorus is a principal limiting factor for establishment and maintenance of alfalfa stands within many soil areas. Thomas (25) and Nelson (15) reviewed and summarized the abundant literature published on this subject. Phosphorus relationships with the multitude of soil characteristics influencing availability and fixation of this element are complex. Interactions with levels and plant nutrient element balance of other elements greatly affect alfalfa yields (10, 14). Calcium, magnesium and potassium ratios interacting with phosphorus levels have been particularly confusing in previous studies (8, 26).

## MATERIALS AND METHODS

### Soil

The soil selected for this investigation was Norge fine sandy loam. Approximately 1600 pounds of topsoil from a non-fertilized area in the southeast corner of the Paradise farm were brought to Stillwater. The soil was air-dired, screened, and stored in plastic bags until used in the greenhouse.

The soil was characterized by the following chemical and physical measurements. The pH was determined with a Beckman glass electrode pH meter on a 1:1 soil-water paste. The organic matter percentage was obtained by the potassium dichromate wet oxidation method of Schollenberger (23). Total nitrogen content was determined by the Kjeldahl method according to Harper (9). The cation exchange capacity was measured by the ammonium saturation and distillation method of Peech et al. (19). The exchangeable cations (Ca, Mg, K) were determined in the ammonium acetate leachate by use of the Beckman DU Flame Spectrophotometer with photomultiplier. Available phosphorus was determined by extraction with 0.1 N acetic acid and the development of the molybdate color complex (9). Mechanical analysis of the soil was accomplished by the Bouyoucos method (3). The results of these analyses are in Table I.

TABLE I

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOIL USED IN THE GREENHOUSE EXPERIMENT, NORGE FINE SANDY LOAM

| | |
|---|---|
| Texture | |
| Percent sand | 72.0 |
| Percent silt | 20.0 |
| Percent clay | 8.0 |
| Reaction (pH) | 6.5 |
| Percent organic matter | 1.0 |
| Percent nitrogen | .02 |
| Available phosphorus (pounds per acre) | 10.6 |
| Exchangeable calcium (m.e. per 100 gm.) | 1.5 |
| Exchangeable magnesium (m.e. per 100 gm.) | 0.3 |
| Exchangeable potassium (m.e. per 100 gm.) | 0.2 |
| Cation exchange capacity (m.e. per 100 gm.) | 4.0 |

## Greenhouse Study

The objective of the greenhouse experiment was to determine yield response and chemical composition of alfalfa to fertilization with various Ca-Mg-K treatments at different phosphorus levels grown on a Norge fine sandy loam soil.

Eight thousand grams of the processed soil were placed into each of 66 two-gallon earthenware pots. Twenty-two fertilizer treatments replicated three times were thoroughly mixed with the soil. The soil was watered to 20 percent moisture before planting. The treatments were designated as follows:

| | | | |
|---|---|---|---|
| Check | Mg | K | KMg |
| $P_1$ | $MgP_2$ | $KP_1$ | $KMgP_1$ |
| $P_2$ | CaMg | KCa | $KMgP_2$ |
| Ca | $CaMgP_1$ | $KCaP_1$ | KCaMg |
| $CaP_1$ | $CaMgP_2$ | $KCaP_2$ | $KCaMgP_1$ |
| $CaP_2$ | | | $KCaMgP_2$ |

$P_1$ = (50 ppm P) 1.48 gm $NH_4H_2PO_4$ * per 8000 gm soil.

$P_2$ = (100 ppm P) 2.96 gm $NH_4H_2PO_4$ per 8000 gm soil.

Ca = (5 m.e./100 gm) 29.36 gm $CaCl_2 \cdot 2H_2O$ per 8000 gm soil.

Mg = (4.78 m.e./100 gm) 40.65 gm $MgCl_2 \cdot 6H_2O$ per 8000 gm soil.

K = (1.7 m.e./100 gm) 11.78 gm $K_2SO_4$ per 8000 gm soil.

Ca:Mg combination = (2.5 m.e. Ca and 2.39 m.e. Mg/100 gm soil)

* Urea supplied to bring all N levels equal to N supplied in $P_2$ treatment.

## Analyses of Plant Material

The plants were harvested April 7, April 28, May 20, and June 12, 1962, dried at 95°C, and weighed for total dry weight production. The dry plant material was then ground in a Wiley mill. The three replications were composited. One-gram samples of the dried, composited material were digested by the nitric-perchloric acid procedure as outlined by Harper (9). The residue was dissolved in 200 ml of distilled water and filtered. This solution was used for subsequent determinations of Ca, Mg, K, Na, and P. Total phosphorus was determined by development of the molybdate color complex. Nitrogen content was determined by the Kjeldahl method. Determinations of Ca, Mg, K, and Na were made on the Beckman DU Flame Spectrophotometer with photomultiplier. The Na content was very low (4 ppm. maximum) and therefore omitted from the composition tables. Sulfates were precipitated from the samples with $BaCl_2$ to prevent interference with Ca determinations.

## RESULTS AND DISCUSSION

The fertility status of the soil before treatment is shown in Table I. Low exchangeable Ca, Mg, K and available P contents are typical of this soil in its natural state. Previous experience has shown it to be low in productivity without proper fertility treatments and management practices.

### Yields

Four cuttings of alfalfa were taken from this greenhouse experiment. Mean yields of three replications by treatments and results of the statistical analysis are shown in Table II. The highest forage yield came from the third cutting. The second cutting ranked second in forage yield. The first cutting ranked third and the fourth cutting ranked fourth.

The highest forage yields from each cutting came from the pots that received the $CaMgKP_2$ treatments. This treatment produced an average yield of 11.00 grams per pot while the $MgP_1$ treatment produced the lowest average yield of 2.59 grams per pot. The overall yield average was 5.66 grams per pot, which was less than the check (6.60 grams per pot).

The addition of phosphorus alone resulted in yields lower than the check. The potassium and potassium plus phosphorus treatments increased yields over the check. The mean yield of the $P_2$ treatments

TABLE II

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON YIELD OF CODY ALFALFA ON NORGE FINE SANDY LOAM

| Treatment | Grams dry plant material by cutting | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Mean |
| Check | 6.81 [1] | 7.37 | 7.11 | 5.10 | 6.60 |
| $P_1$ | 5.24 | 6.04 | 3.86 | 4.58 | 4.93 |
| $P_2$ | 6.16 | 5.46 | 6.42 | 5.05 | 5.77 |
| K | 7.11 | 8.94 | 10.69 | 7.04 | 8.45 |
| $KP_1$ | 7.58 | 9.70 | 9.76 | 7.18 | 8.56 |
| $KP_2$ | 7.36 | 7.54 | 7.03 | 6.11 | 7.01 |
| Ca | 6.56 | 4.62 | 5.96 | 4.29 | 5.36 |
| $CaP_2$ | 5.38 | 4.67 | 5.73 | 4.65 | 5.11 |
| CaK | 7.17 | 7.84 | 9.86 | 5.13 | 7.50 |
| $CaKP_1$ | 3.25 | 4.24 | 5.49 | 3.04 | 4.01 |
| $CaKP_2$ | 6.36 | 8.57 | 9.46 | 6.59 | 7.75 |
| Mg | 2.70 | 2.85 | 4.84 | 3.93 | 3.58 |
| $MgP_1$ | 1.30 | 2.94 | 3.12 | 2.99 | 2.59 |
| MgK | 2.13 | 3.36 | 4.59 | 4.06 | 3.54 |
| $MgKP_1$ | 7.56 | 9.87 | 11.81 | 8.23 | 9.37 |
| $MgKP_2$ | 4.83 | 3.92 | 4.87 | 4.47 | 4.52 |
| CaMg | .62 | 3.33 | 4.26 | 3.52 | 2.93 |
| $CaMgP_1$ | 4.46 | 4.06 | 4.11 | 3.53 | 4.04 |
| $CaMgP_2$ | 6.19 | 4.84 | 5.30 | 4.85 | 5.30 |
| CaMgK | 2.56 | 3.68 | 5.14 | 3.95 | 3.83 |
| $CaMgKP_1$ | 2.23 | 4.74 | 4.98 | 3.68 | 3.91 |
| $CaMgKP_2$ | 9.90 | 12.61 | 12.64 | 8.87 | 11.00 |
| Treatment F | 5.23** | 6.51** | 4.86** | 6.15** | |

[1] Figures in table are means of three replications.
** Significant at 1% level.

in combination with Ca, Mg and K was higher than the mean yield of the $P_1$ treatment with the same Ca, Mg, and K combinations. The mean yield of the pots that received Ca were higher than those that received Mg.

Yields generally were decreased with addition of only magnesium and calcium, but potassium fertilization resulted in increased yields at all treatment levels. Response to phosphorus levels was not consistent in these experiments with the various calcium, magnesium and potassium combinations. Other studies (10) reported that alfalfa grown in the greenhouse on Port loam yielded best with the addition of 10 tons of $CaCO_3$ per acre. Lowest yield was obtained from pots that received 8.4 tons of $MgCO_3$ per acre.

Results for this experiment are in agreement with others (10) indicating need for evaluation of exchangeable potassium, calcium and magnesium for determination of plant nutrient requirements of alfalfa Limitations of soil pH measurements as sole criteria for determination of lime and fertilizer application are apparent.

## Plant Analyses

The effects of various soil fertility treatments on the chemical composition of alfalfa grown in the greenhouse on Norge fine sandy loam are given for each of the four cuttings in Tables III, IV, V, and VI. Table VII shows mean analyses of the four cuttings. The ratios of Ca, Mg and K for each of the four cuttings are summarized in Table VIII. Correlations of plant yields with Ca:Mg:K ratios in composition are shown in Figure 1, 2 and 3.

Plant composition as influenced by soil treatment was generally consistent between cuttings. However, calcium and magnesium contents

TABLE III

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON CHEMICAL COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, FIRST CUTTING

| Treatment | %P | m.e. per 100 g. | | | Ratio of m.e. | | |
|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | K/Ca+Mg | Ca/K+Mg | Mg/K+Ca |
| Check | .272[1] | 165 | 68 | 77 | .33 | 1.14 | .28 |
| $P_1$ | .440 | 125 | 62 | 87 | .47 | .84 | .29 |
| $P_2$ | .475 | 134 | 62 | 79 | .40 | .95 | .29 |
| K | .303 | 125 | 68 | 126 | .65 | .64 | .27 |
| $KP_1$ | .385 | 107 | 65 | 133 | .77 | .54 | .27 |
| $KP_2$ | .434 | 87 | 55 | 110 | .78 | .53 | .28 |
| Ca | .370 | 226 | 63 | 62 | .21 | 1.81 | .22 |
| $CaP_2$ | .548 | 176 | 52 | 61 | .27 | 1.56 | .22 |
| CaK | .216 | 190 | 38 | 96 | .42 | 1.42 | .13 |
| $CaKP_1$ | .405 | 163 | 52 | 103 | .48 | 1.05 | .20 |
| $CaKP_2$ | .495 | 130 | 45 | 94 | .54 | .94 | .20 |
| Mg | .288 | 79 | 122 | 69 | .34 | .41 | .82 |
| $MgP_1$ | .572 | 58 | 133 | 75 | .39 | .28 | 1.00 |
| MgK | .225 | 111 | 128 | 129 | .54 | .43 | .53 |
| $MgKP_1$ | .358 | 88 | 97 | 113 | .61 | .42 | .48 |
| $MgKP_2$ | .557 | 68 | 105 | 121 | .70 | .30 | .56 |
| CaMg | .360 | 114 | 103 | 65 | .30 | .68 | .58 |
| $CaMgP_1$ | .518 | 128 | 90 | 71 | .33 | .80 | .45 |
| $CaMgP_2$ | .516 | 117 | 50 | 42 | .25 | 1.27 | .31 |
| CaMgK | .246 | 136 | 97 | 37 | .16 | 1.01 | .56 |
| $CaMgKP_1$ | .368 | 113 | 68 | 110 | .61 | .63 | .30 |
| $CaMgKP_2$ | .503 | 78 | 58 | 85 | .63 | .55 | .36 |

/1 Figures are analyses of composite samples from three replications.

TABLE IV

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON CHEMICAL COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, SECOND CUTTING

| Treatment | %P | m.e. per 100 g. | | | Ratio of m.e. | | |
|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca |
| Check | .320[1] | 79 | 52 | 93 | .71 | .55 | .30 |
| $P_1$ | .572 | 63 | 52 | 110 | .96 | .39 | .30 |
| $P_2$ | .650 | 73 | 55 | 92 | .72 | .50 | .33 |
| K | .300 | 57 | 52 | 128 | 1.17 | .32 | .28 |
| $KP_1$ | .465 | 48 | 52 | 141 | 1.41 | .25 | .28 |
| $KP_2$ | .562 | 39 | 52 | 126 | 1.38 | .22 | .31 |
| Ca | .335 | 115 | 45 | 92 | .58 | .84 | .22 |
| $CaP_2$ | .555 | 108 | 48 | 87 | .56 | .81 | .25 |
| CaK | .280 | 96 | 45 | 118 | .84 | .59 | .21 |
| $CaKP_1$ | .464 | 98 | 45 | 137 | .96 | .54 | .19 |
| $CaKP_2$ | .488 | 79 | 42 | 104 | .86 | .54 | .23 |
| Mg | .326 | 59 | 105 | 87 | .53 | .31 | .72 |
| $MgP_1$ | .488 | 59 | 133 | 75 | .39 | .28 | .99 |
| MgK | .223 | 103 | 100 | 141 | .69 | .43 | .41 |
| $MgKP_1$ | .355 | 58 | 68 | 126 | 1.00 | .30 | .37 |
| $MgKP_2$ | .607 | 37 | 75 | 141 | 1.26 | .17 | .42 |
| CaMg | .335 | 106 | 55 | 63 | .39 | .90 | .33 |
| $CaMgP_1$ | .610 | 96 | 75 | 90 | .53 | .58 | .40 |
| $CaMgP_2$ | .830 | 80 | 45 | 69 | .55 | .70 | .30 |
| CaMgK | .355 | 80 | 73 | 118 | .77 | .42 | .37 |
| $CaMgKP_1$ | .430 | 75 | 68 | 128 | .90 | .38 | .33 |
| $CaMgKP_2$ | .530 | 54 | 49 | 109 | 1.06 | .34 | .30 |

[1] Figures are analyses of composite samples from three replications.

TABLE V

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON CHEMICAL COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, THIRD CUTTING

| Treatment | %P | m.e. per 100 g. | | | Ratio of m.e. | | |
|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca |
| Check | .278 /1 | 67 | 48 | 74 | .64 | .55 | .34 |
| $P_1$ | .475 | 77 | 52 | 84 | .65 | .57 | .32 |
| $P_2$ | .510 | 65 | 52 | 69 | .59 | .54 | .39 |
| K | .222 | 48 | 52 | 108 | 1.08 | .30 | .33 |
| $KP_1$ | .357 | 46 | 48 | 133 | 1.41 | .25 | .27 |
| $KP_2$ | .470 | 46 | 45 | 104 | 1.14 | .31 | .30 |
| Ca | .200 | 108 | 48 | 69 | .44 | .92 | .27 |
| $CaP_2$ | .415 | 97 | 45 | 65 | .46 | .88 | .28 |
| CaK | .204 | 72 | 38 | 96 | .87 | .54 | .23 |
| $CaKP_1$ | .312 | 88 | 45 | 103 | .77 | .59 | .24 |
| $CaKP_2$ | .375 | 75 | 38 | 82 | .73 | .63 | .24 |
| Mg | .213 | 55 | 97 | 68 | .45 | .33 | .79 |
| $MgP_1$ | .407 | 59 | 140 | 63 | .33 | .29 | 1.13 |
| MgK | .158 | 78 | 87 | 121 | .73 | .38 | .44 |
| $MgKP_1$ | .288 | 50 | 62 | 113 | 1.01 | .29 | .38 |
| $MgKP_2$ | .496 | 51 | 80 | 107 | .88 | .22 | .54 |
| CaMg | .195 | 82 | 48 | 54 | .41 | .80 | .35 |
| $CaMgP_1$ | .488 | 94 | 87 | 63 | .35 | .63 | .55 |
| $CaMgP_2$ | .520 | 72 | 43 | 54 | .47 | .74 | .34 |
| CaMgK | .140 | 72 | 70 | 82 | .58 | .47 | .45 |
| $CaMgKP_1$ | .345 | 81 | 80 | 100 | .62 | .45 | .44 |
| $CaMgKP_2$ | .392 | 51 | 42 | 81 | .87 | .41 | .32 |

/1 Figures are analyses of composite samples from three replications.

TABLE VI

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON CHEMICAL COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, FOURTH CUTTING

| Treatment | %P | m.e. per 100 g. | | | Ratio of m.e. | | |
|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca |
| Check | .286 /1 | 65 | 48 | 74 | .66 | .53 | .35 |
| $P_1$ | .445 | 71 | 52 | 84 | .68 | .52 | .34 |
| $P_2$ | .532 | 63 | 58 | 66 | .60 | .55 | .37 |
| K | .223 | 48 | 48 | 103 | 1.07 | .32 | .32 |
| $KP_1$ | .357 | 46 | 48 | 133 | 1.41 | .25 | .27 |
| $KP_2$ | .475 | 45 | 42 | 103 | 1.18 | .31 | .28 |
| Ca | .200 | 106 | 42 | 69 | .47 | .95 | .24 |
| $CaP_2$ | .435 | 97 | 45 | 63 | .44 | .90 | .28 |
| CaK | .184 | 98 | 38 | 89 | .65 | .77 | .20 |
| $CaKP_1$ | .290 | 119 | 42 | 92 | .57 | .89 | .20 |
| $CaKP_2$ | .382 | 75 | 42 | 84 | .72 | .60 | .26 |
| Mg | .178 | 61 | 97 | 59 | .37 | .39 | .81 |
| $MgP_1$ | .442 | 67 | 153 | 63 | .29 | .31 | 1.18 |
| MgK | .138 | 83 | 90 | 116 | .67 | .40 | .45 |
| $MgKP_1$ | .258 | 56 | 65 | 118 | .98 | .31 | .37 |
| $MgKP_2$ | .445 | 46 | 90 | 110 | .81 | .23 | .58 |
| CaMg | .175 | 96 | 52 | 52 | .35 | .92 | .35 |
| $CaMgP_1$ | .480 | 85 | 80 | 75 | .45 | .55 | .50 |
| $CaMgP_2$ | .544 | 72 | 43 | 54 | .47 | .74 | .34 |
| CaMgK | .145 | 82 | 73 | 84 | .54 | .52 | .44 |
| $CaMgKP_1$ | .298 | 103 | 83 | 95 | .51 | .58 | .42 |
| $CaMgKP_2$ | .372 | 51 | 42 | 84 | .90 | .40 | .34 |

/1 Figures are analyses of composite samples from three replications.

TABLE VII

EFFECT OF VARIOUS SOIL FERTILITY TREATMENTS ON CHEMICAL COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, GREENHOUSE EXPERIMENT, MEAN ANALYSES OF THE FOUR CUTTINGS

| Treatment | %P | m.e. per 100 g. | | | Ratio of m.e. | | |
|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca |
| Check | .289 | 94 | 54 | 80 | .59 | .69 | .32 |
| $P_1$ | .483 | 84 | 55 | 91 | .69 | .58 | .31 |
| $P_2$ | .542 | 84 | 54 | 77 | .58 | .64 | .35 |
| K | .262 | 70 | 55 | 116 | .99 | .40 | .30 |
| $KP_1$ | .391 | 62 | 53 | 135 | 1.25 | .32 | .27 |
| $KP_2$ | .485 | 54 | 49 | 111 | 1.12 | .34 | .29 |
| Ca | .276 | 139 | 50 | 73 | .43 | 1.13 | .24 |
| $CaP_2$ | .488 | 120 | 48 | 69 | .43 | 1.04 | .26 |
| CaK | .221 | 114 | 50 | 100 | .70 | .83 | .19 |
| $CaKP_1$ | .368 | 117 | 46 | 109 | .70 | .77 | .21 |
| $CaKP_2$ | .435 | 90 | 42 | 91 | .71 | .68 | .23 |
| Mg | .251 | 65 | 105 | 71 | .42 | .36 | .79 |
| $MgP_1$ | .477 | 61 | 140 | 70 | .35 | .29 | 1.08 |
| MgK | .186 | 94 | 101 | 127 | .66 | .41 | .46 |
| $MgKP_1$ | .415 | 63 | 73 | 118 | .90 | .33 | .40 |
| $MgKP_2$ | .526 | 48 | 88 | 120 | .91 | .23 | .53 |
| CaMg | .266 | 100 | 65 | 59 | .36 | .83 | .40 |
| $CaMgP_1$ | .524 | 101 | 83 | 75 | .51 | .64 | .48 |
| $CaMgP_2$ | .602 | 85 | 45 | 55 | .47 | .86 | .32 |
| CaMgK | .222 | 93 | 78 | 80 | .51 | .61 | .46 |
| $CaMgKP_1$ | .360 | 93 | 75 | 108 | .66 | .51 | .37 |
| $CaMgKP_2$ | .449 | 54 | 48 | 90 | .87 | .43 | .33 |

TABLE VIII

EFFECTS OF VARIOUS SOIL FERTILITY TREATMENTS ON MILLIEQUIVALENT RATIOS OF K, Ca, AND Mg IN COMPOSITION OF CODY ALFALFA, NORGE FINE SANDY LOAM, BY CUTTING

| Treatment | 1st cutting | | | 2nd cutting | | | 3rd cutting | | | 4th cutting | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca | K/ Ca+Mg | Ca/ K+Mg | Mg/ K+Ca |
| Check | .33 [1] | 1.14 | .28 | .71 | .55 | .30 | .64 | .55 | .34 | .66 | .53 | .35 |
| $P_1$ | .47 | .84 | .29 | .96 | .39 | .30 | .65 | .57 | .32 | .68 | .52 | .34 |
| $P_2$ | .40 | .95 | .29 | .72 | .50 | .33 | .59 | .54 | .39 | .60 | .55 | .37 |
| K | .65 | .64 | .27 | 1.17 | .32 | .28 | 1.08 | .30 | .33 | 1.07 | .32 | .32 |
| $KP_1$ | .77 | .54 | .27 | 1.41 | .25 | .28 | 1.41 | .25 | .27 | 1.41 | .25 | .27 |
| $KP_2$ | .78 | .53 | .28 | 1.38 | .22 | .31 | 1.14 | .31 | .30 | 1.18 | .31 | .28 |
| Ca | .21 | 1.81 | .22 | .58 | .84 | .22 | .44 | .92 | .27 | .47 | .95 | .24 |
| $CaP_2$ | .27 | 1.56 | .22 | .56 | .81 | .25 | .46 | .88 | .28 | .44 | .90 | .28 |
| CaK | .42 | 1.42 | .13 | .84 | .59 | .21 | .87 | .54 | .23 | .65 | .77 | .20 |
| $CaKP_1$ | .48 | 1.05 | .20 | .96 | .54 | .19 | .77 | .59 | .24 | .57 | .89 | .20 |
| $CaKP_2$ | .54 | .94 | .20 | .86 | .54 | .23 | .73 | .63 | .24 | .72 | .60 | .26 |
| Mg | .34 | .41 | .82 | .53 | .31 | .72 | .45 | .33 | .79 | .37 | .39 | .81 |
| $MgP_1$ | .39 | .28 | 1.00 | .39 | .28 | .99 | .33 | .29 | 1.13 | .29 | .31 | 1.18 |
| MgK | .54 | .43 | .53 | .69 | .43 | .41 | .73 | .38 | .44 | .67 | .40 | .45 |
| $MgKP_1$ | .61 | .42 | .48 | 1.00 | .30 | .37 | 1.01 | .29 | .38 | .98 | .31 | .37 |
| $MgKP_2$ | .70 | .30 | .56 | 1.26 | .17 | .42 | .88 | .22 | .54 | .81 | .23 | .58 |
| CaMg | .30 | .68 | .58 | .39 | .90 | .33 | .41 | .80 | .35 | .35 | .92 | .35 |
| $CaMgP_1$ | .33 | .80 | .45 | .53 | .58 | .40 | .35 | .63 | .55 | .45 | .55 | .50 |
| $CaMgP_2$ | .25 | 1.27 | .31 | .55 | .70 | .30 | .47 | .74 | .34 | .47 | .74 | .34 |
| CaMgK | .16 | 1.01 | .56 | .77 | .42 | .37 | .58 | .47 | .45 | .54 | .52 | .44 |
| $CaMgKP_1$ | .61 | .63 | .30 | .90 | .38 | .33 | .62 | .45 | .44 | .51 | .58 | .42 |
| $CaMgKP_2$ | .63 | .55 | .36 | 1.06 | .34 | .30 | .87 | .41 | .32 | .90 | .40 | .34 |

[1] Figures are analyses of composite samples from three replications.

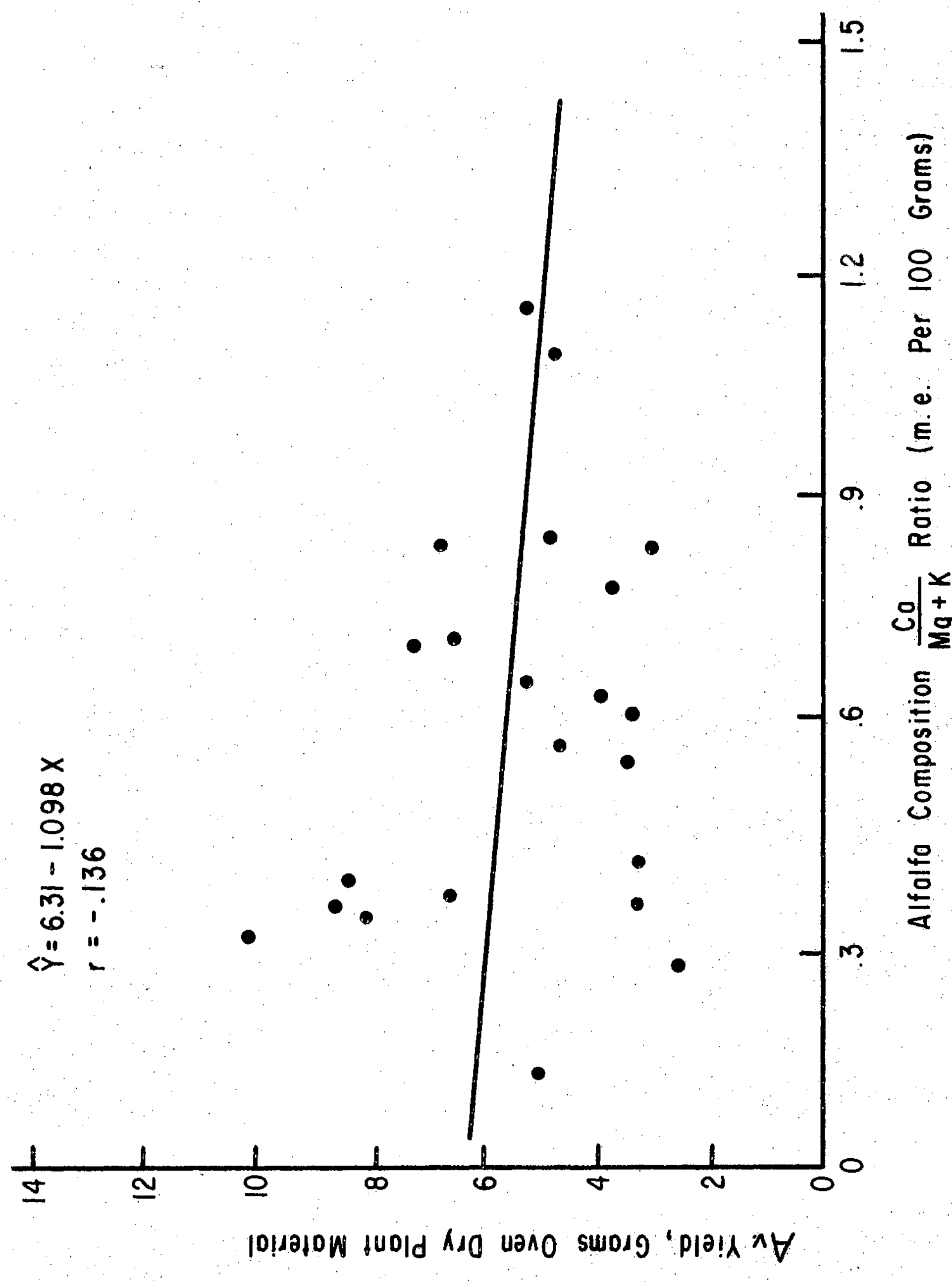


Figure 1. Alfalfa Yield Related to $\frac{Ca}{Mg+K}$ Ratio in Plant Composition, Norge Fine Sandy Loam, Greenhouse Experiments.

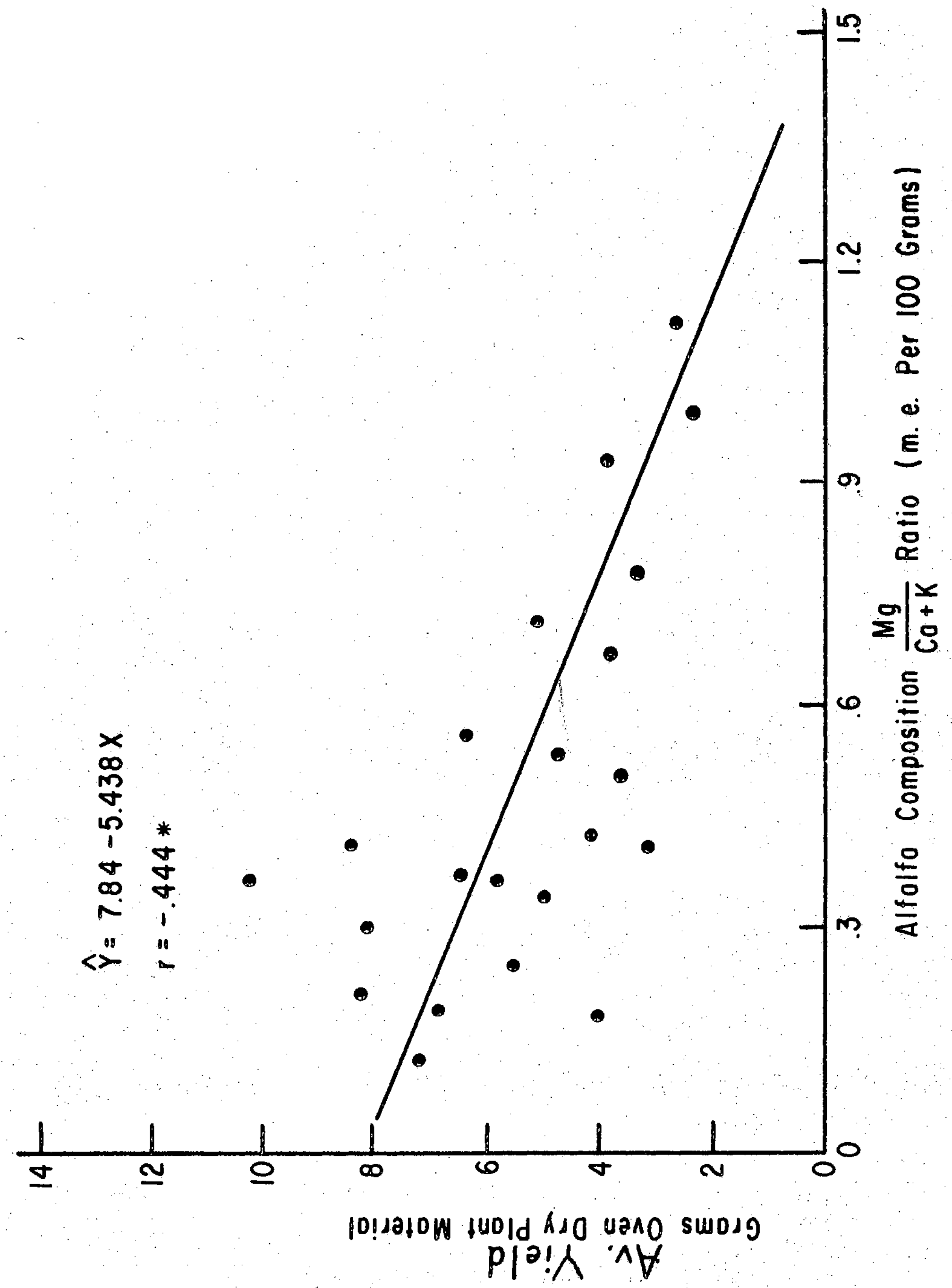


Figure 2. Alfalfa Yield Related to $\frac{Mg}{Ca+K}$ Ratio in Plant Composition, Norge Fine Sandy Loam, Greenhouse Experiments.

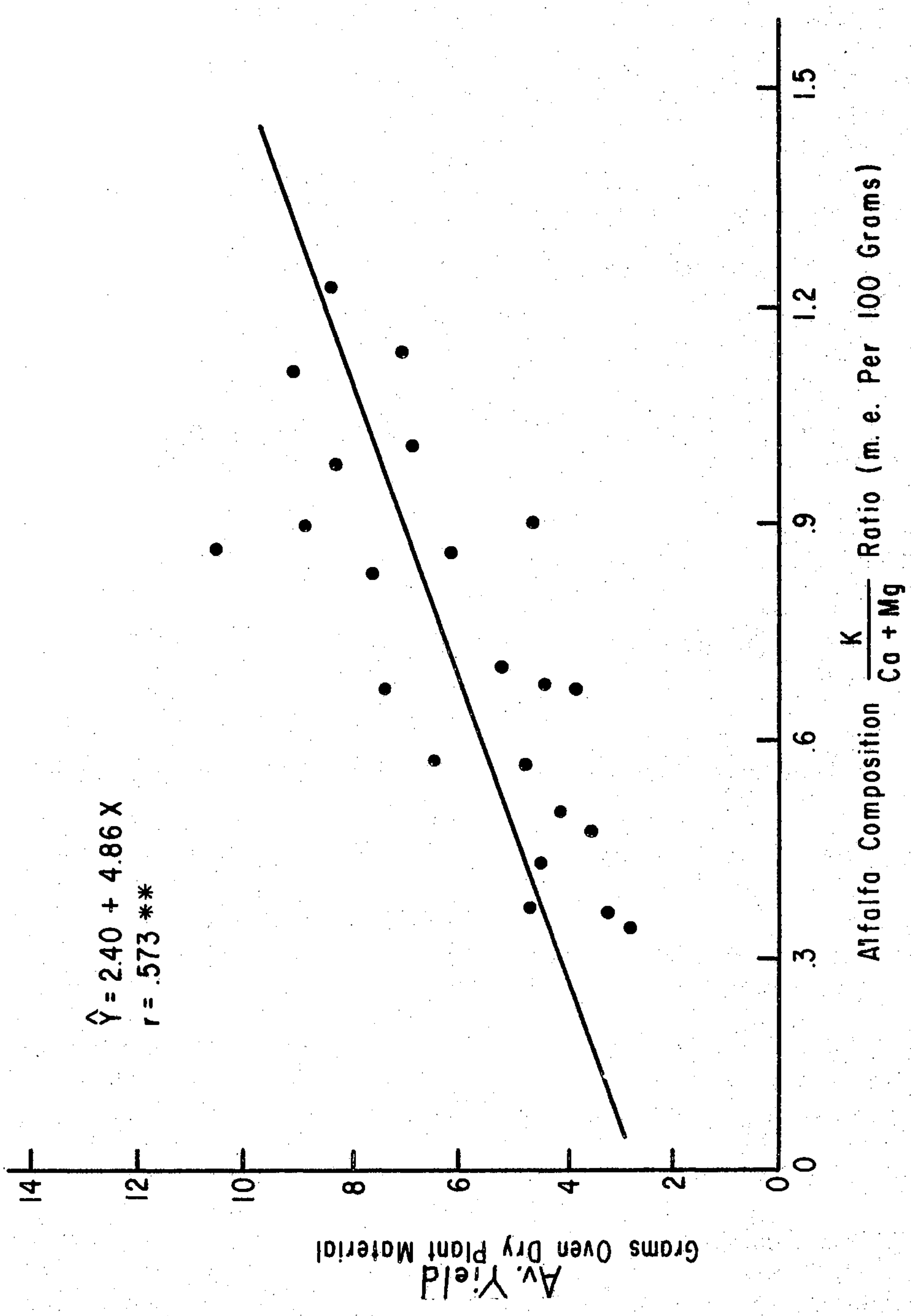


Figure 3. Alfalfa Yield Related to $\frac{K}{Ca+Mg}$ Ratio in Plant Composition, Norge Fine Sandy Loam, Greenhouse Experiments.

were higher in the first cutting as compared to the other three cuttings. Phosphorus and potassium were highest in the second cutting. Average calcium content expressed as m.e. per 100 grams plant material decreased linearly from 123.5 for the first cutting to 74.3 for the fourth cutting. Similarly, average magnesium content as m.e. decreased linearly from 76.4 in the first cutting to 62.0 in the fourth cutting. Potassium content gave a quadratic trend with average composition as m.e. of 88.4, 108.0, 86.0, and 85.0 for the first, second, third and fourth cutting respectively. Phosphorus content also indicated a quadratic trend ranging in percent from .403, .458, .340 and .330 for the first, second, third, and fourth cuttings.

Comparisons between cuttings generally reflected trends in potassium, calcium and magnesium content. The K/Ca+Mg ratios were quadratic increasing from .46 for the first cutting to .83 in the second cutting, then decreasing to .70 for the third and .67 for the fourth cutting. Ca/K+Mg ratios decreased linearly from .83 for the first to .54 in the fourth cutting. Mg/Ca+K remained about constant with .39, .36, .39 and .40 for the first, second, third and fourth cuttings respectively.

In general, the addition of magnesium to the calcium treated plots resulted in slightly decreased phosphorus, potassium and calcium with increased magnesium contents.

The addition of phosphorus to the calcium-magnesium combined treatments resulted in increased phosphorus and potassium contents with decreased magnesium and calcium contents.

Potassium when combined with calcium only treatments resulted in decreased phosphorus, magnesium and calcium with increased potassium content.

Potassium combined with the calcium-magnesium treatments gave increased content of phosphorus, potassium and magnesium with decreased calcium.

The addition of potassium to the calcium-magnesium-phosphorus treatments resulted in decreased phosphorus and calcium content with increased potassium and magnesium.

Correlations of yield as related to Ca/Mg+K ratios (Figure 1) indicated slightly decreasing yields with increased ratios expressed as m.e. per 100 grams plant material. The $r = -.136$ was not statistically significant. Yields also decreased as the Mg/Ca+K ratio increased (Figure 2) with $r = -.444$ statistically significant at the 5% level. The K/Ca+Mg ratio gave a positive highly significant correlation coefficient $r = .573$ (Figure 3).

Although interrelationships between the base elements and phosphorus were apparently very complex, yields were increased as a function of potassium fertilization and were relected in the K:Ca:Mg balance in plant composition.

## SUMMARY AND CONCLUSIONS

The objective of this study was to determine the influence of soil calcium, magnesium and potassium at three phosphorus levels upon alfalfa yield and composition. A Norge fine sandy loam soil was used in a greenhouse experiment with the Cody variety of alfalfa.

Four alfalfa cuttings were harvested. Yields and plant composition were determined. Results were evaluated with statistical procedures and correlations of plant composition and yields were obtained.

Treatments of calcium, magnesium and potassium influenced both yield and composition of alfalfa grown on this soil. Highest forage yields were obtained with combinations of all three elements, Ca, Mg, and K, at the high $P_2$ level. Lowest yield was from the Mg $P_1$ treatment. Response to phosphorus levels was not consistent with the various calcium, magnesium and potassium combinations. Yields generally were decreased with the magnesium and calcium only additions. Potassium fertilization resulted in increased yields at all treatment levels.

Correlations of yield to Ca/Mg+K composition ratios indicated slight decreased yields with increased ratios. Yields also significantly decreased as the Mg/Ca+K ratios increased. The K/Ca+Mg ratio gave a positive highly significant correlation coefficient.

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