RESPONSE OF THE PEANUT (*Arachis hypogaea* L.) TO SOME NUTRITIONAL FACTORS

By

JOHN PAUL CLAY

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1964

Submitted to the faculty of the Graduate School
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1967

RESPONSE OF THE PEANUT (*Arachis hypogaea* L.)

TO SOME NUTRITIONAL FACTORS

Thesis Approved:

Lester W. Reed

Thesis Adviser

Ralph S. Matlock

D. D. Durham

Dean of the Graduate School

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the Agronomy Department of Oklahoma State University for the use of its facilities which made these studies possible.

Special appreciation is extended to my major adviser, Dr. Lester W. Reed, for the inspiration, advice, and encouragement he provided during the course of this research. The assistance of the other members of my graduate committee, Dr. Ralph Matlock, Dr. Gene Guinn, and Dr. Billy Tucker, is also acknowledged and appreciated.

To his parents, Mr. and Mrs. Floyd Clay, the author wishes to express his gratitude for their constant encouragement throughout his college career. Special thanks is also given to my wife, Wilma, for her patience and helpfulness which made this course of study a more enjoyable one.

Appreciation is also extended to Mrs. Gary Roach for the final typing of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Peanuts are an important cash crop in Oklahoma, ranking third in total cash income behind wheat and cotton. The acreage of peanuts in Oklahoma is approximately 120,000 acres and the value of the 1964 crop was 19.4 million dollars. Peanuts have the highest gross income per acre of any crop grown in Oklahoma.

In view of the contribution peanuts make to Oklahoma's agricultural economy, any type of research which might potentially increase the yield, quality, or the efficiency of production of peanuts is of obvious importance. Soil fertility research with peanuts in the United States has not resulted in the characterization and subsequent prediction of the response of peanuts to added plant nutrient elements as has been accomplished with certain other crops. Spanish peanuts have shown inconsistent response to applications of primary, secondary, or micronutrients in soil fertility research in Oklahoma. This lack of response has occurred in spite of the fact that most peanut soils are low in fertility, with respect to other crops, and that a substantial portion of the crop is irrigated. Generally, crops that are irrigated exhibit larger responses to fertilizers than do non-irrigated crops.

Even though no consistent fertilizer responses have been obtained with peanuts, large amounts of fertilizers are applied to peanuts in

Oklahoma each year. Thus, from a cost-of-production standpoint, it is important to the peanut producers in Oklahoma to know more precisely the yield response of peanuts to different levels of plant nutrient elements.

Experiment I was designed to determine the effects of diluting a typical western Oklahoma peanut soil with silica sand, thereby decreasing the soil nutrient levels, on selected characteristics of Spanish peanuts.

Experiment II was designed to study the response of Spanish peanuts, grown in sand cultures, to four levels of phosphorus.

CHAPTER II

LITERATURE REVIEW

Critical Soil Nutrient Levels

A rather extensive review of peanut soil fertility work reveals little useful data that can be used to establish critical soil nutrient levels. Much of the early work has no accompanying soil data, and no indication of the statistical design, number of replications, or statistical significance of treatments. As will be illustrated in this review, large differences in the response of different varieties to plant nutrients have been exhibited, which confuses the situation even more.

Calcium. Several studies have demonstrated the requirement of several varieties of peanuts for an adequate supply of Ca in the fruiting zone (3, 4, 5, 6, 9, 22, 28). Bledsoe et al. (2) have shown that Ca is not translocated from the stem into the peg in sufficient quantities to allow normal kernel development. The necessary Ca for kernel development is absorbed by the pegs and developing fruit from the medium in which they are growing, provided sufficient Ca is available. Consequently, a deficiency of Ca in the fruiting medium usually results in a large number of unfilled pods.

The response of peanuts to Ca additions has been found to be better correlated with exchangeable Ca levels in the soil than with percentage Ca saturation (9, 28). Rogers (28) reported that the critical level of exchangeable Ca for runner and Spanish peanuts on Norfolk soils in Alabama was between 0.6 and 0.8 m.e. per 100 grams of soil. The data shown in Rogers' paper supports his critical Ca level for runner peanuts, however, no data was presented from which the critical Ca level for Spanish peanuts could be estimated. Colwell and Brady (9) obtained correlation coefficients of 0.948 between yield response to Ca additions and exchangeable Ca and 0.898 between yield responses to Ca and percent Ca saturation with Virginia Bunch peanuts. Exchangeable Ca in the soils ranged from 0.21 to 2.21 m.e. per 100 grams.

Different varieties and strains of Spanish peanuts were found to differ greatly in their response to lime in Arkansas studies by McClelland (18). Unfortunately, no information was given relative to the experiment design, replications, or significant differences. However, this work points out the tremendous variation in response to plant nutrients that may be encountered between different varieties and even different strains of Spanish peanuts.

Middleton et al. (22) compared the response of Virginia Bunch, North Carolina Runner, Spanish 2B, and White Spanish peanut varieties to applications of calcium. Virginia Bunch gave significant yield increases to gypsum applications on four soils ranging in exchangeable Ca from 0.21 to 1.15 m.e. per 100 grams. N. C. Runner yields were significantly increased on three of the same soils having 0.21, 0.54, and 0.54 m.e. of Ca, but not on the soil having 1.15 m.e. of Ca. Seemingly, Spanish 2B responded somewhat erratically, giving significant yield increases on the soils having exchangeable Ca levels of 0.21, 0.54, and 1.15 m.e. per 100 grams, while no significant yield increase was observed on another soil that had 0.54 m.e. of exchangeable Ca. Yields of White Spanish peanuts were increased with gypsum only on the soil with 0.21 m.e. of exchangeable Ca. In this experiment, the Virginia Bunch variety was found to have the highest calcium requirement, followed by North Carolina Runner, Spanish 2B, and White Spanish, in that order.

Potassium. Peanuts absorb relatively large amounts of K compared to the other plant nutrients. Even when grown on soils relatively low in K, application of K fertilizers often results in little or no yield increases. Contrary to the speculation of many investigators, Reid and York (26) found that peanuts (variety not given) have no unique ability for extracting K from soil that is unavailable to other plants. This work indicates that the reason peanuts often do not respond to K fertilizers lies in the fact that the peanut can more efficiently use potassium than certain other crops. Consequently, peanuts can make good yields on much less K than can many other crops. Colwell, Brady, and Reed (10) in North Carolina found that the yields of Virginia Bunch peanuts were increased (no indication of significance) by muriate of potash on a Norfolk sand with 0.04 m.e. of exchangeable K, while on a Norfolk sandy loam with 0.10 m.e. of exchangeable K, no increase in yields was observed where potassium had been applied. The Ca requirement had been met on both soils.

Approximately 75 pounds of exchangeable K per acre was found to be adequate for maximum yields of Dixie runner peanuts on a Red Bay fine sandy loam in Florida by Robertson et al. (27). Significant yield drecreases resulted when more than 12.5 pounds per acre of K as potassium chloride was applied.

Of three soils in North Carolina that had exchangeable K levels of 0.04 m.e., on only one were Spanish 2B, Virginia Bunch, and White Spanish peanut yields significantly increased by the application of potassium (22). Yields of N. C. Runner peanuts were not significantly increased on any of the three soils. On another soil with 0.12 m.e. of exchangeable K, yields of White Spanish peanuts were significantly decreased by the application of K, with insignificant effects on the other varieties. Gypsum had been applied to all four soils.

Since Ca has been shown to be so important for fruit fill, the Ca requirements of the plant must be met before responses to K will be exhibited. Brady and Colwell (5) concluded that K could be expected to increase yields only where there was an adequate supply of Ca and a very low level of soil K.

Several workers (10, 22) agree that where K increases yields, it does so because vegetative growth is stimulated and a larger number of fruit are formed. K has been found (5, 10, 22) to have little effect on kernel development.

Phosphorus. Robertson et al. (27) studied the response of Dixie Runner peanuts to five levels of N, P, and K and two levels of lime in a complete factorial arrangement on a Red Bay fine sandy loam in western Florida for four consecutive years. These investigators reported a highly significant yield response to P every year. They concluded that when the soil was adequately limed, maximum yields were obtained when the soil contained 19.6 pounds per acre of Truog phosphorus (0.002 N H_2SO_4 extracting solution buffered at pH 3 with $(NH_4)_2SO_4$) or 48 pounds per acre of Bray No. 2 phosphorus (0.03 N NH_4F in 0.1 N HCl extracting solution; extractant to soil ratio of 10:1). A close examination of their paper reveals that it is difficult to evaluate accurately the results of their experiment for several reasons. First, the source of P was superphosphate, which contains about 56 percent $CaSO_4$ by weight (19). Some peanut varieties are very sensitive to Ca and respond readily to gypsum applications. Therefore, the significant yield response each year to applications of superphosphate may have been due to Ca or sulfur rather than P, or to all three. This situation was pointed out by York and Colwell (34) who observed that some of the yield increases that have been attributed to P may have been due to the Ca contained in the phosphatic fertilizers. Second, there is some question that the lime treatment actually gave split plots that were adequately limed, as these workers stated. One ton of lime was applied the first year and two tons per acre the third year. Their data show that the exchangeable Ca levels in the limed plots were lower the first and third years than the second and fourth years. That the level of soil Ca may have been limiting is suggested by the fact that the lime treatment was highly significant the second and fourth years when soil Ca levels were highest. Also, much higher F values were obtained for the main effects of P the first and third years when soil Ca was lowest. Of course, it may be possible that the lime increased the availability of the native soil phosphorus. Third, there was only one replication of each plot.

In Senegal, Ollagnier and Prevot (24) found that no response to P fertilizers can be expected unless the total soil P is below 150 parts per million. The work of Evelyn and Thornton (11) in the Gambia tend to support this generalization. Highly significant yield responses were obtained from the application of superphosphate at three locations whose total P levels were below 150 ppm, but no response was observed at a location that had a total P level greater than 150 ppm. However, since exchangeable Ca was low in the soils that gave responses to superphosphate, it may be that the effects were at least partly due to the Ca and S in the superphosphate, even though the authors discount this possibility.

Lynd and Brensing (17) obtained no yield response of Spanish peanuts (Argentine variety) to triple superphosphate on a Dougherty loamy sand which had 17-25 ppm of Bray No. 1 phosphorus.

Compared to the other primary plant nutrients, relatively small amounts of P are absorbed by the peanut plant. York and Colwell (34) think this suggests that only on soils extremely low in P would phosphatic fertilizers increase peanut yields.

Critical Levels of Phosphorus in Nutrient Solutions

As nothing is reported in the literature concerning critical phosphorus levels of peanuts grown in nutrient solutions, critical levels of phosphorus for some other legumes will be reviewed.

Howell (15) grew three varieties of soybeans to maturity in sand cultures at eight levels of phosphorus ranging from 0.4 to 112 ppm of P. Solutions were changed at 10-11 day intervals. Two of the varieties had maximum growth at 10 ppm P and the other variety at 22.4 ppm P. Decreased growth occurred at concentrations both above and below these P concentrations.

Biddulph and Woodbridge (1) reported that phosphorus levels as low as 5.0×10^{-5} M (1.55 ppm) supplied at the rate of one liter per plant per four days (less than 0.4 mg. P/plant/day) was sufficient to meet the phosphorus requirement of soybeans having several trifoliate leaves.

Ulrich and Berry (31) grew lima beans in nutrient solutions at ten P concentrations ranging from zero to 124 ppm P. The plants were grown in 20 liters of solution which was not changed during the six weeks the plants were grown. Dry weight of top growth was still increasing at the highest P level (124 ppm), however, dry root weight reached a maximum at 1.94 ppm P and remained approximately the same as the P concentration increased above that level. Dry weights of tops were plotted against the P content of various plant parts to give nutrient calibration curves. Using the P content of the second leaf petioles as being most indicative of the P status of the plant, the estimated critical P level of the petioles was set at 570 ppm of total phosphorus.

Wilkinson and Gross (33) grew ladino clover plants in nutrient solutions at three levels of P (1.55, 6.2, and 31.0 ppm P) for 62 days. They were grown in pots containing two liters of solution and the solution was changed seven times during the growth period. The 6.2 ppm P level gave significantly higher top and root weights than the 1.55 or the 31.0 ppm P levels. The phosphorus content of the leaves and roots significantly increased as the phosphorus levels increased.

CHAPTER III

METHODS AND MATERIALS

Experiment I

This greenhouse experiment was designed to evaluate the effects of decreasing the level of soil nutrients with a silica sand dilution method on the growth of Argentine peanuts (*Arachis hypogaea* L.).

The soil used in this experiment has been tentatively classified as a Cobb loamy sand and was obtained in the western part of Caddo county (NW ¼, Sec. 6, T9N, R13W). This soil is probably representative of much of the soil in the Caddo county area on which peanuts are grown. This site was also chosen because the soil profile had not been disturbed by deep-plowing. This soil has been under cultivation for many years and only small amounts of fertilizers have been applied in recent years. Only the surface soil (0-6 in.) was used, which was obtained in February of 1965.

Samples of the soil used in the pots were crushed so that all aggregates would pass an eighteen mesh sieve in preparation for laboratory analyses. The results of the laboratory tests are shown in Table I.

Samples of the silica sand* were analyzed for exchangeable cations and available phosphorus. Eight replicate samples had mean values

---

*Ottawa Flint Shot, Ottawa Silica Co., Ottawa, Illinois.

TABLE I

CHEMICAL CHARACTERISTICS OF COBB LOAMY SAND*

Percent organic matter	0.43
Available phosphorus (ppm)	47.5
Cation exchange capacity (m.e./100 g.)	3.67
Exchangeable cations (m.e./100 g.)	
Calcium	2.57
Magnesium	3.73
Potassium	0.65
Sodium	0.06
Soil reaction (water paste pH)	6.7

*Values are the means of three samples.

of 15.7, 14.0, 3.2, and 7.3 ppm of exchangeable Ca, Mg, K, and Na, respectively. A mean value of 0.7 ppm Bray No. 1 phosphorus was found for two replicate samples of the sand.

The soil pH was determined with a Bechman glass electrode pH meter. Organic matter content was measured with the potassium dichromate wet combustion method of Schollenberger (29), modified by Harper (12). The cation exchange capacity was determined in the following manner: A five gram sample of soil was shaken and centrifuged four times with 25 ml. of neutral 1 N NH_4OAc. The soil was then washed two times with 95 percent ethanol containing 1 ml. of 1 N NH_4OH per liter and two times with 95 percent ethanol. The alcohol washing was performed in the same manner as the ammonium saturation. The adsorbed ammonium was then determined by Kjeldahl distillation. Exchangeable cations were determined from the ammonium acetate extract on a Beckman Model DU flame spectrophotometer. Available phosphorus was determined by a method of Bray and Kurtz (7) using the weak extracting solution (0.025 N HCl) and one gram of soil to 20 ml. of extracting solution.

The soil used in the greenhouse study was dried and pulverized and seived through a quarter-inch screen. The appropriate amounts of soil and silica sand (Table II) were then mixed together and placed in two-gallon glazed pots.

TABLE II

COMPOSITION OF PEANUT GROWTH MEDIA

Percentage of growth media by weight Soil	 Sand	Kilograms of soil added per pot
100	0	9.40
80	20	7.52
60	40	5.64
40	60	3.76
20	80	1.88
0	100	0.00

The pots were arranged on a greenhouse benchtop in a randomized complete block design with three replications. Four inoculated

Argentine peanut seeds were planted in each pot on March 28, 1965. Plants had emerged in all pots six days after planting and cotyledons were clipped within 2-3 days after emergence. Plants were thinned to one plant per pot on April 15, leaving plants with as uniform growth as possible. The plants were watered daily with distilled water as needed and daily flower counts were made.

The plants became infested with red spider mites about the second week in June. Control was not obtained with several applications of malathion and various other insecticides. The mites were finally controlled with an application of kelthane on June 26.

On July 1 (95 days after planting), four cores of the growth media, the entire depth of the pot, were taken from each pot and the plants were removed from the pots and separated into five parts: leaves, stems, roots, pegs without or with very small pods, and pegs with fully developed pods. The aerial portion of the plants was soaked in 0.1 N HCl for approximately 30 seconds and then rinsed in three washes of distilled water to remove dust and similar foreign material in preparation for chemical analysis. The roots were recovered by washing the growth media from the pots with a jet of tap water. The fruit were air dried and all other plant parts were dried in a forced-air oven at 200 degrees F.

The air-dry fruit were shelled and the kernels were separated into three sizes: kernels held on a screen with 15/64 X 3/4-inch slotted openings, kernels passing the 15/64 X 3/4-inch screen, but held on a screen with circular 16/64-inch openings, and kernels passing through the screen with circular 16/64-inch openings.

The leaves were ground in a Wiley mill and analyzed for total phosphorus by the method of Shelton and Harper (30).

Experiment II

This experiment was designed to study the effect of four widely spaced phosphorus concentrations on the growth of Spanish peanuts in sand cultures.

A special type of culture vessel was constructed for this experiment which presented a large surface area for the plants to peg into and produce fruit. This was felt necessary because the lower branches of Spanish peanuts become almost prostrate as the plants grow older, consequently, pegs will be formed at some distance from the center of the plant. Unless a large pegging surface is available, some of the pegs normally will grow outside the culture vessel and thus never have an opportunity to produce fruit. These culture vessels were constructed by attaching a circular galvanized livestock feeding pan to the top of a two gallon glazed pot with epoxy cement. A circular opening, 6-7 inches in diameter, was cut in the center of the pan and the inside of the pan was coated with black enamel paint. Caulking compound was applied to the outside of the junction of the pan and the pot to insure water tightness.

The white silica sand* used to fill the culture vessels was treated in the following manner: First, it was soaked in 5 N NaOH for 12 hours, then rinsed with distilled water until the pH of the

*Ottawa Flint Shot, Ottawa Silica Co., Ottawa, Illinois.

effluent was neutral. Next it was soaked in 3 N HCl for 12 hours, the HCl removed, and soaked again in 3 N HCl for another 12 hours. Then the sand was rinsed with distilled water until the effluent was free of chlorides. The sand was dried and 26 Kg. was added to each culture vessel.

The concentrations of the salts used to supply the macronutrients in the nutrient solutions used in this experiment were those used by Van Andel, et al. (32). The sources and concentrations of the micronutrients, except iron, were the same as those used by Reid and York (25). All nutrient solutions were prepared using reagent grade chemicals and deionized water. The basic composition of the nutrient solutions is shown in Table III and the P and K concentrations in the differential P treatments are shown in Table IV.

Potassium bicarbonate was used to obtain the same ionic concentration in all of the four P levels.

The experiment was conducted in a greenhouse using a completely randomized design with three replications. The culture vessels were saturated with the nutrient solutions (approximately 3.5 liters per pot) and allowed to evaporate several days to alleviate the saturated condition in the surface of the sand. Four uninoculated Argentine peanut seeds were planted in each pot on December 28, 1965. Seedlings had emerged in all pots by the fifth day after planting. Seven days after planting the plants were thinned to two plants per culture vessel and the cotyledons were removed at this time.

The plants were watered daily with sufficient distilled water to keep the pots saturated to within 2-4 inches from the top of the

TABLE III

BASIC COMPOSITION OF NUTRIENT SOLUTIONS

Compound	Nutrient Supplied	Concentration of nutrient millimoles/liter	ppm
KNO_3	K	2.5	97.8
	NO_3	2.5	177.5
$Ca(NO_3)_2$	Ca	1.5	60.1
	NO_3	3.0	213.0
$MgSO_4$	Mg	1.0	24.3
	S	1.0	32.1
$(NH_4)_2SO_4$	NH_4	1.0	18.0
	S	0.5	16.0
H_3BO_3	B		0.5
$MnCl_2 \cdot 4H_2O$	Mn		0.5
	Cl		0.6
$ZnSO_4 \cdot 7H_2O$	Zn		0.05
$CuSO_4 \cdot 5H_2O$	Cu		0.02
$H_2MoO_4 \cdot H_2O$	Mo		0.01
NaHFe DTPA*	Fe		1.00

*Monosodium-hydrogen-ferric diethylenetriamine pentaacetate (Geigy 330-10% Fe).

TABLE IV

CONCENTRATIONS OF P AND K FURNISHED BY KH_2PO_4 AND $KHCO_3$

IN THE DIFFERENTIAL P NUTRIENT SOLUTION TREATMENTS

KH_2PO_4 moles/liter	$KHCO_3$ moles/liter	Phosphorus ppm	Phosphorus moles/liter	Potassium ppm
5.0×10^{-6}	5.0×10^{-3}	0.155	5.0×10^{-6}	195.7
5.0×10^{-5}	5.0×10^{-3}	1.550	5.0×10^{-5}	197.5
5.0×10^{-4}	4.5×10^{-3}	15.500	5.0×10^{-4}	195.5
5.0×10^{-3}	0.0	155.000	5.0×10^{-3}	195.5

sand. Initially, the nutrient solutions were changed at approximately four-week intervals. Later, the solutions were changed at two-week intervals. The solutions were removed from the pots by attaching a vacuum pump to a gas dispersion tube which extended from about four inches above the sand to the bottom of each pot. After the old solution had been removed, the sand in the pots was resaturated with fresh nutrient solutions. The first two times the nutrient solutions were removed, a distilled water rinse was used, but this was discontinued for the later removals. The used solutions were analyzed for phosphorus by Jackson's Method I (16).

A daily record of flower production was made during the flowering period. All plants were harvested May 4, 1966 (126 days after planting) and separated into five parts: leaflets, stems (including petioles), roots, pegs with pods, and pegs without pods. The roots were washed from the sand with a jet of tap water. The plant parts were dried and the kernels were separated according to size as in Experiment I. The leaves, stems, and roots were ground and analyzed for total phosphorus also as in Experiment I.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

Uniformly lowering the soil nutrient levels with an inert sand dilution technique had some very interesting effects on the vegetative and reproductive characteristics of the peanuts. As expected, the plants grown in the zero percent soil growth media were very stunted and exhibited deficiency symptoms which were not observed on the plants in growth media containing soil. Approximately a month after planting, the leaflets of these plants growing in 100 percent silica sand remained folded both night and day. Normally, the leaflets fold up at night and then reopen during the day. Chlorotic and then necrotic areas on the leaflets also began to appear in about one month. In addition, some of the older leaflets were observed to have their tips pointed in a downward direction. By the sixth week after planting, a very dark reddish-purple color had developed on the lower part of the main stems of these plants. By the end of the growth period, most of the lower leaves had fallen off, but the plants were still alive, having only a few small green leaves at the top of the plants. Visual deficiency symptoms were not observed on any of the plants in the growth media containing soil.

The stunted condition of the plants growing in the zero percent soil treatment is shown by the small amount of vegetative growth produced by these plants. As shown in Table V, the dry weight of the leaves and stems of these plants was significantly lower than the other treatments. As the soil level in the growth media increased from 20 to 100 percent, there was a fairly uniform decrease in dry weight of the leaves and stems, which was somewhat unexpected. In fact, the 20 percent soil treatment gave a significantly higher yield of leaves and stems than either the 80 or the 100 percent soil treatments.

Root weights are not presented because it was not possible to obtain reasonably accurate values for two reasons. First, a substantial portion of the roots in some of the pots was not recovered due to partial disintegration of the root systems. Second, many grains of the silica sand became tightly attached to the roots and it was impossible to remove the sand grains without further disintegration of the roots.

The total phosphorus content of the leaves was significantly higher at the 100 percent soil level than at the other soil levels except the 60 percent soil level. The leaves from the 20 percent soil level had a significantly lower total phosphorus content than the other soil levels, except the zero percent level which was significantly lower than all other soil levels (Table V).

Some of the reproductive characteristics of the peanuts were also affected by the amount of soil in the growth media. The number of flowers produced at the zero percent soil level was significantly

TABLE V

VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF ARGENTINE PEANUTS AS INFLUENCED BY DIFFERENT AMOUNTS OF SOIL IN THE GROWTH MEDIUM*

% of soil in growth medium	Dry wt. of stems and leaves (g.)	Total P in leaves (%)	Number of flowers	Number of pegs	Kernels held on 15/64" X 3/4" screen Number	Weight (g.) Total	Weight (g.) Mean	Flowers producing pegs (%)	Flowers producing fruit (%)	Pegs producing fruit (%)
0	0.87 a**	0.121 a	10.0 a	***	***	***	***	***	***	***
20	18.53 c	0.165 b	84.0 c	47.0	36.7 c	12.99 c	0.356 a	55.3 a	24.6 a	44.9 a
40	16.20 bc	0.216 c	66.0 b	40.3	32.3 b	10.43 b	0.322 a	61.0 a	28.9 a	48.0 a
60	15.93 bc	0.231 cd	67.7 b	35.0	27.3 a	8.38 a	0.307 a	52.0 a	27.2 a	52.1 a
80	14.70 b	0.217 c	60.3 b	36.0	30.3 ab	9.55 ab	0.315 a	59.3 a	32.4 a	54.3 a
100	13.53 b	0.243 d	73.7 bc	34.7	28.0 a	8.40 a	0.303 a	47.7 a	21.1 a	44.3 a
F-value	24.81	61.08	22.6	1.78	9.26	18.11	2.00	2.29	2.59	0.82
5% level†	3.48	3.48	3.48	4.12	4.12	4.12	4.12	4.12	4.12	4.12
1% level†	6.06	6.06	6.06	7.85	7.85	7.85	7.85	7.85	7.85	7.85
C.V. (%)‡	16.4	5.1	15.6	17.8	6.9	7.8	7.8	11.3	16.9	15.8

*All values are the means of three replications.
**Means within a column having different letters are significantly different at the 5% level.
***No value obtained for this treatment. Statistical analysis based on five treatments.
†F-values required for significance at the indicated level of probability.
‡Coefficient of variation.

lower than at the other soil levels (Table V). However, flower production at the 20 percent soil level was significantly higher than flower production at the 40, 60, and 80 percent soil levels, but not at the 100 percent soil level. The number of pegs produced per pot was not significantly affected by the soil level in the growth media, excluding the zero percent soil level in which no pegs were produced (Table V).

Total kernel yield, expressed either as the number of kernels held on a 15/64 X 3/4-inch screen or as the air-dry weight of the kernels held on a 15/64 X 3/4-inch screen, was significantly higher at the 20 percent soil level than at the higher soil levels. Kernel yield at the 40 percent soil level was significantly higher than the 60 and 100 percent soil levels, but not the 80 percent soil level. The mean weights of kernels held on a 15/64 X 3/4-inch screen were not significantly different among the five soil levels. The number of smaller kernels produced per pot and their mean weights are shown in Table VI.

Reproductive efficiency was measured by computing the percentage of flowers producing pegs, the percentage of flowers producing fruit, and the percentage of pegs producing fruit. None of these components of reproductive efficiency were significantly affected by the amount of soil in the growth medium (Table V).

The theoretical levels of exchangeable cations and available phosphorus in the various media are shown in Table VII. Since the zero percent soil level was extremely deficient in all plant nutrients, it will not be considered in the following discussion regarding critical levels of nutrients.

TABLE VI

NUMBER AND MEAN WEIGHT OF KERNELS HELD ON AND PASSING A SCREEN WITH CIRCULAR 16/64-INCH OPENINGS*

	Number of kernels per pot				Air-dry weight (grams per pot)			
	Replicate				Replicate			
% Soil**	1	2	3	$\bar{X}$	1	2	3	$\bar{X}$
				Held on screen				
20	1	4	2	2.3	0.284	0.196	0.304	0.261
40	6	0	-***	3.0	0.182	0.000	-***	0.182
60	7	3	4	4.7	0.206	0.195	0.274	0.225
80	4	1	4	3.0	0.220	0.273	0.158	0.217
100	0	2	1	1.0	0.000	0.272	0.135	0.204
				Passed screen				
20	0	4	0	1.3	0.000	0.149	0.000	0.149
40	0	0	-***	0.0	0.000	0.000	-***	0.000
60	6	2	0	2.7	0.170	0.166	0.000	0.168
80	0	4	3	2.3	0.000	0.170	0.147	0.158
100	0	0	1	0.3	0.000	0.000	0.062	0.062

*Does not include kernels which were held on a 15/64 X 3/4-inch screen.
**No kernels were produced at the zero percent soil level.
***Missing value.

TABLE VII

AMOUNT OF EXCHANGEABLE Ca, Mg, and K IN THE GROWTH MEDIA

AT THE BEGINNING OF THE EXPERIMENT*

% Soil	Calcium		Magnesium		Potassium	
	ppm	m.e.**	ppm	m.e.	ppm	m.e.
100	490	2.45	445	2.71	250	0.64
80	392	1.96	356	2.97	200	0.51
60	294	1.47	267	2.22	150	0.38
40	196	0.98	178	1.48	100	0.26
20	98	0.49	89	0.74	50	0.13

*Values were computed from the data on exchangeable cations given in Table I and are not actual measurements.
**Milliequivalents per 100 grams of soil.

The exchangeable Ca level in the 20 percent soil growth medium of 98 ppm is lower than the critical exchangeable Ca level of 120-160 ppm for Spanish peanuts reported by Rogers (28). According to the results obtained from Experiment I, the critical Ca level for the Argentine variety was lower than the value given by Rogers. However, it must be pointed out that the type of clay has been found to have an influence on the Ca requirement of large-seeded types of peanuts by Mehlich and coworkers (20, 21). Their experiments have shown that Ca is more available to the fruit in a kaolinite system than in a bentonite system. It seems possible that the same would be true for Spanish peanuts as well as for the large-seeded types. Since the clay fraction of the soil used in this experiment is probably of the 2:1 type, it may not be valid to compare the critical Ca level found by Rogers to the results of this experiment because the clay fraction of the soil used by Rogers was the 1:1 type.

A calcium deficiency in peanuts seems to manifest itself first in reducing the number of filled ovarian cavities. However, an examination of the fruit revealed that there was no increase in unfilled cavities at the 20 percent soil level over the other soil levels. The above fact and the data presented in Table V indicate that a Ca deficiency did not exist at the 20 percent soil level. Therefore, 98 ppm of exchangeable Ca apparently was sufficient for good growth and reproduction of Argentine peanuts in this experiment.

There were no indications in the literature concerning the critical level of Mg for peanuts, but Brady and Colwell (5) reported that Mg is needed in lesser quantities than Ca. Since exchangeable Mg was higher than Ca in the Cobb soil, it was assumed that Mg was adequate at all soil levels.

The critical soil levels of exchangeable K have not been reported in the literature for any peanut variety. However, Spanish 2B and White Spanish varieties failed to respond to K when the exchangeable K level in the soil was as low as 0.04 m.e./100 g. (22). The data from the current experiment, given in Table V, indicate that potassium was not deficient at the 20 percent soil level, which contained 0.13 m.e. of exchangeable K.

Only two references (24, 27) were found which attempted to give a critical level of phorphorus for peanuts. As discussed in the literature review, there is some question as to the validity of the conclusions of these investigators. Robertson et al. (27) report that 9.8 ppm of Truog phosphorus or 24 ppm of Bray No. 2 P was the critical P level on a western Florida soil. Since only Bray No. 1 P was determined on the soil used in this experiment, it is difficult to compare their critical P levels with the P levels in the growth media used in this experiment. Ollagnier and Prevot (24), reported that 150 ppm of total phosphorus was the critical P level in Senegal soils. Since total P data for the soil used in this experiment was not available, no comparison can be made. The kernel and vegetative yields shown in Table V indicate that P was probably not deficient in any of the soil levels, including the 20 percent soil level which had only 9.5 ppm of available P.

Samples of the culture media were obtained when the plants were harvested and analyzed for available P. As shown in Table VIII, one crop of peanuts had little or no effect on the amount of available P in the culture media.

TABLE VIII

AMOUNT OF AVAILABLE P* IN THE GROWTH MEDIA AT THE BEGINNING AND END OF THE EXPERIMENT

% Soil	Available P (ppm) At beginning of experiment**	At end of experiment	(Avail. P at end / Avail. P at beginning) X 100
100	47.5	48.2	101.5
80	38.0	36.5	96.0
60	28.5	26.2	91.9
40	19.0	19.8	104.2
20	9.5	9.4	98.9

*Bray No. 1 phosphorus.
**Values were computed from the data on available P given in Table I and are not actual measurements.

Experiment II

The phosphorus concentrations of the nutrient solutions used in this experiment are shown in Table IV. Since the solutions were changed at intervals, the P concentration in the solutions decreased between changes due to uptake of P by the plants. In view of this fact, the P levels will be shown as the total amount of P added to the culture vessels during the entire experiment.

About five weeks after planting, the plants in the two lower P levels (4.34 and 43.4 mg. P) developed a reddish-purple color on the lower part of the main stems. This was suspected as a P deficiency symptom since Burkhart and Collins (8) found that the stems of phosphate deficient peanut plants become dark red in color. However, after about two months this reddish-purple color had also developed on all of the plants growing in the higher P concentrations. Therefore, it is highly questionable that the reddish-colored stems exhibited by the plants growing in the two lower levels of P were actually P deficiency symptoms. When these same plants were about two months old, the lower leaves become chlorotic, then necrotic, and fell from the plants. This condition become progressively worse until the end of the experiment. Chlorosis of the older leaves of peanut plants in late stages of phosphate deficiency has also been reported by Burkhart and Collins (8).

The lower leaves of the plants growing in the highest P concentration (4340 mg. P) developed brown necrotic areas approximately 13 days after planting. This condition disappeared after a few weeks and then reappeared in about 14 weeks and was visible until the end

TABLE IX

VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF ARGENTINE PEANUTS AS INFLUENCED BY FOUR LEVELS OF P IN SAND CULTURES.*

P level (mg. p/pot)	Dry weight of leaves and stems (g/pot)	Number of flowers per pot	Number of pegs per pot	Flowers producing pegs (%)
4.34	2.61 a**	19.7 a	3.3 a	12.1 a
43.4	4.85 a	51.0 ab	12.7 a	21.5 a
434.	18.75 b	185.0 c	61.7 a	29.1 a
4340.	14.53 b	151.7 bc	51.3 a	29.2 a
F-value***	10.40	4.26	1.76	1.06
C.V. (%)	40.8	65.1	115.7	59.5

*All values are the means of three replications.
**Means within a column having different letters are significantly different at the 5% level.
***F-values required are 4.07 and 7.59 at the 5% and 1% levels, respectively.

of the experiment.

The dry weight of the leaves and stems produced by the plants grown at the two higher levels of P (434 and 4340 mg. of P) was significantly greater than that produced at the two lower levels (4.34 and 43.4 mg. of P), as shown in Table IX.

The number of flowers produced at the highest P level was significantly greater than the number produced at the two lower P levels and the number of flowers produced at the lowest P level was significantly lower than the number produced at the two higher P levels (Table IX).

Neither the number of pegs produced per pot nor the percentage of flowers producing pegs was significantly affected by the different P levels (Table IX). Fruit were produced in only four pots; in one pot at the third highest P level (43.4 mg. P) and in three pots at the second highest P level (434 mg. P). Kernel yield and size distribution are given in Tables X and XI.

The fact that no fruit formed on the plants growing at the highest P level indicates that formation of fruit may be inhibited by high levels of P. Apparently the highest level of P had some effect on fruit development after the pegs entered the sand, because the tips of the pegs which were in the sand were black in color and only slightly enlarged.

In view of this fruit inhibition and the necrosis of the older leaves of the plants growing in the highest P level, which was previously discussed, three reports (1, 8, 23) concerning phosphate injury are of interest. Moore (23) reported that concentrations of P

TABLE X

SIZE DISTRIBUTION OF KERNELS (EXPERIMENT II)

Phosphorus level (mg. P/pot)*	Number of kernels Replicate 1	2	3	$\bar{X}$
	Held on a screen with 15/64 X 3/4-inch openings			
43.4	0	0	0	0.0
434	19	3	2	8.0
	Held on a screen with circular 16/64" openings			
43.4	0	0	1	0.3
434	5	1	0	2.0
	Passed a screen with circular 16/64" openings			
43.4	0	0	5	1.7
434	12	3	2	5.7

TABLE XI

KERNEL YIELD AND MEAN KERNEL WEIGHTS (EXPERIMENT II)

Phosphorus level (mg. P/pot)*	Replicate 1	2	3	$\bar{X}$
	Air-dry kernel weight (g./pot)			
43.4	0.000	0.000	0.626	0.209
434	5.807	1.207	0.586	2.533
	Mean kernel weights (g.)			
43.4	0.000	0.000	0.104	0.104
434	0.161	0.172	0.146	0.160

*No kernels were produced at the lowest and highest levels of P (4.34 and 4340 mg. of P).

ordinarily used in nutrient solutions were injurious to a Spanish variety of peanuts. However, neither the P concentrations which resulted in the P toxicity nor the type of injury were indicated. Burkhart and Collins (8) used a P concentration of 31 ppm, which they felt was sufficiently low to prevent phosphate toxicity. These investigators (8) stated that "phosphate injury as evidenced by excessively high concentrations of soluble phosphate in injured foliage appears to be associated with poorly noduled (sic) plants and high phosphate supply in the root medium." There was no description of the injured foliage nor was any data presented in their paper to support their conclusion that the degree of nodulation is an important factor in the utilization of phosphate by the peanut plant. Biddulph and Woodbridge (1) reported that soybeans became chlorotic when grown in a nutrient solution which had a P concentration of 155 ppm. Although peanut plants in the current experiment were also grown at approximately 155 ppm of P, the plants did not become chlorotic.

The leaves, stems and roots of the plants were analyzed for total P and the results are shown in Figure 1 and Table XII. For all three plant parts, the P content was significantly higher in the plants grown at the highest level of P than the three lower P levels. The total P values for the roots may not be of great significance with respect to absorbed P since the amount of P measured probably included both absorbed and adsorbed P (1).

The considerable amount of variation encountered among replications in this experiment is somewhat difficult to explain. The most probable explanation concerns the duration and intensity of the light

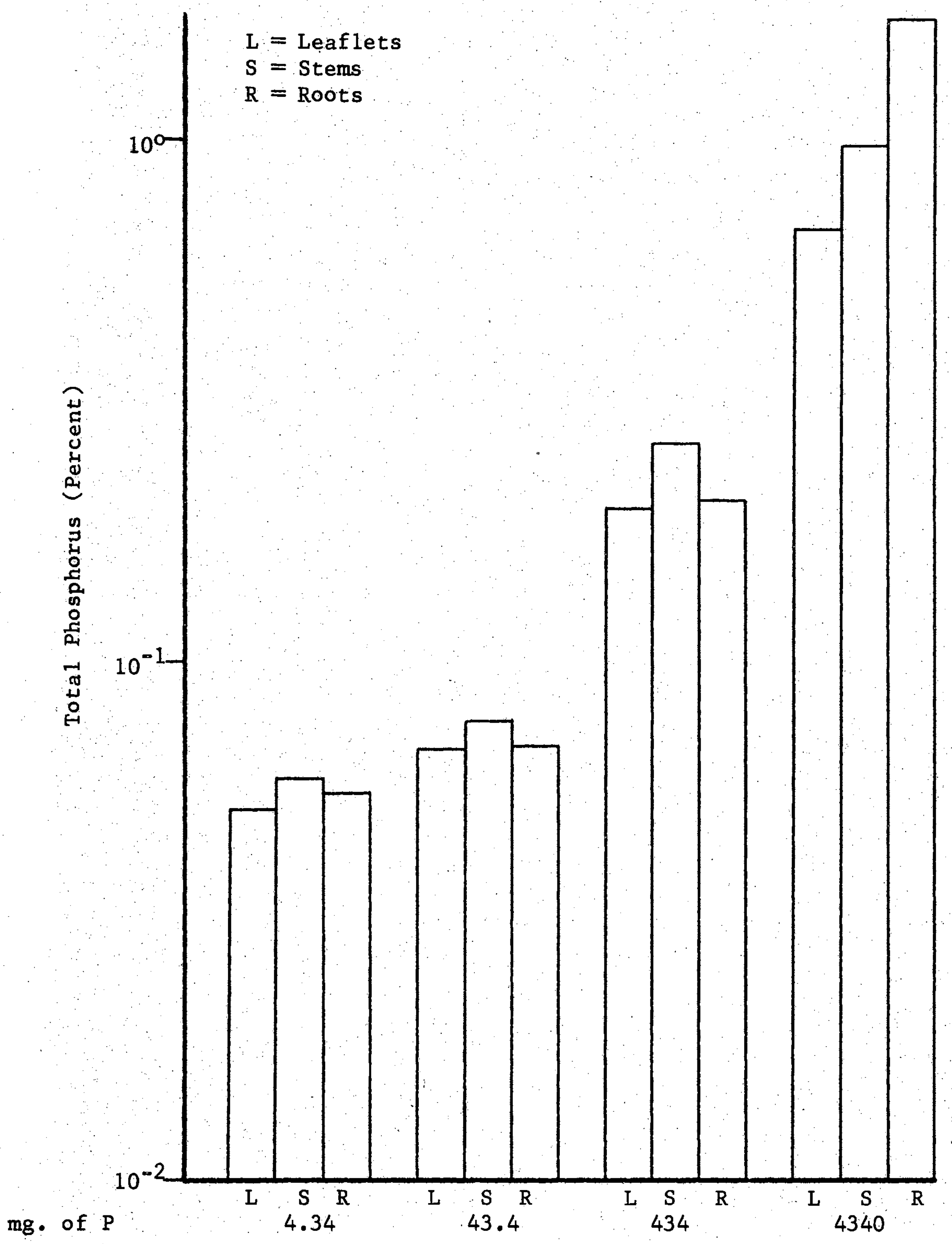

Figure 1. Total P Content of Peanut Plant Parts (Experiment II).

TABLE XII

TOTAL P CONTENT OF PEANUT PLANT PARTS (EXPERIMENT II)*

P level (mg. P/pot)	Total Phosphorus (%) Leaves	Stems	Roots
4.34	0.052 a**	0.060 a	0.056 a
43.4	0.68 a	0.077 a	0.069 a
434.	0.197 a	0.263 a	0.204 a
4340.	0.680 b	0.987 b	1.731 b
F-value***	20.14	27.83	123.06
C.V. (%)	45.8	41.3	24.7

*All values are the means of three replications.
**Means within a column having different letters are significantly different at the 5% level.
***F-values required are 4.07 and 7.59 at the 5% and 1% levels, respectively.

available to the plants. The early growth of the plants occurred at a time when the daylength was short and the light intensity was oftentimes low, due to cloudy weather and the angle of the sun. Since the peanut plant is not known to be sensitive to daylength (14), it is felt that low light intensities during the early part of the growth period may have been responsible for much of the variation among replications. The evidence for this is that some of the plants flowered much later than other plants and that the central stem of most of the plants grew abnormally tall, as though they were under dark conditions. Perhaps there was sufficient genetic variation among the plants with respect to the intensity of light required for normal development to cause considerable variation in the plants' growth and development.

CHAPTER V

SUMMARY AND CONCLUSIONS

Certain vegetative and reproductive characteristics of Argentine peanuts as affected by uniformly lowering the level of the soil nutrients in a Cobb loamy sand were studied in a greenhouse experiment (Experiment I). Plant growth was severely limited by the low level of nutrients in the zero percent soil level. The plant nutrient levels in the growth medium containing the second lowest amount of soil (20 percent) were not sufficiently low to affect adversely the growth and reproduction of the peanuts.

The response of Argentine peanuts in sand cultures to four widely-spaced phosphorus concentrations was studied in a greenhouse experiment (Experiment II). The two lower phosphorus levels (4.34 and 43.4 mg. P/pot) definitely limited the growth and reproduction of the peanuts. The highest phosphorus level (4340 mg. P/pot) completely inhibited fruit formation by preventing the pegs from developing after they entered the growth medium. The second highest phosphorus level (434 mg. P/pot) was superior to the highest phosphorus level on the basis of kernel production, and possibly on the basis of plant weight and flower production. The total phosphorus content of the plants grown at the highest phosphorus level was substantially higher than that of the plants grown at the lower phosphorus levels.

LITERATURE CITED

1. Biddulph, O. and C. G. Woodbridge. The uptake of phosphorus by bean plants with particular reference to the effects of iron. Plant Physiol. 27:431-444. 1952.

2. Bledsoe, R. W., C. L. Comar, and H. C. Harris. Absorption of radioactive calcium by the peanut fruit. Science 109:329-330. 1949.

3. Bledsoe, R. W. and H. C. Harris. The influence of mineral deficiency on vegetative growth, flower, and fruit production and mineral composition of the peanut plant. Plant Physiol. 25: 63-77. 1950.

4. Brady, N. C. The effect of period of calcium supply and mobility of calcium in the plant on peanut fruit filling. Soil Sci. Soc. Amer. Proc. 12:336-341. 1947.

5. Brady, N. C. and W. E. Colwell. Yield and quality of large-seeded type peanuts as affected by potassium, magnesium, and calcium. Jour. Amer. Soc. Agron. 37:429-442. 1945.

6. Brady, N. C., J. F. Reed, and W. E. Colwell. The effect of certain mineral elements on peanut fruit filling. Jour. Amer. Soc. Agron. 40:155-167. 1948.

7. Bray, R. H. and L. T. Kurtz. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:39-45. 1945.

8. Burkhart, L. and E. R. Collins. Mineral nutrients in peanut plant growth. Soil Sci. Soc. Amer. Proc. 6:272-280. 1941.

9. Colwell, W. E. and N. C. Brady. The effect of calcium on yield and quality of large-seeded type peanuts. Jour. Amer. Soc. Agron. 37:413-428. 1945.

10. Colwell, W. E., N. C. Brady, and J. F. Reed. Fertilizing peanuts in North Carolina, N. C. Agr. Expt. Sta. Bul. 356. 1946.

11. Evelyn, S. H. and I. Thornton. Soil fertility and the response of groundnuts to fertilizers in the Gambia. Empire Jour. Expt. Agr. 32:153-160. 1964.

12. Harper, H. J. Methods of analysis for soil and plant material. Soils Laboratory, Oklahoma Agricultural and Mechanical College. 1948.

13. Harris, H. C. The effect on the growth of peanuts of nutrient deficiencies in the root and pegging zone. Plant Physiol. 24: 150-161. 1949.

14. Harris, H. C. and R. W. Bledsoe. Physiology and Mineral Nutrition. pp. 81-121. The Peanut - The Unpredictable Legume. National Fertilizer Assoc. Washington, D. C. 1951.

15. Howell, R. W. Phosphorus nutrition of soybeans. Plant Physiol. 29:477-483. 1954.

16. Jackson, M. L. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N. J. pp. 141-144. 1958.

17. Lynd, J. W., and O. H. Brensing. Forage, peanuts, and special crops fertilization research progress report, 1961. Okla. Agr. Expt. Sta. Processed Series. p. 409. 1962.

18. McClelland, C. K. Peanut production experiments, 1931-1941. Ark. Agr. Expt. Sta. Bul. 448. 1944.

19. McVickar, M. H., G. L. Bridger, and L. B. Nelson, Eds. Fertilizer Technology and Usage. Soil Science Society of America. Madison, Wisconsin. p. 142. 1963.

20. Mehlich, A., and W. E. Colwell. Absorption of calcium by peanuts from kaolin and bentonite at varying levels of calcium. Soil Sci. 61:369-374. 1946.

21. Mehlich, A., and J. F. Reed. The influence of type of colloid and degree of calcium saturation on fruit characteristics of peanuts. Soil Sci. Soc. Amer. Proc. 11:201-205. 1946.

22. Middleton, G. K., W. E. Colwell, N. C. Brady, and E. F. Schultz, Jr. The behavior of four varieties of peanuts as affected by calcium and potassium variables. Jour. Amer. Soc. Agron. 37: 443-457. 1945.

23. Moore, Rufus H. Nutritional levels in the peanut plant. Bot. Gaz. 98:464-490. 1937.

24. Ollagnier, M. and P. Prevot. Fertilite 2:13, 1957. From: Evelyn and Thornton. Soil fertility and the response of groundnuts to fertilizers in the Gambia. Empire Jour. Expt. Agr. 32: 153-160. 1964.

25. Reid, P. H. and E. T. York. Effect of nutrient deficiencies on growth and fruiting characteristics of peanuts in sand cultures. Agron. Jour. 50:63-67. 1958.

26. Reid, P. H. and E. T. York. The relative growth and potassium absorption by four crops under intensive culture in a limited volume of soil. Soil Sci. Soc. Amer. Proc. 19:481-483. 1955.

27. Robertson, W. K., C. E. Hutton, and W. D. Hanson. Crop response to different soil fertility levels in a 5 X 5 X 5 X 2 factorial experiment. II. Peanuts. Soil. Sci. Soc. Amer. Proc. 20:537-543. 1965.

28. Rogers, H. T. Liming for peanuts in relation to exchangeable soil calcium and effect on yield, quality, and uptake of calcium and potassium. Jour. Amer. Soc. Agron. 40:15-31. 1948.

29. Schollenberger, C. J. Determination of organic matter. Soil Sci. 31:483-496. 1931.

30. Shelton, W. R., and H. J. Harper. A rapid method for the determination of total phosphorus in soil and plant material. Iowa State College J. of Sci. 15:403-413. 1941.

31. Ulrich, A. and W. L. Berry. Critical phosphorus levels for lima bean growth. Plant Physiol. 36:626-632. 1961.

32. Van Andel, O. M., W. H. Ariz, and R. Helder. Influence of light and sugar on growth and salt intake by maize. Nederlandsche Akademie Van Wetenschappen Proc. 53:159-171. 1950.

33. Wilkinson, S. R. and C. F. Gross. Responses of ladino clover to phosphorus withdrawal from the nutrient solution. Agron. Jour. 57:357-360. 1965.

34. York, E. T., Jr., and W. E. Colwell. Soil properties, fertilization and maintenance of soil fertility. pp. 122-172. The Peanut - The Unpredictable Legume. National Fertilizer Assoc. Washington, D. C. 1951.

VITA

John Paul Clay

Candidate for the Degree of

Master of Science

Thesis: RESPONSE OF THE PEANUT (*Arachis hypogaea* L.) TO SOME NUTRITIONAL FACTORS

Major Field: Agronomy

Biographical:

Personal Data: Born at Carnegie, Oklahoma, May 6, 1942, the son of Floyd H. and Julia M. Clay.

Education: Graduated from Alfalfa High School, Alfalfa, Oklahoma in 1960; received Bachelor of Science degree, with a major in Agronomy, at Oklahoma State University, Stillwater, Oklahoma in August, 1964; completed the requirements for a Master of Science degree in September, 1966.

Professional Experience: Reared on a farm near Carnegie, Oklahoma and performed general farm duties during summer months of high school and undergraduate years; half-time graduate research assistant, Department of Agronomy, Oklahoma State University, 1964-1966.

Member: Phi Eta Sigma, Alpha Zeta, Phi Kappa Phi, Phi Sigma, American Society of Agronomy, and Soil Science Society of America.