STUDIES ON CALCIUM NUTRITION
OF SPANISH PEANUTS

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CHAPTER I

INTRODUCTION

Approximately 120,000 acres of peanuts were harvested in Oklahoma in 1969. The value of this crop was estimated at 25 million dollars. Therefore, peanuts contribute much to the economy of Oklahoma. The peanut varieties currently produced in Oklahoma are those of the Spanish type, which is considered a small-seeded type.

Certain effects of calcium on kernel development, yield, and its distribution within the plant of large-seeded type peanuts have been determined, but the effects of calcium on peanuts of smaller seed size has not been thoroughly investigated. Problems in peanut nutrition cannot be attacked so successfully when differences in varietal behavior are not taken into account.

One of the principle objectives in a research program concerned with the nutrition of peanuts is that of obtaining good kernel development, or conversely, reducing the number of unfilled ovarian cavities. The abortion of ovules in peanuts is partially responsible for the failure to obtain the maximum productive capacity of a peanut plant. Thus, information on the factors affecting ovule abortion as well as the physiological processes which take place when peanut fruit develop are seen to be of vital importance.

The principle objectives of this study were to compare Spanish and NC2 peanuts in yield, selected reproductive and vegetative characteristics, and distribution of calcium and potassium when the plants were subjected to various calcium treatments. The comparisons were made in hopes of obtaining more information about calcium nutrition and requirements of Spanish peanuts. All experiments were conducted under greenhouse conditions.

CHAPTER II

LITERATURE REVIEW

The peanut (Arachis hypogaea L.) is one of the few plants requiring a transfer of the ovary of the aerial flower by a gynophore to a subterranean position before maturation of the fruit will normally occur. The fact that peanut fruit develop underground complicates any study of its mineral element requirements. This necessitates taking into account the characteristics of the upper few inches of soil in which the fruit develop, as well as the usual consideration of a supply of nutrients available to the roots.

Calcium and Potassium Effects on Yield and Quality of Fruit

Burkhart and Collins (6), in 1941, were able to show the necessity of a calcium supply in the fruit zone for a North Carolina (NC) runner variety of peanuts by separating the root and fruit zone. The presence of only calcium, added as $CaSO_4$, in the fruiting medium had a definite favorable effect on fruit quality irrespective of the nature of the rooting medium. Increasing calcium in the root zone when the fruit zone contained distilled water increased the percentage of good fruit formed. The presence of only potassium in the fruiting medium, added as K_2SO_4, had a definite unfavorable effect on the fruit quality irrespective of the nature of the rooting media. These researchers suggested that it is possible that excessive potassium intake by the growing peanut fruit in a low calcium medium may retard the transport of calcium from the plant into the young embryo, thus resulting in abortion and associated unfilled inferior fruit or "pops."

Colwell and Brady (9) worked with Virginia Bunch, NC Runner, Spanish 2B, and White Spanish varieties of peanuts and found that the use of gypsum increased the proportion of two-cavity size fruit of the Virginia Bunch and NC Runner varieties, but not of the Spanish 2B and White Spanish varieties. These men suggested that calcium sulfate exerted a favorable effect by preventing ovule abortion at a very early stage of fruit development before shell enlargement began.

Colwell and Brady (8) used only Virginia Bunch type peanuts in a similar experiment and reported that gypsum, applied on the top of the row at the time of early bloom, was far superior in meeting the calcium requirements of peanut fruit produced on soils than dolomitic limestone placed in the row at the time of planting. Even with gypsum application, 30-60 per cent of the ovarian cavities still remained unfilled. These workers concluded that although a very low level of soil calcium is adequate for vegetative growth, a relatively large supply is necessary for proper development of fruit.

Middleton et al. (24), in 1945, found that Virginia Bunch peanuts had by far the highest calcium requirement, then NC, Spanish 2B, and White Spanish varieties in decreasing order. At one location, yields of Virginia Bunch peanuts were increased six times, NC two times, and Spanish 2B and White Spanish peanuts were not appreciably affected by application of gypsum. Although Spanish peanuts did not respond to added calcium in Middleton's experiment, Spanish peanuts have been shown to require calcium in the fruit zone for proper development of fruit (31).

Brady and Colwell (4) reported that Vriginia type peanuts were not aided in the filling of fruit by application of potassium to soils and under certain conditions potassium lowered the true shelling percentage of ovarian cavities filled. When potassium was applied to the fruit zone in combination with calcium, it had no unfavorable effect on quality. These researchers concluded that increased yields from the use of potassium may be expected when (a) there is an adequate supply of calcium to bring about good filling of fruit and (b) when the level of soil potassium is extremely low. Potassium seemed to affect yields through its influence on plant size rather than on kernel development. Similar results for potassium were also obtained by Reid and York (28).

Brady et al. (5) worked with Jumbo Runner peanuts in containers where the root and fruit zones were separated. Soil was used for the rooting media while washed quartz sand was used for the fruiting media. Of the ions Ca, K, Mg, Cl, SO_4, KH_2, and PO_4, calcium was found to be the only one which consistently increased fruit filling when supplied to the fruit zone. This was true regardless of the combinations in which it was supplied. The addition of potassium to the fruiting or rooting medium slightly depressed fruit filling in some instances in the absence of calcium in the fruit zone. However, if a solution of $CaSO_4$ containing as little as 20 ppm Ca were supplied to the fruit zone, no detrimental effect resulted from potash addition. This was true even when potassium was added at the rate of 320 ppm K. The application of chloride, sulfate, or phosphate ions did not significantly affect fruit filling.

Strauss and Grizzard (34), in 1947, found the percentage calcium saturation of the exchange complex was correlated with the number of nuts formed per plant when using field grown Jumbo peanuts. If the soil had a high calcium saturation value and low K:Mg ratio, added calcium decreased yields. On the other hand, if the soil had a low calcium value and high K:Mg ratio, increases in yield were obtained from added calcium.

Rogers (30), in working with Spanish and Runner peanuts, suggested that the major beneficial effect of lime on peanuts was the supplying of calcium and magnesium as plant nutrients. Lime improved the quality of peanuts as shown by increased shelling percentages of Runner peanuts when grown successively for several years on the same soil. A high rate of potassium fertilizer, 120 pounds of K_2O per acre, decreased the shelling percentage of sound and mature kernels.

By growing Jumbo Runner peanuts in containers which separated the root and fruit zones, Brady (3) concluded: (1) The most critical period in fruit development from the standpoint of a supply of calcium to the fruit zone was 15 to 35 days after the gynophores reached the sand. (2) The fruit nearest the main stem was much more poorly filled than those of comparable age further out on the stems. Gynophore competition for carbohydrates was offered as a possible explanation of this fact. (3) Supplying calcium to one side of the peanut plant did not improve the quality of fruit on the opposite side of the same plant. This was offered as indirect evidence of the lack of movement of calcium from one side of the plant to the other.

Harris (15) reported that Dixie Runner peanuts were not able to translocate calcium from the roots to the developing fruit in sufficient quantities to supply the needs in that region. In his experiment the root zone contained ample calcium while the fruit zone contained only distilled water. Sulfur was the only element other than calcium that, when left out of the pegging zone, resulted in a statistically significant decrease in yield of nuts. Harris concluded that a deficiency of an element in the root area may possibly increase peg absorption of that element and a balanced supply of nutrients in the root zone as well as calcium and, perhaps, sulfur, in the pegging zone are necessary for the best production of nuts.

Reed and Brady (26) applied dolomitic limestone and gypsum at various times and rates on Virginia type peanuts and found that on soils low in calcium, large increases in yield were obtained from calcium additions. These men concluded that the calcium supply of the soil is the most important single factor in the production of large seeded type peanuts and the level of soil calcium gives a good index of the likelihood of response to added calcium when the type of colloid is taken into account. The type of colloid can be a factor in peanut fruit filling as reported by Mehlich and Colwell (22). Jumbo Runner peanuts produced fruit of good quality, even at relatively low calcium level, when the fruit zone contained the kaolinitic type of colloid. In a montmorillonitic system, larger amounts of calcium at higher degrees of saturation were required to produce similar fruit quality. Similar results were also obtained by Mehlich and Reed (23).

Robertson et al. (29) reported that a negative response to potash was obtained every year when more than 15 pounds of K_2O, added as KCl, were applied to the soil. The lack of response to potassium was attributed either to the application of the fertilizer potassium in the peanut row or to increasing rates of phosphorus applied as superphosphate. Calcium gave significant yield responses three out of four years. No indication of the type of peanut used was given in the article.

Cox and Reid (11), in 1964, found that calcium additions to the soil reduced plumule damage in NC4X peanuts. Increased amounts of calcium added to the soil possibly induced a boron deficiency in the kernels of the peanuts. Reid and York (27) reported similar results in that nitrogen, calcium, and boron all prevented pod formation when they were left out of the root and fruit zone of NC2 peanuts.

Tucker et al. (36), in 1964, found that under irrigated conditions potassium caused a slight decrease in yields of Spanish peanuts when compared to a check plot. Gypsum, at a different location, when applied on the surface of the soil, increased yields but reduced the shelling percentage of peanuts. In 1966 Tucker et al. (35) reported similar results in that K applied alone slightly decreased the yield of Spanish peanuts. A combination of N, P, K, and gypsum at the rates of 40, 80, 80, and 500 pounds per acre, respectively, resulted in the highest yield. Under non-irrigated conditions internal damage in Spanish peanuts was reduced by boron and boron plus gypsum applications to the soil.

Calcium and Potassium Uptake and Distribution in the Peanut Plant

According to Burkhart and Page (7) the vegetative stage of growth of Virginia Bunch peanuts (two months after planting) is the most practical for foliar diagnosis, as fertilizer supplements may be beneficially applied as top or side dressings during this stage. The average concentration of calcium from all leaves analyzed increases with maturity of the peanut plant. The average concentration of potassium decreases from the first to the second sampling, but increases from the second to the third sampling. These workers postulated that the increase in potassium is probably a result of upward translocation of potassium from the lower leaves as the plants mature.

Colwell et al. (10), in 1945, reported the peanut shell potassium levels of Virginia Bunch and North Carolina Runner to be higher than those from Spanish peanuts. This was true whether gypsum was applied to the soil or not. On all but the Virginia Bunch peanut, the potassium content of the shells was increased when gypsum was added to the soil. This was true for shells containing 2, 1, or no kernels. Shells of Spanish 2B and White Spanish peanuts were higher in calcium than those of NC and Virginia Bunch, although Virginia Bunch was higher than NC Runner. Kernel analysis of Virginia Bunch and NC Runner showed that the concentration of all constituents except calcium to be higher in the kernel than in the shell. These men postulated that the decrease in the nutrient content of shells of the two-kernel group resulted from movement of the nutrients from the shells into the developing kernels.

Brady (3) found that calcium sulphate, when supplied to only one side of the fruit zone of Jumbo Runner peanuts, affected the chemical composition on only that side of the plant to which it was added. Calcium sulphate addition to the fruit zone was also found to increase the calcium and potassium content of the stem as compared to distilled water in the fruit zone. Reed and Brady (26) obtained a decrease in potassium content of the plant stem of Virginia type peanuts when lime was broadcast, but localized placement of gypsum resulted in an increase in calcium, magnesium, and potassium in the plant. Nicholaides and Cox (25) analyzed the tops of Virginia type peanut plants at the end of a seven weeks growth period and found that varying the rates of calcium to the roots had no effect on the potassium content of the tops.

Rogers (30) reported that lime additions to the soil decreased the percentage of potassium in the vines of Spanish and Runner peanuts. This reduction in potassium content of peanuts by liming a calcium-depleted soil was attributed in part to increased growth and increased efficiency of utilization of applied potassium by Spanish and Runner peanuts. Rogers concluded that the peanut is a crop which can tolerate a high Ca:K ratio and possesses an ability for luxury absorption of potassium far in excess of that required for normal growth.

Bledsoe et al. (1) reported when labeled calcium was added to the root zone of Dixie Runner peanuts that detectable amounts could be found in young pegs which had not entered the fruit zone. After the pegs entered the fruit zone, calcium absorption decreased. The peanut shells contained small amounts of labeled calcium, but none was found in the seed. When labeled calcium was placed in the fruit zone, it was very actively taken up by pegs, shells, and fruit. These researchers suggested that the capacity for calcium absorption by the gynophore and ovary is limited after a definite point during their development and that further fruit development is apparently dependent upon the external supply of calcium in the fruit zone.

Bledsoe and Harris (2) suggested that the developing gynophores of Dixie Runner peanuts have a greater absorptive intensity for potassium and calcium from the external supply in the fruiting medium than for phosphorus or magnesium. These results were based on the mineral composition of gynophores before and after they entered the fruit zone supplied with a complete nutrient solution. These men also postulated that the root is the primary absorbing organ of the peanut plant and a nutrient balance in the root zone is necessary for optimum growth and fruit production. In no case was the absorption of an element by the gynophores sufficient to offset the appearance of nutrient deficiency symptoms of that element when it was omitted from the rooting medium of the plant.

Hallock et al. (14), in 1969, analyzed six different plant portions from Spanish, Virginia 61R, and Early Runner peanuts at four different time intervals during their growth cycle for various nutrients. The potassium content of leaves of Virginia 61R and Early Runner generally increased with age, while that of Spanish peanuts went up after the first sampling date then remained the same for the remainder of the harvest dates. The potassium content was higher for Virginia 61R and Early Runner peanuts than Spanish for any sampling date. The calcium content of the leaves of Spanish peanuts decreased with age, increased then decreased for Early Runner, and stayed essentially the same for Virginia 61R. Spanish leaves were higher in calcium content over all sampling dates than Early Runner or Virginia 61R. Early Runner was slightly higher in calcium than Virginia 61R.

Mehlich and Colwell (22) reported that calcium uptake by the shells of Jumbo Runner peanuts was increased with increasing calcium levels in montmorillonitic or kaolinitic type fruiting medium. The calcium content of peanut shells produced in a kaolinitic medium was higher than those in a montmorillonitic medium. This difference, due to type of colloid, was more pronounced at high degrees of calcium saturation and at higher cation absorption capacity levels. Uptake of calcium from the kaolinitic system was more directly related to total calcium present than to degree of saturation. In the montmorillonitic system, absorption was more directly related to percentage calcium saturation than to total amount. Mehlich and Reed (23) also reported that for any level of calcium, the calcium content of the shells is highest when fruit is produced in the kaolinitic type colloid as compared to organic type colloids. The calcium content of the Jumbo Runner plant was highest when the roots were growing in the organic-type colloid. Mehlich and Reed suggested that the reason for these differences in colloid effect were based on differences in the release of calcium from colloids in the fruiting and rooting media.

CHAPTER III

METHODS AND MATERIALS

Experiment I

This experiment was designed to compare yield, selected vegetative and reproductive characteristics, and calcium and potassium distribution for Spanish and NC2 peanuts (hereafter referred to several times as only Spanish or NC2) when the fruit zone received various calcium treatments.

The root and fruit zones were separated to permit treatment of each zone independently. A diagram of the growth containers is shown in Figure 1. The fruiting containers were made by constructing a rectangular box 12 inches long, 10 inches wide, and 4 inches deep from 1"x4" lumber. These wooden containers were lined with polyethylene. A 3/4"x4" circular plastic sleeve, located in the center of the fruiting containers, connected the root and fruit zones. Two 1/4"x1/2" plastic tubes, located at the outer edges of each fruiting container, served as a means of flushing nutrient solutions from the fruit zone. A 1/4"x5" plastic tube extended from the root zone to above the fruiting area and served as a means by which nutrients could be added to the root zone. The root containers were number ten food cans lined with polyethylene. A small 1/4"x1" plastic drainage outlet was located 2 inches from the bottom of the rooting containers. This

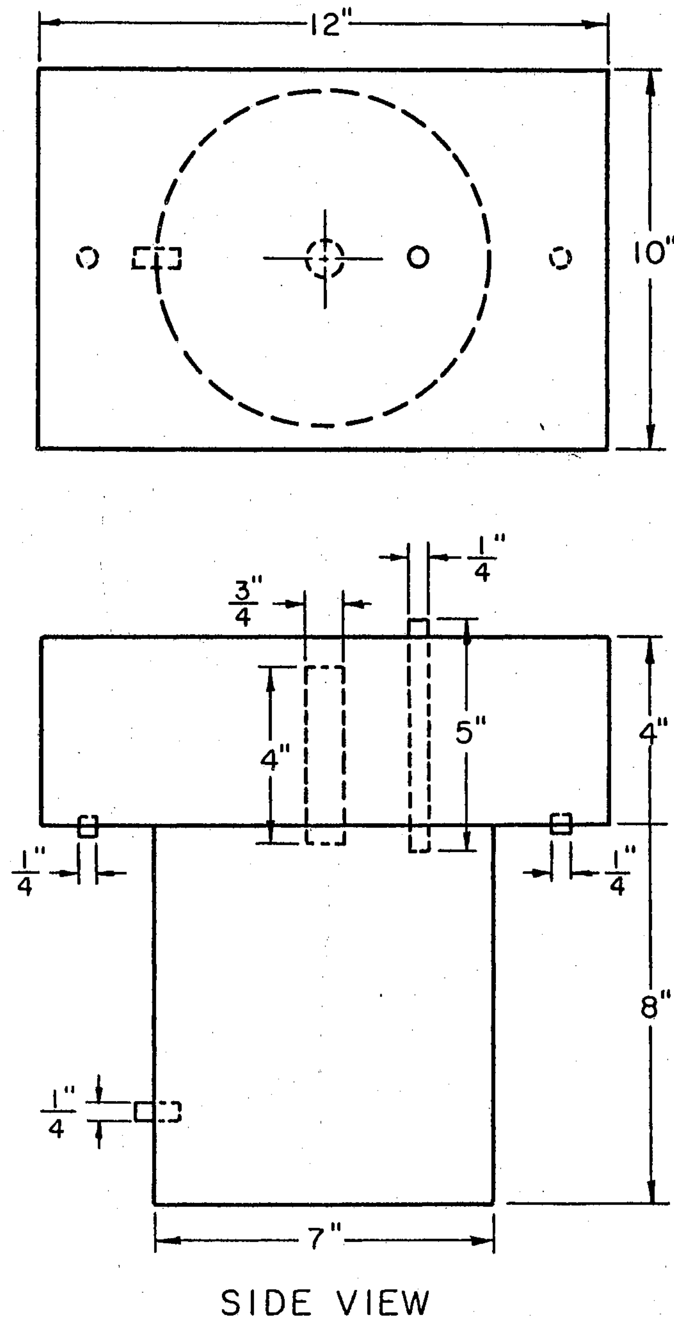


Figure 1. Top and Side Views of Rooting and Fruiting Containers

outlet prevented flooding and permitted the periodic flushing of the root zone.

Acid washed silica sand was used in both the root and fruit zones. The sand was washed with dilute hydrochloric acid and then rinsed several times with distilled water to remove the remaining chlorides. The sand was air dried for one week and then placed into the rooting and fruiting containers. Each fruiting container received 6.56 kilograms of sand, resulting in a fruit zone of 3.50 inches in depth. The rooting container received 4.99 kilograms of acid washed sand.

Hoagland and Arnon (18) originally developed the concentration of nutrients used to supply the root and fruit zones, but a slight modification of a "complete nutrient solution" recommended by Bledsoe et al. (1) proved to be of more benefit for growth of peanuts. All nutrient solutions were prepared using reagent grade chemicals and distilled water. The root zone received a "complete nutrient solution," while the fruit zone received a complete nutrient solution minus calcium. Calcium was then added to the fruit zone at rates of 0, 5, 10, 20, and 40 ppm as calcium chloride. Composition of the complete nutrient solution used is shown in Table I.

The experiment was conducted in a greenhouse and each treatment was replicated four times in a completely random design. Each fruit zone received 1 liter of its respective fresh nutrient solution every two weeks after being flushed with distilled water. Each root container received 500 ml of a complete nutrient solution, twice weekly and was flushed with distilled water once a week. The root and fruit zones were kept moist by application of distilled water as needed.

TABLE I

BASIC COMPOSITION OF A COMPLETE NUTRIENT SOLUTION

Source	Nutrient Supplied	Concentration of Nutrient (ppm)
$Ca(NO_3)_2 \cdot 4H_2O$	Ca	100.00
	NO_3	310.00
KNO_3	K	98.50
	NO_3	156.00
$MgSO_4 \cdot 7H_2O$	Mg	24.18
	S	31.83
KH_2PO_4	K	20.08
	P	15.95
H_3BO_3	B	0.10
$CuSO_4 \cdot 5H_2O$	Cu	0.004
$ZnSO_4 \cdot 7H_2O$	Zn	0.010
$H_2MoO_4 \cdot H_2O$	Mo	0.010
$FeSO_4$	Fe	1.000
$MnCl_2$	MN	0.06

Spanish and NC2 peanut seeds were planted in one-gallon containers filled with washed quartz sand on October 4, 1968. On October 14, one plant was transplanted into the rooting medium of each container. Care was taken to select 20 plants of each kind with as uniform growth as possible. Nutrient solution treatment was started immediately for the root zone. Fruit zone nutrient treatments were begun on November 23, immediately after pegging was observed.

Flowers of all plants were counted daily. Since the peanut flower is ephemeral and wilts after a few hours, an accurate record of flower production is easily obtained. All plants were harvested on March 1, 1969 (147 days after planting) and separated into four parts: leaves and stems, pegs with pods, pegs without pods, and roots. The peanut tops and pegs were dried in a forced air oven, ground in a Wiley mill, and then prepared for analysis of total calcium and potassium as suggested by Jackson (21). The analysis was made with a Perkin Elmer Atomic Absorption Spectrophotometer, model 303. The unshelled fruit were air dried for seven days, hand shelled and then counted and weighed. The shells were also analyzed for total calcium and potassium. Statistical analyses were performed according to Steele and Torrie (33).

Because of limited greenhouse space for Experiment I, a similar experiment was started on January 23, 1969, and harvested on June 8. This experiment was essentially a continuation of Experiment I but had to be counducted at a different location. The levels of calcium added to the fruit zone were 80, 160, and 320 ppm. Everything else was carried out exactly as above.

Experiment II

Experiment II was conducted to compare calcium and potassium uptake and distribution in Spanish and NC2 peanut plants at various intervals during their maturation.

The root and fruit zones were separated as in Experiment I except the fruiting area was reduced to a circular container measuring 4 inches in height and 4 inches in diameter. This reduced size of fruit zone was used in order to be able to harvest pegs of similar age which entered or had not entered a fruiting medium containing a complete nutrient solution.

Additional Spanish and NC2 peanuts were planted on June 3, 1969. On June 16, these plants were transplanted into the root zone. Each treatment was replicated four times in a completely random design. Harvest dates were August 6, which was considered representative of early pegging; September 6, which was considered representative of early maturing of the fruit; and October 10, which was considered representative of a mid-to-late maturing of most fruit. On each harvest date the most extended, fully developed leaves from the main stem and first and second lateral branches were collected. Also, pegs of comparable age which entered and had not entered the fruit zone were collected at each harvest. After each harvest the plant material was dried and milled. Total calcium and potassium were determined for each plant part. Data were subjected to statistical analyses as in Experiment I.

Experiment III

Experiment III was designed to determine if peanut gynophores have a cation exchange capacity (CEC) and, if so, how the CEC changes as Spanish and NC2 peanut plants mature.

Two Spanish and NC2 peanuts were planted in polyethylene lined one-gallon cans filled with Eufaula soil on July 7, 1969. The cans were thinned to one plant per pot on July 28, leaving plants with as uniform growth as possible.

Some chemical and physical properties of the Eufaula soil used are shown in Table II.

TABLE II

SOME CHEMICAL AND PHYSICAL PROPERTIES OF EUFAULA SOIL

Available phosphorus (ppm)	20.96
Cation exchange capacity (meq/100g)	1.78
Exchangeable cations (meq/100g)	
Calcium	.60
Potassium	.13
Soil reaction (water paste, pH)	6.95
Sand (%)	89.59
Silt (%)	7.90
Clay (%)	2.51

Soil treatments consisted of what was considered a low and a high calcium treatment. On July 29, every pot received 200 ml of complete nutrient solution minus calcium. Then half of these pots received 40.22 mg of calcium added as calcium chloride, the high calcium treatment. Because of poor plant appearances, an additional 200 ml of a complete nutrient solution minus calcium were added to every pot on August 15. Also, 40.22 mg of calcium were again added to each high calcium pot. Distilled water was used throughout the growing season to maintain soil moisture for good growth. The first harvest date was September 13 and consisted of the peg portion below the soil. The CEC of pegs of comparable age was determined by the method suggested by Helmy and Elgabaly (17). For the second and third harvests, October 11 and November 7, CEC was determined on peanut shells rather than on pegs. Pegs and shells of comparable age to those used for CEC determination were also analyzed for total calcium and potassium after each harvest.

Experiment IV

Experiment IV was designed to evaluate the effects of a strong and weak acid organic resin, placed in the fruit zone, on selected reproductive and vegetative characteristics of Spanish and NC2 peanuts as well as the uptake and distribution of calcium and potassium within the peanut plants. The strong and weak acid resins were products of Fisher Scientific Company and were designated as R-231 and R-234, respectively. The chemical and physical characteristics of these resins are shown in Table III.

The strong and weak acid resins were placed in large plastic containers and saturated with a solution of 0.5 M $CaCl_2$. The resins were stirred several times during a two-day saturation period. The $CaCl_2$ solution was then drained off and the resins were rinsed with distilled water a sufficient number of times to remove the remaining chlorides. The resins were air dried for two weeks and samples were collected to be analyzed for water soluble and 1 N ammonium acetate extractable Ca. The analytical results, giving the Ca removed, are shown in Table IV.

TABLE III

CHEMICAL AND PHYSICAL PROPERTIES OF STRONG AND WEAK ACID SYNTHETIC ORGANIC RESINS (Rexyn R-231 and Rexyn R-234)

	Organic strong acid*	Organic weak acid**
Porosity	medium	medium
Mesh size	16-50	16-50
Total exchange capacity (meq/ml)	1.95	3.70
Moisture content	45.00%	46.50%
Active working density (dry/basis)	.43	.36

*Sulfonated polystyrene copolymer, hydrogen form, Rexyn R-231.

**Methacrylic acid containing carboxylic acid groups, hydrogen form, Rexyn R-234.

TABLE IV

WATER SOLUBLE AND 1 N NH_4Ac EXTRACTABLE CALCIUM

Type of resin	Water soluble calcium (ppm)	1 N NH_4Ac extractable calcium (ppm)
Strong acid	5	990
Weak acid	15	810

Spanish and NC2 peanuts were planted on July 7, 1969 and transplanted into their respective rooting containers on July 26. The fruiting and rooting containers were essentially the same as in

Experiment I except the fruiting containers were reduced to 8"x6" to better accommodate the limited amounts of resins. A complete nutrient solution was used in the root zone as in Experiment I. The exchange resins were placed in the fruit zones on August 20, immediately after pegging had begun. Distilled water was added to the resins throughout the experiment to maintain a slightly moist condition. This study was a completely randomized design with a factorial arrangement of treatments replicated four times.

On December 13, all plants were harvested and separated into five parts: (1) stems and leaves, (2) pegs which had not entered the fruit zone, (3) pegs which had entered the fruit zone but had developed no fruit. These individual pegs were further divided up into that portion which was in the fruit zone and that portion above the fruit zone (4) pegs which had developed mature fruit. These pegs were also divided as in (3) above, and (5) fruit.

Leaves, stems, and pegs were dried in a forced air oven, milled, and analyzed for total calcium and potassium. The fruit was air dried, counted and weighed, and the shells of mature fruit analyzed for total calcium and potassium. Statistical analyses were run on the experimental results as before.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

Adding different levels of calcium to the fruit zone, when the root zone contained a complete nutrient solution, had varied effects upon yield, vegetative and reproductive characteristics, and upon calcium and potassium content of Spanish and NC2 peanut plant parts.

Calcium levels in the fruiting zone in excess of 10 ppm caused decreases in dry weights of peanut leaves and stems (Table V). Leaves and stems of NC2 peanuts were somewhat heavier at all calcium levels than leaves and stems of Spanish peanuts.

Fruiting zone calcium levels in excess of 10 ppm also decreased the number of flowers and pegs produced, but increased the percentage of pegs which produced fruit (Table V). Both the number of fruit and the percentage of pegs which produced fruit increased with increasing levels of calcium in the fruiting medium. (A fruit was considered any peg which had begun enlarging). In general, Spanish peanuts produced more flowers, pegs, and fruit per plant than did NC2 peanuts.

Yields, as measured by weights of unshelled and shelled nuts, were increased by increasing levels of calcium in the fruiting zone (Table VI). Fruit of NC2 peanuts appeared to be more sensitive than Spanish peanuts to a deficiency of calcium in the fruiting zone, but

TABLE V

MEAN VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF SPANISH AND NC2 PEANUTS AS AFFECTED BY CALCIUM ADDITIONS TO THE FRUIT ZONE*

Treatment	Ca level (ppm)	Dry weight of leaves and stems (g/plant)	No. of flowers per plant	No. of pegs per plant	No. of fruit per plant	Pegs producing fruit (%)
Spanish						
	0	11.9	159	85	4.0	4.7
	5	11.2	143	81	7.0	8.6
	10	11.6	154	74	10.8	14.6
	20	8.2	54	46	7.8	17.0
	40	7.9	63	54	15.0	27.8
NC2						
	0	13.4	62	49	1.8	3.7
	5	13.1	70	54	2.8	5.2
	10	13.2	58	50	4.5	9.0
	20	10.9	35	27	7.0	25.9
	40	9.8	33	25	7.0	28.0
$LSD_{.05}$		1.8	18.1	22.4	5.7	9.9

*All values are the means of four replications

TABLE VI

MEAN WEIGHT OF UNSHELLED AND SHELLED NUTS OF SPANISH AND NC2 PEANUTS AS AFFECTED BY CALCIUM ADDITIONS TO THE FRUIT ZONE*

Treatment		Weight of unshelled nuts (g/plant)	Weight of shelled nuts (g/plant)
Spanish	Ca level (ppm)		
	0	0.40	0.13
	5	0.97	0.68
	10	1.75	1.05
	20	3.80	2.93
	40	4.46	3.38
NC2			
	0	0.13	0.00
	5	0.83	0.30
	10	0.70	0.15
	20	4.10	2.80
	40	5.23	3.88
$LSD_{.05}$		1.98	0.83

*All values are the means of four replications

the data indicate that both varieties require a supply of calcium in the fruiting zone for satisfactory production.

Many pegs were observed to darken and then deteriorate after entering their respective fruiting zones, especially in zones with the lower concentrations of calcium. However, of the kernels which did develop, very few showed internal damage regardless of variety or calcium level in the fruiting zone.

The total calcium content of Spanish and NC2 leaves fluctuated slightly, but in general, increased as the calcium content of the fruit zone increased (Fig. 2). The leaves analyzed were a conglomerate of all leaves on the plant and included both young and old leaves. Spanish leaves at any given calcium level were generally higher in calcium than NC2. Calcium appears to be transported from the developing gynophores to the leaves for both varieties. The potassium content of Spanish leaves varied widely with increasing calcium additions to the fruit zone (Fig. 3). There was a trend for NC2 to increase in potassium as the calcium level increased, but this trend was not significantly different at the 5 per cent level. In general, Spanish peanuts were higher in potassium than NC2 for any given calcium level. Brady (3) obtained somewhat similar results for both calcium and potassium using Jumbo Runner peanuts.

Spanish and NC2 were essentially the same in peg calcium content regardless of the rates of calcium added to the fruit zone (Fig. 4). These pegs were a conglomeration of all pegs on a particular plant. Increasing the calcium concentration in the fruit zone did not significantly effect the calcium content of Spanish or NC2 pegs. The

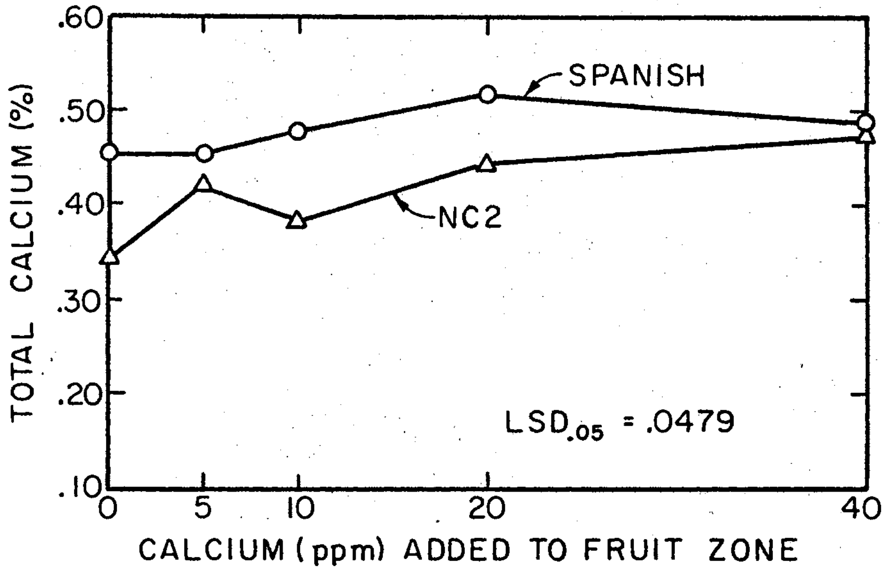


Figure 2. Total Calcium Content of Peanut Leaves

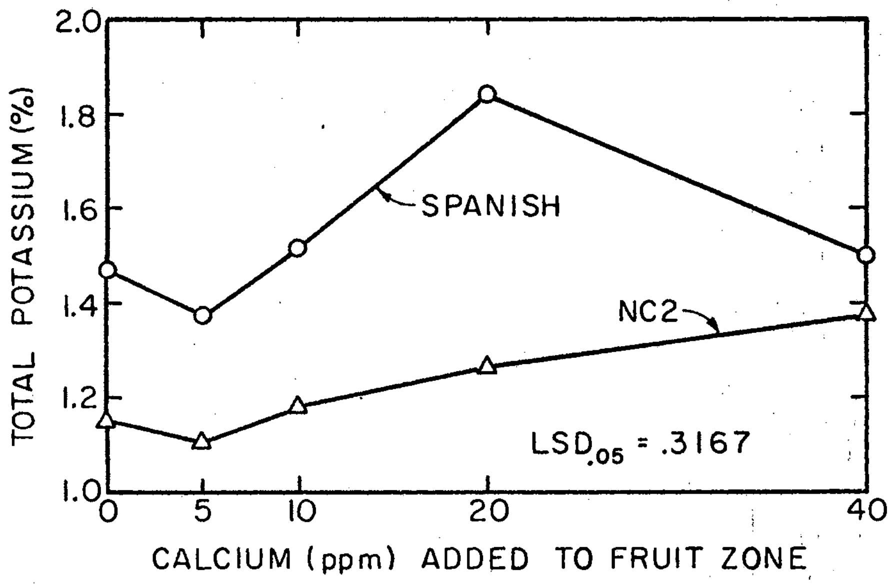


Figure 3. Total Potassium Content of Peanut Leaves

NC2 pegs were generally higher in potassium content than were Spanish over all levels of calcium additions (Fig. 5). Neither variety showed a significant increase or decrease in potassium due to added calcium in the fruit zone.

The total calcium content of both Spanish and NC2 peanut shells followed the same pattern, but this pattern was very irregular (Fig. 6). The shells analyzed consisted of a combination of those which had developed mature or immature fruit. There were significant differences within either variety due to added calcium to the fruit zone, but no explanation can be given for the varied composition. Because of limited amount of plant material and misplaced solutions, no data are given on total potassium content of peanut shells.

Limited greenhouse space at the time Experiment I was undertaken forced a continuation experiment to be carried out at a later date in a different greenhouse. As the lighting and temperature were slightly different from the first part of the experiment, the results will be presented separately.

The addition of high rates of calcium to the fruit zone had only a slight effect on dry weight of leaves and stems of Spanish and NC2 (Table VII). The dry weight of leaves and stems from Spanish for the 160 ppm Ca level represented the only significantly different weight obtained.

The number of flowers and pegs per plant followed a similar pattern for both Spanish and NC2 (Table VII). Increased additions of calcium to the fruit zone had no noticeable effect on flower or peg production within either variety, but at any calcium level Spanish was higher in flower or peg production than NC2.

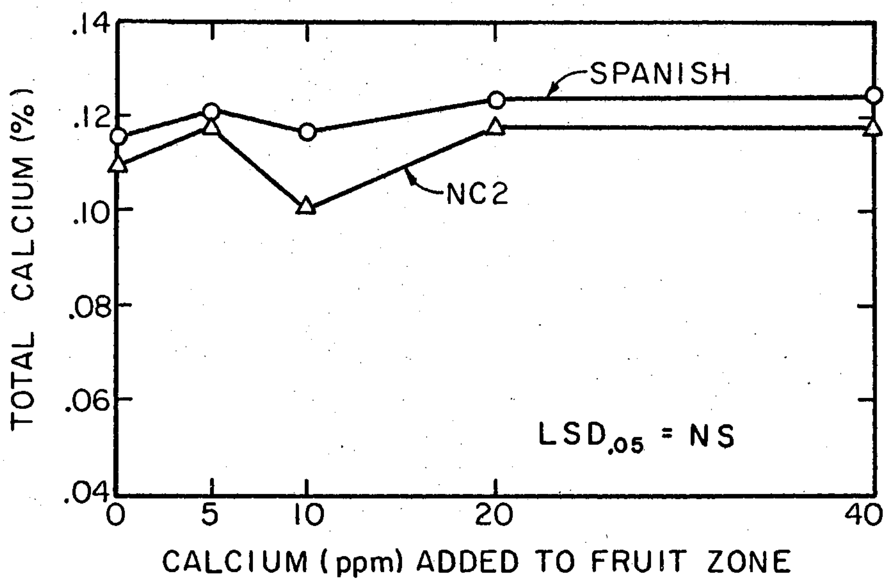


Figure 4. Total Calcium Content of Peanut Pegs

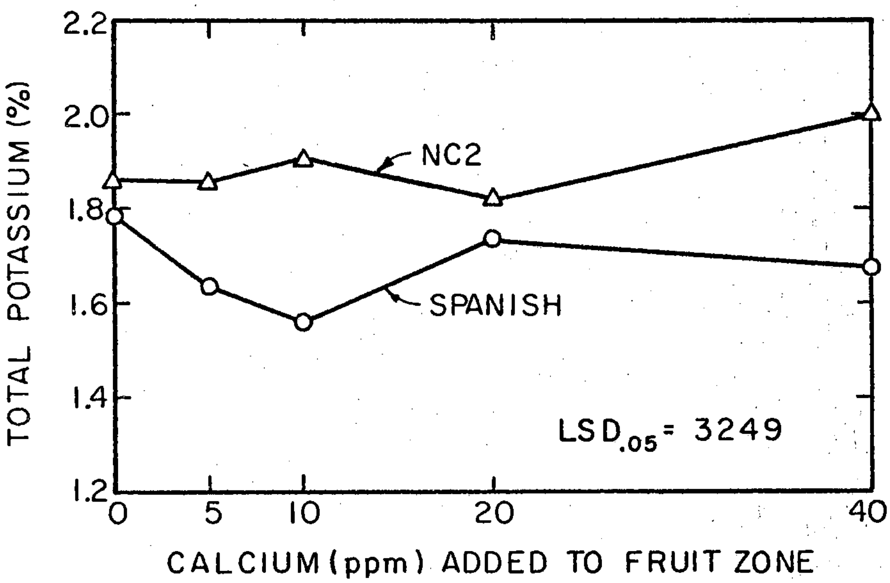


Figure 5. Total Potassium Content of Peanut Pegs

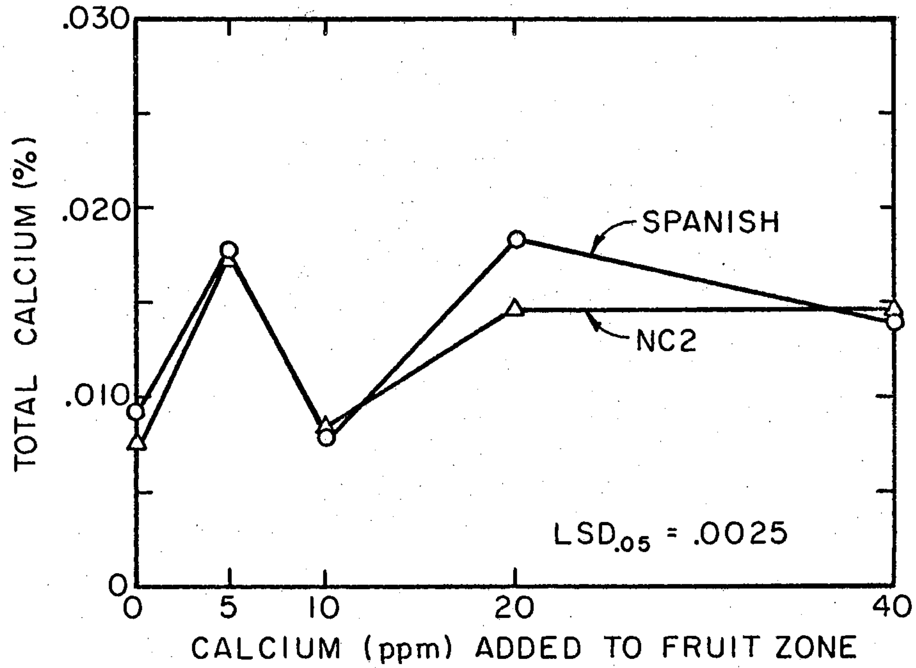


Figure 6. Total Calcium Content of Peanut Shells

TABLE VII

MEAN VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF SPANISH AND NC2 PEANUTS AS AFFECTED BY HIGH CALCIUM ADDITIONS TO THE FRUIT ZONE*

Treatment		Dry wt. of leaves & stems (g/plant)	No. of flowers per plant	No. of pegs per plant	No. of fruit per plant	Pegs producing fruit (%)
Spanish	Ca level (ppm)					
	80	18.60	125.25	69.25	29.75	42.96
	160	15.09	124.25	62.00	28.50	45.97
	320	17.53	126.25	64.75	23.25	35.91
NC2						
	80	20.18	75.75	48.50	15.50	31.96
	160	18.33	68.25	40.00	15.25	38.13
	320	19.44	72.50	41.75	16.00	38.32
$LSD_{.05}$		3.05	14.35	12.69	13.59	NS

*All values are the means of four replications

The number of fruit produced per plant was greater for Spanish than NC2, but was not significantly affected by Ca levels (Table VII). The percentage of pegs producing fruit was essentially the same for Spanish and NC2 at any concentration of calcium in the fruit zone (Table VII).

Unshelled fruit of Spanish and NC2 were significantly different in weight per plant at the 160 or 320 ppm calcium levels, but were essentially the same at the 80 ppm calcium level. This trend was the same for the weight of shelled nuts per plant also (Table VIII). Both varieties exhibited a marked increase in weight from 80-160 ppm calcium, but from 160-320, no definite improvement was observed. The high level of calcium (320 ppm) appears to be somewhat higher than needed for maximum fruit production for Spanish.

High rates of calcium in the fruit zone did not appreciably increase the calcium content of Spanish or NC2 peanut leaves (Fig. 7). For any given calcium level, both varieties were nearly the same in calcium concentration. Leaves analyzed were a mixture of all leaves on a given plant. Spanish and NC2 leaves increased in potassium content as calcium was increased in the fruit zone (Fig. 8). Spanish was somewhat higher in potassium than NC2 for the 80 ppm calcium level, but both varieties approached similar concentrations for the 160 and 320 ppm levels.

Spanish pegs contained more calcium than those of NC2 at the 80 and 160 ppm calcium additions to the fruit zone, but not at the 320 ppm calcium rate (Fig. 9). Spanish and NC2 increased considerably in calcium content from the 80 to the 160 ppm calcium rate and leveled off somewhat from the 160 to 320 ppm calcium additions. Spanish

TABLE VIII

MEAN WEIGHT OF UNSHELLED AND SHELLED NUTS OF SPANISH AND NC2 PEANUTS AS AFFECTED BY HIGH LEVELS OF CALCIUM ADDED TO THE FRUIT ZONE*

Treatment		Unshelled nuts (g/plant)	Shelled nuts (g/plant)
Spanish	Ca level (ppm)		
	80	6.40	4.43
	160	10.07	7.75
	320	9.25	7.39
NC2			
	80	7.43	5.29
	160	12.30	9.52
	320	11.83	10.16
$LSD_{.05}$			
		2.19	1.07

*All values are the means of four replications

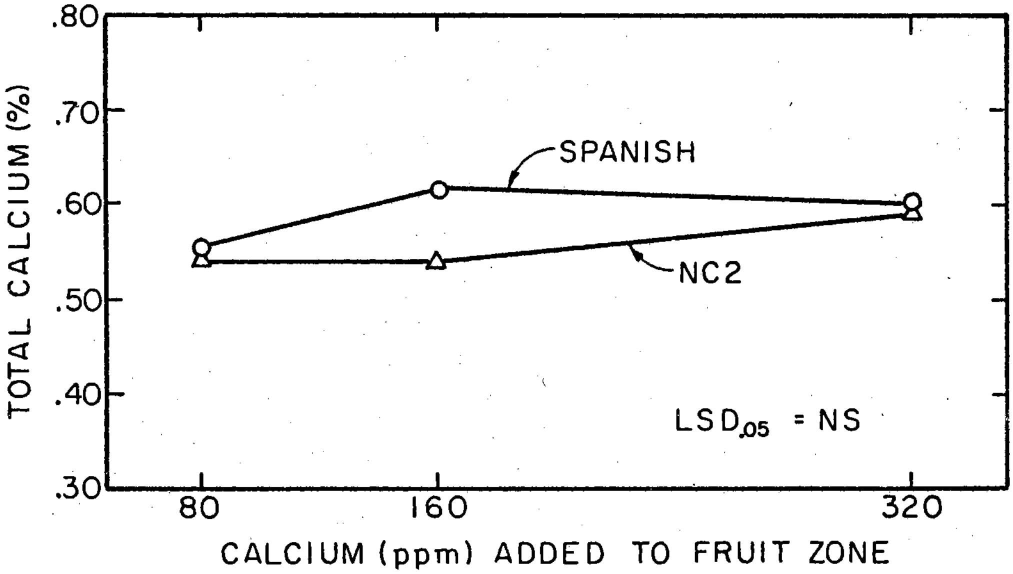


Figure 7. Total Calcium Content of Peanut Leaves

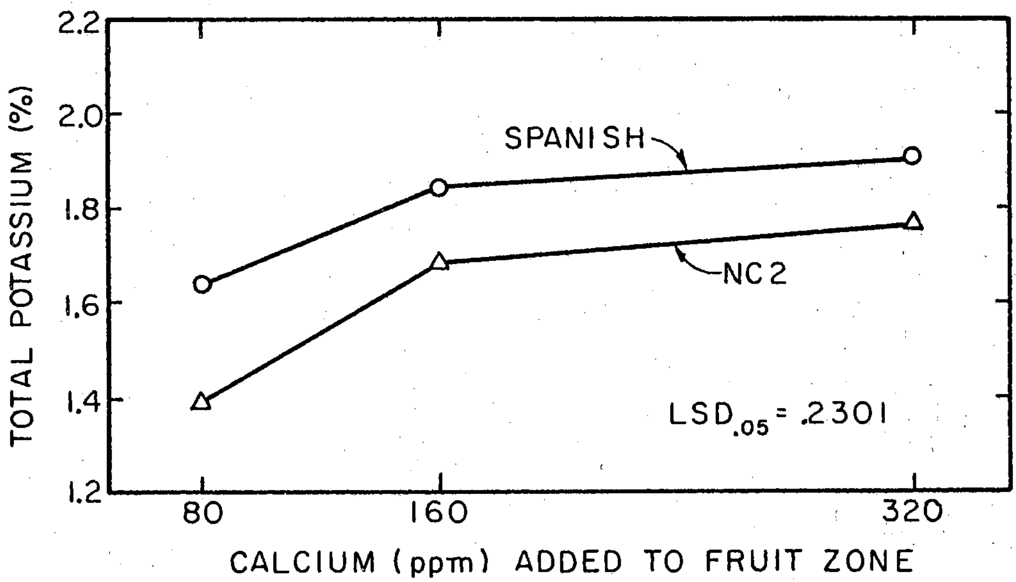


Figure 8. Total Potassium Content of Peanut Leaves

exhibited a tendency to absorb considerably more calcium than NC2 at the lowest level of calcium (80 ppm) in this part of the experiment. Both Spanish and NC2 pegs increased slightly then decreased in potassium content with increasing additions of calcium to the fruit zone (Fig. 10). No difference was observed between varieties at any given calcium concentration in the fruit zone. All pegs analyzed for calcium or potassium included a combination of all pegs produced on a given plant.

At increasing rates of calcium in the fruit zone, the calcium content of Spanish and NC2 peanut shells increased (Fig. 11). Spanish and NC2 were essentially the same in calcium concentrations for any given level of calcium addition to the fruit zones. In general, the potassium content of Spanish and NC2 peanut shells decreased as calcium levels in the fruit zones increased (Fig. 12). Although Spanish was higher in potassium content than NC2 for any given calcium level. This was not a statistically significant difference at the 5 per cent level. It appears that as the calcium concentration increases in the shells the potassium concentration decreases. All shells analyzed were a composite of shells from mature and immature nuts.

Increasing the calcium concentration in the fruit zone apparently increased the calcium concentration in roots of Spanish but not NC2 peanuts (Fig. 13). The fact that root calcium but not leaf calcium increased in Spanish peanut plants as the calcium level was increased cannot be explained. These data could possibly be biased as sand particles were very hard to remove completely from the roots and upon digestion of the root material some sand was found to remain. Because

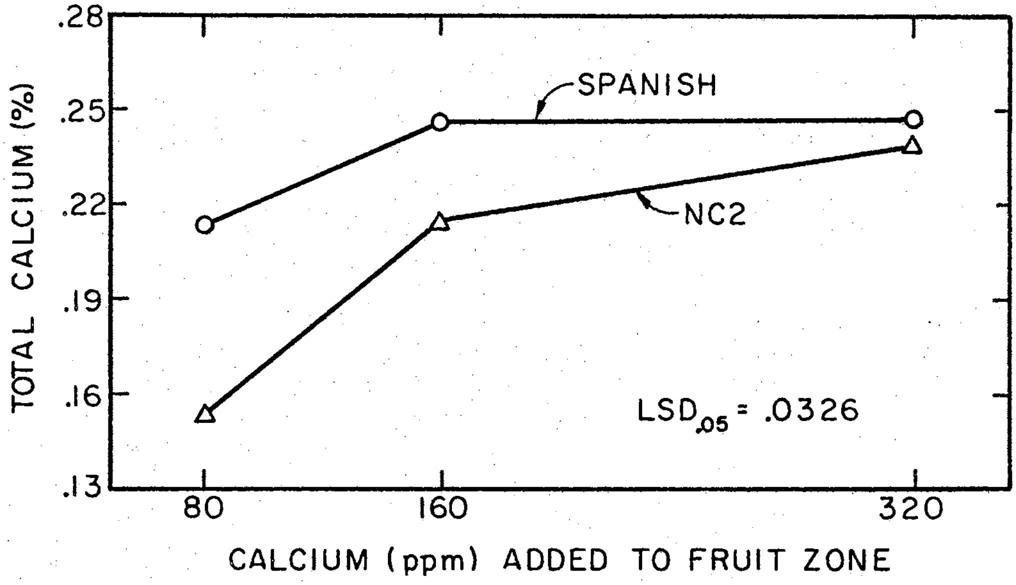


Figure 9. Total Calcium Content of Peanut Pegs

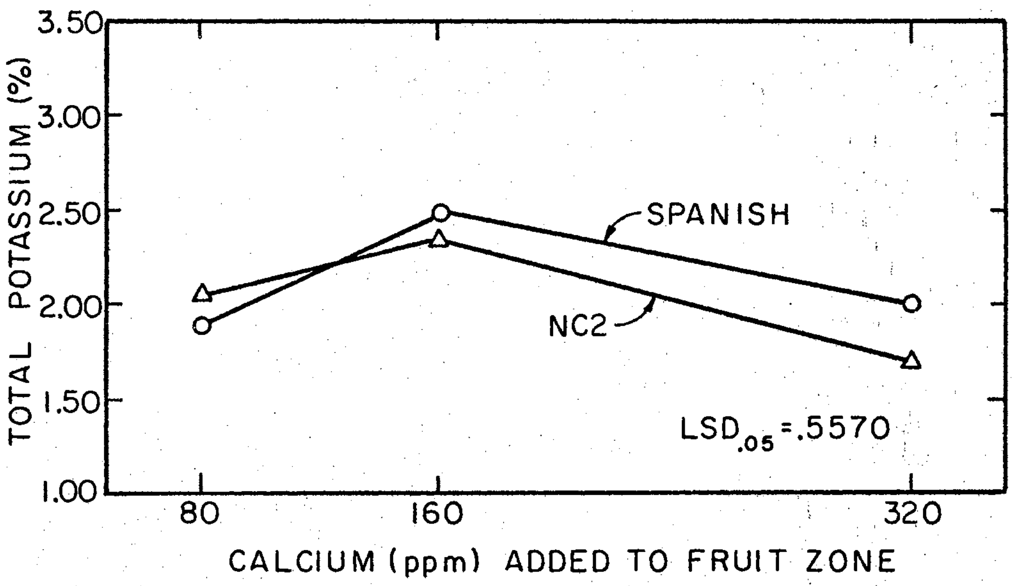


Figure 10. Total Potassium Content of Peanut Pegs

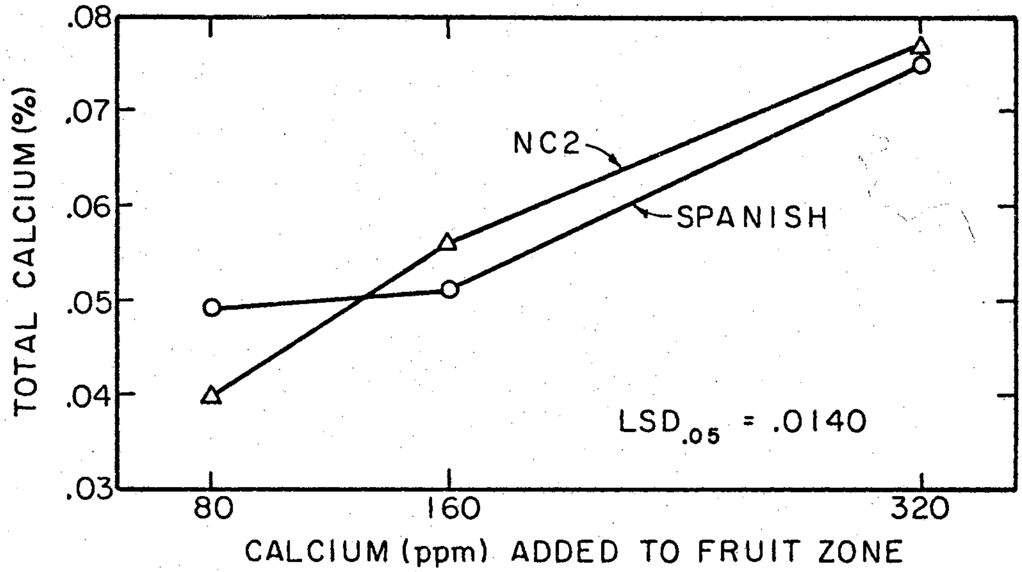


Figure 11. Total Calcium Content of Peanut Shells

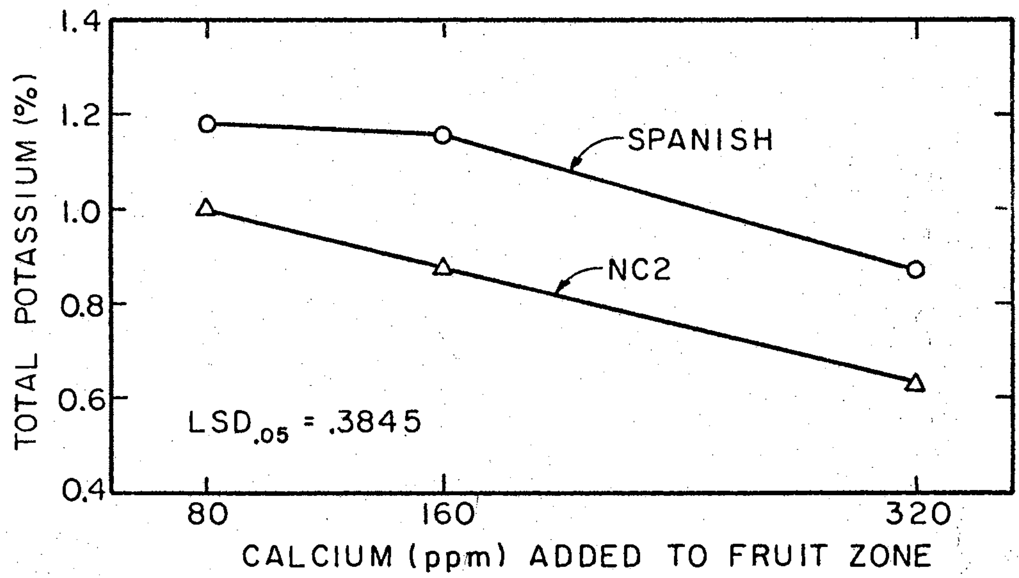


Figure 12. Total Potassium Content of Peanut Shells

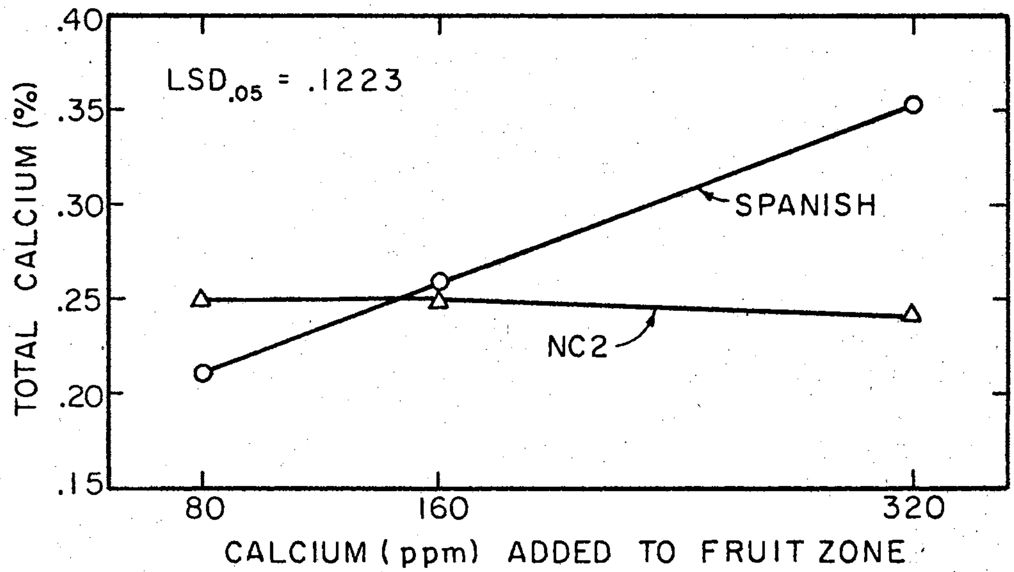


Figure 13. Total Calcium Content of Peanut Roots

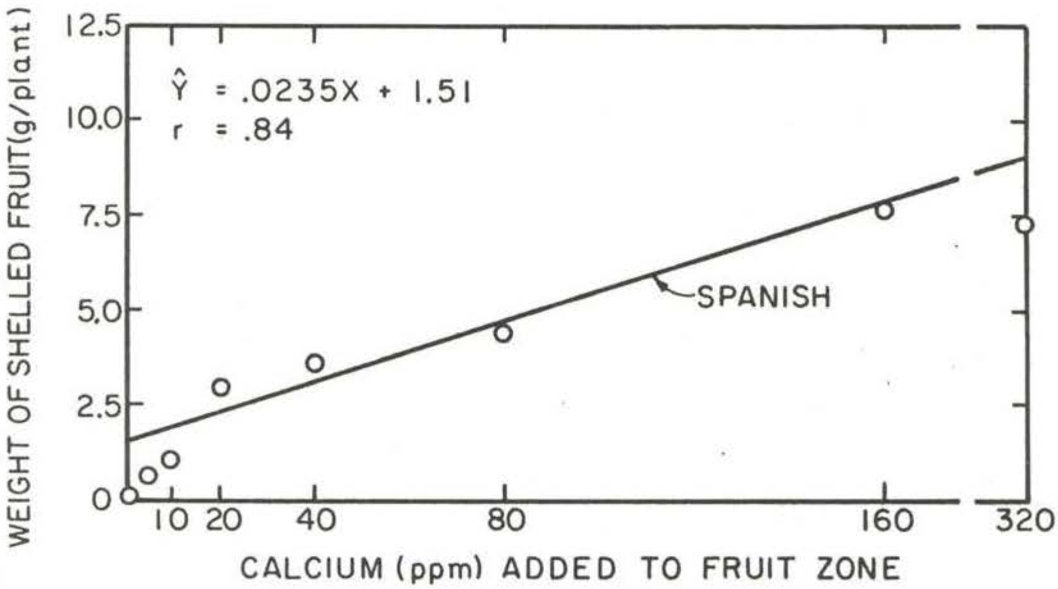
of the consistency of the measured root calcium concentrations, the general tendency is thought to hold and represents a difference between varieties.

Even though the two parts of the experiment were presented separately, the weight of shelled fruit per plant followed a very similar pattern for both parts. Because of this similarity, correlation coefficients, and regression equations were calculated over all the data for Spanish and NC2 (Fig. 14). Both Spanish and NC2 show correspondingly high "r" values between weight of shelled fruit per plant and ppm of calcium added to the fruit zone. The fruit weight of NC2 appears to have a slightly stronger relationship to added calcium than does Spanish.

Experiment II

The total calcium and potassium content of Spanish and NC2 plant parts varied considerably over three harvest dates. A definite pattern was observed for most plant parts analyzed.

Spanish was somewhat lower than NC2 in calcium content of main stem leaves for the August 6 harvest (Fig. 15). With increasing maturity of the plants, however, the calcium level of Spanish surpassed that of NC2. Both varieties increased in calcium content over each subsequent harvest. The potassium content of main stem leaves of Spanish was higher than that of NC2 for the first harvest, but for succeeding harvests both varieties differed only slightly (Fig. 16). Spanish and NC2 decreased in potassium content as the plants approached maturity. Spanish decreased rapidly from the first



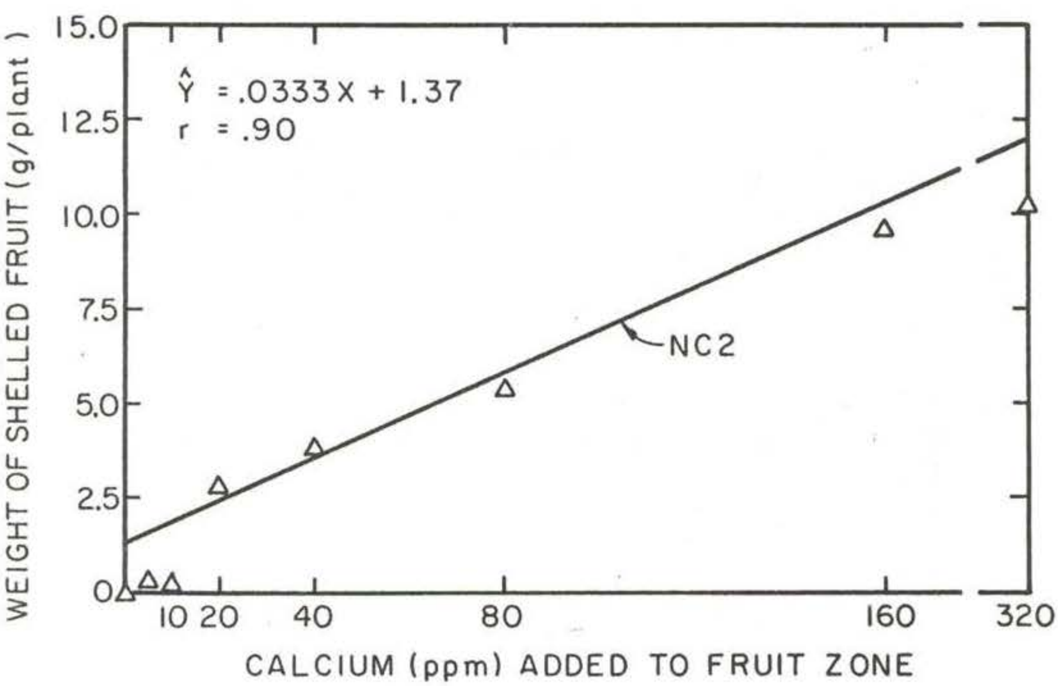


Figure 14. Relationship Between Calcium Added to the Fruit Zone and Weight of Shelled Fruit of Spanish and NC2 Peanuts

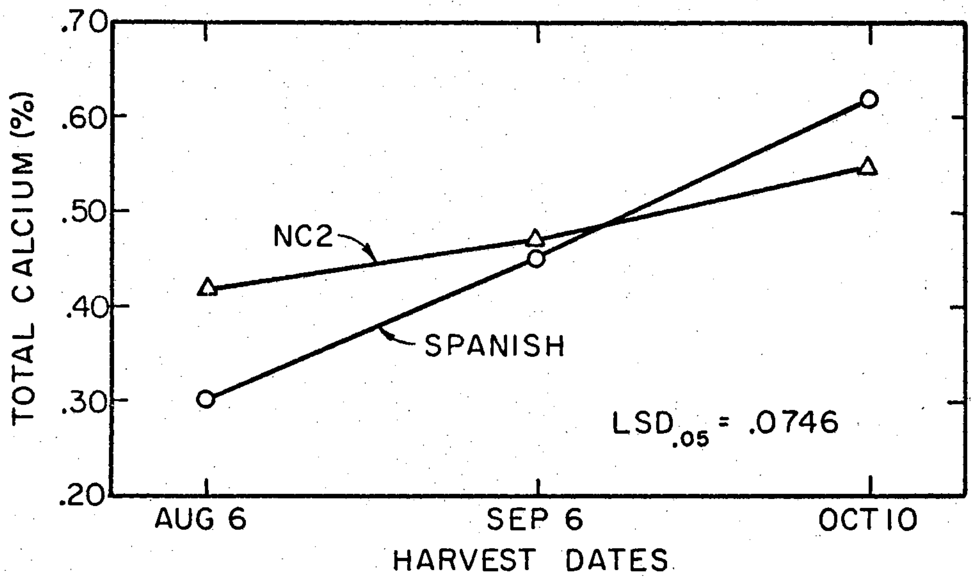


Figure 15. Total Calcium Content of Main Stem Leaves

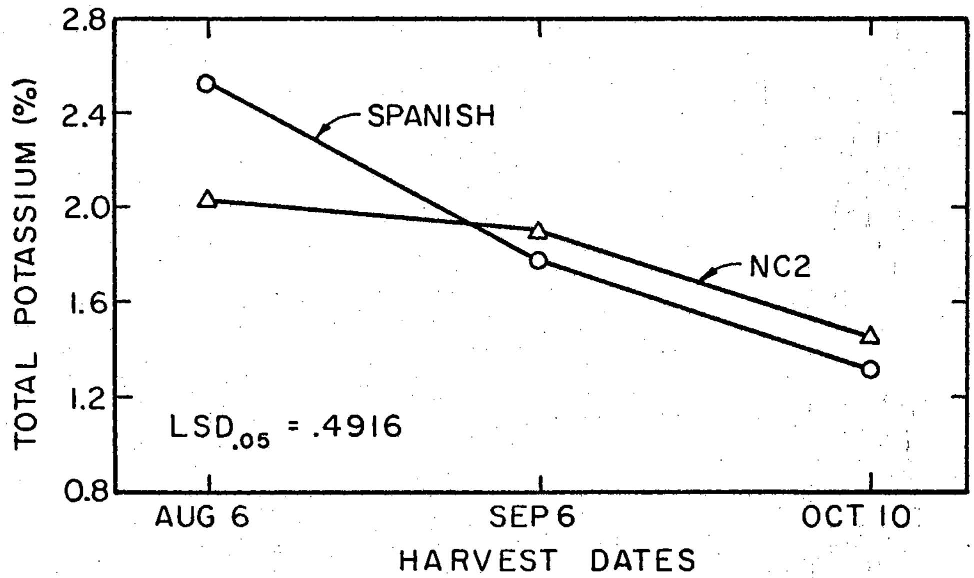


Figure 16. Total Potassium Content of Main Stem Leaves

to the second harvest and then leveled off somewhat, while NC2 leveled off from the first to the second harvest and decreased rapidly from the second to the third harvest.

Spanish and NC2 were essentially the same in calcium concentration of second lateral branch leaves on the August 6 harvest (Fig. 17). At the September 6 harvest NC2 was higher in calcium than Spanish while at the last harvest Spanish surpassed that of NC2. Both varieties in general increased in calcium content with increasing maturity of the plants. Spanish and NC2 second lateral branch leaves differed in potassium content only at the September 6 harvest date (Fig. 18). With increasing maturity of these plants, the potassium concentration decreased. Spanish, again, decreased rapidly from the first to the second harvest and then leveled off somewhat, while NC2 was essentially the same in potassium content for the first and second harvest but dropped considerably at the third harvest.

The calcium content of the first lateral branch leaves from Spanish and NC2 differed only slightly at any one harvest (Fig. 19). Both varieties tended to increase in calcium as the plants matured. Spanish and NC2 first lateral branch leaves were essentially the same in potassium levels at any one harvest (Fig. 20). Both varieties tended to decrease in potassium as the plants matured. This decrease in potassium followed the same pattern as was observed for the other leaf positions analyzed.

Spanish pegs not touching the fruit zone contained considerably more calcium than similar pegs for NC2 at any harvest (Fig. 21). Both Spanish and NC2 pegs increased in calcium as the plants approached maturity, although Spanish increased more rapidly than did NC2. The

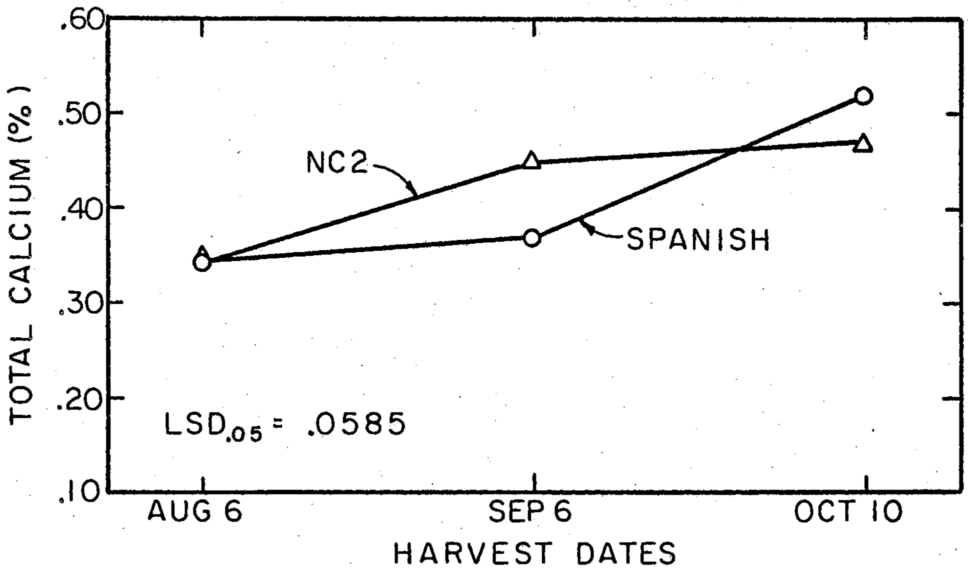


Figure 17. Total Calcium Content of Second Lateral Branch Leaves

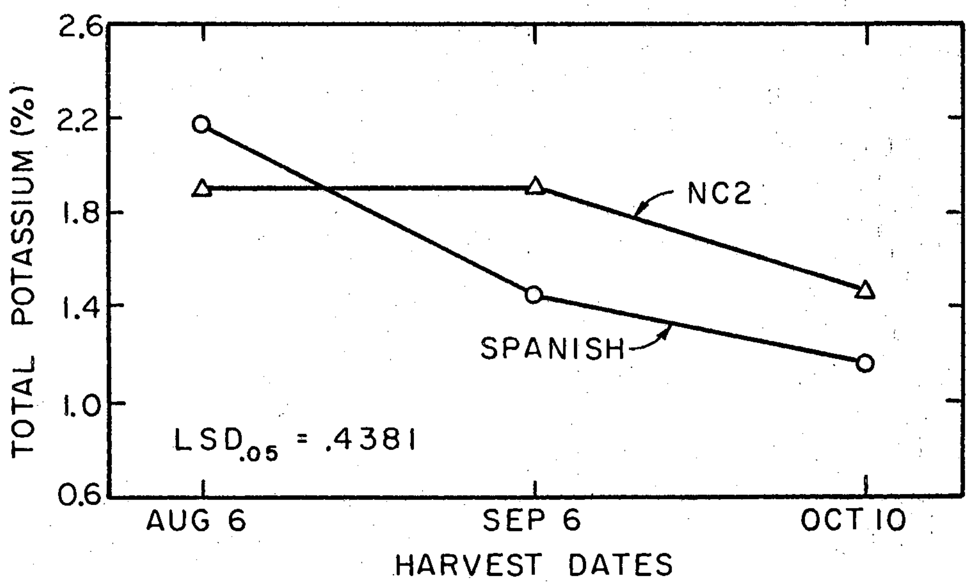


Figure 18. Total Potassium Content of Second Lateral Branch Leaves

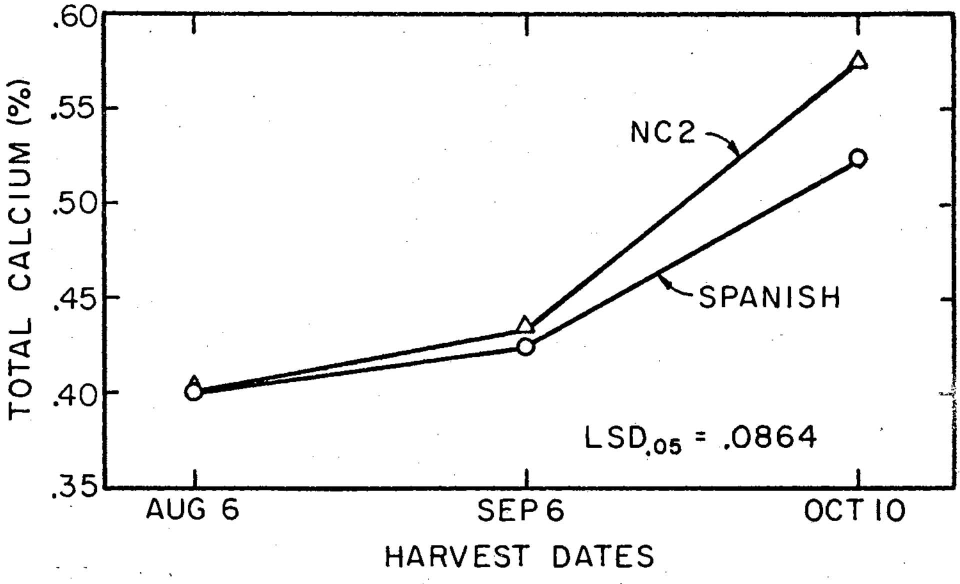


Figure 19. Total Calcium Content of First Lateral Branch Leaves

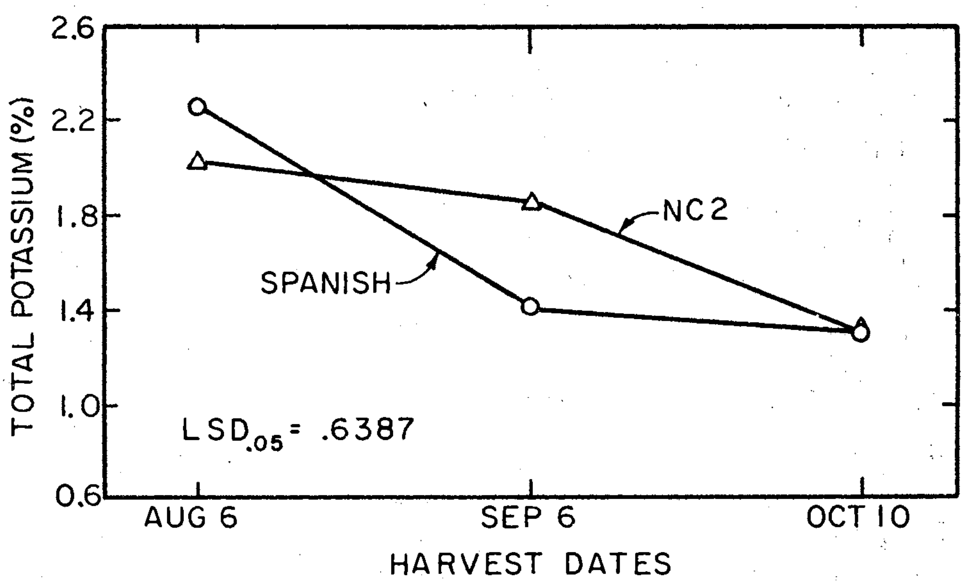


Figure 20. Total Potassium Content of First Lateral Branch Leaves

total potassium content of these pegs increased and then decreased as the season progressed (Fig. 22). Neither variety differed statistically from each other for any one harvest.

The total calcium content of the peg portion in the fruit zone followed a completely different pattern from that of pegs not touching the fruit zone (Fig. 23). Spanish pegs in the fruiting zone contained more calcium than NC2 pegs only at the first harvest, but their calcium content then declined to a lower level. Brady (3) suggested that the most critical period in fruit development from the standpoint of a supply of calcium to the fruit zone was 15-35 days after the gynophores reached the sand. The August 6 harvest corresponds to approximately this time period. Spanish pegs which did not touch the fruit zone were considerably higher in calcium than those of NC2. This may suggest that Spanish has a more adequate supply of calcium to begin fruit formation with than does NC2. The NC2 peg portion in the fruit zone remained essentially the same in calcium concentration for the first two harvests, but decreased somewhat at the last harvest. Spanish decreased rapidly in calcium from the first to the second harvest and leveled off from the second to the third harvest. The NC2 peg calcium was considerably higher than Spanish for the September 6 harvest. The potassium content of these pegs followed a similar pattern as did the pegs which had not touched the fruit zone (Fig. 24). The NC2 pegs increased in potassium very rapidly at the second harvest and then decreased very rapidly for the third harvest. Spanish pegs were essentially the same for all harvests. The NC2 pegs were much higher in potassium than Spanish for the September 6 harvest. Burkhart and Collins (6) hypothesized that an excessive potassium

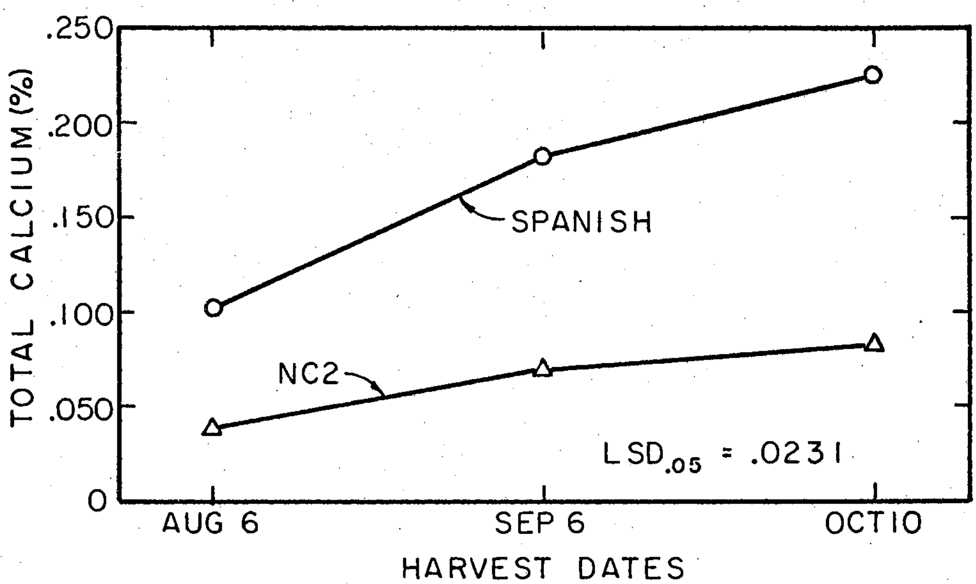


Figure 21. Total Calcium Content of Pegs Not Touching Fruit Zone

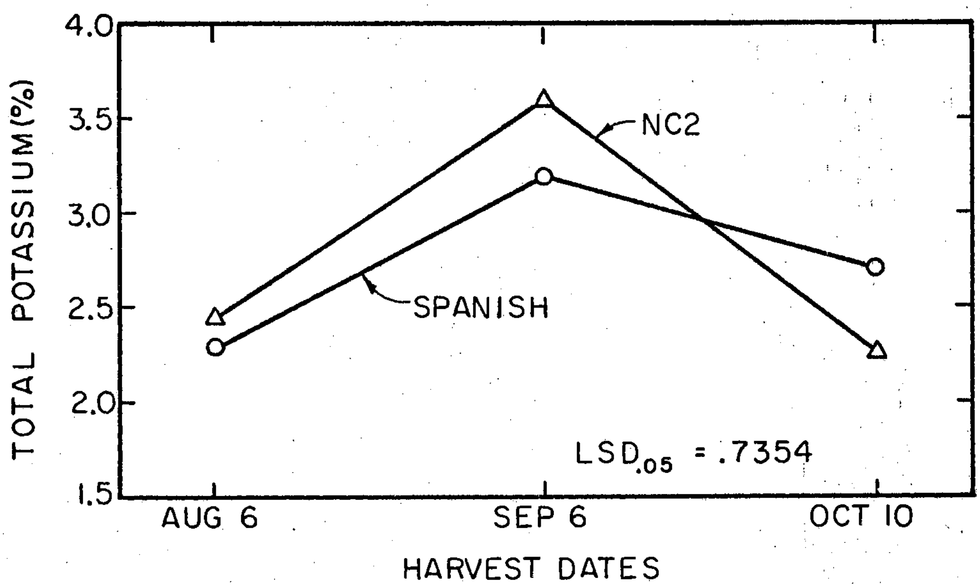


Figure 22. Total Potassium Content of Pegs Not Touching Fruit Zone

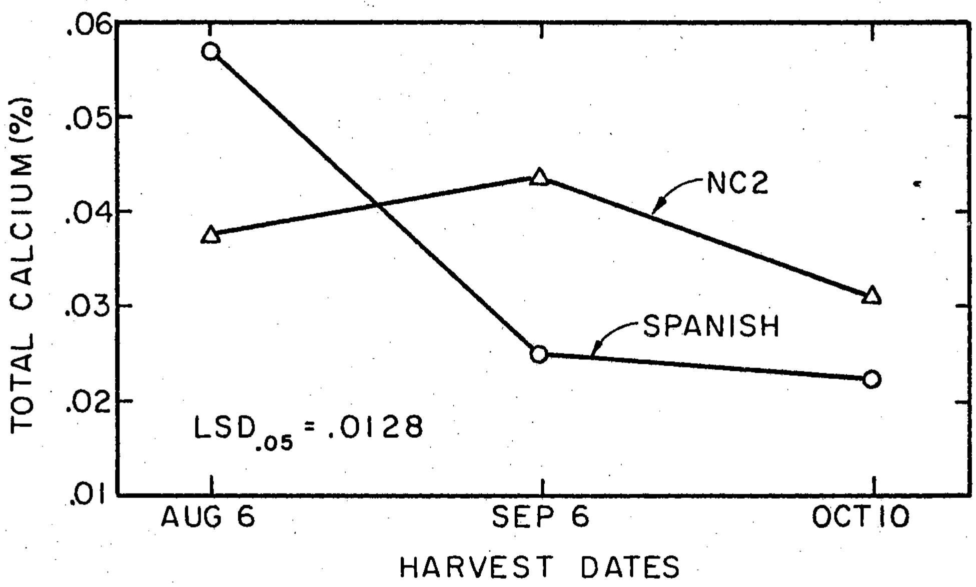


Figure 23. Total Calcium Content of Peg Portion in Fruit Zone

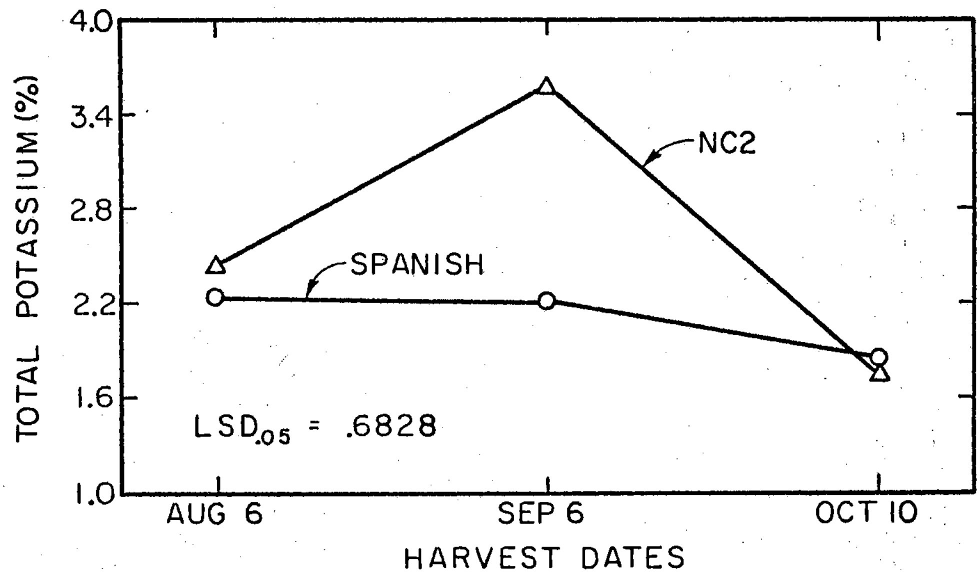


Figure 24. Total Potassium Content of Peg Portion in Fruit Zone

absorption by the roots of the plants or by the developing fruit may retard the transport of calcium from the vegetative organs to the fruit or the direct intake of calcium by the fruit. How important this large amount of potassium is on fruit development of NC2 peanuts for the September 6 harvest is not known.

Experiment III

Many researchers (12, 13, 19, 32, 37) have suggested that root CEC is related to cation uptake by plants and may regulate the relative amounts of calcium versus potassium taken up by the plant. The root CEC within plant species can be changed by nutritional variables (20). In Experiment III developing peanut gynophores were considered to act in a like manner as plant roots.

Under low soil calcium conditions, the calcium content of shells of Spanish and NC2 were essentially the same for the September 13 harvest (Fig. 25). As the plants matured, Spanish shells increased in calcium concentration while those of NC2 remained the same. At the October 11 and especially at the November 7 harvests, Spanish shells were considerably higher in calcium than NC2. Both varieties produced good quality mature nuts at the November 7 harvest. The potassium content of the shells of Spanish and NC2 peanuts declined in a similar pattern from one harvest to the next (Fig. 26). Both Spanish and NC2 decreased in shell potassium as the plants approached maturity. Only slight differences existed between Spanish and NC2 at any one harvest date.

Under high soil calcium conditions, the calcium content of shells of Spanish and NC2 differed statistically at the October 11 and

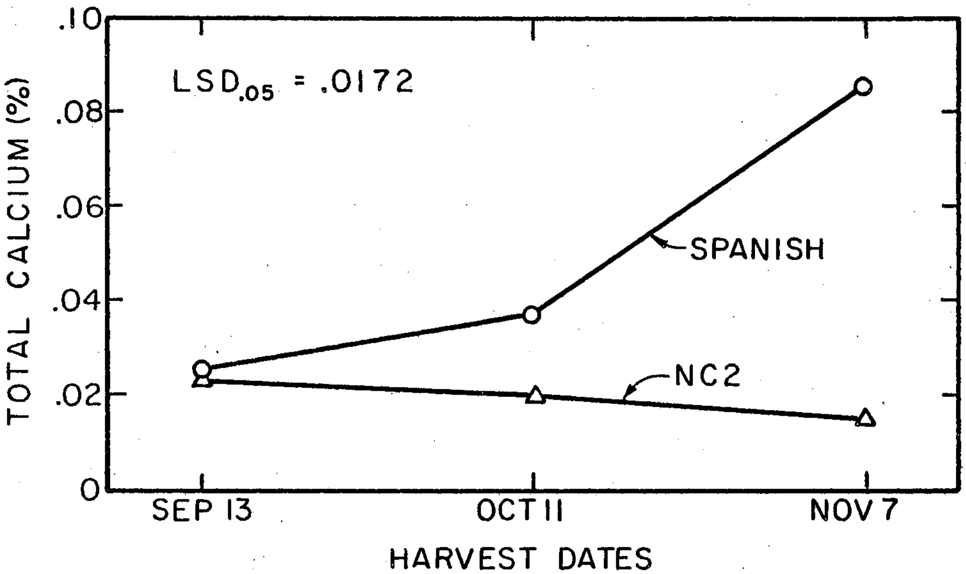


Figure 25. Total Calcium Content of Peanut Shells on Low Calcium Soil

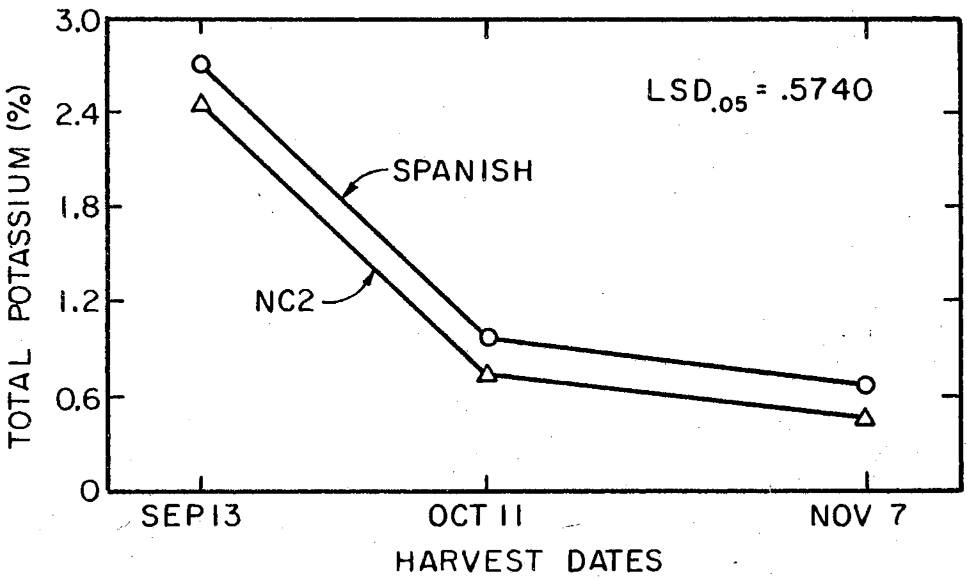


Figure 26. Total Potassium Content of Peanut Shells on Low Calcium Soil

November 7 harvests (Fig. 27). The difference in shell calcium of Spanish and NC2 for the September 13 harvest was not significant at the 5 per cent level. Spanish appears to be able to absorb more calcium than NC2 from a low or a high calcium soil, but for either soil, Spanish and NC2 produced good quality fruit. The potassium content of Spanish and NC2 shells on a high calcium soil varied somewhat from that on a low calcium soil (Fig. 28). The potassium content of NC2 was substantially higher than Spanish only at the September 13 harvest, then NC2 decreased rapidly over the last two harvests. Spanish decreased from the first to the second harvest and then leveled off somewhat at the last harvest. At an early period in fruit development, NC2 apparently absorbed more potassium from a high calcium soil than from a low calcium soil.

The CEC of Spanish shells on a low calcium soil was much higher than that of NC2 on the September 13 harvest (Fig. 29). Heintze (16) reported that plants with a high CEC favored divalent to monovalent cation uptake and vice versa. This suggests that Spanish is more capable of absorbing potassium than Spanish. However, shell calcium and potassium levels do not substantiate this. Shell CEC of Spanish decreases as the plants mature, which agrees with the work of Helmy and Elgabalys (17) with roots of barley plants. The CEC of NC2 increases then decreases from the first to the second and from the second to the third harvests, respectively. This suggests that NC2 shells are absorbing more calcium at the October 11 harvest. Only small differences existed in the calcium content of NC2 shells for any harvest date.

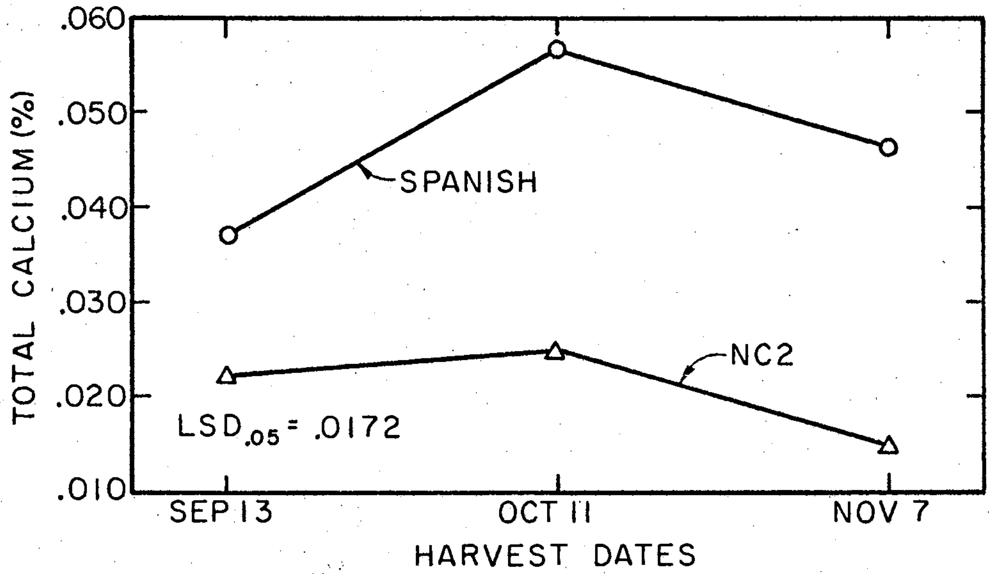


Figure 27. Total Calcium Content of Peanut Shells on High Calcium Soil

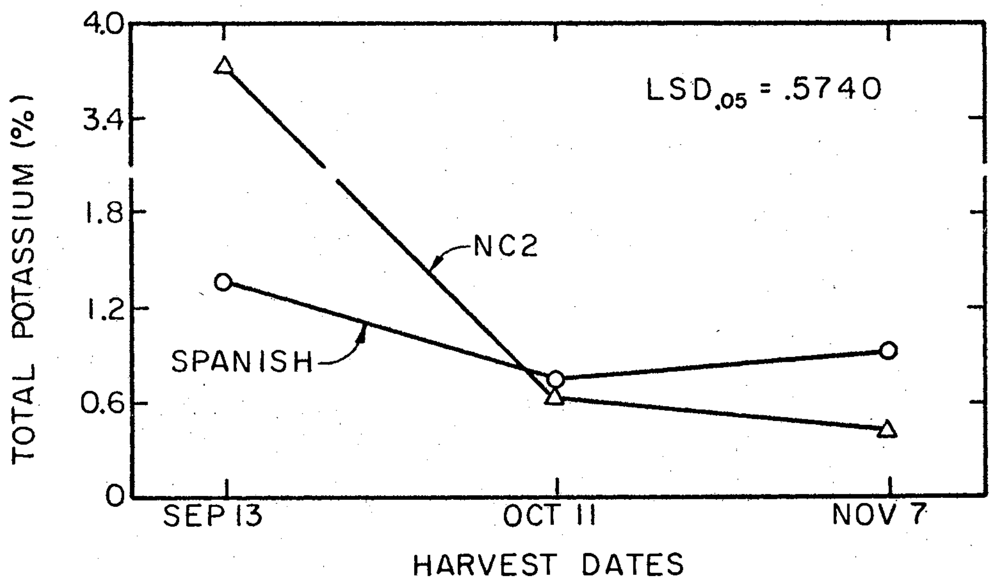


Figure 28. Total Potassium Content of Peanut Shells on High Calcium Soil

Under high soil calcium conditions, the CEC of Spanish and NC2 shells followed the same trend as under low soil calcium conditions for all harvest dates (Fig. 30). The large difference in CEC of Spanish and NC2 agrees somewhat with the difference in calcium content of the shells for the first harvest, but little agreement is observed for the succeeding harvests. The potassium content of NC2 shells suggests a relationship to the CEC for this first harvest, but there is a somewhat inverse relationship for the remaining harvests. This inverse relationship of CEC to shell potassium concentration was exhibited by Spanish also.

Experiment IV

All of the measured vegetative and reproductive characteristics of Spanish and NC2 peanuts were substantially affected by the use of synthetic cation exchange resins in the fruit zone (Table IX). The dry weight of leaves and stems for either Spanish or NC2 was the least when the fruit zone contained the strong acid resin. The dry weight of leaves and stems of Spanish was somewhat less than that of NC2 for either type of resin used.

Although the strong acid resin increased the number of pegs per plant, it drastically decreased the percentage of pegs which produced fruit and, thus, decreased the number of fruit per plant (Table IX) and decreased yield of nuts (Table X). This large difference in yield is suggested to result from differences in the release of calcium from the two types of resins. The ammonium acetate extractable calcium was nearly the same for both resins, but the water extractable calcium was three times as high for the weak as for the strong acid resin

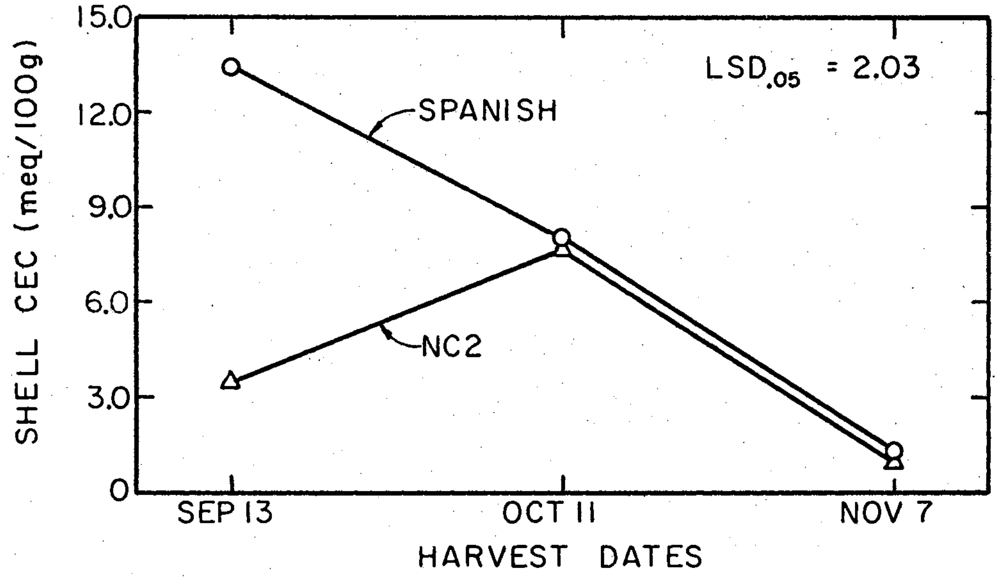


Figure 29. CEC of Peanut Shells on Low Calcium Soil

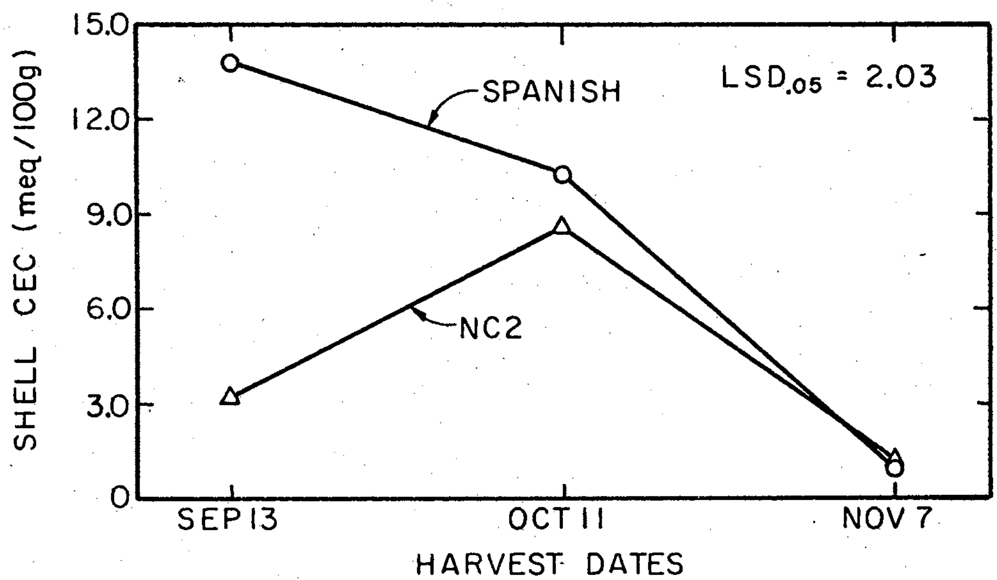


Figure 30. CEC of Peanut Shells on High Calcium Soil

TABLE IX

MEAN VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF SPANISH AND NC2 PEANUTS AS AFFECTED BY EXCHANGE RESINS CONTAINED IN THE FRUIT ZONE*

Treatment	Dry weight of leaves and stems (g/plant)	No. of pegs per plant	No. of fruit per plant	Pegs producing fruit (%)
Spanish				
*Strong acid	37.75	132.50	10.25	7.74
**Weak acid	18.13	76.25	51.75	67.87
NC2				
Strong acid	55.63	131.25	4.25	3.24
Weak acid	24.38	73.25	40.75	55.63
$LSD_{.05}$	6.23	21.77	9.54	14.71

*All values are the means of four replications
**Sulfonated polystyrene copolymer, hydrogen form, Rexyn R-231
***Methacrylic acid containing carboxylic acid groups, hydrogen form, Rexyn R-234

(Table IV). Therefore, the weak acid resin is considered to release calcium more readily than the strong acid resin. If an analysis of variance is computed on the weight of shelled fruit of NC2 and Spanish for just the fruit produced in a strong acid resin, the kernel weight of Spanish is statistically larger than that of NC2 at the 5 per cent level of significance.

TABLE X

MEAN WEIGHT OF UNSHELLED AND SHELLED FRUIT OF SPANISH AND NC2 PEANUTS AS AFFECTED BY EXCHANGE RESINS CONTAINED IN THE FRUIT ZONE*

Treatment	Weight of unshelled fruit (g/plant)	Weight of shelled fruit (g/plant)
Spanish		
Strong acid	4.48	2.78
Weak acid	25.53	18.58
NC2		
Strong acid	1.48	.75
Weak acid	27.50	20.85
$LSD_{.05}$	5.51	4.45

*All values are the means of four replications.

The total calcium content of the main stem leaves of Spanish and NC2 was considerably decreased by the use of a strong or weak acid resin in the fruit zone (Fig. 31). Spanish was higher in leaf calcium than NC2 when the strong acid resin was placed in the fruit zone, but both peanut varieties had essentially the same calcium concentration when the weak acid resin was used as a fruiting medium. Use of the weak acid resin produced a much higher level of calcium in the leaves for both varieties than did the strong acid resin. It appears that more calcium was absorbed by the developing gynophores from the weak acid resin than from the strong acid resin for both varieties and then transported to the leaf area. The total potassium content of the leaves of Spanish and NC2 differed statistically when the fruit zones contained the weak acid resin, which gave the lowest potassium content of either variety (Fig. 32). Spanish was much higher than NC2 in leaf potassium when the fruit zone contained the weak acid resin. Both varieties exhibited a tendency to decrease in potassium as the calcium concentration of the leaves increased.

A strong acid resin in the fruit zone significantly reduced the calcium content of Spanish and NC2 peanut shells when compared to the calcium content of shells produced in a weak acid resin (Fig. 33). There was no appreciable difference in shell calcium of Spanish and NC2 when the fruit zone contained a strong acid resin, but shell calcium of Spanish was substantially higher than that of NC2 when a weak acid resin was used as a fruiting medium. Spanish appears to be able to absorb more calcium than NC2 under one set of conditions (high amounts of water extractable calcium from the fruiting media), but is very similar to NC2 in calcium absorption under another set of conditions (low amounts of water extractable calcium from the fruiting media). Regardless of the kind of resin used in the fruit zone, NC2 was considerably higher than Spanish in shell potassium content (Fig. 34). Spanish exhibited an increase in shell potassium concentration when the type of resin was changed from a strong to a weak acid, while NC2 remained essentially the same in shell potassium for either type of resin. Burkhart and Collins (6) indicated that the known antagonism between potassium and calcium may come into play when the

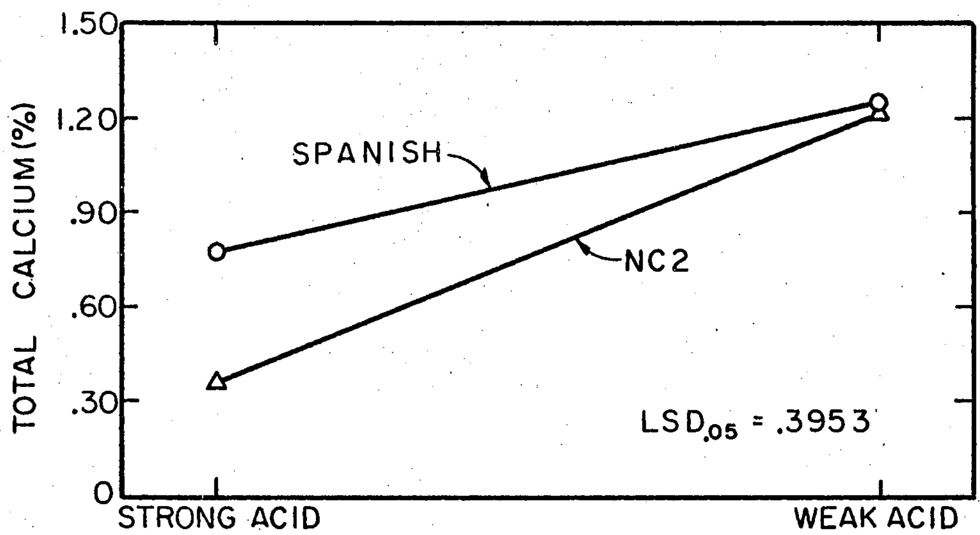


Figure 31. Total Calcium Content of Peanut Leaves as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

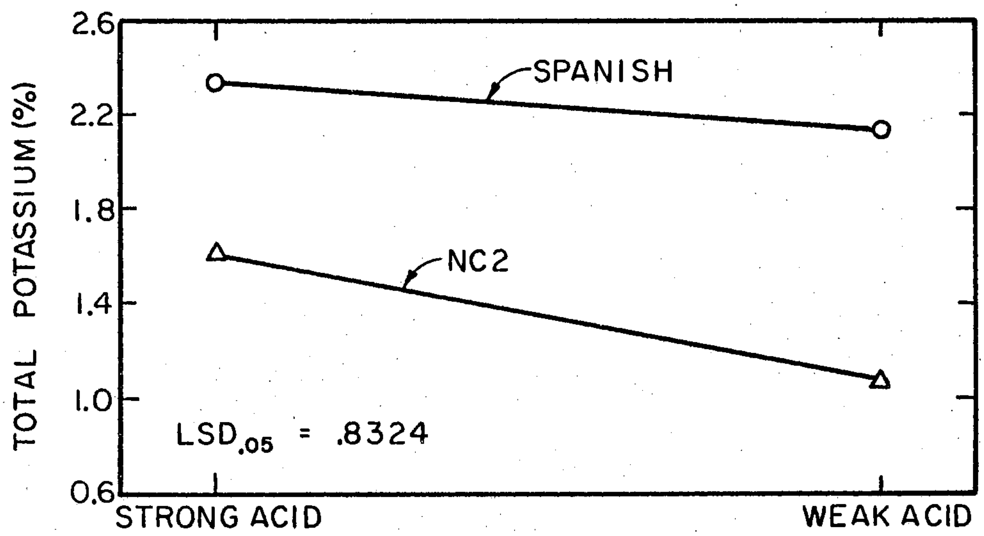


Figure 32. Total Potassium Content of Peanut Leaves as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

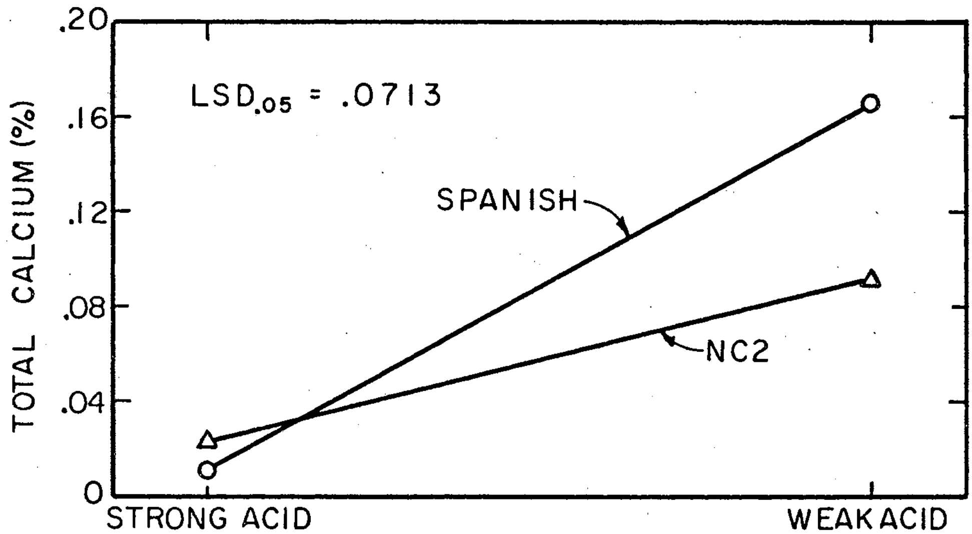


Figure 33. Total Calcium Content of Peanut Shells as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

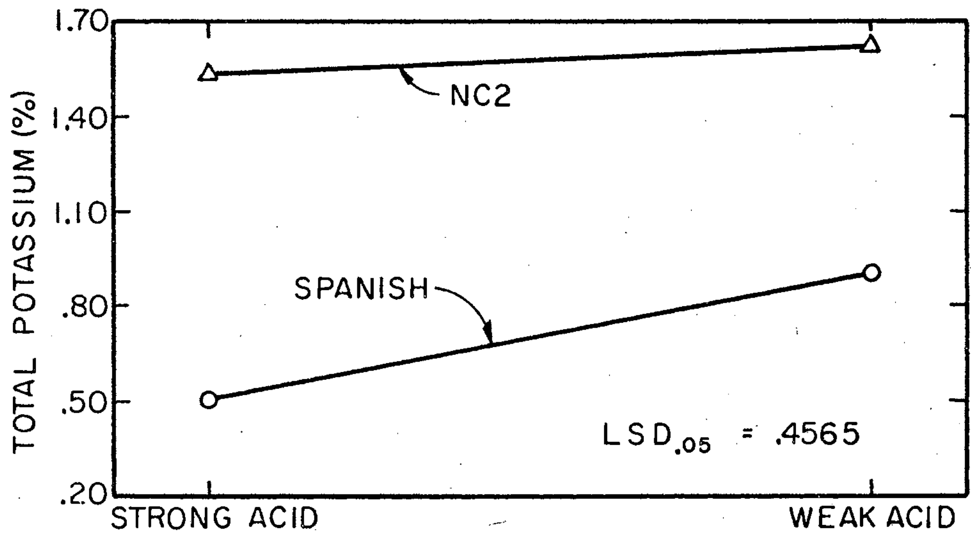


Figure 34. Total Potassium Content of Peanut Shells as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

fruiting medium has a low available calcium supply and it is probable that an excessive potassium absorption by the roots of the plant or by the developing fruit may retard the transport of calcium from the vegetative organs to the fruit or the direct intake of calcium by the fruit. It appears that under low available calcium conditions (strong acid resin in fruit zone) that either NC2 roots or tops transfer quite a large supply of potassium to the developing shells as conpared to Spanish. As no potassium was added to the fruit zone, this could be one of the reasons NC2 produced such a small yield of fruit in the strong acid resin. The availability of calcium, in the fruit zone, not potassium translocation to the shells, apparently limited the fruit production of Spanish when a strong acid resin was used in the fruit zone. Under high available calcium conditions (weak acid resins in the fruit zone) NC2 absorbs the same shell potassium content but produces many more fruit than under low calcium conditions, thus, it appears that a high potassium uptake by the roots or potassium translocation by the tops of NC2 has little effect on nut production when sufficient calcium is available in the fruit area. Spanish absorbed more shell potassium under high available calcium conditions than under low available calcium conditions, but still produced better yields under the high available calcium conditions. It appears that increased root absorption or top translocation of potassium to the developing fruit had little or no effect on yield of Spanish peanuts, but could possibly be partially responsible for reduced yields of NC2 peanuts.

The calcium content of NC2 kernels was only slightly altered when the fruiting medium was changed from a strong to a weak acid resin

(Fig. 35). This agrees somewhat with the work of Burkhart and Collins (6) who stated that the effects of fertilizer treatments on the composition of Virginia Bunch peanut fruit is small compared to differences in shell composition. This was not the case for Spanish, as the calcium content of the kernels increased considerably when the fruiting media was changed from a strong to a weak acid resin. The kernel calcium content of NC2 was substantially higher than that of Spanish under strong acid resin conditions, but Spanish surpassed NC2 in kernel calcium under weak acid resin conditions. Because of the large difference in kernel calcium and the small difference in kernel yield of Spanish and NC2 under strong acid resin conditions, it is suggested that Spanish kernels need less calcium than NC2 to produce a similar quantity of fruit.

Regardless of the type of resin used in the fruit zone, Spanish and NC2 did not differ statistically, at the 5 per cent level, in the total potassium concentration of their respective kernels (Fig. 36). Neither variety exhibited a significant tendency to increase or decrease in kernel potassium when the fruiting medium was changed from a strong to a weak acid resin.

The peg portion not in the fruiting media (PN) which developed mature fruit of Spanish was higher in calcium concentration than that of NC2 for either type of resin used in the fruit area (Fig. 37). Both Spanish and NC2 increased in PN calcium as the fruiting media changed from a strong to a weak acid resin. Spanish and NC2 were essentially the same in calcium content of the peg portion in the fruiting media (PI) which developed mature fruit in a strong acid resin, but when a weak acid resin was used in the fruit area NC2 surpassed Spanish in PI

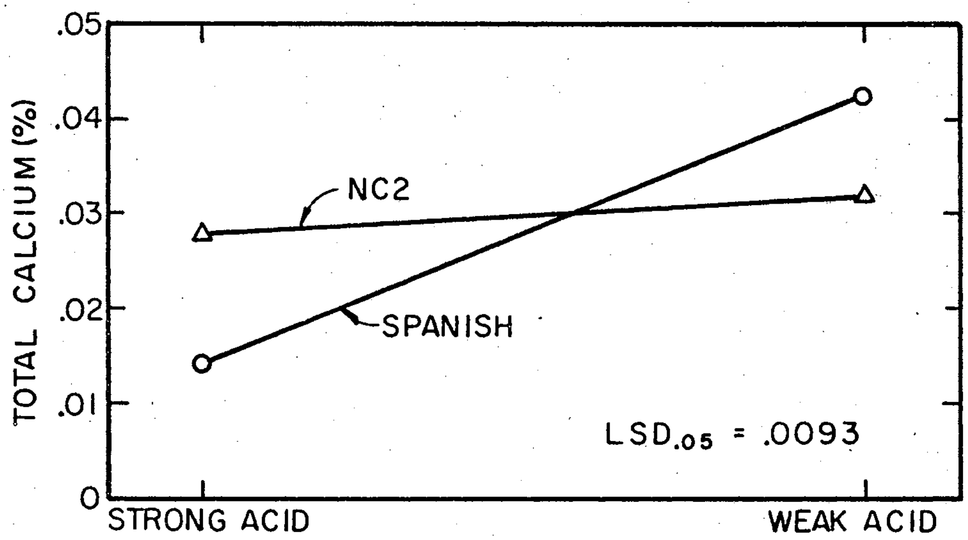


Figure 35. Total Calcium Content of Peanut Kernels as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

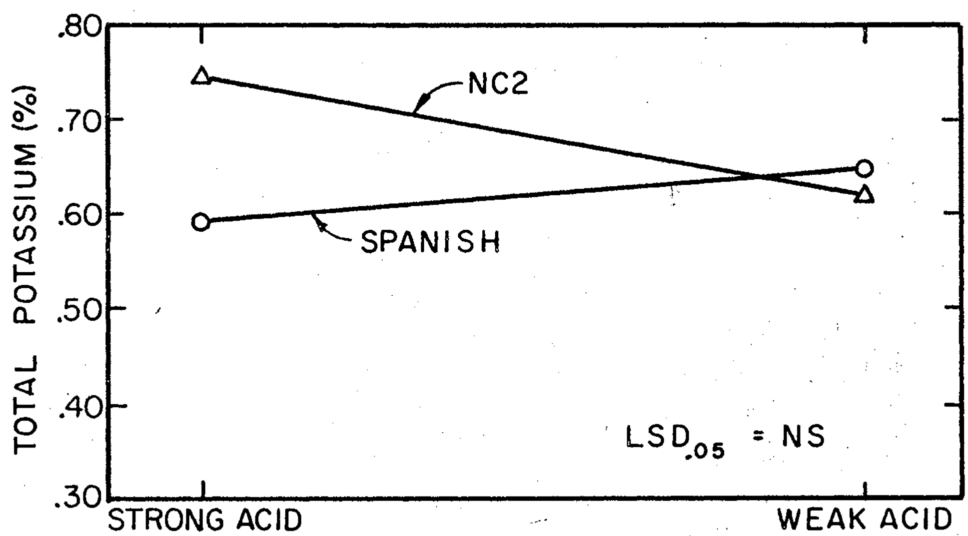


Figure 36. Total Potassium Content of Peanut Kernels as Influenced by the Use of a Strong or Weak Acid Resin in the Fruit Zone

calcium content (Fig. 37). When going from a strong to a weak acid resin NC2 increased in PI calcium, but Spanish remained the same in PI calcium for either resin. For any one particular resin NC2 was the same in calcium concentration of PN or PI, while Spanish dropped in PI calcium content as compared to PN calcium. No good explanation can be given for this except that possibly calcium is being transported from the PN and PI peg portion into the developing fruit of Spanish peanuts, more so under weak than under strong acid resin conditions.

Spanish and NC2 were very similar in potassium concentration of the PI peg portion which developed mature fruit for either type of resin used in the fruit zone (Fig. 38). Both varieties did not exhibit a significant increase or decrease in PI potassium when the fruiting medium was changed from a strong to a weak acid resin. The PI potassium content of pegs which developed mature fruit of Spanish was slightly lower than that of NC2 for any one particular type of resin (Fig. 38). Both varieites exhibited a tendency to increase in PI potassium as the fruiting media changed from a strong to a weak acid resin. Very little differences were observed within either variety in the PN or PI potassium content for any one particular resin. The PN and PI potassium concentrations of Spanish and NC2 acted in a similar manner as did their respective shells.

When conditions were such that no fruit were developed, the above ground peg portion (PN) of Spanish was appreciably higher in calcium than that of NC2 for either type of resin used in the fruit zone (Fig. 39). Both varieties increased in calcium content as the fruiting media was changed from a strong to a weak acid resin. The calcium concentration of the peg portion below the soil (PI) was the same for

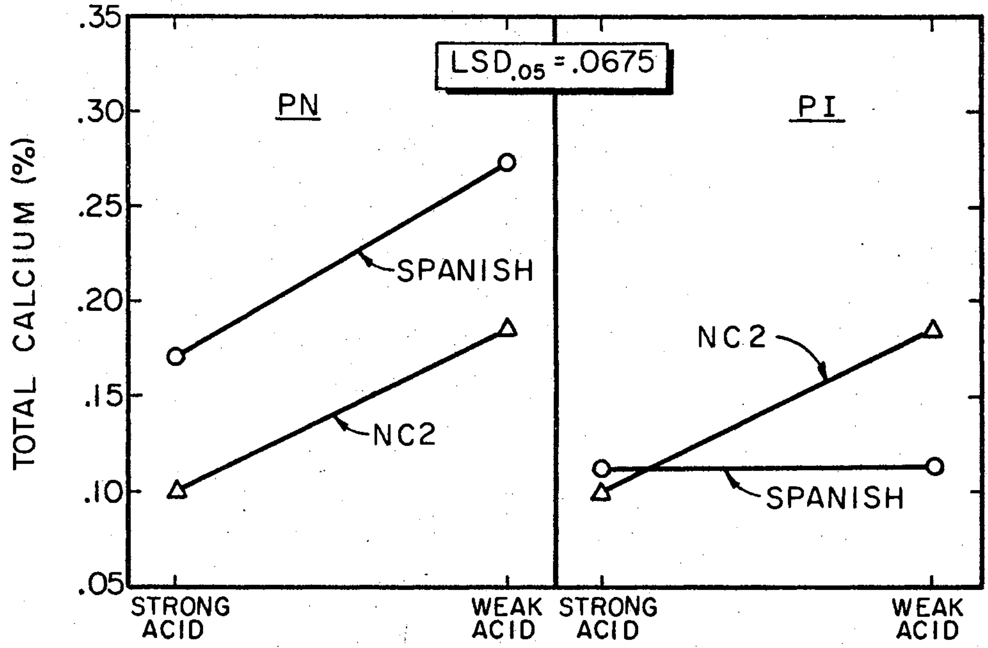


Figure 37. Total Calcium Content of Peg Portions Which Developed Mature Fruit

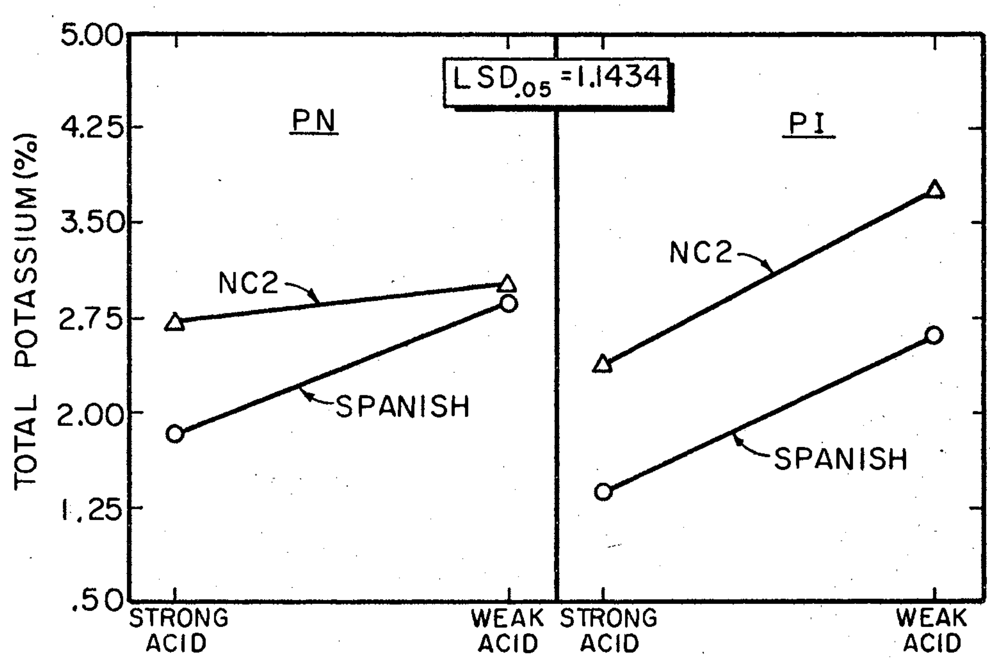


Figure 38. Total Potassium Content of Peg Portions Which Developed Mature Fruit

Spanish or NC2 when a strong acid resin was contained in the fruit area, but NC2 surpassed Spanish in PI calcium when a weak acid resin was used as a fruiting media (Fig. 39). The PI calcium content of NC2 increased sharply as the fruiting media was changed from a strong to a weak acid resin, while Spanish remained essentially the same in PI calcium content for either type of resin used. The PN and PI calcium levels followed the same pattern as did the PN and PI which developed mature fruit except the PN and PI which developed no fruit were generally somewhat higher in calcium than were those peg portions which developed mature fruit. No drain in calcium needed for fruit development could be an explanation for these calcium level differences.

Spanish and NC2 were very nearly the same in potassium content of the PN peg portion which developed no fruit for either a strong or a weak acid resin (Fig. 40). Neither variety exhibited a tendency to increase or decrease in PN potassium when the fruit zone was changed from a strong to a weak acid resin. The PI peg portion of NC2 was slightly higher in potassium when a strong acid resin was used in the fruit zone, but both varieties were essentially equal in potassium concentration when a weak acid resin was contained in the fruit area (Fig. 40). Spanish increased in PI potassium as the fruiting medium was changed from a strong to a weak acid resin, while NC2 remained about the same in PI potassium regardless of the type of resin used in the fruit zone. The PN peg portion was appreciably higher in potassium than the PI peg portion of Spanish when the fruiting area contained the strong acid resin. No other significant differences were observed when comparing like varieties and resins. The PN and PI

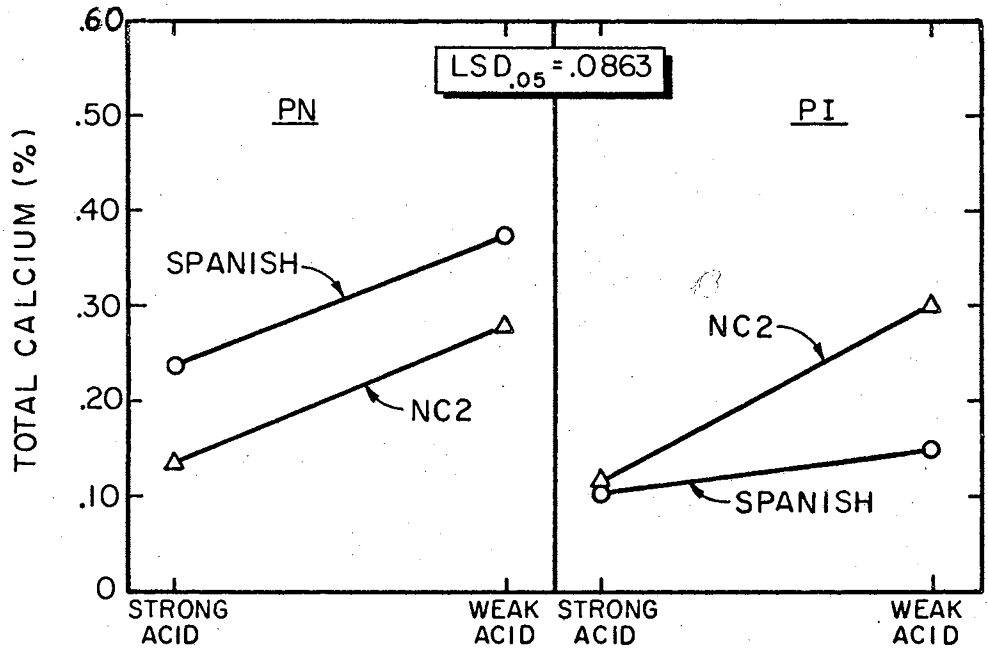


Figure 39. Total Calcium Content of Peg Portions Which Developed No Fruit

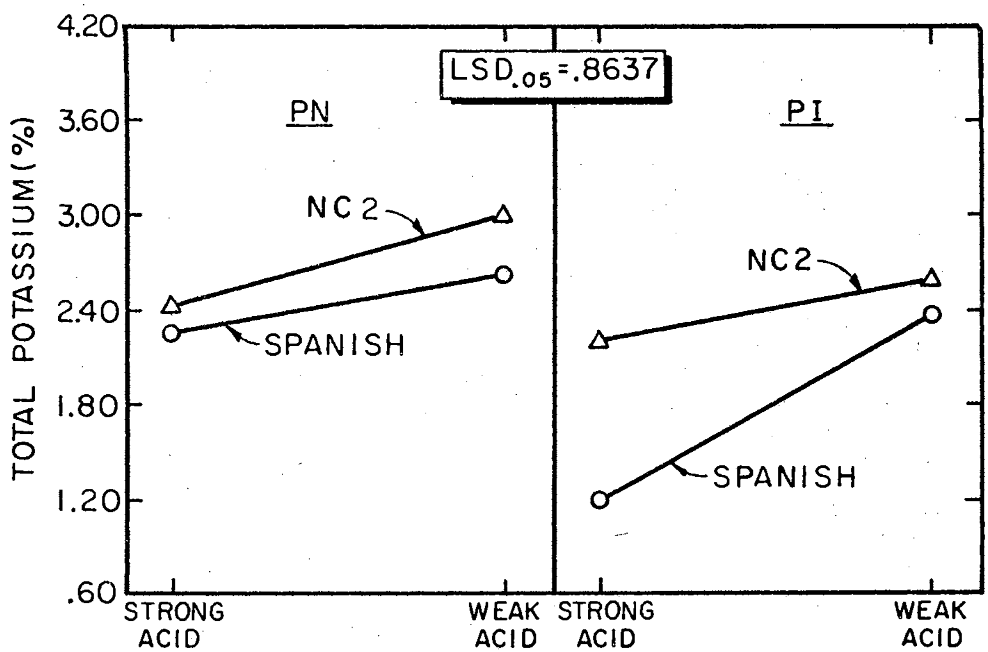


Figure 40. Total Potassium Content of Peg Portions Which Developed No Fruit

peg portions which developed no fruit were in general comparable in potassium content to the same peg portions which developed mature fruit.

The calcium content of pegs which never entered the fruit zone was higher for Spanish than NC2 peanuts regardless of the type of resin used in the fruit zone (Fig. 41). Both varieties increased in peg calcium as the fruiting media was changed from a strong to a weak acid resin. It appears that both varieties are capable of translocating calcium from pegs which are in the fruit zone to pegs which have never entered the fruit zone or that there is a decreased drain of calcium from the plant when pegs developing fruit can - or are able - to obtain their own calcium. It also appears that regardless of the available supply of calcium in the fruit zone that Spanish peanuts have a higher supply of peg calcium to begin fruit formation with than do NC2 peanuts.

Spanish peanuts were higher in potassium content of the pegs which never reached the fruiting area than NC2 peanuts for either type of resin used in the fruit zone (Fig. 42). Both varieties increased in potassium concentration as the fruiting medium was changed from a strong to a weak acid resin. When considering the potassium content of above ground peg portions from Spanish and NC2 peanuts a difference was noted. The potassium content of Spanish pegs not yet reaching the soil, those just entering the soil, and those which had developed mature fruit were uniform in potassium content. The potassium content of NC2 above ground peg portions increased with age, that is the pegs with the mature fruit contained higher amounts of potassium than pegs not yet entering the soil.

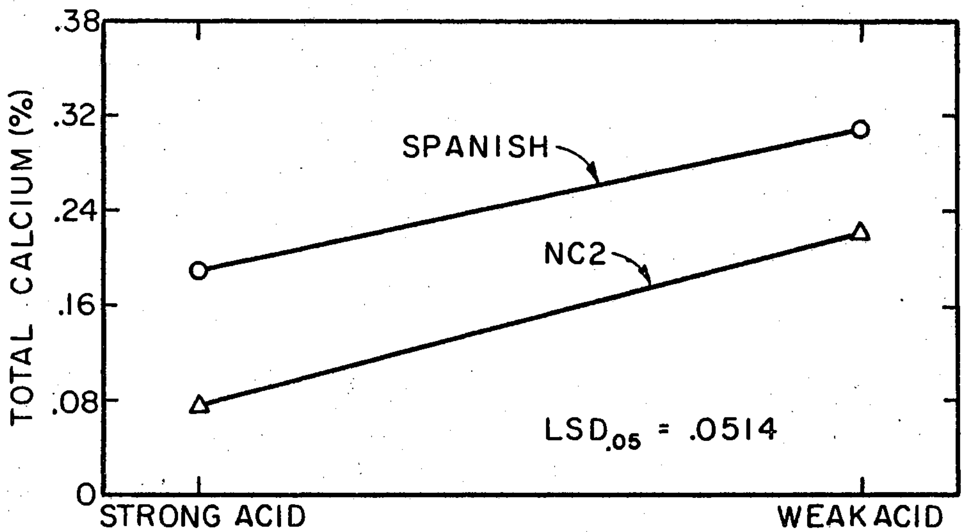


Figure 41. Total Calcium Content of Pegs Which Never Entered a Fruit Zone Supplied with a Strong or Weak Acid Resin

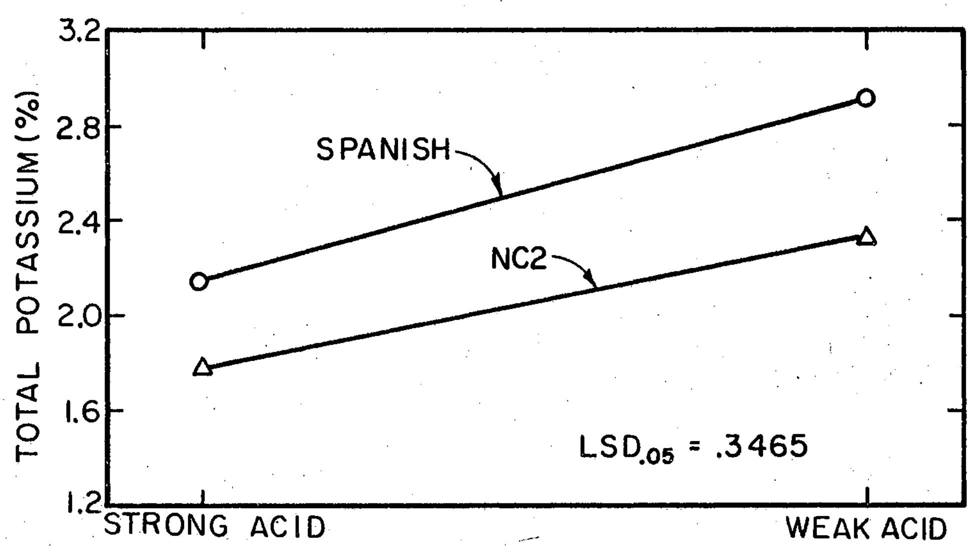


Figure 42. Total Potassium Content of Pegs Which Never Entered a Fruit Zone Supplied with a Strong or Weak Acid Resin

CHAPTER V

SUMMARY AND CONCLUSIONS

Several greenhouse experiments were conducted in order to compare various calcium treatments on selected vegetative and reproductive characteristics as well as calcium and potassium uptake and distribution in Spanish and NC2 plant parts. More information concerning the calcium nutrition of Spanish peanuts was the major objective of these comparisons.

Experiment I

Selected vegetative and reproductive characteristics of Spanish and NC2 peanut plants responded similarly when increasing levels of calcium were added to the fruit zone. Both varieties were shown to be dependent upon a calcium supply in the fruit zone for proper development of fruit although Spanish produces a somewhat larger weight of kernels at the lower calcium levels than does NC2. The calcium and potassium content of various plant parts, except the roots, followed essentially the same pattern for Spanish and NC2. The roots of Spanish exhibited a tendency to increase in calcium concentration as the calcium level of the fruit zone was increased, while this was not the case for NC2. The importance of this, if any, on fruit production and transport of calcium by Spanish peanuts as compared to NC2 is not known.

Experiment II

Both Spanish and NC2 increased in calcium content of three leaf positions as the plants matured and correspondingly decreased in potassium content. The peg portion in the fruit zone of Spanish was higher in calcium concentration than NC2 at the first harvest date (August 6) which suggested that Spanish was capable of absorbing more peg calcium than NC2 at a time period considered critical for absorption of calcium for good production of nuts. Spanish pegs not in the fruit zone of comparable age to those which were in the fruit zone were considerably higher in calcium content than those of NC2 at any harvest. This may indicate that Spanish normally has a more nearly adequate supply of peg calcium to begin fruit formation with than does NC2.

Experiment III

Peanut pegs and shells of Spanish and NC2 were shown to have a cation exchange capacity (CEC) which decreased as the plants matured. The CEC of Spanish pegs on the first harvest date (September 13) suggested that Spanish should be able to absorb more calcium than NC2 at this date, but there was not an apparent relationship between the CEC of shells and the corresponding calcium and potassium content of these shells for all harvest dates. The CEC could possibly be a function of stage of development of the fruit when considering only one particular date.

Experiment IV

Selected vegetative and reproductive characteristics of Spanish and NC2 peanut plants acted in a like manner when either one of two types of exchange resins were placed in the fruit zone. Fruit production was considerably reduced for either Spanish or NC2 when a strong acid resin was used as a fruiting medium as compared to a weak acid resin. The differences in fruit yield were considered to be due to the calcium releasing ability of the resins. Spanish appears to be able to absorb more shell calcium than NC2 under high available calcium conditions in the fruit area, but is very similar to NC2 in shell calcium under low available calcium conditions in the fruit area.

The transport of high quantities of potassium to the developing fruit of NC2, when the available calcium supply is low in the fruit area, was suggested as a partial cause for reduced yields of NC2. Limited availability of calcium in the fruit zone, not potassium translocation to the developing fruit, appears to limit the fruit production of Spanish peanuts under low available calcium conditions in the fruit area. In general all plant parts analyzed increased in calcium and potassium concentration as the fruiting medium was changed from a strong to a weak acid resin.

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APPENDIX

TABLE XI

MEAN MINERAL COMPOSITION (PPM) OF PEANUT PLANT PARTS AS INFLUENCED BY VARIOUS LEVELS OF CALCIUM ADDED TO THE FRUIT ZONE*

Treatment	Ca level (ppm)	Leaves Ca	Leaves K	Pegs Ca	Pegs K	Shells Ca	Shells K	Roots Ca
Spanish								
	0	4517	14781	1172	17880	91		
	5	4579	13788	1208	16490	172		
	10	4779	15281	1173	15700	83		
	20	5208	18438	1249	17380	184		
	40	4847	14906	1272	16780	114		
	80	5534	16500	2134	18938	494	11813	2116
	160	6204	18469	2425	25219	516	11625	2572
	320	5966	19125	2439	20062	750	8719	3532
NC2								
	0	3331	11470	1102	18594	77		
	5	4216	11156	1184	18562	171		
	10	3951	11813	1008	19125	87		
	20	4491	12656	1190	18225	146		
	40	4747	13781	1194	20594	117		
	80	5425	13969	1519	20719	396	10031	2500
	160	5410	16844	2159	23594	563	8750	2516
	320	5925	17688	2379	17219	772	7219	2410

*All values are the means of four replications

TABLE XII

MEAN MINERAL COMPOSITION (PPM) OF PEANUT PLANT PARTS AT DIFFERENT TIME INTERVALS DURING THEIR MATURATION*

Dates & positions of harvests	Spanish		NC2	
	Ca	K	Ca	K
August 6**				
1LB	4000	22750	4000	20250
2LB	3375	21750	3375	18875
MSL	3000	25500	4250	20500
PNS	1050	22875	375	24250
PS	575	22875	375	24500
September 6				
1LB	4250	14125	4313	18500
2LB	3688	14375	4500	18750
MSL	4563	17750	4750	19000
PNS	1813	32000	688	36250
PS	250	22500	438	36200
October 10				
1LB	5250	12875	5750	12750
2LB	5250	12750	4750	14625
MSL	6250	13000	5500	14750
PNS	2250	26750	813	22250
PS	225	18750	313	17625

*All values are the means of four replications

**1LB = first lateral branch leaves, 2LB = second lateral branch leaves, MSL = main stem leaves, PNS = pegs which had not entered the fruit zone, and PS = the below soil portion of pegs which had entered the fruit zone

TABLE XIII

MEAN MINERAL COMPOSITION (PPM) AND CATION EXCHANGE CAPACITY VALUES (meq/100g) OF PEANUT SHELLS AT DIFFERENT TIME INTERVALS DURING THEIR MATURATION*

	Spanish					
	Low Ca Soil			High Ca Soil		
Harvest Dates	Ca	K	CEC	Ca	K	CEC
September 13	250	27000	13.54	375	13750	13.79
October 11	364	9646	8.13	576	7523	10.29
November 7	863	6750	1.38	463	9250	1.20

	NC2					
	Low Ca Soil			High Ca Soil		
Harvest Dates	Ca	K	CEC	Ca	K	CEC
September 13	225	24250	3.54	225	37500	3.22
October 11	200	7500	7.93	250	6417	8.70
November 7	150	4375	1.05	150	4125	1.25

*All values are the means of three replications

TABLE XIV

MEAN MINERAL COMPOSITION (PPM) OF PEANUT PLANT PARTS AS INFLUENCED BY USE OF A STRONG OR WEAK ACID RESIN IN THE FRUIT ZONE*

Treatment	Leaves**		Shells**		Kernels**		PI of F**		PN of F**	
	Ca	K	Ca	K	Ca	K	Ca	K	Ca	K
Spanish										
Strong acid resin	7771	23500	110	4958	146	5944	1102	14158	1723	18658
Weak acid resin	12406	21375	1656	10669	425	6427	1110	26288	2773	29051
NC2										
Strong acid resin	3625	16081	224	15268	279	7425	993	24288	976	27225
Weak acid resin	12203	10844	919	16313	323	6298	1828	37625	1788	30587

Treatment	PI of NF**		PN of NF**		PN**	
	Ca	K	Ca	K	Ca	K
Spanish						
Strong acid resin	1040	11935	2864	22467	1888	21375
Weak acid resin	1500	23622	3732	26804	3102	29127
NC2						
Strong acid resin	1166	22324	1360	24188	722	17688
Weak acid resin	3063	26375	2782	30291	2250	23563

*All values are the means of four replications

**Leaves = main stem leaves; shells = only shells which developed mature fruit; kernels = only mature kernels; PI of F = below soil portion of pegs which developed mature fruit; Pn of F = above soil peg portion of pegs which developed mature fruit; PI of NF = below soil portion of pegs which developed no fruit; PN of NF = above soil peg portion of pegs which developed no fruit; and PN = pegs which never reached the fruit zone.

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