Effects of Dolomitic Limestone, Gypsum, and Potassium on Yield and Seed Quality of Peanuts[1]

G. A. Sullivan, G. L. Jones, and R. P. Moore[2]

ABSTRACT

The interactive effects of dolomitic limestone, gypsum, and potassium on yield and seed quality of a Virginia-type peanut was investigated. Responses were assessed in field experiments using a split-plot design with varying rates and combinations of dolomitic limestone and gypsum as the main plots. Two rates of potassium applied at planting were used as the split plots. Treatment effects were measured by changes in soil mineral composition, mineral content of the plant and fruit, yield, seed maturity, and seed quality.

Applications of dolomitic limestone increased soil pH and soil calcium levels, but did not improve seed quality or increase yields or kernel content of the fruits. Applications of gypsum improved seed germination, seedling survival, seedling vigor, and root growth. Dark plumule abnormality was reduced by addition of gypsum. Soil pH was reduced and chemical composition of peanut leaves, hulls, and seed was influenced more by gypsum than by either dolomitic limestone or potassium. Potassium was less detrimental to fruit yield and seed quality when applied in combination with gypsum. Two seedling abnormalities, watery hypocotyl and physiological root breakdown, were associated with low levels of seed calcium.

Additional key words: Tetrazolium testing, watery hypocotyl, physiological root breakdown, **Arachis hypogaea** L., groundnuts.

Virginia-type peanuts, *Arachis hypogaea* L., require high levels of available calcium within the fruiting zone for normal fruit development (3, 4, 8). Failure of the fruit to obtain adequate calcium results in an abnormal condiaion in hte seed identified as dark plumule. Other abnormalities related to calcium deficiency have been discussed by Reid and Cox (15).

Hartley and Bailey (10) often found the dark plumule abnormality in seed from plants that had been subjected to severe drought. Cox and Reid (6) attributed dark plumules in seed to a deficiency of calcium. Gypsum was effective in reducing plumule damage. Seed containing 0.06% or more calcium did not have dark plumule.

Harris and Brolmann (9) found that the development of dark plumule was prevented by the application of $CaCO_3$ to the soil. They noted the deleterious effect of calcium deficiency to be most obvious within the vascular system at the base of the plumule. Calcium influences nucleic acid and nitrogen metabolism, serves as an activator of enzymes, and affects the selective permeability of cell membranes (12). Moore (14) developed and utilized the tetrazolium test for detection of dark plumule in peanut seed.

[1]Paper No. 140 of the Journal Series of the North Carolina State University Agricultural Extension Service, Raleigh, N. C. 27607. Received Sept. 9, 1974.

[2]Extension Assistant Professor; Professor, in Charge, Agronomy Extension; and Research Professor, Crop Stands; Crop Science Department, North Carolina State University, Raleigh, N. C. 27607.

Previous research (5) and field demonstrations (unpublished data of Astor Perry, N. C. State University) show that supplemental calcium fertilization can be eliminated or reduced without affecting yield when peanuts are grown on soils with high soil calcium levels. Peanut production would be more economical if gypsum applications could be reduced. The effects of eliminating supplemental calcium fertilization on the production of seed has not been adequately investigated.

The primary objectives of this research were to evaluate the single and interaction effects of dolomitic limestone, gypsum, and potassium on (1) soil mineral composition; (2) chemical properties of peanut leaves, hulls, and seed; (3) yield and market grade; and (4) seed quality as measured by standard germination and tetrazolium testing.

Materials and Methods

Four test locations were selected in 1971 to provide sites with a range of soil calcium and pH levels (Table 1). All soil test analyses were conducted by the Agronomic Division, North Carolina Department of Agriculture. A single seed lot of the cultivar 'NC5' was used in the experiments.

A factorial arrangement of treatments in a split-plot design was used in the study. Main treatments were arranged in randomized complete blocks and were:

1. L_0G_0 - limestone or gypsum applied to plots.
2. L_0G_1 - No limestone with gypsum applications at rate of 673 kg/ha.
3. L_0G_2 - Limestone with gypsum applications at rate of 1346 kg/ha.
4. L_1G_0 - Limestone applied according to soil test recommendations and no gypsum applied.
5. L_1G_1 - Limestone applied according to soil test recommendations and gypsum at rate of 673 kg/ha.
6. L_1G_2 - Limestone applied according to soil test recommendations and gypsum at rate of 1346 kg/ha.

Table 1. County locations, soil types, and soil chemical properties of field test plots at planting.

Location	Soil type	Limestone Rate	Limestone Date	pH	Ca	K	Mg
		-kg/ha-			---meq/100 g-----		
Bladen	Marlboro fsl[a/]	2240	Dec 70	5.5	1.00	0.11	0.28
	Marlboro fsl	0	---	5.1	0.80	0.11	0.14
Martin	Duplin fsl[b/]	2240	Dec 70	5.6	2.58	0.27	0.37
	Duplin fsl	0	---	5.4	2.35	0.25	0.18
Northampton	Wagram fsl[c/]	1680	Dec 70	5.1	1.06	0.16	0.27
	Wagram fsl	0	---	4.9	1.03	0.16	0.22
Pitt	Altavista sl[d/]	3360	Feb 71	5.5	1.57	0.09	0.59
	Altavista sl	0	---	5.4	1.37	0.09	0.45

a/ Typic Paleudult; clayey, kaolinitic, thermic.
b/ Aquic Paleudult; clayey, kaolinitic, thermic.
c/ Arenic Paleudult; loamy, siliceous, thermic.
d/ Aquic Hapludult; fine-loamy, mixed, thermic.

Subplot treatments were either 0 or 67 kg/ha of potassium. Dolomitic limestone containing 54% $CaCO_3$ and 43% $MgCO_3$ was broadcast by hand and disced into the soil. Gypsum (90% $CaSO_4$) was applied at flowering in a 30 cm band centered over the row. Each subplot consisted of two 4.5 m rows with 91 cm middles. Treatments were replicated five times at each location.

Fruits were hand picked, placed in mesh bags and artificially dried to 10% moisture. Yields were estimated based on 8% moisture, wet weight basis. Fruits were stored in an unheated dry room prior to seed quality evaluations.

Post-treatment soil samples to a depth of 10 cm and leaf tissue samples were taken from each plot 70 days after the gypsum applications. Leaf tissue samples were dried and ground in a Wiley mill using a 1 mm sieve. The tissues were ashed at 500° C. in a muffle furnace. Calcium and magnesium were determined by atomic absorption and potassium by flame photometry. Nitrogen was determined by the Kjeldahl method.

Market grades were determined according to USDA Consumer and Marketing Service instructions, except fruits were hand shelled. A sample of hulls and seed from each plot were chemically analyzed similarly to the leaf tissue.

Sound mature kernels (SMK) from each plot were equally divided into three sub-samples and designated as A-1, A-2, and A-3. Germination tests were conducted on sub-sample A-1 according to recommended procedures (1). Seed were treated with a 50:50 mixture of Captan-Maneb. Each test consisted of 50 seed for each plot in rolled paper towels. Root growth values were determined for each seed where:

1.0 = primary root length <100 mm

1.5 = primary root length of 100-160 mm; and

2.0 = primary root length 160 mm

Total values were designated as root growth index and were adjusted to 100 seed per plot. Percentage determinations were made for abnormal seedlings and for abnormal conditions designated as physiological root breakdown and watery hypocotyl. These conditions are described in the discussion section.

Tetrazolium tests were performed on sub-sample A-2 according to recommended techniques (7). Seed of sub-sample A-3 were stored at − 5° C. until field plantings were made at Lewiston, N. C. on May 8, 1972. Seed were spaced 12 cm in the row and covered to a depth of 4 cm. Emerged seedlings were counted on May 26.

A regression procedure utilizing the method of least squares was used for the analysis of variance for data combined over locations.

Results and Discussion

Changes in soil chemical properties due to limestone and gypsum treatments are given in Table 2. Applying either 673 or 1346 kg of gypsum per hectare decreased the soil pH 0.4 unit. The reduction was of the same magnitude at each location, even though initial soil pH levels were different. Such a reduction in pH is expected and is normally short-lived. These results indicate that where gypsum is applied, fruit development occurs in soil with a significantly lower pH than the pH in which earlier vegetative growth occurred. Mann (11) stated that gypsum treatments retarded plant growth when compared to check or limestone treatments. The effects of this pH change on reproductive growth physiology should be investigated more thoroughly.

The application of limestone increased soil pH by 0.3 unit at the Bladen and Martin locations, by 0.4 unit at the Pitt location, and only 0.1 unit at the Northampton location. A larger increase in pH was expected since the limestone was applied in the preceding fall at all but the Pitt location.

Table 2. Mean treatment effects combined over locations for soil pH and extractable calcium, potassium, and magnesium.

Treatment	pH	Extr. Ca	Extr. K	Extr. Mg
		----------meq/100 g	----------	
L_0	5.2	1.61	0.14	0.15
L_1	5.5	1.81	0.14	0.24
LSD.05	0.2	0.19	N.S.	0.07
G_0	5.6	1.27	0.16	0.26
G_1	5.2	1.72	0.13	0.19
G_2	5.2	2.15	0.13	0.15
LSD.05	0.1	0.16	N.S.	0.04
L_0G_0	5.4	1.25	0.16	0.22
L_0G_1	5.0	1.55	0.13	0.13
L_0G_2	5.0	2.04	0.12	0.10
L_1G_0	5.7	1.28	0.15	0.29
L_1G_1	5.4	1.89	0.13	0.24
L_1G_2	5.3	2.26	0.13	0.19
LSD.05	0.1	0.23	0.02	0.05

The limestone and gypsum combination appears to be synergistic in increasing soil calcium levels. Gypsum applications increased extractable calcium but decreased extractable magnesium and potassium. Magnesium and potassium are likely replaced on cation exchange sites by calcium and probably leach from the fruiting area.

The reduction in the nitrogen content of leaves (Table 3) attributable to gypsum application may be due to a reduction in soil pH which affected the efficacy of *Rhizobium* bacteria. It may be due, however, to an increased translocation of nitrogen from the leaves to fruits created by the heavier fruiting. Gypsum applications also reduced the nitrogen content of the hulls. This reduction probably resulted from an increased direct uptake of calcium and magnesium by the developing fruit. The nitrogen composition of the seed was unchanged by the treatments.

The most dramatic changes in chemical composition occurred in the increased calcium content of hulls and seed resulting from gypsum applications. The increases were approximately 50 and 100% for the low and high rate of gypsum, respectively, over the no-gypsum treatment.

These data show the importance of the relative concentration of mineral elements in the fruiting zone. Mineral element concentration in the fruiting zone has more influence on composition of hulls and seed than the concentration in the rooting zone. Absorption of ions appears to be directly proportional to their concentration around the pod.

Limestone did not affect yield or fruit and seed characteristics (Table 4). Increases in yield and percentages of SMK and ELK due to gypsum rates

Table 3. Nitrogen, potassium, calcium, and magnesium content of peanut leaves, hulls, and seeds combined over locations.

Treatment	Chemical Composition											
	Nitrogen			Potassium			Calcium			Magnesium		
	Leaves	Hulls	Seeds	Leaves	Hulls	Seeds	Leaves	Hulls	Seeds	Leaves	Hulls	Seeds
						%						
L_0	3.46	1.16	4.35	1.86	0.71	0.70	2.13	0.31	0.065	0.34	0.11	0.16
L_1	3.52	1.12	4.49	1.86	0.66	0.70	2.09	0.30	0.067	0.40	0.12	0.16
LSD.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S	N.S	N.S	N.S	N.S.
G_0	3.61	1.57	4.50	1.90	0.81	0.73	1.95	0.21	0.045	0.43	0.15	0.16
G_1	3.45	0.98	4.39	1.86	0.66	0.69	2.14	0.31	0.068	0.35	0.11	0.16
G_2	3.41	0.89	4.46	1.82	0.60	0.68	2.25	0.41	0.085	0.34	0.10	0.15
LSD.05	0.12	0.14	N.S.	N.S.	0.06	N.S.	0.03	0.02	0.006	0.03	0.01	N.S.
L_0G_0	3.61	1.70	4.39	1.91	0.85	0.72	1.94	0.21	0.043	0.41	0.14	0.16
L_0G_1	3.38	0.93	4.29	1.86	0.68	0.69	2.15	0.30	0.068	0.32	0.10	0.16
L_0G_2	3.38	0.86	4.38	1.81	0.60	0.68	2.31	0.42	0.084	0.30	0.09	0.15
L_1G_0	3.61	1.43	4.61	1.89	0.76	0.74	1.96	0.19	0.047	0.45	0.15	0.16
L_1G_1	3.52	1.03	4.48	1.85	0.64	0.68	2.13	0.31	0.068	0.38	0.11	0.16
L_1G_2	3.44	0.91	4.54	1.83	0.59	0.69	2.19	0.40	0.085	0.37	0.10	0.15
LSD.05	0.14	0.17	N.S.	N.S.	0.07	0.04	0.03	0.03	0.007	0.03	0.01	N.S.

were highly significant. Gypsum supplied adequate calcium for peanut fruit development. Limestone alone or a high soil calcium level was not sufficient at any location for maximum fruit development. Variations among locations were much greater for yield and quality characteristics than for soil chemical properties and plant chemical composition. Patterns of response, however, were the same at all locations.

Data presented in Table 5 show changes in seed quality due to dolomitic limestone and gypsum treatments. These data reveal that the dolomitic limestone applications did not affect any of the seed quality characteristics measured.

Table 4. Average treatment effects combined over location on yield, and market grade characteristics.

Treatment	Yield	Market Grade	
		SMK	ELK
	-kg/ha-	%	
L_0	3290	71.1	46.0
L_1	3205	71.7	47.2
LSD.05	N.S.	N.S.	N.S.
G_0	2782	62.7	37.6
G_1	3440	75.6	51.9
G_2	3521	76.1	50.8
LSD.05	200	2.6	2.7
L_0G_0	2768	61.7	36.9
L_0G_1	3519	75.5	50.4
L_0G_2	3583	76.2	50.8
L_1G_0	2796	63.6	38.2
L_1G_1	3360	75.6	52.7
L_1G_2	3458	76.0	50.8
LSD.05	247	3.3	3.4

Favorable changes in all seed quality characteristics resulting from gypsum applications were statistically significant. Significant differences between responses to the low and high rate of gypsum did not occur, although a trend existed toward improvement in all seed quality characteristics measured from the high rate as opposed to the low rate of gypsum. These trends suggest a favorable influence on seed quality of the higher rate of gypsum in addition to its benefit of decreasing the percentage of dark plumules. It is hypothesized that these advantages may be due to improved seed physiological conditions. Calcium has been shown to help maintain cell membrane integrity and selective permeability (12, 18).

Both standard germination tests and tetrazolium tests overpredicted seedling establishment in the field. It should be noted, however, that laboratory tests are designed to evaluate seed under favorably controlled conditions, whereas many additioal and uncontrollable environmental factors affect germination and emergence in the field.

The degree of dark plumule was more easily revealed by the tetrazolium than by the standard germination tests. The greater detection of dark plumule by the tetrazolium test was probably due to less variation in testing conditions, use of magnification, and the focusing of attention on each seed during evaluation. Seedlings with observed dark plumules in the standard germination tests were counted as non-germinative. Some seed with non-critical plumule damage as revealed by the tetrazolium test were counted as germinable. These findings are similar to those reported by Harris and Brolmann (9) in that some of the seed declared as non-germinable by tetrazolium evalu-

Table 5. Average treatment effects combined over locations on seed quality characteristics and seedling abnormalities.

	Seed quality characteristics					Abnormalities				
	Standard germination		Tetrazolium		Field Planting	Standard germination				Tetrazolium
Treatment	Root Growth Index	Germination	Potential germination	High vigor	Seedling survival	Abnormal seedlings	Physiological root breakdown	Watery hypocotyl	Dark plumule	Dark plumule
		%								
L_0	171	86.7	87.0	84.9	80.0	13.27	4.9	3.5	8.2	15.1
L_1	173	87.6	87.1	84.5	78.6	12.77	4.4	4.0	7.6	14.4
LSD.05	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
G_0	157	71.3	70.3	66.1	58.9	27.8	8.5	8.0	19.8	35.9
G_1	178	94.1	94.5	92.9	88.4	6.5	3.2	2.0	2.1	5.5
G_2	182	96.1	96.4	95.2	90.7	4.8	2.3	1.4	1.7	3.0
LSD.05	3	3.5	3.0	3.2	3.6	3.4	1.1	1.2	2.6	3.4
L_0G_0	154	69.7	69.8	66.4	60.4	28.7	9.3	7.0	20.9	36.9
L_0G_1	178	94.3	94.6	92.8	88.4	6.4	3.1	2.2	2.2	5.7
L_0G_2	182	96.2	96.6	95.4	91.2	4.7	2.3	1.4	1.6	2.7
L_1G_0	161	72.9	70.8	65.7	57.4	26.8	7.7	8.9	18.6	34.8
L_1G_1	178	93.9	94.4	92.9	88.3	6.6	3.2	1.8	2.4	5.2
L_1G_2	181	95.9	96.2	95.0	90.2	4.9	2.3	1.3	1.8	3.2
LSD.05	4	4.4	3.8	4.0	4.5	4.2	1.4	1.5	3.3	4.3

ation are considered germinable by evaluation techniques of standard germination tests. A more detailed evaluation was made on a few samples from standard germination tests by slicing the epicotyl in longitudinal halves. These more precise evaluations sometimes revealed deterioration of the vascular region that was believed to be associated with calcium deficiency.

Two abnormalities, not reported previously to be associated with calcium deficiency in peanut seedlings, were found to be reduced by gypsum applications. One condition was identified as physiological root breakdown (Fig. 1) and the other was watery hypocotyl (Fig. 2).

Physiological root breakdown was first observed approximately three days after initiation of the standard germination test. The hypocotyl and root appear to elongate normally prior to evidence of the abnormality. In affected seedlings, the first symptoms of physiological breakdown was a leaky apppearance at the hypocotyl and root juncture. Later, the root area continues to deteriorate without evidence fo fungal infection. Normal elongation seems to occur initially, but in affected seedlings normal cell division in the root area is inhibited. This condition was frequently found in seedlings with abnormal plumules, but was not limited to such seedlings.

Watery hypocotyl was first observed after approximately three or four days of germination. The first symptom was a leaky, liquid-logged area about midway of the elongated hypocotyl. Tissues in the leaky area gradually enlarged, often completely encircling the hypocotyl.

Seedlings with each type of abnormality were surface sterilized in sodium hypochlorite (5%)

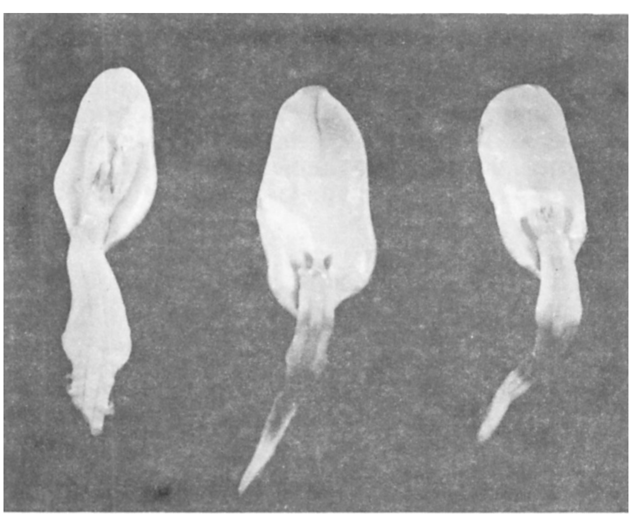

Fig. 1. Physiological root breakdown after three days in the germinator; Left, a normal seedling (primary root cut off because of length).

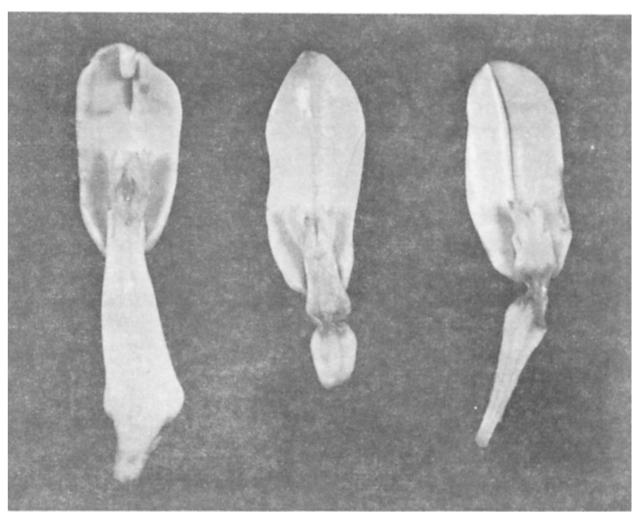

Fig. 2. Watery hypocotyl after three days in the germinator; Left, a normal seedling (primary root cut off ebcause of length).

and segments of the tissues plated. No evidence was found that these abnormalities were caused by pathogens.

The symptoms are similar to those described by Moore (13) and reported as hypocotyl collar rot on bean by Williams (16). Williams, Hollis, and Day (17) later suggested that either a deficiency of calcium or a failure of it to be translocated from the cotyledons into the hypocotyl area was the cause of hypocotyl collar rot. These findings suggest that hypocotyl collar rot of beans and watery hypocotyl of peanuts are related to calcium deficiency or immobility.

The major effects of potassium applications were reductions in yield and percentages of SMK and ELK. The absolute decrease was less than five percent but was highly significant for each of these factors. Potassium applications slightly increased the percentage of dark plumules.

Interactions were found between the potassium and gypsum treatments. Generally, yield and quality were reduced by direct potassium applications in the no-gypsum plots, but when gypsum was applied, potassium did not affect yield or seed quality. This was due, apparently, to the much higher concentration of calcium relative to potassium in the fruiting zone. Bolhuis and Stubbs (2) reported an improvement in fruit quality when potassium was applied to soils with a high pH. Our studies did not show improvement in any factor measured due to potassium within the fertility range tested.

Literature Cited

1. Anonymous. 1970. Rules for testing seed. Proc. Assoc. Off. Seed Anal. 60(2):1-116.
2. Bolhuis, G. G., and R. W. Stubbs. 1955. The influence of calcium and other elements on the fruitification of the peanut in connection with the absorption capacity of its gynophores. Netherlands J. of Agr. Sci. 3:220-237.
3. Bracho, E. A., E. B. Whitty, W. G. Blue, and A. J. Norden. 1971. Effect of soil pH and calcium source on yield, grade, and mineral composition of Virginia botanical type peanuts. J. Amer. Peanut Res. Ed. Assoc., Inc. 3:87-95.
4. Brady, N. C., J. F. Reed, and W. E. Colwell. 1948. The effect of certain mineral elements on peanut fruit filling. J. Amer. Soc. Agron. 37:696-708.
5. Colwell, W. E., N. C. Brady, and J. F. Reed. 1946. Fertilizing peanuts in North Carolina. N. C. Agr. Exp. Sta. Bul. 356. 21 pp.
6. Cox, F. R., and P. H. Reid. 1964. Calcium-boron nutrition as related to concealed damage in peanuts. Agron. J. 56:173-176.
7. Grabe, D. F. (ed.). 1970. Tetrazolium Testing Handbook for Agricultural Seeds. Assoc. Off. Seed Anal., Corvallis, Oreg. 62 pp.
8. Harris, H. C., and J. B. Brolmann. 1966. Comparisons of calcium and boron deficiencies of peanut. I. Physiological and yield differences. Agron. J. 58:575-578.
9. Harris, H. C., and J. B. Brolmann. 1966. Comparisons of calcium and boron deficiencies of peanut. II. Seed quality in relation to histology and viability. Agron. J. 58:578-582.
10. Hartley, C., and W. K. Bailey. 1959. Stub-leaf of peanut (**Arachis hypogaea**). Plant Dis. Reporter 43:360-362.
11. Mann, H. B. 1935. The relation of soil treatment to nodulation of peanuts. Soil Sci. 40:423-437.
12. Meyer, B. S., D. B. Anderson, and R. H. Bohung. 1960. Introduction to Plant Physiology. D. Vann Nostrand Co., Inc., Princeton, N. J. 541 pp.
13. Moore, R. P. 1965. Tender Crop snapbeans—Germination problem. Newsletter. Assoc. Off. Seed Anal. 39(1):22-23.
14. Moore, R. P. 1967. Seed facts from tetrazolium tests. Proc 1967 Short Course for Seedsmen, Seed Technology Laboratory, Miss. State Univ., State College. pp. 73-78.
15. Reid, P. H., and F. R. Cox. 1973. Soil properties, mineral nutrition and fertilization practices, p. 271-297. **In**: Peanuts—Culture and Uses. American Peantu Research and Education Association, Inc., Stillwater, Oglahoma.
16. Williams, F. J. 1965. A hypocotyl collar rot of **Phaseolus vulgaris**. Plant Dis. Reptr. 49:134.
17. Williams, F. J., W. L. Hollis, and M. H. Day. 1966. Incidence of hypocotyl collar rot of **Phaseolus vulgaris** in the field and in germination tests. Phytopathology 56:531-535.
18. Wyn Jones, R. G., and O. R. Lunt. 1967. The function of calcium in plants. The Botanical Review 33:407-426.