EVALUATION OF THE ROLE OF ELEMENTS, Ca, Mg, S AND B IN THE NUTRITION OF GROUNDNUT WITH REFERENCE TO MONOVALENT (K) TO DIVALENT (Ca+Mg) CATIONIC RATIOS

BY
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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Evaluation of the role of elements, Ca, Mg, S and B in the nutrition of groundnut with reference to monovalent (K) to divalent (Ca+Mg) cationic ratios" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title, at any other University or Society.

(SURESH KUMAR, P.)

Vellayani,
18-1-1985.

CERTIFICATE

Certified that this thesis entitled "Evaluation of the role of elements, Ca, Mg, S and B in the nutrition of groundnut with reference to monovalent (K) to divalent (Ca+Mg) cationic ratios" is a record of research work done by Shri. SURESH KUMAR, P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

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Vegetable oil production from various sources in our country is fairly stagnant at 10 million tonnes for the last 35 years. In spite of the green revolution of the 1960's with the cereal crops wheat and rice and the further extension of the "high yielding variety concept" to oil seed crops, increase has not been registered. At present India imports 10 lakh tonnes of vegetable oils annually in view of the stagnancy in production and to meet the enhanced demands due to a growing population. To off set this drain of foreign exchange resources considerable importance is currently being given to develop technologies for raising vegetable oil production. Aptly this has found a place as point number 2 of the Twenty Point programme of the Nation.

Several methods have been used lately in improving the vegetable oil production. Some of them are extension of area, introduction of exotic oil seed crops, introduction of annual oil seed crops as intercrops to enhance net area sown in non-traditional areas, improvements in management techniques of individual oil seed crops etc.

Among the various oil seed crops, groundnut offers greatest scope not only for varietal improvement, but also for improvement in management techniques in view of the widely varying agro-climatic situations in which it is grown as a field crop. In view of this attempts to introduce the same in non-traditional areas and also as intercrop especially with cassava has met with some degree of success in Kerala mainly because of the cafeteria of varieties available. Further groundnut covers 40 per cent of the total oil seed area of the country and meets 60 per cent of the total oil production in the country.

In Kerala groundnut can be successfully grown as a monocrop in upland situations, as an under crop in old coconut plantations and as an inter crop along with cassava. These have been successfully experimented and is being demonstrated by the Kerala Agricultural University, Central Plantation Crops Research Institute and Central Tuber Crops Research Institute.

While attempts are currently made to dovetail the cultivation of groundnut as an under crop in coconut gardens and as an inter crop in cassava, there is a need to work out the requirements of amendments, especially of calcium and magnesium, for the soil and climatic situations of Kerala. Though considerable work has been conducted in other States, the soil situations in them often do not warrant or necessitate addition of calcium and or magnesium as amendments to enhance the yield of pods and oil. In States such as Gujarat and Tamil Nadu, the black and the red soils where groundnut is often cultivated are rich in calcium and/or magnesium. Contrary is the situation in Kerala where the red and laterite soils have a deplorably low content of both calcium and magnesium.

The divalent cations calcium and magnesium and their importance in the gynaphoric nutrition of groundnut has been well brought out from the basic studies conducted by Wolt and Adams (1979). However under the soil situations of Kerala, the carrier of these elements have to be standardised both in relation to their nature and to the quantity of monovalent cation potassium added as potassic fertilizers.

In view of this, the present study has been projected with the following limited objectives initially:

1. To elucidate the role of calcium, magnesium, sulphur and boron in the nutrition of groundnut in relation to yield and oil content.
2. To study the effect of carrier of calcium and magnesium in the nutrition of groundnut.
3. To study the effect of K/Ca+Mg ratios in the nutrition of groundnut.
4. To bring out the role of calcium, magnesium and calcium plus magnesium in relation to application of boron.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The importance of N, P, K together with calcium, magnesium, sulphur and boron in the nutrition of groundnut with reference to yield, yield attributes, oil content and other characters, was brought out by many experiments conducted in India and abroad. Some of the salient findings relevant are briefly reviewed hereunder.

1. Effect of nutrients on yield

a. Effect of nitrogen, phosphorus and potassium on yield and yield attributes.

Colwell et al. (1945) showed that poorly filled groundnut shells had higher nitrogen and potassium than the shells with well developed seeds.

Rogers (1948) reported that peanut possesses an ability for luxury consumption of potassium. Goldin and Har-Tzook (1966) found that NPK fertilization increased total plant weight, prolonged the period of flowering, increased shelling percentage and increased pod yields.

Sreedharan and George (1968) observed that application of potassium along with calcium and magnesium increased the pod yield, yield of haulms and shelling percentage.

Chokhey Singh and Pathak (1969) noted that the combined application of NPK gave significantly much higher yields than N, P and K applied singly and when any two were applied together.

Tella et al. (1971) observed an increase in pod yield by application of NPK fertilizers in soils of pH near neutrality.

Ofori (1972) reported that application of 30 kg ammonium sulphate per hectare with 50 kg P_2O_5/ha gave the highest increase in yield.

Lipscomb et al. (1966) observed that annual applications of 6, 10 and 20 kg P/ha to a well drained deep sandy loam soil increased groundnut yield.

Fageria (1974) reported that for groundnut plants grown in nutrient solution for 55 days, maximum yield was obtained at a potassium concentration of about 200 µm and above this concentration there was no significant results.

Bromfield (1975) observed that phosphorus applied as ground rock phosphate - sulphur mixture outyielded ground rock phosphate and it was as effective as single super phosphate in increasing the yield. Hall (1975) reported that phosphorus together with calcium greatly increased the yield of groundnut but potassium chloride decreased the yield when applied together with phosphorus and calcium.

Jayadevan and Sreedharan (1976) reported that phosphorus application increased the yield significantly, but nitrogen application significantly reduced the yield.

Eweida et al. (1980) had studied several aspects of NPK fertilizer application together with calcium. 100 pod weight was increased by calcium only. Nitrogen, phosphorus or calcium alone decreased 100 seed weight. Phosphorus or calcium alone increased shelling percentage while nitrogen alone decreased pod yield per plant whereas potassium increased it. Pod yield was greatest with nitrogen and calcium in variety Giza-I and greatest with phosphorus, potassium and calcium in another variety Giza-4.

Rathee and Chahal (1977) observed that in soils of low, medium and high P_2O_5 and sulphur contents, application of phosphorus and sulphur significantly increased the plant nitrogen content, dry matter and pod yield and shelling percentage.

There are contradictory reports also about the effect of NPK in groundnut nutrition.

Davis (1951) observed that the use of large amounts of potash decreased the yield.

Omueti and Oyenuga (1970) reported results of field experiments where groundnut was fertilized with NPK. They found that application of phosphorus fertilizers did not significantly affect the yield of groundnut.

b. Effect of calcium on yield and yield attributes

Burkhart and Collins (1942) pointed out the importance of calcium in relation to the yield of groundnut.

Calcium was found to be very beneficial and necessary in the soil medium for the production of good pods. They also showed that calcium might be further absorbed by the developing pods.

Colwell et al. (1945) reported that the most serious ill effect of calcium deficiency was its adverse influence on the filling and quality of pods in groundnut.

Mehlich and Colwell (1946) indicated that increased yield and better quality of groundnut could be obtained by the application of calcium.

Brady et al. (1948) reported that application of calcium consistently increased pod filling when supplied to the pegging zones. Strauss and Grizzard (1948) pointed out that percentage calcium saturation of the exchange complex was correlated with average weight of nut produced by a plant.

Harris (1949) reasoned that poor pod development was observed when calcium was withheld from the pegging zone. An increase in shelling percentage of nuts in groundnut due to gypsum application was observed by Nye (1952).

York and Reed (1953) observed a reduction in number of flowers and hence the number of pegs, due to a deficiency of calcium.

Bolhuis and Stubbs (1955) found that calcium was the only element that had a favourable influence on pod filling and felt its presence was absolutely essential.

Piggot (1960) observed an increase in yield of groundnut due to application of superphosphate. He reported that the beneficial effect was due to its calcium content rather than to the phosphorus supplied.

Mizuno (1961) found a significant depression in top growth, flowering, peg and pod formation in groundnut when calcium was withheld for a period following early growth.

Mizuno (1965) observed that deficiency of calcium in the pegging zone induced 'pops'.

According to Harris and Brolmann (1966), calcium deficiency lowered the quality and yield of groundnut.

Robertson et al. (1966) found that application of gypsum at flowering stage increased the yield and reduced the number of empty pods.

Veeraraghavan and Madhavan Nair (1966) reported an increase in pod yield by six and twelve per cent with the application of lime at the rate of 750 and 1500 kg/ha respectively.

Harris (1968) observed a reduction in seedling growth due to calcium deficiency (5 ppm Ca in the nutrient solution). During the last half of the growing season there was also a marked decrease in the production of foliage, flowers, roots and kernels.

Mani and Romamoorthy (1969) observed that lack of calcium caused a reduction in the number of mature pods.

Slack and Morrill (1972) found in green house experiments that groundnut crop depends on calcium supply in the fruit zone for proper fruit development.

Loganathan and Krishnamoorthy (1977) observed an increase in pod yield upto a level of 150 kg Ca/ha. The peak period of calcium uptake was found to be between flowering and pegging for certain varieties but it was between pegging and maturity for certain other varieties. This was noted by Bathia et al. (1978).

Inanaga et al. (1979) observed in pot trials that when the soil in which pods developed, was low in calcium, seed and pod development were retarded and the proportion of unfilled pods increased markedly.

Adams and Hartzog (1979) found that even 560 kg lime/ha was inadequate for maximum yield of groundnut in calcium deficient soil.

Wolt and Adams (1979) studied the effect of calcium on vegetative growth as well as on fruit development. At low levels of rooting-zone calcium both vegetative and fruit growth were influenced by rooting and fruiting zone calcium acting in concert. As root zone calcium was increased above the critical level for maximum vegetative growth, the plant changed from being almost fruitless to a weak-fruited plant.

Ferreira et al. (1979) found an increase in yield due to gypsum application but there was no significant effect due to different rates and time of application on seed yield.

Walker and Csinos (1980) found that by gypsum application there was increase in yield and quality of kernels. A reduced incidence of pod rot was also observed under such conditions.

Brar et al. (1980) found that critical level of calcium in peanut leaves at pre-flowering stage is 1.25 per cent.

In field trials at 43 sites on different soils in Virginia, Hallock and Allison (1981) obtained yield responses to calcium averaging 0.49 t/ha with a maximum of 1.27 t/ha. The proportion of ground mature seeds was increased upto 23 per cent.

Keisling et al. (1982) obtained a linear relationship between the total calcium content and seed weight.

Contradicting the above views, there are a few results.

Greenwood (1951) observed that gypsum alone had no significant effect either on kernel yields or haulms weight of groundnut but with phosphate, substantial increase was seen in both.

De and Chatterjee (1976) failed to get any effect for 1.8 ton of lime in yield.

Walker et al. (1976) obtained no effect for gypsum on yield or sound mature kernels of Florunner when they applied gypsum in a split- plot design using different peanut cvs.

Satyanarayana et al. (1975) observed that beyond 3 t/ha of gypsum or 1 t/ha of lime, the yield of groundnut was reduced.

c. Effect of magnesium on yield and yield attributes

Brady et al. (1948) observed that magnesium sulphate was beneficial in improving fruit characteristics not only in terms of percentage of cavities filled but also in increasing the percentage of mature and two cavity size fruits in groundnut. Blair et al. (1949) found that magnesium sulphate commonly increased the crop yield in groundnut.

Hashimoto and Okamoto (1953) observed that much magnesium was required for forming the pods in peanuts.

Hallock and Garren (1968) noticed an increase in pod breakdown in groundnut for a heavy dose of K_2SO_4 or $MgSO_4$.

Nair et al. (1970) noted an increase in dry matter yield due to magnesium on groundnut. They have also observed that lack of magnesium affected nodulation.

Sreedharan and George (1968) observed that magnesium significantly increased the number of nodules per plant.

Tajuddin (1971) in pot experiments on groundnut observed that lime and magnesium increased the yield, the greatest response being obtained at the highest level of lime and magnesium.

Raniperumal (1972) observed an increase in the number of nodules, pod yield and protein content in groundnut by the application of magnesium.

Subramanian et al. (1975) noted an yield increase due to magnesium alone. They also found that application of magnesium increased the availability of potassium and calcium to the crop from sowing to vegetative and reproductive stages. It increased the availability of nitrogen from pre-sowing to post harvest stage.

Bathla et al. (1978) observed that magnesium accumulation was greatest between grand growth and flowering for certain varieties while it was between flowering and pegging for certain other varieties and between pegging and maturity for certain other varieties.

Chahal and Sukhpal Singh (1979) found that calcium and magnesium uptake was highest at 40 to 60 days of growth and the calcium and magnesium contents were in the order: leaves > stem > shell > seeds.

d. Effect of sulphur on yield and yield attributes

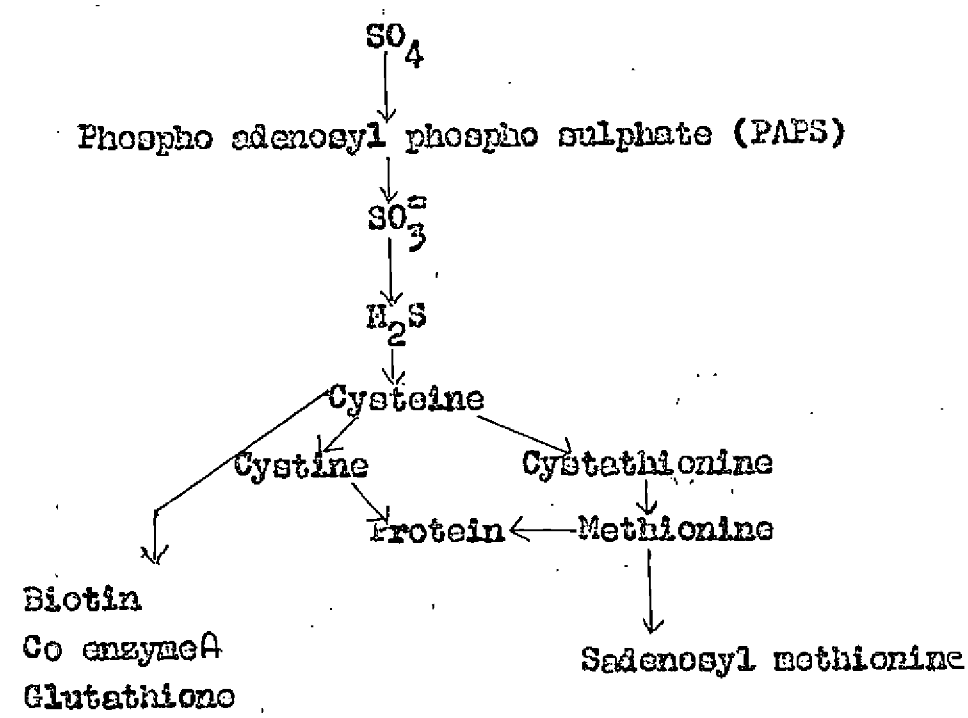
Harris (1949) observed an increase in yield when sulphate ion was used in the fruiting medium. Greenwood (1954) suggested that the beneficial effects of gypsum in the soils of Nigeria was not due to its calcium but due to the sulphur content. Orem (1958) had shown that sulphur could increase the size of plant, encourage nodulation, improve colour and prevent premature leaf-fall. Sulphur also helped in the development of more pods which are more strongly attached to the plants.

Panikkar (1961) observed that application of sulphur along with NPK has increased the yield in groundnut.

Kanwar (1963) obtained a higher yield ranging from 13-15 per cent by the application of sulphur as gypsum.

Naphade (1963) found that sulphur applied as gypsum increased the pod yield in groundnut by 20-27 per cent and when it was applied in combination with nitrogen maximum dry matter yield was produced.

Allaway and Thompson (1966) worked out the sulphur metabolic pathway in groundnut as follows:



Chopra and Kanwar (1966) fixed a level of 10 ppm soluble sulphur as the critical limit of available sulphur for groundnut. Sanjeevaiah (1969) stated that sulphur application increased the yield in groundnut. Palaniappan (1970) observed that pod yield was increased by phosphorus and sulphur application at higher doses. Subbiah et al. (1970) noted an increase in the yield of groundnut in sandy soil but not in loamy soil.

Ofori (1972) found that application of 30 kg ammonium sulphate per hectare with 50 kg P_2O_5/ha gave the highest increase in yield.

Chahal and Virmani (1973) found that gynophores absorbed 23 per cent of the total sulphur and 10 per cent of the total calcium present in the plant. Pods contained 32 per cent of sulphur and 43 per cent of calcium absorbed by the fruiting organs.

Virmani (1973) reported that critical limit of available sulphur for groundnut crop is 10 ppm.

Bromfield (1973) noted that sulphur uptake in groundnut was maximum upto 11th week after sowing and declined during the later periods. Application of sulphur dust as fungicide in Malawi improved the kernel yield (Laurence and Gibbons, 1976).

When sulphur treated rock phosphate was used, Bromfield (1975) obtained, a significant increase in the yield and total dry matter in groundnut.

Dongale and Zende (1976) noted that application of sulphur alone and in combination with B or FYM increased NPK uptake by plants and reduced their excessive vegetative growth.

Rathi and Chahal (1977) found that application of phosphorus and sulphur significantly increased the plant nitrogen content, dry matter and pod yields and shelling percentage in soils of low and medium fertility.

Mishra (1980) observed that at concentrations below 0.25 ppm of sulphur dioxide, it appeared to have a slight beneficial effect on plant productivity.

Mariakulandai and Morachan (1965) found no beneficial effects for application of cattle manure, lime, sulphur and gypsum under conditions at Palur and Tindivanam.

Ashrif (1965) showed that there was no need to include sulphur in fertilizers for groundnut and so sulphur has no significant effect on groundnut yield and shelling percentage.

Ofori (1973) in pot experiments, got no significant effect for sulphur or nitrogen on P uptake. Addition of 34 kg sulphur as Na_2SO_4 significantly lowered the kernel yield at 5 per cent level.

Nadarajan (1981) observed that there was no response for both calcium and sulphur on yield, dry matter and oil content.

Walker et al. (1982) applied NPK and sulphur as combined foliar spray and failed to get any significant effect on yield but at higher concentrations, caused severe foliar burns.

e. Effect of boron on yield and yield attributes

Colwell and Baker (1939) observed that whenever boron deficiency was found, the application of boron to alfalfa and sunflower increased the quality of the produce.

Odhnoff (1957) noted that the primary influence of boron was exerted on the cell elongation stage of the cell development.

Piland et al. (1944) found that borax applied to the soil at the rate of 5 lb/acre improved the quality of groundnut.

Haynes and Robbins (1948) noted that roots growing with all essential mineral nutrients except calcium perished. When root environment contained both calcium and boron roots maintained their functional integrity even when no other mineral nutrients were supplied to the medium.

Smith (1954) observed a complete inhibition of pegging due to boron deficiency.

Harris and Gilman (1957) had seen that boron improved the grade of groundnut but decreased the foliage yield.

Rotini (1956) found that yield was increased by 15 per cent by the application of 100-200 g of borax per

200 sq. metres.

Leveque and Beloy (1960), when applied excess of boron it was found to be accumulated in the leaves leading to malformations and decrease in flowering and fruiting.

Harigopal and Rao (1968) observed an adverse effect of boron application on the chlorophyll content. When compared to control a decrease of 28 per cent, 40 per cent and even 55 per cent of total chlorophyll occurred due to the application of 1, 5 and 10 ppm of boron respectively. Toxic effects of boron were noted in plants by Stroller (1966) with a concentration of more than 100 ppm in the shoots.

Koter (1964) noted that boron deficiency caused weak root and stem development and shedding of flowers.

Harris and Brolmann (1966) observed that plants given fertilizer plus boron had an early peak flower production period and were free of abnormalities and produced maximum groundnut pods.

Harigopal and Rao (1967) noted an adverse effect of boron on normal flowering, with higher boron doses.

Harigopal (1968) found that boron deficiency (10 u/g in culture solution) reduced root and stem elongation when compared to control (0.5 ppm B). Plants received boron as boric acid or borax upto 6 kg per acre is found to increase plant height by Asokan and Raj (1974). Beyond that it will decrease. It also increased yield and improved pod formation.

Yadahalli et al. (1970) observed that application of 450 kg gypsum and 7.5 kg borax per hectare along with nitrogen and phosphorus to groundnut in red sandy soils gave significantly increased yields over nitrogen and phosphorus alone.

Pothiraj (1972) found that boron has significant effect on yield in combination with calcium but not independantly.

Hill and Morrill (1974) by applying boron in four carriers, upto 60 days after planting, could effectively control internal damage due to boron deficiency.

Asokan and Raj (1974) found that on red loam and sandy loam soils, application of boron as 6 kg boric acid or borax per acre increased groundnut yield, and improved pod formation.

Harigopal (1976) noted that in sand culture, when boron was applied at 10 ppm to groundnut cv. TMV-2, high amounts were accumulated in all plant parts.

Morrill et al. (1977) noted that detrimental effects (toxicity and reduced yield) of applied boron appeared at rates between 1.0 and 1.5 lb per acre and at the rate of 0.5 lb, it consistently reduced the internal damage due to boron deficiency.

Blamey and Chapman (1979) noted a reduction in pod yield by 10 per cent due to higher doses of boron.

Brar et al. (1980) found that the yield increased with the application of 2.5 kg Zn/ha and 1 kg B/ha. The proposed critical levels of zinc and boron in leaves for groundnuts grown in Punjab was 25 ppm for both. Maximum increase in yield, 120 per cent was achieved with B+Zn+P fertilization.

2. Effect of nutrients on oil and protein

a. Effect of N, P and K on oil and protein

York (1952) observed that peanuts usually responded little to direct application of potassium fertilizers except in soils extremely poor in the nutrients. Oil content in groundnut was increased by phosphorus and potassium (Satyanarayana and Krishna Rao, 1962).

Hava (1964) noted that application of potassium bisulphate increased the crude protein content of groundnut kernels.

Anderson (1970) found that application of potassium without phosphorus depressed the yield and oil content of Natal-Common and Podona Bold groundnuts.

Verma et al. (1973) found that application of various sources of sulphur in combination with NPK markedly increased the shelling percentage and the oil and protein contents of the kernels.

Bhuiya and Chowdhury (1974) observed the following:

In the wet season, groundnut on the Brahmaputra flood plain soil, was given 0, 16.8 or 33.6 kg N/ha, 0 or 67.2 kg P/ha, 0 or 44.8 kg K/ha and 0 or 112 kg S/ha. Application of 16.8 and 33.6 kg N, 67.2 kg P or 112 kg S/ha increased the seed protein content. Potassium application did not increase the protein content. Phosphorus, potassium or sulphur application at 67.2, 44.8 and 112 kg/ha respectively increased seed oil content but there was no response to applied N.

Basha and Rao (1981) reported that P deficiency affects growth, total N, protein N, soluble N, starch, total sugar, phosphorus, magnesium, potassium and calcium contents of 30 day old peanut plants grown in sand culture.

Basha and Rao (1981) also reported that phosphorus and potassium deficiency resulted in accumulation of all the keto acids and amino acids in 30 day old and 20 day old groundnut leaves respectively. This was due to sluggish metabolism of the tissue under phosphorus and potassium deficiency.

Jayadevan and Sreedharan (1976) noted that protein content of "Asiriya Mwitunda" was significantly increased by nitrogen and phosphorus and a maximum protein content of 29.8 per cent was recorded by combined treatment with 30 kg N and 100 kg N/ha. The oil content of the crop was significantly reduced by N application but significantly enhanced by phosphorus.

b. Effect of calcium on oil and protein contents

There is not much effect for calcium on oil or protein content of peanuts. Calcium deficiency will definitely affect the quality of kernel and pod fill, cause to form poppy pods as reported by Mani and Ramamoorthy (1969). Harris and Brollman (1966) also reported that quality was affected by calcium deficiency.

Veeraraghavan and Madhavan Nair (1966) observed that oil yield is greatly depressed by liming red loam soils of Kerala.

Saini et al. (1975) found in a three year experiment, that Ca, Zn, Mn, Mo, Cu, Fe or B increased the oil content of seeds from an average of 48.2 per cent to an average of 49-51 per cent.

Blamey and Chapman (1982) found that lime application improved nodulation, increased hay, pod and seed yields, shelling percentage, percentage of mature pods, 100 seed weight and seed protein concentration.

c. Effect of magnesium on oil and protein contents

Trepachev and Atrashkova (1965) observed that magnesium increased the protein content of groundnut kernel.

Nair et al. (1970) and Sreedharan and George (1968) observed that lack of magnesium affected nodulation and hence the nitrogen content.

Rani perumal (1972) found that magnesium increased the number of nodules and protein content in groundnut.

Subramanian et al. (1975) observed that oil content was enhanced by magnesium.

d. Effect of sulphur on oil and protein contents

Gilbert (1951) suggested the dominant role of sulphur in protein synthesis.

Jorden and Reisenauer (1957) observed that protein synthesis was reterted by sulphur deficiency.

Jacob and Von Vexkull (1960) recommended sulphur containing fertilizers for oil producing crops especially for groundnut, caster, linseed and oil palms.

Venema (1962) noted that application of magnesium as magnesium sulphate enhanced the production of oil.

Naphade (1963) observed that sulphur fertilization had no effect on oil content in groundnut. But it increased protein content in groundnut in Nagpur conditions. Chopade (1964) found that sulphur alone had no marked effect on oil content in groundnut but in combination with phosphorus or with nitrogen and phosphorus there was improvement in oil content.

Russel (1966) suggested that sulphur is necessary for the synthesis of amino acids cystine, cysteine and melthionine and hence essential for protein elaboration.

Stanford and Howard (1966) and Kampfer and Zehler (1967) noted that oil crops have higher sulphur requirements because the oil storage organs are rich in protein.

Chopra and Kanwar (1966) contradicting the above findings, noted that application of sulphur alone decreased the oil content in legumes; protein content also was decreased.

Hanower and Brzozowska (1969) in pot experiments studied that sulphur deficient plants contained markedly less protein than those adequately supplied with sulphur.

Dafterdar et al. (1969) found a decrease in oil content of groundnut seeds with an increase in sulphur application but it increased protein content.

Hanower (1971) noted that sulphur deficiency affected the total and soluble protein.

Pathak and Pathak (1972) noted that sulphur favourably affected nodulation and oil percentage.

Laurence and Gibbson (1976) observed the following: In improved sulphur status soil, the application of sulphur will contribute very little to the oil content of kernel. In lower sulphur status, application of sulphur increases the protein content.

Reddy and Patil (1980) observed that application of elemental sulphur increased the oil content in groundnut kernel. Nadarajan (1981) found that there was no response for both calcium and sulphur in oil synthesis.

e. Effect of boron on oil and protein contents

Purvis (1939) observed that boron deficiency caused accumulation of carbohydrates and decrease in protein content in plants.

Mohr (1942) noted that the tissues of plants inadequately supplied with boron contained in most cases higher percentages of calcium, nitrogen, magnesium and iron.

Piland et al. (1944) observed that borax at the rate of 5 lb per acre improved the quality of groundnut.

Harris and Gilmann (1957) noticed that boron improved the grade of groundnut but mineral and oil content were not affected.

Rotini (1956) found that application of 100-200 g of borax per 200 sq.metres improved the content and quality of groundnut. It also increased the protein content.

Harigopal and Rao (1968) got the following observations:boron at 10 ppm applied to five weeks old groundnut plants induced leaf chlorosis. In the chlorotic leaves total chlorophyll, chlorophyll 'a', chlorophyll 'b', protein and total nitrogen content decreased but boron and soluble N content increased. Boron applied as boric acid or borax upto 6 kg/ha was found to give significantly higher oil yield over control which received no boron, by Asokan and Raj (1974).

Harigopal (1976) observed that protein and total nitrogen contents were decreased by application of 10 ppm boron.

Sankaran et al. (1977) found an increase in oil content from 47.8 to 49 per cent with increasing borax application from 0 to 30 kg/ha.

3. Effect of sources of calcium, magnesium, sulphur and boron in the nutrition of groundnut.

Rogers (1948) used 10 calcium sources of which, except calcium silicate and blast furnace slags, all others were found equally effective in increasing groundnut yield significantly.

Venema (1962) noted that application of sulphate anion containing fertilizers caused an increase in yield.

Naphade (1963) noted that application of sulphur as gypsum was more effective than elemental sulphur.

Lachover (1965) studied the effect of calcium carbonate and calcium sulphate on two soils in pot experiments and found that both $CaCO_3$ and $CaSO_4$ at 2000 kg/ha gave similar yields.

Asokan and Raj (1974) found that application of boron as boric acid or borax at 6 kg per acre is found to be equally effective.

Verma et al. (1973) when applied various sources of sulphur in combination with NPK found that gypsum greatly improved the protein and oil content.

Hall (1975) observed that phosphorus as serpentine superphosphate and calcium hydroxide together greatly increased the yield but either element supplied separately was ineffective.

Loganathan and Krishnamoorthy (1977) found that pod yield increased with increasing $CaCO_3$ or $CaSO_4$ application upto 150 kg/ha, but yield was higher with $CaSO_4$. Nadarajan (1981) noted that uptake of S and Ca from the added source was more from $CaSO_4$ than from K_2SO_4 and $CaCl_2$.

4. Interaction effects of calcium, magnesium, sulphur, boron and potassium.

Dal and Laborayem (1967) found that calcium inhibited the rate of sodium absorption, but promoted the uptake of K+, $SO_4^{=}$, Cl^- and $PO_4^{=}$ in ground crops.

Ofori (1972) failed to get any significant effect of sulphur and nitrogen applications on P_2O_5 uptake by the groundnut crop.

Habeebullah (1973) observed that flower production decreased for increased doses of potassium in the absence of calcium and it increased for increased doses of potassium in presence of gypsum.

Hill and Morrill (1975) observed interactions for boron and calcium with yield, per cent sound mature kernels and external damage. No significant interactions were found for boron and calcium in the field but a boron-potassium interaction was found.

Subramanian et al. (1975) noted that magnesium application increased the availability of nitrogen from pre-sowing to post-harvest stage while phosphorus and magnesium availability decreased. Potassium and calcium availability increased from sowing to vegetative and reproductive stages. Magnesium application greatly increased the uptake of nitrogen and phosphorus by groundnut.

Singh et al. (1977) noted that in a second crop of groundnut after soybean, groundnut pod yield was reduced by increasing copper in the absence of sulphur. Sulphur uptake by groundnut was greatly reduced by Mo in the absence of applied sulphur but increased by Mo in the presence of applied sulphur.

Warrington (1934) stated that calcium absorbed was approximately proportional to the calcium supplied irrespective of the presence or absence of boron, although the total calcium taken up was much reduced under the latter condition.

In a green house experiment, Powers (1939) noted that boron was less effective in some cases where lime was used whereas availability of boron was somewhat improved when sulphur was added.

Fudge (1946) observed a depression in the uptake of potassium by the grape fruits due to the application of calcium and magnesium as dolomite.

Bear and Toth (1948) concluded that the optimum conditions for cation nutrition of alfalfa was reached when 65 per cent of exchange complex of the soil was occupied by calcium, 10 per cent by magnesium and 5 per cent by potassium.

Powers and Jordan (1950) noted that lime tended to tie up part of the boron in unavailable form thereby reducing the available boron. Gypsum was more effective in reducing the availability of boron than sulphur alone.

Chopra and Kanwar (1966) observed that uptake of nitrogen, phosphorus and potassium in legumes increased after sulphur application.

Lund (1970) found that ratios of Ca/Ca+Mg of 0.1 or less reduced growth.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to study the effect of application of calcium, magnesium, sulphur and boron on the yield and nutrition of groundnut under the agro-climatic conditions of the southern region of Kerala.

Experimental site :

The experiment was carried out in the red loam soils of the Instructional Farm, College of Agriculture, Vellayani. The nutrient status of the soil is furnished in Table 1.

Season :

The experiment was conducted from June to October, 1983.

Seed materials :

The seeds of groundnut variety, TMV-2 obtained from Nagercoil having a germination of 98 per cent were used in the experiment.

Details of experiment

The experiment was laid out in a 5 x 2 x 2 factorial RBD, replicated thrice and with five sources/levels of calcium and/or magnesium, two levels of potassium and two levels of boron.

Treatments

The different treatment combinations are given below:

T_1	-	M_1 K_1 B_0
T_2	-	M_1 K_2 B_0
T_3	-	M_1 K_1 B_1
T_4	-	M_1 K_2 B_1
T_5	-	M_2 K_1 B_0
T_6	-	M_2 K_2 B_0
T_7	-	M_2 K_1 B_1
T_8	-	M_2 K_2 B_1
T_9	-	M_3 K_1 B_0
T_{10}	-	M_3 K_2 B_0
T_{11}	-	M_3 K_1 B_1
T_{12}	-	M_3 K_2 B_1
T_{13}	-	M_4 K_1 B_0
T_{14}	-	M_4 K_2 B_0
T_{15}	-	M_4 K_1 B_1
T_{16}	-	M_4 K_2 B_1
T_{17}	-	M_5 K_1 B_0
T_{18}	-	M_5 K_2 B_0
T_{19}	-	M_5 K_1 B_1
T_{20}	-	M_5 K_2 B_1

M_1	-	$CaCO_3$ to give 560 kg CaO/ha
M_2	-	$MgCO_3$ to give 140 kg MgO/ha
M_3	-	Dolomite to give 560 kg CaO/ha + 140 kg MgO /ha
M_4	-	Gypsum to give 560 kg CaO/ha + 960 kg SO_4/ha
M_5	-	Gypsum + $MgCO_3$ to give 560 kg CaO/ha + 960 kg SO_4/ha + 140 kg MgO/ha

K_1	-	40 kg K/ha
K_2	-	60 kg K/ha
B_0	-	0 kg B/ha
B_1	-	10 kg B/ha

Fertilizers :

Urea (44.6% N), Mussorie rock phosphate (18.7% P_2O_5) and Muriate of potash (59.6%) were used as fertilizer. A uniform dose of nitrogen and phosphorus at the rate of 10 kg per hectare and 75 kg per hectare respectively was given as basal dressing for all the treatments. Potassium, calcium, magnesium, sulphur and boron were given in accordance with the specified treatments.

The lay-out plan of the experiment is given in Figure 1.

Size of plot:

Gross plot size	-	3 x 3 m
Net plot size	-	2.5 x 2.5 m
Net area of the plot	-	6.25 m^2
Spacing	-	25 x 25 cm

Plant population:

Number of plants per gross plot	-	169
Number of plants per net plot	-	121

Field preparation:

The experimental site was dug once. Tillage

REP. 1	T_{18}	T_{13}	T_{10}	T_{8}	T_{6}	T_{9}	T_{20}	T_{12}	T_{7}	T_{1}
	T_{17}	T_{16}	T_{3}	T_{5}	T_{14}	T_{19}	T_{15}	T_{2}	T_{11}	T_{4}
REP. 2	T_{17}	T_{5}	T_{15}	T_{19}	T_{9}	T_{12}	T_{10}	T_{1}	T_{11}	T_{3}
	T_{7}	T_{14}	T_{13}	T_{4}	T_{2}	T_{6}	T_{8}	T_{18}	T_{20}	T_{16}
REP. 3	T_{8}	T_{19}	T_{7}	T_{14}	T_{20}	T_{3}	T_{5}	T_{2}	T_{11}	T_{1}
	T_{12}	T_{15}	T_{17}	T_{6}	T_{10}	T_{9}	T_{13}	T_{16}	T_{18}	T_{4}

FIG.1 LAY OUT

Table 1. Initial nutrient status of soil.

Nutrients	Replications R_1	R_2	R_3
Total nitrogen (Per cent)	0.041	0.041	0.068
Available phosphorus (kg/ha)	25.09	21.11	20.30
Exchangeable potassium (me/100 g)	0.113	0.113	0.118
Exchangeable calcium (me/100 g)	0.528	0.483	0.762
Exchangeable magnesium (me/100 g)	0.177	0.222	0.197

operations were resumed after the receipt of sufficient showers. Weeds and stubbles were removed and the field was laid out into blocks and plots as per the experimental design. The plots were dug thoroughly to obtain a fine tilth and then levelled before the sowing of seeds.

The seeds were sown on 28-6-1983 and gap filling was done on 7th day to ensure a perfect and uniform stand of the crop.

Manuring:

The entire quantity of manures and fertilizers, except the sources of calcium and magnesium were applied as basal dose. Calcium and magnesium were applied two weeks after sowing.

After cultivation :

The first round of intercultivation was done two weeks after sowing when calcium and magnesium sources were applied. The second round of intercultivation was done at peg forming (45 days after sowing) stage for loosening the top soil and controlling the weeds.

Irrigation was given whenever found necessary.

There were no serious attack of any pest or disease during the cropping period except the appearance of tikka leaf spots at the time of harvest.

Harvesting:

The crop started yellowing after 100 days and was harvested on 15-10-1983.

The biometric observations and chemical analysis were carried out on five plants randomly selected from each plot.

Biometric observations

Height of the plant

The height of the selected plants was measured from the base of the plant to the terminal bud. Mean height of the plant was recorded at the stages of flowering, pegging pod forming and harvest.

Number of branches per plant

The number of branches was counted and average number of branches per plant was worked out and recorded at the above stages.

Yield of pods per plot

Fresh weight of pods was recorded after their separation from the plant. The dry weight was also recorded after sun drying.

Yield of haulms per plot

The dry weight of haulms per plot was recorded after separation of pods.

Weight of 100 kernels

This was obtained by weighing randomly selected kernels from each plot.

Shelling percentage

The dry weight of pods was recorded. The kernels from these pods were separated and weighed. From these weights, shelling percentage was calculated.

Chemical analysis

Plant samples

Sampling for chemical analysis at different stages was done as follows. Five plants selected at random from the inside border rows, were dug out at a uniform depth of approximately 40 cm, after completely wetting the soil for one day.

The collected plant samples were washed to remove adhering soil particles, air dried and then dried in an oven at 70°C and powdered. The powdered sample was used for chemical analysis.

Samples of plant materials such as haulms, kernel and shell were analysed by the following methods.

Nitrogen:

The percentage nitrogen was estimated by micro-kjeldahl method (Jackson, 1973).

Phosphorus:

Phosphorus content was estimated by vanado-molybdate yellow colour method (Jackson, 1973) after digestion of the plant samples using nitric acid-perchloric acid mixture.

Potassium:

The nitric acid-perchloric acid digest was used for estimation of potassium by flamephotometry in an EEL flame photometer.

Calcium:

Calcium in the di-acid digest of plant samples was estimated in an Atomic Absorption Spectrophotometer.

Magnesium:

Magnesium content was estimated from the di-acid mixture in an Atomic Absorption Spectrophotometer.

Sulphur:

Sulphur content was estimated by turbidimetric method using $BaCl_2.2H_2O$ and gum acasia (Chopra and Kanwar, 1976).

Protein content of the kernel:

From the nitrogen content of the kernel, the protein content was worked out by multiplying by 6.25.

Oil content of the kernel:

Oil content of kernel samples was estimated by cold percolation method (Kartha and Sethi, 1957).

Soil samples:

Soil samples were collected before the starting of experiment as well as at the different stages such as flowering, peg forming, pod forming and harvest when the plant samples were removed for analysis.

The collected soil samples were air-dried, ground, sieved through 2mm sieve and used for analysis of the following:

Total nitrogen:

Total nitrogen was estimated by micro-kjeldhal method (Jackson, 1973).

Available phosphorus:

Available phosphorus was estimated by colorimetric method as detailed by Bray and Kurtz (1954).

Exchangeable potassium:

Available potassium extracted by using neutral normal ammonium acetate and was estimated by flame-photometry (Jackson, 1973).

Exchangeable calcium:

Available calcium was extracted by neutral normal ammonium acetate and estimated in an Atomic Absorption Spectrophotometer.

Exchangeable magnesium:

Exchangeable magnesium was extracted with neutral normal ammonium acetate and was estimated by Atomic Absorption Spectrophotometry.

Statistical analysis:

Data relating to different observations were analysed statistically following the methods of Clarke (1980) and Steel and Torrie (1981).

RESULTS

RESULTS

The data based on observations in the field and from chemical analysis in the laboratory were analysed statistically. The mean values of various observations are given in tables 2 to 21. The analysis of variance tables are given in Appendices I to XXI.

Height of the plant

Data on the mean height of plants at flowering, peg forming, pod forming and harvest stages were analysed and the following results were obtained.

The main effects of sources of either calcium or magnesium and also that of potassium showed no significant effect in increasing plant height while a marked decrease in height was noted duo to application of boron at all the stages. Application of potassium also showed a negative trend in height though the difference was not significant. None of the interactions were found to be significant.

Number of branches

Only the main effect of boron was found to be significant. A marked decrease in number of branches was noted due to application of 10 kg B/ha. Though the main effect of K was not significant, its interaction with boron was significant at flowering stage. At this stage with an increase of 20 kg K/ha, an increase in the number of

Table 2(a) Height of the groundnut plant at flowering and peg forming stages of growth (cm)

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	5.19	4.92	5.02	5.99	5.06	13.76	13.21	15.36	11.61	13.48
M_2	4.94	5.10	5.71	4.33	5.02	14.38	14.25	16.67	11.96	14.31
M_3	5.43	4.90	5.47	4.86	5.17	14.13	13.81	15.06	12.88	13.97
M_4	5.81	4.90	5.56	5.15	5.36	14.31	13.42	14.25	13.48	13.87
M_5	4.76	5.00	5.14	4.61	4.88	12.81	14.90	16.54	11.17	13.86
B_0	5.46	5.30	-	-	-	15.48	15.67	-	-	-
B_1	4.99	4.63	-	-	-	12.27	12.17	-	-	-
Mean	5.23	4.96	5.38	4.81	-	13.88	13.92	15.58	12.22	-

S.E. per plot = 0.490 S.E. per plot = 1.760

C.D. for B = 0.443 C.D. for B = 1.594

Table 2(b) Height of the groundnut plant at pod forming and harvest stages of growth (cm)

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	28.44	28.79	32.25	29.48	28.62	50.11	48.79	52.26	46.65	49.45
M_2	31.13	31.08	33.17	29.04	31.10	51.13	51.08	53.16	49.04	51.10
M_3	30.63	31.46	32.04	30.04	31.04	31.04	50.63	51.46	52.04	51.04
M_4	30.25	32.64	33.40	29.49	31.45	51.92	52.64	53.39	51.16	52.28
M_5	31.25	31.61	31.25	31.61	31.43	51.25	51.61	51.25	51.61	51.43
B_0	32.06	32.78	-	-	-	53.06	52.78	-	-	-
B_1	28.62	29.45	-	-	-	49.95	49.45	-	-	-
Mean	30.34	31.12	32.42	29.03	-	51.01	51.12	52.42	49.70	-

S.E. per plot = 2.868 S.E. per plot = 2.978

C.D. for B = 2.597 C.D. for B = 2.701

Table 3. Number of branches in groundnut at different stages of growth

	1. Flowering					2. Peg forming					3. Pod forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	4.7	4.8	4.6	4.8	4.7	6.4	6.9	6.8	5.6	6.2	6.9	6.8	7.0	6.6	
M_2	4.9	4.7	5.4	4.2	4.8	6.9	6.9	6.4	6.4	6.9	7.6	7.5	8.2	6.9	
M_3	4.8	4.8	5.3	4.3	4.8	6.3	6.3	6.7	5.9	6.3	6.9	6.9	7.1	6.7	
M_4	5.2	4.8	5.2	4.7	4.9	7.8	6.3	6.8	6.6	6.7	7.9	6.6	7.5	7.0	
M_5	4.2	4.4	4.3	4.3	4.3	6.3	6.5	6.4	6.3	6.4	7.2	6.9	7.0	6.9	
B_0	4.8	5.2	-	-	-	6.9	6.7	-	-	-	7.7	7.1	-	-	
B_1	4.7	4.2	-	-	-	6.3	6.0	-	-	-	6.9	6.8	-	-	
Mean	4.8	4.7	4.9	4.5	-	6.6	6.4	6.8	6.2	-	7.3	6.9	7.4	6.9	-

S.E. per plot	= 0.43	S.E. per plot	= 0.64	S.E. per plot	= 0.56
C.D. for B	= 0.38	C.D. for B	= 0.58	C.D. for B	= 0.50

branches was noted in the absence of boron while an inverse result was observed in the presence of boron. But this interaction was absent during peg and pod forming stages.

Dry weight of haulms

The main effects of potassium, boron and the sources of calcium and magnesium were not significant while MK interaction was found to be significant. The interaction effects between different sources of calcium and levels of potassium were significant.

Number of pods per plant

Significant differences in the number of pods were noted due to application of various sources which supply either calcium or magnesium or both. Application of gypsum gave maximum number of pods (31) followed by application of the same quantity of gypsum (1720 kg/ha) together with $MgCO_3$ (300 kg/ha) (28). No significant difference was noted due to application of $CaCO_3$, $MgCO_3$ or dolomite. Application of potassium also gave a positive result. The number of pods increased from 25 to 29 with an increase of 20 kg K/ha. However no significant difference could be observed under treatments with and without the application of boron (27). All the two-factor and three-factor interactions were found to be significant.

When the dose of potassium was increased with an application of 1000 kg $CaCO_3$/ha or 300 kg $MgCO_3$/ha, a slight

Table 4(a) Dry weight of haulms and number of pods per plant

	Dry weight of haulms (kg)					No.of pods per plant				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	4.26	3.45	4.16	3.55	3.85	27.23	25.40	26.53	26.10	26.32
M_2	3.33	3.55	3.54	3.33	3.44	24.57	23.78	27.41	20.93	27.41
M_3	3.66	4.07	3.58	4.15	3.86	23.27	27.87	20.77	30.37	20.77
M_4	4.92	3.74	4.00	4.66	4.33	26.20	35.00	28.13	32.07	29.13
M_5	3.87	3.77	3.93	3.70	3.82	25.62	30.67	30.23	26.05	30.23
B_0	3.93	3.75	-	-	-	26.72	26.91	-	-	-
B_1	4.08	3.68	-	-	-	24.03	30.17	-	-	-
Mean	4.01	3.72	3.84	3.88	-	25.38	28.54	26.82	27.10	-

S.E. per plot = 0.4053

C.D. for MK = 0.8207

S.E. per plot = 1.7722

C.D. for M = 2.5376

C.D. for K = 1.6049

C.D. for MK & MB = 3.5887

C.D. for KB = 2.2697

non-significant reduction on the number of pods was observed. But when the same increased dose of potassium was applied together with gypsum, dolomite and gypsum plus $MgCO_3$ (Treatment M_5) on the contrary a significant increase in the number of pods was observed. The maximum increase (35) is noted with gypsum (1720 kg/ha) with higher level of potassium (60 kg/ha).

MB interaction was also significant though boron alone was not significant. A significant decrease in number of pods was noted due to interaction of boron with magnesium carbonate (21) or gypsum plus $MgCO_3$ (26.05). A remarkable increase was observed when boron was applied with dolomite (30) or gypsum (32). So it is revealed that a negative interaction was present when boron is combined with magnesium carbonate.

Significant interaction between boron and potassium was also noted. In the absence of boron, the number of pods were found to be equal at both levels of potassium (27). Boron when applied, with 40 kg K/ha, gave only 24 pods while with 60 kg K gave 30 pods per plant.

100-kernel weight

An increase in the rate of potassium by 20 kg/ha decreased the 100-kernel weight significantly by 0.70 g. The interactions of sources of calcium and/or magnesium

Table 4(b) 100 kernel weight and shelling percentage

	100 kernel weight					Shelling percentage				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	41.28	42.68	42.92	41.25	41.98	67.12	67.32	67.15	67.28	67.22
M_2	43.83	40.83	40.93	45.73	42.33	66.55	66.58	66.48	66.65	66.57
M_3	41.95	41.70	41.73	41.92	41.83	69.10	69.20	69.03	69.27	69.15
M_4	42.98	42.23	42.55	42.67	42.61	75.25	75.46	75.27	75.45	75.36
M_5	43.43	42.55	42.63	43.35	42.99	75.53	75.62	75.53	75.62	75.58
B_0	42.35	41.87	-	-	-	70.64	70.75	-	-	-
B_1	43.04	42.13	-	-		70.78	80.93	-	-	-
Mean	42.70	42.00	42.11	42.58	-	70.71	70.84	70.69	70.85	-

100 kernel weight			Shelling percentage		
S.E. per plot	=	0.6001	S.E. per plot	=	0.0509
C.D. for M	=	0.8593	C.D. for M	=	0.0730
C.D. for K	=	0.5435	C.D. for K & B	=	0.0462
C.D. for MK & MB	=	1.2152			

with potassium and also with boron were found to be significant though the main effects of calcium and/or magnesium and boron were not significant.

Application of $MgCO_3$ (300 kg/ha) with 40 kg potassium was found to be the most superior one though it was not significantly different from application of lime with higher rate of potassium (60 kg/ha) and application of gypsum with lower rate of potassium. It was found that application of gypsum plus magnesium carbonate was also equally good.

Shelling percentage

The main effects of sources of calcium and/or magnesium and that of potassium and boron were significant.

Treatment M_5 (Gypsum+$MgCO_3$) was found to be the best treatment in increasing the shelling percentage. The lowest shelling percentage was recorded under treatment M_2 ($MgCO_3$).

Application of higher level of potassium and application of boron were also found to increase shelling percentage significantly.

Yield of pods

The main effects of different sources of calcium and magnesium and levels of potassium were found to be significant.

Application of gypsum or gypsum plus magnesium carbonate increased yield significantly (3.0 kg and 2.5kg per plot respectively) than that produced by application of lime, magnesium carbonate or dolomite.

An increase in the dose of potassium from 40 kg/ha to 60 kg/ha increased yield significantly from 2.30 to 2.51 kg per plot.

The interaction between sources of calcium and magnesium and potassium was found to be significant. Gypsum plus magnesium carbonate together with higher dose of potassium (60 kg/ha) gave the highest yield (3.13 kg/plot) though it is not statistically different from gypsum plus $MgCO_3$ with lower dose of potassium (3.05 kg/plot) or from gypsum and higher dose of potassium (2.90 kg/ha). Magnesium carbonate with lower dose of potassium recorded the lowest yield (1.99 kg per plot).

The interaction of potassium with boron was significant though the main effect of boron was not significant.

Application of potassium with and without boron is equally good. However, a decrease in yield due to boron application at lower level of potassium (40 kg/ha) occurs.

Oil content of the kernel

The main effects of sources of calcium and magnesium, and boron were found to be significant.

Application of dolomite is found to increase the oil content significantly (48.71 per cent) than that of gypsum alone. But when gypsum plus $MgCO_3$ was applied there was a slight decrease (46.94 per cent) though not significantly different from dolomite application or from gypsum

Table 5. Yield of pods, oil content and protein content of kernels

	Yield					Oil content (per cent)					Protein content (per cent)				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	2.28	2.09	2.32	2.06	2.19	40.00	35.83	38.50	37.33	37.92	22.98	26.19	25.48	24.69	24.58
M_2	1.99	2.13	2.19	1.93	2.06	35.33	40.80	32.00	43.33	37.67	24.69	21.19	21.90	23.98	22.94
M_3	2.01	2.23	2.17	2.07	2.12	46.67	50.75	49.50	47.92	48.71	23.23	23.04	22.48	23.78	23.14
M_4	2.14	2.95	2.40	2.69	2.55	45.67	46.17	45.67	46.17	45.92	34.73	33.95	35.32	33.35	34.34
M_5	3.05	3.13	3.12	3.16	3.09	50.88	43.00	46.00	47.58	46.94	22.61	22.01	22.31	22.30	22.31
B_0	2.41	2.47	-	-	-	42.80	41.87	-	-	-	25.63	25.38	-	-	-
B_1	2.18	2.54	-	-	-	44.62	44.43	-	-	-	25.67	25.18	-	-	-
Mean	2.30	2.51	2.44	2.36	-	43.71	43.15	42.33	44.53	-	25.65	25.28	25.50	25.42	-

Yield:
- S.E. per plot = 0.1442
- C.D. for M = 0.2091
- C.D. for K = 0.1305
- C.D. for MK = 0.2918
- C.D. for KB = 0.1846

Oil content:
- S.E. per plot = 1.6800
- C.D. for M = 2.4056
- C.D. for B = 1.5214
- C.D. for MK & MB = 3.4020

Protein content:
- S.E. per plot = 1.9259
- C.D. for M = 2.7576

alone (45.92 per cent). Application of $MgCO_3$ alone significantly decreased oil content (37.67 per cent), while increased the oil content when applied along with other liming materials. Further, application of lime alone, devoid of magnesium gave an oil content equal to that obtained when magnesium alone is applied and considerably less than the oil content obtained for calcium together with magnesium.

Boron has increased the oil content significantly from 42.33 per cent to 44.53 per cent.

The interaction effects of sources of calcium and magnesium, both with potassium and boron were significant. Dolomite with higher dose of potassium and gypsum plus $MgCO_3$ with lower dose of potassium were superior to all other combinations. Between the two the former is slightly superior though not significant. With a lime a lower dose of potassium was found to give better oil content while with $MgCO_3$, a higher dose gave better oil content but these two were not significantly different. For gypsum, potassium at both the doses were not differing significantly from one another.

Dolomite application with and without boron was not significantly different from the treatment gypsum plus $MgCO_3$ with boron.

Protein content

Only the main effect of sources of calcium and magnesium was found to be significant. Gypsum application is found to increase the protein content significantly (34.34 per cent). All other treatments did not have a significant effect on protein content. Gypsum plus $MgCO_3$ recorded the lowest percentage of protein.

Nutrient status of the soil:

Total nitrogen

At flowering stage the total nitrogen content of the soil was very high (0.113 and 0.102 per cent) in plots where lime and gypsum had been added when compared to other treatments.

When lime was added with lower or higher rates of potassium or magnesium carbonate was added with higher dose of potassium or gypsum was added with lower dose of potassium or gypsum plus $MgCO_3$ was added with higher dose of potassium, the total nitrogen content of the soil was very high. At peg forming stage only in the case of lime treated plots, total nitrogen content was observed to be high.

At pod forming stage, highest N content was recorded in plots where $MgCO_3$ was applied. This was followed by the treatment under gypsum. At harvest stage, total nitrogen status was generally lower though among the various treatments a higher content of nitrogen was observed in dolomite and gypsum applied plots.

Table 6(a) Total nitrogen in the soil (per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.107	0.118	0.110	0.115	0.113	0.096	0.132	0.110	0.118	0.114
M_2	0.088	0.107	0.088	0.107	0.098	0.107	0.080	0.093	0.093	0.093
M_3	0.093	0.080	0.093	0.080	0.087	0.102	0.080	0.083	0.098	0.091
M_4	0.110	0.093	0.110	0.093	0.102	0.097	0.070	0.102	0.065	0.083
M_5	0.083	0.105	0.095	0.093	0.094	0.085	0.075	0.070	0.090	0.090
B_0	0.091	0.107	-	-	-	0.095	0.088	-	-	-
B_1	0.101	0.094	-	-	-	0.099	0.087	-	-	-
Mean	0.096	0.101	0.099	0.098	-	0.097	0.087	0.092	0.093	-

S.E. per plot	= 0.0084	S.E. per plot	= 0.0106
C.D. for M	= 0.0122	C.D. for M	= 0.00152
C.D. for MK & MB	= 0.0173	C.D. for K	= 0.0096
C.D. for KB	= 0.0110	C.D. for MK & MB	= 0.0215

Table 6(b) Total nitrogen in the soil (per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.105	0.088	0.097	0.097	0.097	0.085	0.083	0.093	0.075	0.084
M_2	0.123	0.108	0.113	0.118	0.116	0.070	0.083	0.065	0.088	0.077
M_3	0.083	0.103	0.080	0.097	0.093	0.098	0.100	0.102	0.097	0.099
M_4	0.098	0.110	0.103	0.105	0.104	0.097	0.088	0.080	0.105	0.093
M_5	0.098	0.097	0.097	0.098	0.098	0.060	0.060	0.050	0.070	0.060
B_0	0.105	0.095	-	-	-	0.074	0.082	-	-	-
B_1	0.099	0.107	-	-	-	0.090	0.084	-	-	-
Mean	0.102	0.101	0.100	0.103	-	0.082	0.083	0.078	0.087	-

Pod forming		Harvest	
S.E. per plot	= 0.0114	S.E. per plot	= 0.098
C.D. for M	= 0.0163	C.D. for M	= 0.0241
		C.D. for B	= 0.0089
		C.D. for MB	= 0.0200

At peg forming stage application of potassium at higher dose reduced the nitrogen content significantly while at harvest stage boron application increased the nitrogen content significantly.

Available phosphorus

At flowering stage the available P status in the soil decreases as follows:

Gypsum > Dolomite > Gypsum + $MgCO_3$ > $CaCO_3$ > $MgCO_3$

The same trend was observed at peg forming stage also. But at pod forming stage no significant difference was observed between treatments. At harvest stage a slight difference was noted as follows.

$CaCO_3$ > Gypsum + $MgCO_3$ > Dolomite > Gypsum > $MgCO_3$

At flowering and peg forming stage, application of 60 kg K/ha increased the soil available phosphorus status while no significant difference was observed in the other two stages between the treatments.

Exchangeable potassium

At flowering stage the exchangeable potassium status was affected as follows:

Gypsum + $MgCO_3$ > $MgCO_3$ > Dolomite > $CaCO_3$ > Gypsum

So the status of exchangeable potassium was higher in Gypsum + $MgCO_3$ treatments.

Table 7(a) Available phosphorus (kg/ha) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	41.37	57.54	54.35	47.56	53.45	61.37	64.90	70.59	55.65	63.14
M_2	48.58	39.93	40.93	47.58	44.25	42.36	50.12	44.82	67.61	46.21
M_3	60.16	62.84	51.65	71.35	61.50	62.42	69.05	56.85	74.62	65.73
M_4	67.56	68.80	75.12	61.23	68.18	70.25	67.44	78.98	56.71	68.84
M_5	33.09	61.54	38.96	55.67	47.32	44.35	53.12	46.21	51.26	48.74
B_0	48.92	57.49	-	-	-	54.09	64.88	-	-	-
B_1	54.58	58.77	-	-	-	58.19	56.87	-	-	-
Mean	51.75	58.13	53.20	56.68	-	56.14	60.93	59.49	57.58	-

S.E. per plot	=	4.132	S.E. per plot	=	3.808
C.D. for M	=	5.917	C.D. for M	=	5.453
C.D. for K	=	3.742	C.D. for K	=	3.448
C.D. for MK & MB	=	8.367	C.D. for MB	=	7.711
C.D. for KB	=	5.292	C.D. for KB	=	4.877

Table 7(b) Available phosphorus (kg/ha) at pod forming and harvest stages of growth

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	60.74	54.08	57.60	57.22	57.41	61.49	60.11	60.46	61.15	60.80
M_2	58.09	52.31	53.77	56.63	55.20	56.50	52.34	52.31	56.53	54.42
M_3	59.60	61.93	57.51	64.12	60.76	60.78	59.15	60.41	59.51	59.96
M_4	56.08	58.42	56.22	59.28	57.25	56.60	56.55	58.92	54.22	56.57
M_5	62.55	57.31	62.09	57.77	59.93	61.72	59.15	58.79	62.08	60.43
B_0	58.15	56.69	-	-	-	58.32	58.04	-	-	-
B_1	60.67	56.93	-	-	-	60.51	56.88	-	-	-
Mean	54.41	56.81	57.42	58.80	-	59.42	57.46	58.18	58.70	-

S.E. per plot = 3.1611

S.E. per plot = 8.1029

C.D. for M = 3.9660

At the next two stages, main effects of calcium and magnesium were not significant. At harvest stage, the exchangeable potassium status in the decreasing order is given below.

$MgCO_3$, > Domomite > Gypsum > Gypsum + $MgCO_3$ > $MgCO_3$

Main effect of levels of potassium was significant in all the stages except in pod forming stage. An increase in application rate by 20 kg K/ha increased the exchangeable potassium status in flowering stage. But in peg forming stage exchangeable potassium status was higher for lower dose (40 kg K/ha). Again at the harvest stage, it was high for the higher rate of potassium application.

The main effect of boron was significant in all the stages. At flowering stage boron application decreased the exchangeable potassium, while at peg forming stage, it increased potassium status. The same decreasing and increasing trends were observed at pod forming and harvest stages respectively.

The interaction effects of source of calcium and magnesium with potassium was found to be significant at all the four stages. The interaction effects of sources of calcium and magnesium with boron was also found to be significant except at harvest stage.

The interaction effects of potassium and boron were significant at flowering and pegging stage but not at

Table 8(a) Exchangeable potassium in the soil (me/100 g) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.182	0.148	0.188	0.142	0.165	0.147	0.110	0.147	0.110	0.128
M_2	0.140	0.210	0.207	0.143	0.175	0.130	0.125	0.142	0.113	0.128
M_3	0.173	0.163	0.172	0.165	0.168	0.147	0.133	0.130	0.150	0.140
M_4	0.165	0.162	0.162	0.163	0.163	0.135	0.135	0.138	0.132	0.135
M_5	0.188	0.222	0.205	0.195	0.200	0.125	0.142	0.147	0.120	0.133
B_0	0.177	0.196	-	-	-	0.140	0.141	-	-	-
B_1	0.162	0.162	-	-	-	0.133	0.117	-	-	-
Mean	0.170	0.179	0.187	0.162	-	0.137	0.129	0.107	0.125	-

Flowering		Peg forming	
S.E. per plot	= 0.0080	S.E. per plot	= 0.0073
C.D. for M	= 0.0113	C.D. for K & B	= 0.0066
C.D. for K & B	= 0.0071	C.D. for MK & MB	= 0.0147
C.D. for MK & MB	= 0.0157	C.D. for KB	= 0.0093
C.D. for KB	= 0.0101		

Table 8(b) Exchangeable potassium in the soil (me/100 g) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.127	0.103	0.120	0.110	0.115	0.137	0.140	0.157	0.120	0.138
M_2	0.122	0.113	0.132	0.103	0.118	0.143	0.167	0.167	0.143	0.155
M_3	0.120	0.128	0.122	0.127	0.124	0.133	0.168	0.173	0.128	0.151
M_4	0.108	0.122	0.115	0.115	0.115	0.152	0.130	0.147	0.135	0.141
M_5	0.112	0.115	0.133	0.093	0.113	0.133	0.147	0.158	0.122	0.140
B_0	0.126	0.123	-	-	-	0.157	0.163	-	-	-
B_1	0.109	0.110	-	-	-	0.122	0.137	-	-	-
Mean	0.118	0.116	0.124	0.110	-	0.140	0.150	0.160	0.130	-

S.E. per plot = 0.0071

C.D. for K & B = 0.0065

C.D. for MK & MB = 0.0145

S.E. per plot = 0.0082

C.D. for M = 0.0118

C.D. for K & B = 0.0074

C.D. for MK = 0.0167

other stages. Exchangeable potassium was found to be higher with higher rate of potassium without boron application at flowering stage while at peg forming stage exchangeable potassium was lowest at higher dose of potassium with boron application.

Exchangeable calcium

The main effects of sources of calcium and magnesium was significant in all the stages.

At flowering stage, gypsum application increased the exchangeable calcium significantly followed by gypsum plus $MgCO_3$, calcium carbonate and dolomite in the descending order while exchangeable calcium was lowest in $MgCO_3$ treated plots.

At peg forming stage also the same trend was observed.

At pod forming stage dolomite application increased the exchangeable calcium significantly followed by lime, gypsum plus $MgCO_3$, gypsum and $MgCO_3$.

At harvest stage dolomite treated plots also showed maximum exchangeable calcium status followed by gypsum plus $MgCO_3$, $MgCO_3$, gypsum and lime. The main effect of potassium was significant at flowering and harvest stages only. At both these stages, higher rate of potassium application increased calcium availability.

Application of boron significantly affected the exchangeable calcium at peg forming stage by increasing the availability. This effect of boron was not noted at any

Table 9(a) Exchangeable calcium in the soil (me/100 g) at flowering and peg forming stages of growth

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.863	0.853	0.955	0.762	0.858	0.490	0.643	0.673	0.460	0.567
M_2	0.495	0.468	0.493	0.470	0.482	0.0.307	0.318	0.320	0.305	0.313
M_3	0.630	0.538	0.468	0.700	0.584	0.473	0.407	0.358	0.522	0.440
M_4	1.028	1.525	1.433	1.120	1.277	0.893	0.975	1.037	0.832	0.934
M_5	1.095	1.348	1.110	1.330	1.222	0.885	0.870	0.912	0.843	0.898
B_0	0.811	0.973	-	-	-	0.583	0.737	-	-	-
B_1	0.834	0.920	-	-	-	0.637	0.548	-	-	-
Mean	0.822	0.947	0.892	0.877	-	0.610	0.643	0.660	0.923	-

S.E. per plot	= 0.0440	S.E. per plot	= 0.0379
C.D. for M	= 0.0630	C.D. for M	= 0.0544
C.D. for K	= 0.0398	C.D. for B	= 0.0344
C.D. for MK & MB	= 0.0891	C.D. for MK & MB	= 0.0770
		C.D. for KB	= 0.0487

Table 9(b) Exchangeable calcium in the soil (me/100 g) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.585	0.885	0.797	0.673	0.735	0.573	0.400	0.653	0.320	0.487
M_2	0.465	0.312	0.363	0.413	0.388	0.527	0.607	0.488	0.645	0.567
M_3	1.083	1.117	1.078	1.122	1.100	0.618	1.053	0.865	0.807	0.836
M_4	0.593	0.603	0.627	0.570	0.598	0.345	0.670	0.433	0.582	0.508
M_5	0.618	0.635	0.685	0.568	0.627	0.813	0.713	0.767	0.760	0.763
B_0	0.626	0.794	-	-	-	0.646	0.637	-	-	-
B_1	0.712	0.627	-	-	-	0.505	0.741	-	-	-
Mean	0.669	0.710	0.710	0.669	-	0.575	0.689	0.641	0.623	-

S.E. per plot	= 0.0490	S.E. per plot	= 0.0424
C.D. for M	= 0.0703	C.D. for M	= 0.0632
C.D. for MK & MB	= 0.0994	C.D. for K	= 0.0400
C.D. for KB	= 0.0629	C.D. for MK & MB	= 0.0894
		C.D. for KB	= 0.0565

other stage.

The interactions of sources of calcium and magnesium both with potassium and boron were significant in all the stages.

Exchangeable magnesium

The main effects of sources of calcium and magnesium were significant at all the four stages.

The exchangeable magnesium content was maximum (0.353 me/100 g) in treatment $MgCO_3$ alone followed by treatment dolomite. Application of gypsum plus $MgCO_3$ and lime were on par while the lowest exchangeable magnesium content was noted in gypsum treated plots. This was the observation at the flowering stage.

At peg forming stage the maximum availability was for $MgCO_3$ treatment and the minimum for gypsum applied plots. But the plots treated with gypsum plus magnesium carbonate recorded a significant decrease in exchangeable magnesium when compared with lime application.

At pod forming stage similar results as in flowering stage were observed.

At harvest stage similar trends were observed for exchangeable magnesium in all treatments except gypsum + $MgCO_3$ which recorded ah higher exchangeable megnesium content than lime alone.

The main effect of potassium was significant at

Table 10(a) Exchangeable magnesium in the soil at flowering and peg forming stages (me/100 g)

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.235	0.227	0.282	0.180	0.231	0.232	0.310	0.260	0.282	0.271
M_2	0.388	0.317	0.310	0.395	0.353	0.433	0.383	0.437	0380	0.408
M_3	0.268	0.272	0.275	0.265	0.270	0.362	0.289	0.277	0.365	0.321
M_4	0.117	0.137	0.120	0.133	0.127	0.090	0.103	0.105	0.088	0.097
M_5	0.233	0.217	0.233	0.217	0.225	0.202	0.167	0.207	0.192	0.199
B_0	0.253	0.235	-	-	-	0.243	0.271	-	-	-
B_1	0.244	0.232	-	-	-	0.284	0.239	-	-	-
Mean	0.248	0.234	0.244	0.238	-	0.264	0.255	0.251	0.261	-

1. Flowering		2. Peg forming	
S.E. per plot	= 0.0183	S.E. per plot	= 0.0265
C.D. for M	= 0.0262	C.D. for M	= 0.0377
C.D. for MK & MB	= 0.0371	C.D. for MK & MB	= 0.0534
		C.D. for KB	= 0.0338

Table 10(b) Exchangeable magnesium in the soil at pod forming and harvest stages (me/100 g)

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.170	0.183	0.202	0.152	0.177	0.201	0.213	0.230	0.183	0.207
M_2	0.548	0.339	0.423	0.455	0.430	0.402	0.443	0.363	0.452	0.423
M_3	0.397	0.322	0.320	0.398	0.359	0.305	0.443	0.367	0.382	0.374
M_4	0.088	0.117	0.103	0.087	0.095	0.102	0.117	0.110	0.108	0.109
M_5	0.188	0.173	0.195	0.167	0.181	0.260	0.328	0.297	0.292	0.294
B_0	0.280	0.217	-	-	-	0.262	0.297	-	-	-
B_1	0.277	0.227	-	-	-	0.245	0.381	-	-	-
Mean	0.276	0.222	0.249	0.252	-	0.254	0.309	0.279	0.283	-

Pod forming		Harvest	
S.E. per plot	= 0.0151	S.E. per plot	= 0.0191
C.D. for M	= 0.0216	C.D. for M	= 0.0268
C.D. for K	= 0.0137	C.D. for K	= 0.0170
C.D. for MK & MB	= 0.0306	C.D. for MK & MB	= 0.0379
		C.D. for KB	= 0.0240

pod forming and harvest stages. At pod forming stage increase in dose of potassium decreased exchangeable magnesium while the reverse result was observed at harvest stage.

The interaction effects of sources of calcium and magnesium both with potassium and boron were significant at all the four stages whereas potassium-boron interaction effects were observed in peg forming and harvest stage.

<u>Nutrient content in haulms</u>

Nitrogen

The main effect of sources of calcium and magnesium was significant only at peg forming and pod forming stages. Application of lime increased the nitrogen content significantly at peg forming stage. At pod forming stage, the treatment with gypsum alone decreased the nitrogen content significantly.

The main effect of potassium and boron were not significant at any stage.

The interaction effects of sources of calcium and magnesium with potassium was significant at flowering and harvest stages while that with boron was significant only at peg forming stage.

Phosphorus content of the haulms

The main effect of calcium and magnesium was

Table 11(a) Nitrogen content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_0	K_1	B_0	B_1	Mean	K_0	K_1	B_0	B_1	Mean
M_1	3.465	3.650	3.604	3.511	3.557	3.419	3.465	3.373	3.511	3.442
M_2	3.863	3.937	3.863	3.937	3.900	3.412	3.234	3.049	3.326	3.188
M_3	3.816	3.557	3.788	3.586	3.687	3.234	3.818	3.911	3.142	3.026
M_4	3.355	3.973	3.511	3.816	3.664	3.003	3.003	3.373	3.633	3.003
M_5	3.614	3.511	3.585	3.538	3.562	2.818	2.818	2.772	2.865	2.818
B_0	3.587	3.753	-	-	-	3.114	3.077	-	-	-
B_1	3.658	3.979	-	-	-	3.132	3.058	-	-	-
Mean	3.662	3.726	3.670	3.678	-	3.123	3.068	3.096	3.095	-

S.E. per plot = 0.1835

C.D. for MK = 0.3715

S.E. per plot = 0.1655

C.D. [illegible] = [illegible]

C.D. for M = 0.2370

C.D. for MB = 0.3516

Table 11(b) Nitrogen content of haulms (per cent) at pod forming and harvest stages

	3. Pod forming					5. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	3.327	3.234	3.372	3.188	3.280	2.680	2.726	2.726	2.680	2.703
M_2	3.465	3.465	3.373	3.537	3.465	2.818	2.865	2.818	2.865	2.841
M_3	3.465	3.234	3.234	3.465	3.350	3.188	2.818	2.864	3.142	3.003
M_4	2.234	3.865	3.003	3.085	3.049	2.485	3.049	2.772	2.762	2.767
M_5	3.280	3.373	3.326	3.327	3.327	2.772	2.633	2.726	2.680	2.703
B_0	3.317	3.206	-	-	-	2.800	2.763	-	-	-
B_1	3.391	3.262	-	-	-	2.777	2.874	-	-	-
Mean	3.354	3.234	3.262	3.326	-	2.789	2.818	2.781	2.826	-

S.E. per plot = 0.1748   S.E. per plot = 0.1942

C.D. for M = 0.2503   C.D. for MK = 0.3933

Table 12(a) Phosphorus content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.622	0.568	0.826	0.362	0.595	0.778	0.627	0.795	0.610	0.703
M_2	0.767	0.573	0.450	0.890	0.670	0.909	0.693	0.597	1.005	0.808
M_3	0.588	0.472	0.605	0.405	0.505	0.537	0.618	0.850	0.305	0.578
M_4	0.443	0.700	0.387	0.757	0.572	0.323	0.545	0.473	0.395	0.434
M_5	0.800	0.393	0.555	0.638	0.597	0.372	0.230	0.367	0.235	0.301
B_0	0.635	0.495	-	-	-	0.588	0.645	-	-	-
B_1	0.653	0.567	-	-	-	0.579	0.441	-	-	-
Mean	0.644	0.531	0.565	0.610	-	0.584	0.543	0.616	0.510	-

S.E. per plot	=	0.0757	S.E. per plot	=	0.0611
C.D. for K	=	0.0686	C.D. for M	=	0.0875
C.D. for MK & MB	=	0.1535	C.D. for MK & MB	=	0.1237
			C.D. for KB	=	0.0782

Table 12(b) Phosphorus content of haulms (Per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.430	0.350	0.350	0.430	0.300	0.640	0.673	0.450	0.863	0.657
M_2	0.368	0.838	0.795	0.412	0.603	0.590	0.348	0.493	0.445	0.469
M_3	0.378	0.355	0.393	0.340	0.367	0.420	0.527	0.455	0.492	0.473
M_4	0.762	0.518	0.720	0.560	0.640	0.585	0.505	0.568	0.572	0.545
M_5	0.275	0.348	0.267	0.357	0.312	0.345	0.423	0.457	0.312	0.384
B_0	0.428	0.582	-	-	-	0.499	0.471	-	-	-
B_1	0.457	0.382	-	-	-	0.533	0.520	-	-	-
Mean	0.443	0.482	0.505	0.420	-	0.516	0.495	0.485	0.527	-

S.E. per plot = 0.0542

C.D. for M = 0.0778

C.D. for B = 0.0492

C.D. for KB = 0.0696

S.E. per plot = 0.0539

C.D. for M = 0.0771

C.D. for MK & MB = 0.1090

significant at all the three stages except at flowering.

At peg forming stage maximum phosphorus content was noted in $MgCO_3$ treatment which was significantly different from others. The lowest phosphorus content was recorded in gypsum plus $MgCO_3$ treated plots.

At pod forming stage also maximum phosphorus content was for $MgCO_3$ treatment and minimum for lime application. At harvest stage the maximum phosphorus content was observed in plants from plots under lime treated and the least from plots under gypsum plus $MgCO_3$.

The main effect of potassium was significant only at flowering time. An increase in potassium reduced the plant phosphorus content considerably. The main effect of boron was significant at peg forming and pod forming stages. In both the cases application of boron reduced the phosphoru content of haulms.

The interactions of calcium and magnesium with potassium and also with boron were significant at all the stages. The interaction of potassium with boron was significant at peg and pod forming stages only. Without boron, higher rate of potassium increased the phosphorus content while with boron the reverse was true at both stages.

Potassium content of haulms

The main effect of sources of calcium and magnesium

Table 13(a) Potassium content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	2.693	2.293	2.360	2.627	2.493	2.727	2.173	2.507	2.383	2.450
M_2	2.273	2.860	2.820	2.313	2.567	2.847	2.700	2.907	2.640	2.773
M_3	2.667	2.693	2.967	2.393	2.680	2.693	2.367	2.687	2.373	2.530
M_4	2.713	2.767	2.807	2.673	2.740	2.667	2.047	3.000	2.713	2.857
M_5	2.380	2.553	2.547	2.387	2.467	2.513	2.940	3.333	2.320	2.727
B_0	2.632	2.768	-	-	-	2.861	2.832	-	-	-
B_1	2.458	2.499	-	-	-	2.509	2.467	-	-	-
Mean	2.545	2.633	2.700	2.479	-	2.685	2.649	2.847	2.488	-

S.E. per plot	= 0.1858	S.E. per plot	= 0.1982
C.D. for B	= 0.1683	C.D. for M	= 0.2839
C.D. for MK & MB	= 0.3764	C.D. for MK	= 0.402
		C.D. for B	= 0.1796

Table 13(b) Potassium content of haulms (Per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	2.040	2.080	2.153	1.967	2.060	1.653	1.513	1.607	1.560	1.583
M_2	2.127	1.847	2.000	1.973	1.987	1.907	0.536	1.753	1.800	1.777
M_3	1.947	2.167	1.947	2.167	2.057	1.993	1.507	2.000	1.500	1.750
M_4	2.127	2.060	2.167	2.020	2.093	1.627	1.647	1.393	1.880	1.637
M_5	1.893	2.000	1.987	1.907	1.947	1.607	2.097	1.730	1.973	1.852
B_0	2.077	2.024	-	-	-	1.752	1.641	-	-	-
B_1	1.976	2.037	-	-	-	1.763	1.723	-	-	-
Mean	2.037	2.031	2.051	2.007	-	1.757	1.682	1.697	1.743	-

S.E. per plot = 0.2128

S.E. per plot = 0.1963

C.D. for MK & MB = 0.3975

was significant only at peg forming stage. Application of gypsum, $MgCO_3$ and gypsum plus $MgCO_3$ increased potassium content significantly when compared to lime and dolomite.

The main effect of potassium was not significant.

The main effect of boron was significant at flowering and peg forming stages. At both these stages application of boron reduced potassium content of haulms significantly.

The interaction effects of sources of calcium and magnesium with potassium was significant at all the stages except at pod filling while that with boron was significant at flowering and harvest stages. The maximum potassium content was noted when lower dose (40 kg/ha) was applied with $MgCO_3$. With the exception of gypsum and gypsum plus $MgCO_3$, in all other cases higher dose of potassium (60 kg/ha) reduced the potassium content of haulms. This was the observation at peg forming stage. But at peg forming stage maximum content of potassium was obtained when higher dose of potassium was applied with $MgCO_3$.

Calcium content

The main effect of calcium and magnesium was significant at all the stages except at peg forming stage. The result in the first stage is as follows:

Lime $MgCO_3$ Dolomite   Gypsum + $MgCO_3$ Gypsum

But at peg forming stage, a significantly higher calcium content was obtained with lime application.

Table 14(a) Calcium content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	1.872	2.160	1.870	2.617	2.016	1.657	1.910	1.663	2.703	1.783
M_2	1.818	1.568	1.670	1.713	1.693	1.745	1.798	1.738	1.805	1.772
M_3	1.722	1.672	1.730	1.663	1.697	1.682	1.860	1.455	1.087	1.771
M_4	1.913	1.798	1.952	1.760	1.756	1.590	1.735	1.598	1.726	1.663
M_5	1.705	1.752	1.663	1.820	1.729	1.730	1.808	1.685	1.913	1.749
B_0	1.847	1.698	-	-	-	1.525	1.787	-	-	-
B_1	1.765	1.882	-	-	-	1.837	1.857	-	-	-
Mean	1.806	1.790	1.772	1.824	-	1.680	1.822	1.656	1.847	-

S.E. per plot	= 0.1288	S.E. per plot	= 0.1083
C.D. for M	= 0.1842	C.D. for K & B	= 0.0900
C.D. for KB	= 0.1647	C.D. for MB	= 0.2193

Table 14(b) Calcium content of haulms (Per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	2.152	2.118	2.213	2.057	2.135	2.765	2.327	2.505	2.587	2.546
M_2	1.777	1.680	1.703	1.753	1.728	2.307	2.495	2.215	2.587	2.401
M_3	1.703	1.687	1.908	1.482	1.695	2.805	3.010	2.698	3.117	2.908
M_4	1.877	1.938	1.935	1.880	1.908	3.412	3.327	3.418	3.320	2.369
M_5	2.003	1.778	1.627	2.155	1.891	2.893	2.845	2.560	3.178	2.869
B_0	1.920	1.835	-	-	-	2.772	2.587	-	-	-
B_1	1.885	1.846	-	-	-	2.901	3.015	-	-	-
Mean	1.902	1.840	1.877	1.865	-	2.836	2.801	2.679	2.958	-

S.E. per plot = 0.1229

C.D. for M = 0.1759

C.D. for MB = 0.2488

C.D. for KB = 0.1574

S.E. per plot = 0.3666

C.D. for M = 0.5269

At harvest stage a slightly higher content of calcium was in gypsum treated plots though it was not significantly different from that of dolomite or gypsum plus $MgCO_3$.

The main effects of potassium and boron were significant only at peg forming stage. Higher potassium dosage increased calcium content significantly but the reverse was the result with boron application.

The potash-boron interaction was significant at flowering as well as pod filling stages while that of calcium and magnesium with boron was significant at peg and pod forming stages. The potash-(Ca+Mg) interaction was not significant at any stages.

When boron was applied with gypsum+$MgCO_3$ or with dolomite or with $MgCO_3$ alone, calcium content was increased but with gypsum alone or lime alone, calcium was slightly or significantly reduced.

Magnesium content

The main effects of sources of calcium and magnesium were significant at all the stages.

The magnesium content in plants was significantly reduced only in lime applied plots at flowering stage while it was low in plants under gypsum treatment at peg forming stage, and in plants under dolomite treatment at pod formation and again in plants under gypsum treatment at harvest.

Table 15(a) Magnesium content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.398	0.607	0.468	0.537	0.503	0.588	0.577	0.570	0.595	0.583
M_2	0.568	0.600	0.570	0.619	0.594	0.610	0.637	0.635	0.612	0.623
M_3	0.620	0.583	0.582	0.622	0.602	0.575	0.605	0.585	0.595	0.590
M_4	0.585	0.638	0.642	0.582	0.612	0.483	0.560	0.518	0.535	0.527
M_5	0.588	0.657	0.623	0.622	0.623	0.600	0.622	0.571	0.650	0.611
B_0	0.539	0.615	-	-	-	0.559	0.593	-	-	-
B_1	0.573	0.619	-	-	-	0.587	0.607	-	-	-
Mean	0.556	0.617	0.577	0.590	-	0.573	0.600	0.576	0.598	-

S.E. per plot = 0.0503

C.D. for M = 0.0722

C.D. for K = 0.0457

C.D. for MK = 0.1022

S.E. per plot = 0.0321

C.D. for M = 0.0461

Table 15(b) Magnesium content of haulms (Per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.448	0.430	0.442	0.437	0.439	0.552	0.560	0.518	0.593	0.556
M_2	0.602	0.595	0.643	0.553	0.598	0.602	0.592	0.520	0.693	0.597
M_3	0.252	0.452	0.455	0.248	0.352	0.620	0.585	0.535	0.670	0.603
M_4	0.473	0.460	0.470	0.464	0.467	0.493	0.503	0.420	0.577	0.498
M_5	0.505	0.503	0.492	0.517	0.504	0.672	0.667	0.748	0.590	0.664
B_0	0.502	0.499	-	-	-	0.589	0.498	-	-	-
B_1	0.410	0.477	-	-	-	0.577	0.565	-	-	-
Mean	0.456	0.488	0.500	0.444	-	0.588	0.581	0.548	0.621	-

S.E. per plot	= 0.0224	S.E. per plot	= 0.0746
C.D. for M	= 0.0321	C.D. for M	= 0.1067
C.D. for K & B	= 0.0203	C.D. for B	= 0.0675
C.D. for MK & MB	= 0.0453	C.D. for MB	= 0.1509
C.D. for KB	= 0.0287	C.D. for KB	= 0.0954

At all stages magnesium content was high in plants from $MgCO_3$ applied plots except at harvest stage where it was higher for gypsum+$MgCO_3$ treatment.

The main effect of potassium was significant at flowering and pod forming stage and that of boron was significant at pod forming and harvest stage.

Due to increase in the rate of potassium, magnesium content in plants was increased.

By application of boron-magnesium content was reduced at pod forming stage, but increased at harvest stage. The interaction of calcium or magnesium with potassium was significant at flowering and pod forming stages whereas that with boron was significant at pod forming and harvest stage. The potassium-boron interaction was also significant at pod forming and harvest stages.

At flowering, the application of 60 kg K/ha with gypsum plus $MgCO_3$ increased magnesium content while it was considerably reduced when 40 kg K/ha was applied with lime. At pod forming stage, considerable reduction in magnesium content was noted when a lower rate of potassium was applied along with dolomite.

When boron was applied with dolomite, magnesium content was significantly reduced at pod forming stage while a considerable increase in magnesium content was noted when gypsum + $MgCO_3$ was applied without boron, at harvest stage.

Sulphur content

The main effect of sources of calcium and magnesium was significant at all stages. The sulphur content was significantly higher for dolomite treated plants and lowest for gypsum plus $MgCO_3$ treated plants at flowering stage. At peg forming stage it was higher for plants from gypsum treated plots followed by gypsum plus $MgCO_3$. At pod forming stage sulphur content was significantly reduced for dolomite applied plants. At harvest stage it was maximum for plants under gypsum plus $MgCO_3$ treatment.

The main effect of potassium was not significant at any stage. The main effect of boron was significant at peg forming and harvest stages. By boron application (10 kg/ha) sulphur content was significantly increased at both the stages.

Nutrient content of the kernel

Nitrogen

Only the main effect of sources of calcium and magnesium was found to be significant. The nitrogen content of the kernel was significantly high in the case of gypsum treatment.

Phosphorus

The main effect of sources of calcium and magnesium was significant. The phosphorus content was significantly

Table 16(a) Sulphur content of haulms (Per cent) at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.138	0.178	0.127	0.190	0.158	0.128	0.147	0.130	0.145	0.138
M_2	0.155	0.110	0.162	0.103	0.133	0.190	0.157	0.158	0.188	0.173
M_3	0.160	0.128	0.160	0.128	0.331	0.158	0.165	0.147	0.177	0.162
M_4	0.210	0.208	0.187	0.232	0.209	0.233	0.193	0.210	0.217	0.213
M_5	0.207	0.192	0.210	0.188	0.199	0.210	0.215	0.217	0.213	0.213
B_0	0.188	0.150	-	-	-	0.187	0.155	-	-	-
B_1	0.160	0.177	-	-	-	0.181	0.195	-	-	-
Mean	0.174	0.163	0.169	0.168	-	0.184	0.175	0.171	0.183	-

S.E. per plot	= 0.0120	S.E. per plot	= 0.0132
C.D. for M	= 0.0172	C.D. for M	= 0. 188
C.D. for MK & MB	= 0.0243	C.D. for B	= 0.0119
C.D. for KB	= 0.0154	C.D. for KB	= 0.0168

Table 16(b) Sulphur content of haulms (Per cent) at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.167	0.127	0.182	0.112	0.147	0.150	0.145	0.103	0.192	0.148
M_2	0.160	0.175	0.150	0.185	0.168	0.132	0.133	0.113	0.152	0.133
M_3	0.133	0.117	0.145	0.105	0.125	0.125	0.118	0.120	0.123	0.122
M_4	0.148	0.205	0.147	0.207	0.166	0.127	0.142	0.128	0.140	0.134
M_5	0.150	0.185	0.185	0.170	0.168	0.162	0.200	0.192	0.190	0.191
B_0	0.165	0.151	-	-	-	0.123	0.139	-	-	-
B_1	0.139	0.183	-	-	-	0.163	0.156	-	-	-
Mean	0.152	0.162	0.158	0.156	-	0.143	0.148	0.131	0.159	-

S.E. per plot	= 0.0132	S.E. per plot	= 0.0129
C.D. for M	= 0.0188	C.D. for M	= 0.0185
C.D. for MK & MB	= 0.0266	C.D. for B	= 0.0116
C.D. for KB	= 0.0168	C.D. for MB	= 0.0261

low in lime treatment while it was highest under gypsum treatment though not significantly different from gypsum + $MgCO_3$ treatment.

By application of boron, phosphorus content of kernel was significantly raised.

All the interactions except potassium-boron were significant.

Potassium

Only the effect of potassium was significant. An increased rate of potassium application from 40 to 60 kg/ha reduced potassium content in kernel.

Calcium

The main effects of sources of calcium and or magnesium potassium and boron were significant. All the interaction effects were also significant.

Applied lime caused significant increase in calcium content. Higher rate of potassium decreased the calcium content of kernels while the reverse happened by the application of boron.

When lime was applied with lower dose of potassium, calcium content was significantly high, similarly boron application with lime also caused an increase in calcium content.

Magnesium

All the main effects and interaction effects were

Table 17(a) Nutrient content of kernels of groundnut (Per cent)

	Kernel nitrogen					Kernel phosphorus					Kernel potassium				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	3.675	4.189	4.075	3.789	3.932	0.295	0.417	0.300	0.412	0.356	0.813	0.827	0.867	0.773	0.820
M_2	3.951	3.389	3.503	3.837	3.670	0.447	0.330	0.392	0.385	0.383	0.873	0.893	0.867	0.900	0.883
M_3	3.717	3.689	3.589	3.808	3.703	0.412	0.413	0.453	0.372	0.413	0.880	0.747	0.813	0.813	0.813
M_4	5.555	5.432	5.651	5.356	0.493	0.427	0.432	0.375	0.483	0.429	0.893	0.807	0.840	0.860	0.850
M_5	3.618	3.522	3.571	3.570	3.570	0.410	0.433	0.412	0.432	0.422	0.833	0.710	0.800	0.743	0.772
B_0	4.009	4.060	-	-	-	0.384	0.389	-	-	-	0.867	0.808	-	-	-
B_1	4.107	4.029	-	-	-	0.412	0.421	-	-	-	0.851	0.785	-	-	-
Mean	4.103	4.044	4.079	4.068	-	0.398	0.405	0.386	0.417	-	0.859	0.797	0.837	0.818	-

S.E. per plot = 0.3081
C.D. for M = 0.4412

S.E. per plot = 0.0088
C.D. for M = 0.0126
C.D. for B = 0.0079
C.D. for MK & MB = 0.0178

S.E. per plot = 0.0675
C.D. for K = 0.0612

Table 17(b) Nutrient content of kernels (Per cent)

	1. Calcium					2. Magnesium					3. Sulphur				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.792	0.515	0.528	0.798	0.653	0.612	0.447	0.458	0.600	0.528	0.140	0.110	0.128	0.122	0.125
M_2	0.555	0.502	0.597	0.460	0.528	0.417	0.383	0.420	0.380	0.400	0.128	0.107	0.123	0.117	0.118
M_3	0.370	0.388	0.392	0.367	0.379	0.407	0.323	0.360	0.370	0.365	0.125	0.115	0.103	0.137	0.120
M_4	0.358	0.250	0.230	0.378	0.304	0.353	0.288	0.307	0.335	0.321	0.188	0.203	0.187	0.205	0.196
M_5	0.307	0.382	0.353	0.335	0.344	0.302	0.267	0.315	0.253	0.284	0.207	0.203	0.208	0.202	0.205
B_0	0.501	0.340	-	-	-	0.431	0.313	-	-	-	0.159	0.141	-	-	-
B_1	0.452	0.475	-	-	-	0.405	0.371	-	-	-	0.157	0.154	-	-	-
Mean	0.476	0.407	0.420	0.464	-	0.418	0.342	0.372	0.388	-	0.158	0.148	0.150	0.155	-

1. Calcium		2. Magnesium		3. Sulphur	
S.E. per plot	= 0.0361	S.E. per plot	= 0.0169	S.E. per plot	= 0.0115
C.D. for M	= 0.0513	C.D. for M	= 0.0242	C.D. for M	= 0.0161
C.D. for K & B	= 0.0324	C.D. for K & B	= 0.0153	C.D. for MB	= 0.0228
C.D. for MK & MB	= 0.0726	C.D. for MK & MB	= 0.0342		
C.D. for KB	= 0.0459	C.D. for KB	= 0.0217		

significant. When $MgCO_3$ was applied with gypsum, magnesium content was significantly reduced. As in the case of calcium, higher dose of potassium decreased, magnesium content while lower rate increased it. But when boron was applied magnesium content was increased. When gypsum + $MgCO_3$ was applied with 60 kg K/ha as against 40 kg K, magnesium content decreased significantly. A similar result was observed when gypsum plus $MgCO_3$ was applied with boron.

Sulphur

The main effect of sources of calcium and/ magnesium was significant, highest sulphur content was recorded in gypsum + $MgCO_3$ followed by gypsum alone. Both of these are not significantly different.

The interaction effects of boron with sources of calcium and magnesium were also significant where application of boron reduced sulphur content in gypsum + $MgCO_3$ treatment while boron application increased sulphur content in gypsum alone.

<u>Nutrient contents of the shell</u>

Nitrogen

The main effects of sources of calcium and magnesium, and boron were found to be significant. Lime application increased the nitrogen content significantly followed by $MgCO_3$ application. Boron application reduced the nitrogen content. The interaction effects of sources of calcium both with potassium and boron were also significant.

Phosphorus

All main effects and interaction effects were significant. Application of magnesium carbonate increased the phosphorus content significantly. However it was on par with lime application though there was a slight increase for $MgCO_3$ treatment. Gypsum application reduced the phosphorus content to a considerable level (320 ppm).

An increase in potassium application by 20 kg/ha increased phosphorus content of the shell significantly. Similar was the result with boron application.

Potassium

Here also all the main effects and interactions were significant. Gypsum caused a considerable increase in potassium content when compared to other sources. Potassium at higher dose (60 kg/ha) as well as application of boron increased the potassium content.

Calcium

The main effects of sources of calcium and magnesium as well as that of boron were significant while the effect of potassium was not significant.

Shell calcium content was considerably high for $CaCO_3$ treatment while the least was recorded for gypsum.

Table 18(a) Nutrient content of the shell (N, P and K)

1. Nitrogen (Per cent)

	K_1	K_2	B_0	B_1	Mean
M_1	2.523	2.237	2.571	2.190	2.380
M_2	1.761	1.190	1.856	1.095	1.475
M_3	1.047	1.142	1.190	1.000	1.095
M_4	1.285	1.330	1.142	1.476	1.309
M_5	1.190	1.285	1.142	1.333	1.237
B_0	1.685	1.475	-	-	-
B_1	1.437	1.399	-	-	-
Mean	1.561	1.437	1.580	1.418	-

S.E. per plot = 0.1562
C.D. for M = 0.2357
C.D. for B = 0.1415
C.D. for MK & MB = 0.3164

2. Phosphorus (ppm)

	K_1	K_2	B_0	B_1	Mean
M_1	393.3	953.3	735.0	611.7	673.3
M_2	705.0	686.7	605.0	786.7	695.8
M_3	441.7	365.0	443.3	363.3	403.3
M_4	385.0	155.0	483.3	156.7	820.0
M_5	266.7	838.3	138.3	966.7	552.5
B_0	454.0	508.0	-	-	-
B_1	462.7	691.3	-	-	-
Mean	458.3	599.7	481.0	577.0	-

S.E. per plot = 45.36
C.D. for M = 64.95
C.D. for K & B = 41.07
C.D. for MK & MB = 91.85
C.D. for KB = 58.09

3. Potassium (Per cent)

	K_1	K_2	B_0	B_1	Mean
M_1	0.860	1.150	0.983	1.027	1.005
M_2	0.900	1.160	1.060	1.000	1.030
M_3	1.020	0.980	0.820	1.180	1.000
M_4	1.197	1.093	1.227	1.063	1.145
M_5	1.027	1.020	1.040	1.007	1.023
B_0	0.965	1.087	-	-	-
B_1	1.036	1.075	-	-	-
Mean	1.001	1.081	1.026	1.055	-

S.E. per plot = 0.0277
C.D. for M = 0.0400
C.D. for K & B = 0.0253
C.D. for MK & MB = 0.0566
C.D. for KB = 0.0358

Table 18(b) Nutrient content of shell (Calcium, magnesium and sulphur)

	Calcium (per cent)					Magnesium (per cent)					Sulphur (per cent)				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	3.710	2.950	3.090	3.570	3.330	0.393	0.428	0.405	0.417	0.411	0.083	0.078	0.073	0.088	0.081
M_2	2.633	3.260	3.408	2.485	2.467	0.423	0.215	0.317	0.322	0.319	0.067	0.060	0.070	0.057	0.063
M_3	1.158	1.032	1.058	1.132	1.095	0.377	0.455	0.373	0.458	0.416	0.072	0.050	0.065	0.057	0.061
M_4	1.162	0.833	0.902	1.093	0.998	0.528	0.548	0.483	0.503	0.493	0.103	0.095	0.097	0.102	0.099
M_5	1.165	1.613	2.088	0.902	1.499	0.522	0.598	0.537	0.583	0.560	0.088	0.097	0.102	0.083	0.095
B_0	2.195	2.019	-	-	-	0.429	0.417	-	-	-	0.089	0.073	-	-	-
B_1	1.736	1.937	-	-	-	0.469	0.445	-	-	-	0.076	0.079	-	-	-
Mean	1.966	1.978	2.107	1.836	-	0.449	0.431	0.423	0.451	-	0.083	0.076	0.081	0.077	-

Calcium		Magnesium		Sulphur	
S.E. per plot	= 0.1450	S.E. per plot	= 0.0238	S.E. per plot	= 0.0097
C.D. for M	= 0.2077	C.D. for M	= 0.0340	C.D. for M	= 0.0139
C.D. for B	= 0.1314	C.D. for B	= 0.0215	C.D. for KB	= 0.0124
C.D. for MK & MB	= 0.2937	C.D. for MK	= 0.0481		
C.D. for KB	= 0.1858				

Application of boron increased the shell calcium content. All the interaction effects were also significant.

Magnesium

The main effects of sources of calcium and magnesium as well as that of boron were significant. The highest magnesium content was for gypsum plus $MgCO_3$ treatment. Application of boron reduced the magnesium content.

The interaction effect of sources of calcium and magnesium with potassium was significant though the main effect of potassium was not significant.

Sulphur

The main effect of calcium and magnesium was significant. Highest sulphur content was recorded for gypsum treatment followed by gypsum plus $MgCO_3$. The interaction of potassium with boron was also significant.

<u>Monovalent (K) to Divalent (Ca+Mg) ratio in soil</u>

The main effect of calcium and magnesium was significant at all the stages of flowering, peg forming, pod forming and harvest. The ratio was highest (0.21) for $MgCO_3$ treatment followed by dolomite (0.20) (no significant difference) and least (0.13) for gypsum at flowering stage. But at peg forming, a significantly higher ratio (0.20) for dolomite than that of $MgCO_3$ (0.18) was observed. At pod forming stage it was very low for dolomite (0.09) and

Table 19(a) Monovalent (K) to divalent (Ca+Mg) ratio in soil at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.17	0.15	0.16	0.16	0.16	0.21	0.13	0.19	0.15	0.17
M_2	0.16	0.27	0.25	0.17	0.21	0.18	0.19	0.19	0.17	0.18
M_3	0.21	0.20	0.24	0.17	0.20	0.20	0.20	0.21	0.18	0.20
M_4	0.15	0.10	0.10	0.15	0.13	0.14	0.13	0.12	0.15	0.13
M_5	0.14	0.14	0.15	0.13	0.14	0.12	0.14	0.13	0.12	0.13
B_0	0.18	0.18	-	-	-	0.19	0.15	-	-	-
B_1	0.15	0.16	-	-	-	0.15	0.16	-	-	-
Mean	0.17	0.17	0.18	0.15	-	0.17	0.15	0.17	0.15	-

1. Flowering		2. Peg forming	
S.E. per plot	= 0.012	S.E. per plot	= 0.011
C.D. for M	= 0.018	C.D. for M	= 0.016
C.D. for B	= 0.011	C.D. for K & B	= 0.100
C.D. for MK & MB	= 0.025	C.D. for MK & MB	= 0.022
		C.D. for KB	= 0.014

Table 19(b) Monovalent (K) to divalent (Ca+Mg) ratio in soil at pod forming and harvest stages

	3. pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.17	0.10	0.13	0.14	0.14	0.19	0.23	0.18	0.24	0.21
M_2	0.12	0.18	0.18	0.12	0.15	0.16	0.18	0.20	0.14	0.17
M_3	0.09	0.10	0.09	0.09	0.09	0.14	0.11	0.15	0.11	0.13
M_4	0.16	0.17	0.16	0.18	0.17	0.34	0.17	0.29	0.22	0.26
M_5	0.14	0.14	0.15	0.13	0.14	0.12	0.14	0.15	0.12	0.13
B_0	0.14	0.14	-	-	-	0.20	0.19	-	-	-
B_1	0.13	0.13	-	-	-	0.18	0.15	-	-	-
Mean	0.13	0.14	0.14	0.13	-	0.19	0.17	0.19	0.17	-

S.E. per plot	= 0.011	S.E. per plot	= 0.015
C.D. for M	= 0.015	C.D. for M	= 0.022
C.D. for B	= 0.100	C.D. for K & B	= 0.014
C.D. for MK & MB	= 0.022	C.D. for MK & MB	0.031

Table 20(a) Monovalent (K) to divalent (Ca+Mg) ratio in plant at flowering and peg forming stages

	1. Flowering					2. Peg forming				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	1.04	0.83	1.01	0.86	0.93	1.24	0.89	1.07	1.06	1.07
M_2	0.96	1.52	1.47	1.01	1.24	1.24	1.11	1.24	1.11	1.18
M_3	1.15	1.29	1.33	1.11	1.22	1.26	1.00	1.38	0.89	1.13
M_4	1.10	1.15	1.09	1.16	1.13	1.29	1.35	1.43	1.21	1.32
M_5	1.07	1.08	1.14	1.01	1.08	1.13	1.28	1.47	0.94	1.21
B_0	1.12	1.30	-	-	-	1.40	1.23	-	-	-
B_1	1.01	1.05	-	-	-	1.06	1.02	-	-	-
Mean	1.06	1.18	1.21	1.03	-	1.23	1.13	1.32	1.04	-

S.E. per plot = 0.175

C.D. for B = 0.159

S.E. per plot = 0.112

C.D. for M = 0.161

C.D. for K & B = 0.102

C.D. for MK & MB = 0.227

Table 20(b) Monovalent (K) to divalent (Ca+Mg) ratio in plant at pod forming and harvest stages

	3. Pod forming					4. Harvest				
	K_1	K_2	B_0	B_1	Mean	K_1	K_2	B_0	B_1	Mean
M_1	0.84	0.79	0.80	0.83	0.81	0.51	0.52	0.54	0.50	0.52
M_2	0.91	0.83	0.87	0.87	0.87	0.68	0.56	0.68	0.56	0.62
M_3	0.91	1.05	0.86	1.10	0.98	0.61	0.48	0.69	0.41	0.55
M_4	0.93	0.87	0.92	0.87	0.90	0.43	0.42	0.36	0.48	0.42
M_5	0.77	0.88	0.95	0.69	0.82	0.48	0.63	0.57	0.54	0.55
B_0	0.87	0.89	-	-	-	0.56	0.58	-	-	-
B_1	0.87	0.87	-	-	-	0.52	0.47	-	-	-
Mean	0.87	0.88	0.88	0.87	-	0.54	0.52	0.57	0.50	-

S.E. per plot = 0.119 S.E. per plot = 0.103

the highest ratio at this stage was recorded for gypsum (0.17). At harvest stage the ratio for gypsum was 0.26 which was significantly higher and the lowest ratio (0.13) for dolomite.

The main effect of potassium was significant at peg forming and harvest stages. With a higher rate of potassium (60 kg/ha) the ratio reduced (0.15) as compared to that with 40 kg K (0.17), at peg forming stage. The same trend was noted at harvest stage also (ratio reduced from 0.19 to 0.17).

The main effect of boron was significant at all the four stages. At all stages the ratio was decreased by boron application.

The interaction effect of sources of calcium and magnesium with potassium was also significant at all stages.

Monovalent (K) to Divalent (Ca+Mg) ratio in plant

The main effects of sources of calcium and/or magnesium was significant only at peg forming stage. At this stage, it was highest for gypsum treatment (M_4) and lowest for lime treatment (M_1).

The main effect of boron was significant at flowering and peg forming stages. At both the stages application of boron reduced the ratio. At other stages a definite pattern in the ratios could not be observed.

DISCUSSION

DISCUSSION

Groundnut is being cultivated both as a pure crop and as an intercrop along with cassava in South Kerala. The red loam and lateritic soils and a well distributed rainfall with larger number of rainy days due to the south west and north east monsoons enables the crop to be grown successfully. Agronomists have recommended the crop to be grown as a pure crop in south west monsoon period or as an intercrop along with May/June planting of tapioca.

Though NPK recommendations are available for the crop in the Package of Practices, serious attention has not been paid so far on studies on the requirements of divalent cations such as calcium and magnesium especially in relation to gynophoric nutrition, peg formation and subsequent nutrition of the pods. Further, adequate information is not available on potash nutrition in relation to application of such amendments. Further the best carrier of divalent cations has also not been studied in detail. Boron, though reported to significantly influence yields of groundnut in several situations, has not been studied under our conditions. The results of such a study with multifaceted objectives as enumerated above are discussed in the following pages.

Yield attributes

Plant height

Table 2(a) and 2(b) present data on the height of the plant in centimeters at four different stages of growth namely flowering, peg forming, pod forming and harvest stages. None of the carriers of divalent cations in treatments M_1 to M_5 and combinations there of or the levels of potassium tried namely 40 kg of K/ha (K_1) and 60 kg K/ha (K_2) had any significant effect in increasing the height of the plant. Application of boron at 10 kg/ha significantly decreased the height of the plant. Asokan and Raj (1974) however had noted significant increase in the plant height due to boron application. However levels of potassium though not having an effect on the height of the plants, significantly increased the yield (Table 5 and Fig.2&4). Boron also had a significant interaction with K in increasing the yield of pods (Table 5 and Fig. 5). In view of this it becomes apparent from the present study that the height of the plant is not significantly influenced by many of the nutritional factors nor height expresses itself in the yield.

Number of branches

Table 3 presents the data on number of branches at three stages of growth viz., flowering, peg forming and pod forming stage. Except for the reduction in the number of branches at all stages of growth by application of boron none of the other treatments have a significant effect in either increasing or decreasing the number of branches.

A similar result was obtained by Harris (1968) with respect to the effect of low boron levels in increasing the foliage.

Table 4(a) and 4(b) presents data on the dry weight of haulms in kg per plot, number of pods per plant under various treatments, 100 kernel weight and shelling percentage.

Dry weight of haulms

Different sources of calcium and magnesium, levels of potassium and boron had no significant effect in increasing the dry weight of haulms. However, the interaction effects between different sources of calcium and magnesium and levels of potassium were significant. Leguminous crops usually have a sensitive balance with respect to the levels of nutrition of divalent ions such as calcium and magnesium in relation to monovalent ions such as potassium (Habeebullah, 1973). This sensitive relationship requires simultaneous increase in the supply of monovalent ions when that of either of the divalent ions calcium or magnesium is enhanced. These effects have also been brought out by working out the ratio of the concentration of monovalent ion potassium to the divalent ions calcium and magnesium in the plant (Table 20(a) and 20(b)). It has to be noted that treatments where the interaction effects are highly significant decreased the ratio of monovalent to divalent ions. Blamey and Chapman (1982) have observed increased yield of haulms due to application of lime and magnesium bearing amendments. Sreedharan and George (1968) have reported increased yield of haulms due to application of potassium together with calcium and magnesium. In the present study however interaction effects alone were found to be significant.

Number of pods per plant

Application of various sources of calcium or magnesium or both significantly influences the number of pods per plant. Thus application of gypsum gave the maximum number of pods. Application of gypsum at the same level together with $MgCO_3$ gave number of pods slightly lower but not significantly different. This evidently shows that the use of amendments on the red loam soils of Vellayani and similar red and laterite soils, possibly magnesium nutrition is not as critical as calcium nutrition in increasing the number of pods. Application of amendments such as lime, magnesium carbonate and dolomite to give equivalent amounts of calcium as in the gypsum treatment did not significantly increase the number of pods per plant. This shows that the associated anion, sulphate (SO_4^{--}) has a significant effect in increasing the number of pods. It may also be due to higher solubility of gypsum in soil moisture compared to the carbonate sources of calcium and magnesium. The results of the present study thus are at variance from the findings of Lachover (1965) who found that carbonate sources perform very nearly equal to gypsum sources of calcium. Further table 5 of the present study on the yield of groundnut shows that application of gypsum has produced maximum effect on yield compared to non gypsum sources, and thus it supports the findings of Venema (1962).

Application of potassium at the rate of 60 kg/ha also significantly enhance the number of pods per plant from 25 to 29. But application of boron did not produce any significant effect. Both levels of potassium as well as application of boron produced a significant and positive interaction effect in enhancing the number of pods when combined with gypsum. A perusal of Appendix (IV) for yield and table 5 will reveal that this interaction effect on the number of pods per plant has got reflected in the yield of pods. In fact the treatment combination $M_4K_2B_1$ gives the maximum yield.

100 kernel weight

An increase in the rate of application of potassium by 20 kg/ha as in treatment K_2 compared to K_1 has decreased the 100 kernel weight while the interaction of sources of calcium and/or magnesium with potassium and boron has significantly enhanced the 100 kernel weight. Thus in terms of 100 kernel weight application of $MgCO_3$ with 40 kg K/ha was the best treatment. However this effect on 100 kernel weight could not be reflected in yield since other yield attributes probably were more significantly affected by gypsum treatments which recorded the highest yield. Blamey and Chapman (1982) had already pointed out that gypsum had very little effect in increasing 100 kernel weight when compared to lime.

Shelling percentage

The results indicate significant effects on shelling percentage for treatments under gypsum compared to calcium carbonate or magnesium carbonate treatments. Thus treatments M_4 and M_5 record the highest shelling percentages. Comparison of the shelling percentages under treatments with calcium carbonate and magnesium carbonate on the one hand with gypsum containing treatments M_4 and M_5 on the other indicate that addition of magnesium carbonate has a significant effect, especially in presence of calcium.

Calcium carbonate as a source is not as effective as calcium sulphate in increasing the yield (Table 5) or the shelling percentage (Table 4(b)). This is mainly to be attributed to the slow solubilisation of calcium carbonate which probably is insufficient to meet the demands of gynaphoric nutrition. The greater solubility of calcium sulphate and the effect of the accompanying anion SO_4^{--} on yield might be responsible for both the higher yield and the higher shelling percentage.

A higher dose of potassium and application of boron are also found to increase the shelling percentage. Similar increase in shelling percentage due to application of gypsum has been reported by Robertson et al. (1966). Higher levels of potassium has been observed to increase the shelling percentage (Eweida et al., 1980).

Table 5 presents data on the yield of groundnut, oil content of the kernels and protein content of the kernels.

Yield

In terms of yield of pods it may be seen that application of gypsum (1720 kg/ha) together with $MgCO_3$ (300 kg/ha) and potassium at 60 kg/ha gave the highest yield. However gypsum alone with higher level of potassium (M_4) also produced an yield not significantly different from the highest yield produced when 300 kg of $MgCO_3$ was included. These results thus indicate that among the two divalent cations (Ca^{++} and Mg^{++}), nutrition with respect to calcium appears to be more important in producing an

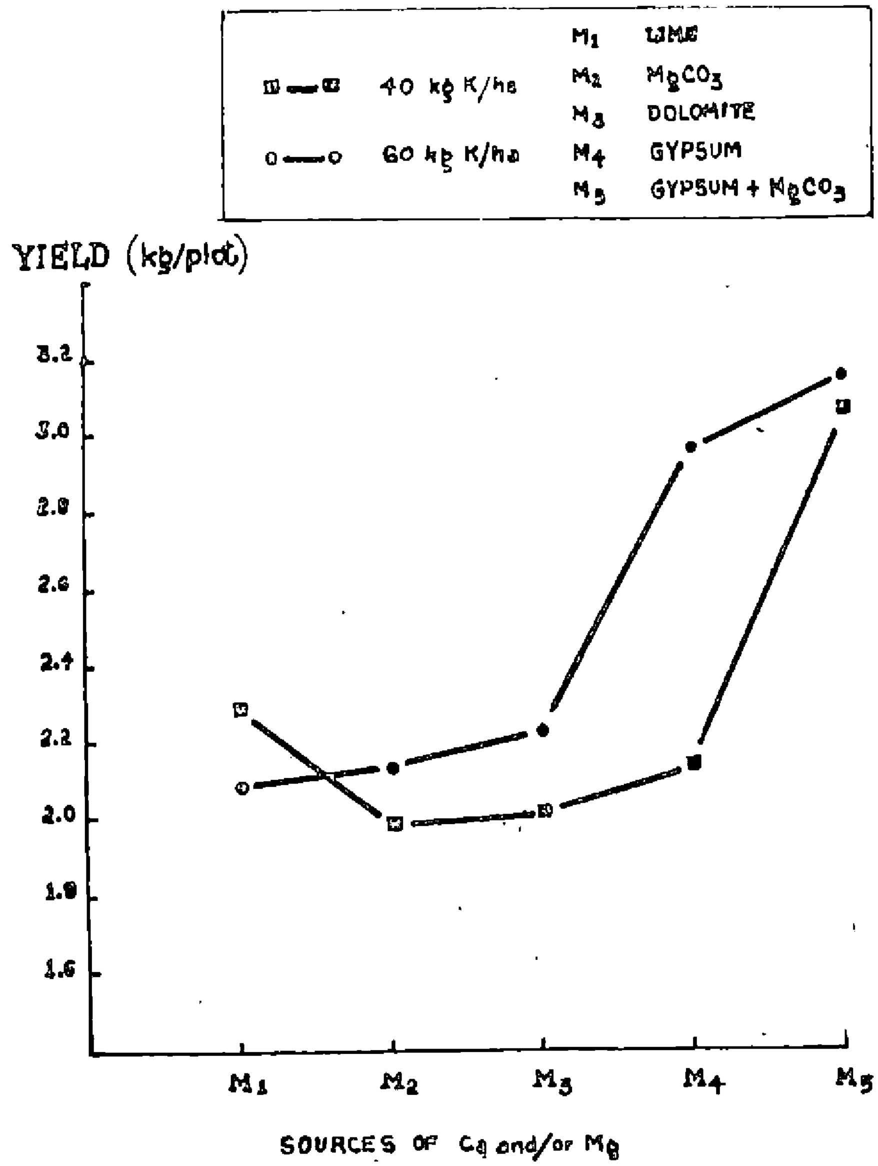


FIG. 2 EFFECT OF DIFFERENT SOURCES OF Ca AND/OR Mg WITH DIFFERENT LEVELS OF K ON YIELD OF GROUNDNUT

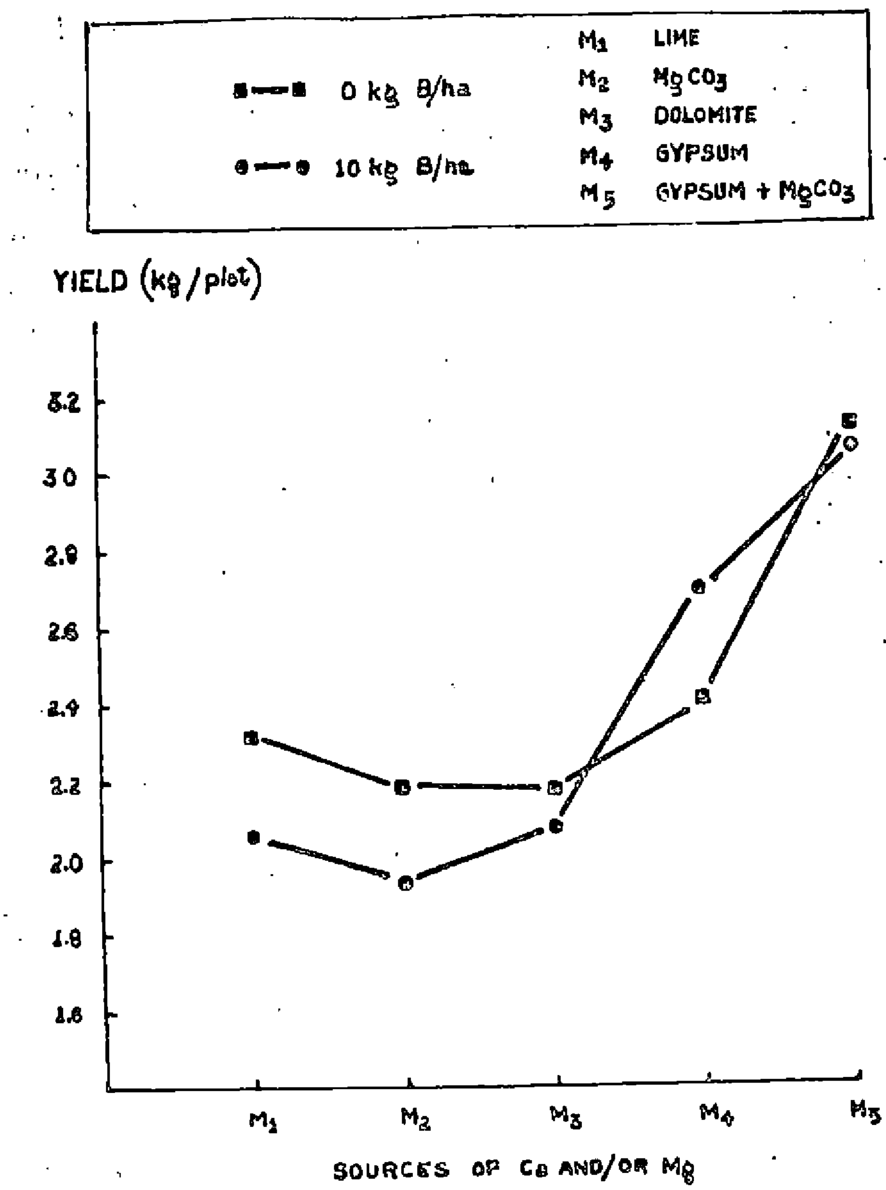


FIG.3 EFFECT OF DIFFERENT SOURCES OF Ca AND/OR Mg WITH AND WITHOUT B ON YIELD OF GROUNDNUT

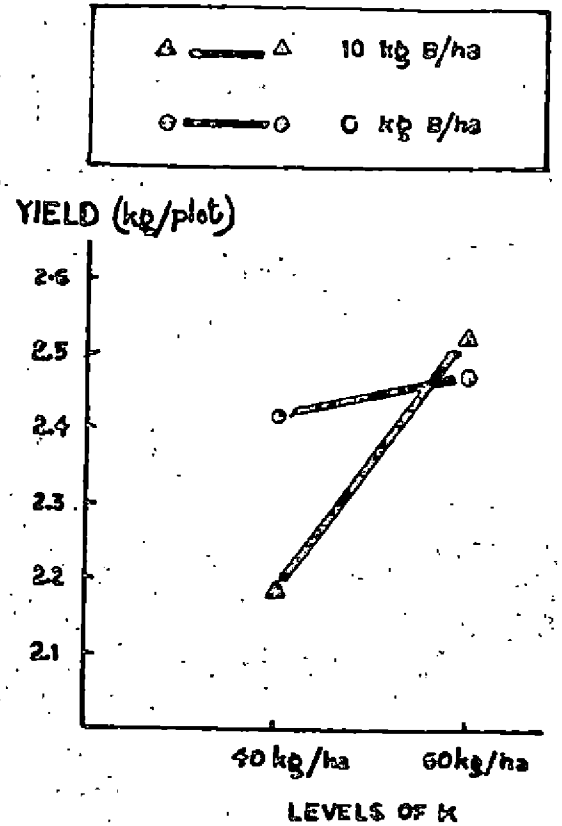


FIG.4 EFFECT OF TWO DIFFERENT LEVELS OF K WITH AND WITHOUT B ON YIELD OF GROUNDNUT

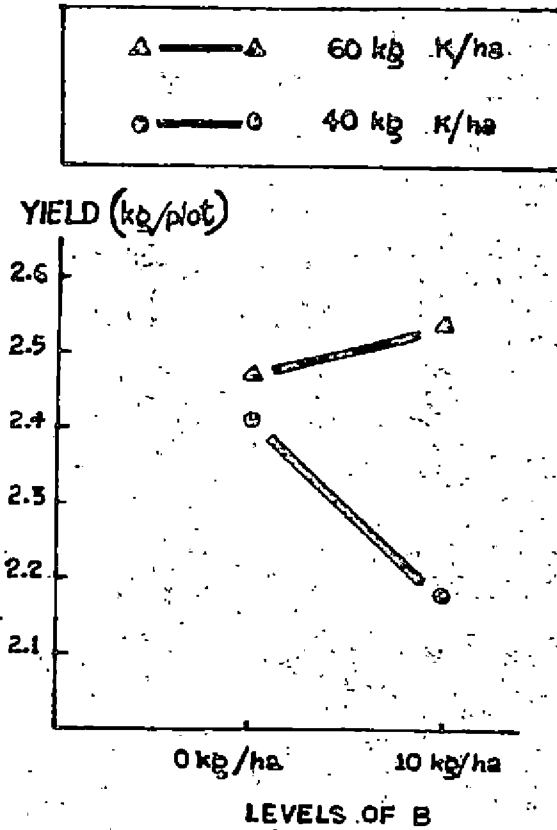


FIG.5 EFFECT OF APPLICATION OF B WITH TWO DIFFERENT LEVELS OF K ON YIELD OF GROUNDNUT

yield increase. Further when such an yield increase is attempted, a concomitant increase in level of potassium nutrition has also to be ensured (Fig.1,4 and 5). Similar results have been obtained by Loganathan and Krishnamoorthy (1977) in calcium deficient red soils of Tamil Nadu.

Oil content

Oil content of kernels from each treatment as against the composition of the amendments reveals that application of magnesium carbonate in combination with calcium significantly enhances the oil content. This is brought out by the low oil content in treatments which include calcium or magnesium alone (M_1 and M_2) and the significantly higher oil content in treatment under dolomite (M_3) and in treatment M_5. However this effect due to magnesium in combination with calcium is variable and dependant upon the level of potassium and the nature of the amendment. Thus in presence of gypsum and a lower level of potassium with 300 kg $MgCO_3$/ha (M_5K_1) is able to achieve the same oil content (50.88 per cent) as that of dolomite with higher level of potassium (M_3K_2 - 50.75 per cent) (Fig. 6). This shows that since M_5 is the treatment which has increased the yield to the maximum extent, in terms of oil yield also this is likely to be the most effective treatment. Similar results delineating the effect of magnesium on oil content has been obtained by Subramanian (1973). This can

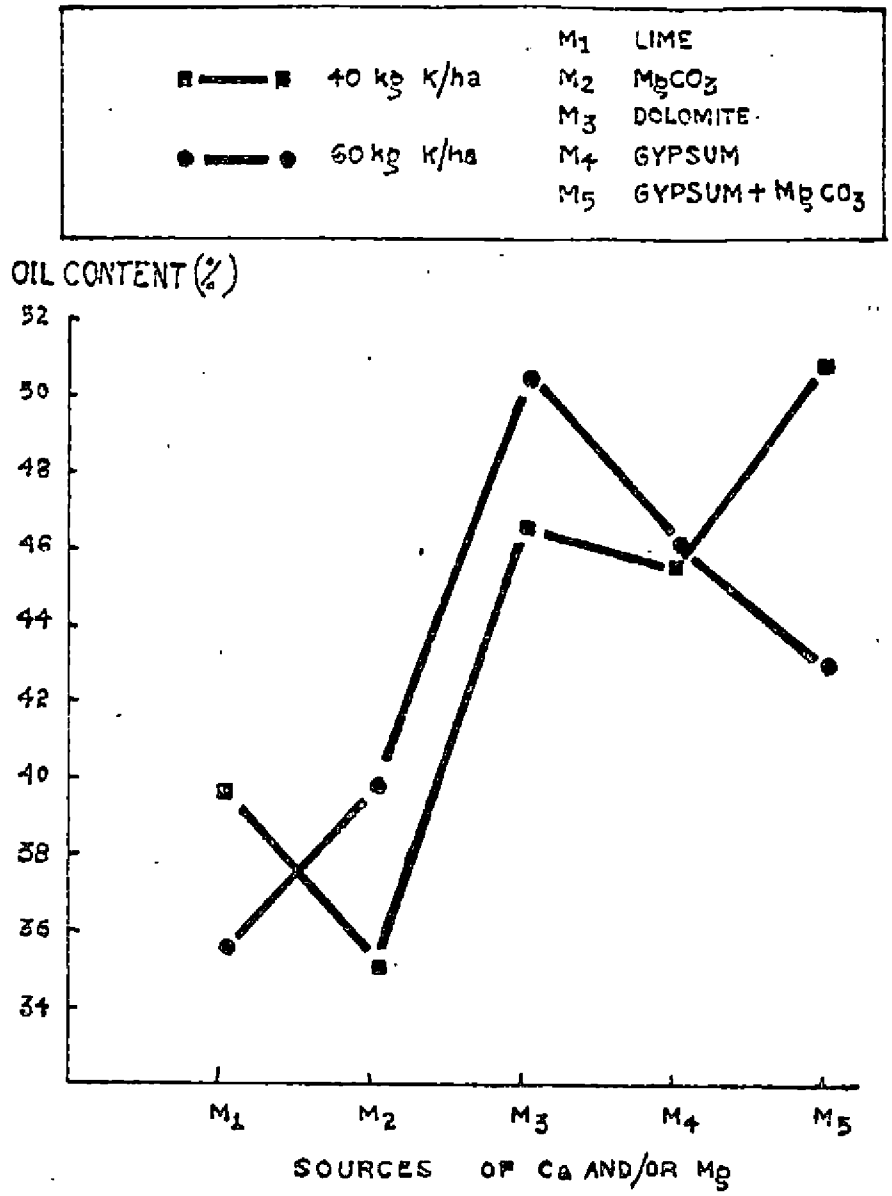


FIG. 6 EFFECT OF DIFFERENT SOURCES OF Ca AND/OR Mg WITH TWO DIFFERENT LEVELS OF K ON OIL CONTENT OF GROUNDNUT

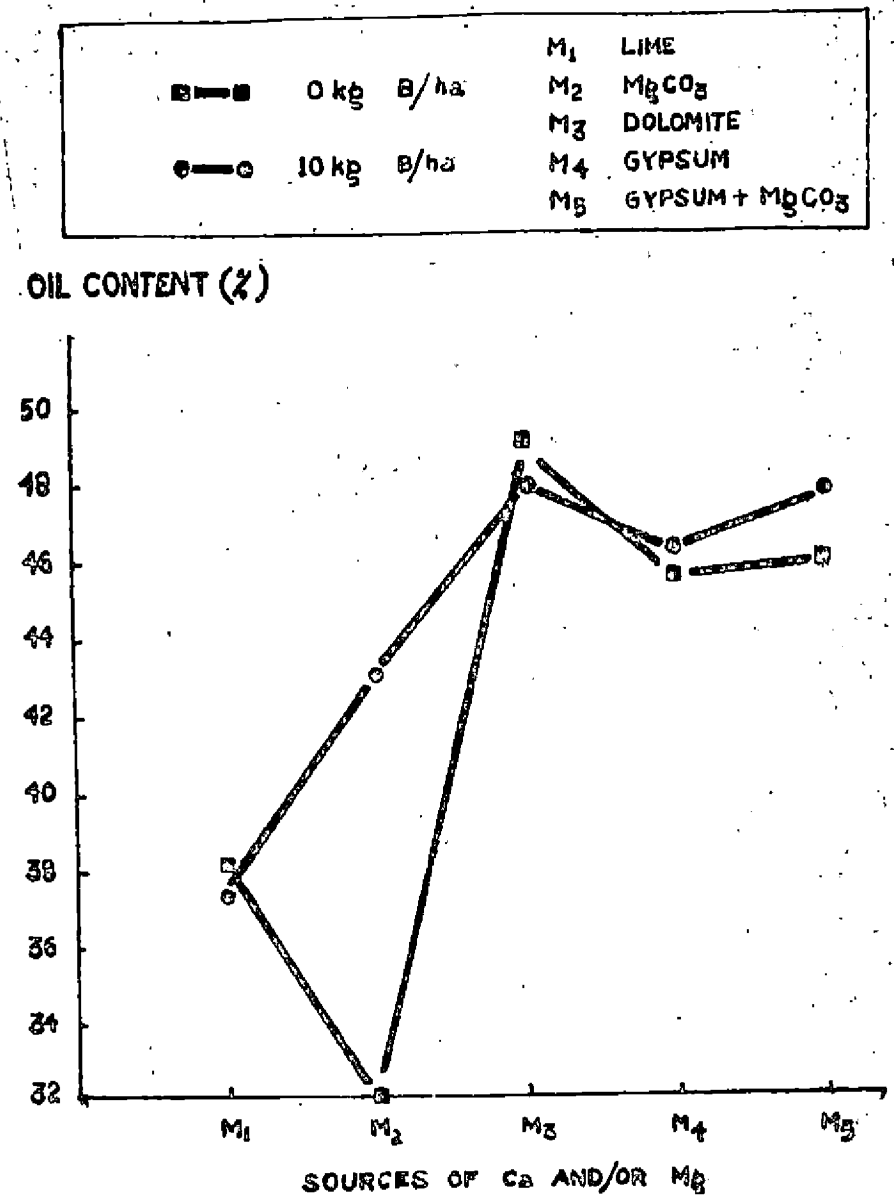


FIG .7 EFFECT OF DIFFERENT SOURCES OF Ca AND/OR Mg WITH AND WITHOUT B ON OIL CONTENT OF GROUNDNUT

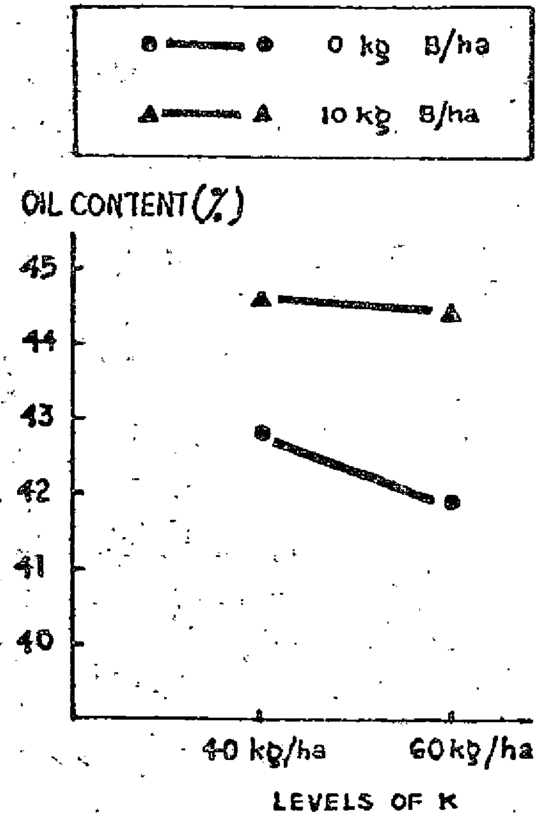


FIG.8 EFFECT OF TWO DIFFERENT LEVELS OF K WITH AND WITHOUT B ON OIL CONTENT OF GROUNDNUT

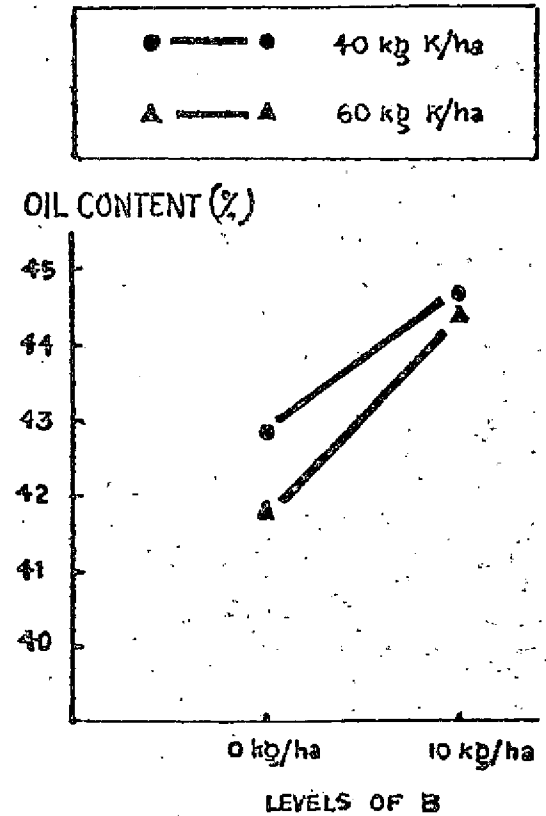


FIG.9 EFFECT OF APPLICATION OF B WITH TWO DIFFERENT LEVELS OF K ON OIL CONTENT OF GROUNDNUT

further be illustrated by taking the oil yield per ha. of selected treatments and working out the economics. However the oil content for treatment M_4 in combination with the higher level of potassium (46.17 percent) is not considerably greater than that for the treatment M_5 (46 per cent) as to make treatment M_5 economically inferior in terms of oil yield. Further, application of boron is found to have significant effect in increasing oil yield from 42 to 45 per cent (Fig.7 and Fig.9). These results thus show that a lower dose of potassium and magnesium containing amendments or magnesium added amendments have an effect on oil content. Thus treatment M_5K_1 is found to be the best in terms of oil content. In terms of oil yield also this is a superior treatment.

Protein content

In terms of protein content, however it is interesting to note that a combination of calcium with magnesium significantly reduces the protein content compared to calcium alone (Compare treatments M_4 with M_3 and M_5). In such a situation it is also important to note that calcium alone as gypsum has a significant role to increase the protein content. This may be attributed to the role of anion sulphate (SO_4^{--}) in protein synthesis as noted by Naphade (1963). In general the effect of potassium is also to marginally decrease the protein content.

In working out the economics and suitability of the treatment combinations on their effect on the two main economic produce of groundnut namely oil and groundnut cake (qualitatively and quantitatively) addition of magnesium along with gypsum, while it enhances the oil content, reduces protein content decreasing the value of the groundnut cake as an animal or human feed. This reduction in protein content no doubt will decrease the market value of the cake. This necessitates a compromise to be struck in terms of the costing of the produce on both quality and quantity basis. However, disregarding this effect on quality and computing the value of the marketable produce a comparison of the economics of selected treatments is presented in table 21. These results indicate that, treatment M_5K_1 is the best in terms of oil and cake yield and thus in terms of benefit. So when magnesium carbonate is added with gypsum, a lower dose of potassium is found to be the most economic treatment.

Total nitrogen

A perusal of table 6(a) and 6(b) shows the general trends in total nitrogen content of the soil at different sampling stages, depicting different stages of growth of the crop. The data also bring out the effect of various treatments *per se* on the total nitrogen content of the soil which may partly be due to stimulation of non-symbiotic nitrogen fixing activity and partly due to

Table 21. *A comparison of MK treatment combinations on the basis of net returns

Treatments	Pod yield (kg/ha)	Kernel yield (kg/ha)	Total input (Rs)	Total output (Rs)	Net income (Rs)
M_1K_1	2533.30	1700.35	5225.00	10202.10	4977.10
M_1K_2	2322.20	1563.31	5300.00	9379.80	4079.86
M_2K_1	2211.10	1471.49	4825.00	8830.74	4005.74
M_2K_2	2366.70	1575.80	4900.00	9454.80	4554.80
M_3K_1	2233.30	1543.21	7225.00	9259.38	2034.38
M_3K_2	2477.80	1714.57	7300.00	10287.42	2987.42
M_4K_1	2377.80	1789.29	9385.00	10735.74	1350.74
M_4K_2	3277.80	2473.42	9410.00	10840.52	5430.52
M_5K_1	3388.90	2559.64	9985.00	15357.84	5372.84
M_5K_2	3477.80	2629.91	10060.00	15779.46	5719.46

*Output is computed @ Rs. 6/- per kg of kernel as the primary producers price.

enhanced symbiotic nitrogen fixation by the associated rhizobial flora in the groundnut crop. In view of these direct and indirect effects on increasing the total nitrogen content of soil over the period of crop growth changed by differing patterns of uptake by the growing crop, only salient and significant general effects can be meaningfully discussed.

In general, there is a decreasing trend for total nitrogen content due to increasing periods of sampling intervals corresponding to the growth of the crop. This has to be attributed to a greater demand on soil nitrogen made by the crop which cannot be fully met by the nitrogen fixing role of either the symbiotic association or by non-symbiotic organisms present in the soils. However in treatment M_3 a slight but steady increase is observed while an alternate decreasing and increasing trend in total nitrogen content could be observed for amendment treatments M_4 and M_5. Such an effect has been produced in treatments under dolomite (M_3) and gypsum (M_4) suggests an intensification of the symbiotic activity and consequently the decreased demand for soil nitrogen at least in some stages of crop growth. Such a stimulation of symbiotic nitrogen fixation activity by amendments containing divalent cations such as calcium and magnesium has been recorded by Subramanian et al. (1975). In the case of treatment under boron an increased total nitrogen content at harvest has been recorded. Boron which is also known to stimulate nitrogen fixation in groundnut might have contributed to enhanced nitrogen fixation resulting in an enhanced total nitrogen content in the soil after harvest. This enhanced total nitrogen might have arisen due to excretion of nitrogen from root nodules and incorporation of sloughed off root tissues into the soil medium.

Available phosphorus

Table 7(a) and 7(b) presents data on available phosphorus status of the soil at different stages of crop growth. Though total phosphorus content of the soil has not been monitored the available phosphorus content studied is sufficient enough to reveal the net result of two types of effects operating viz., (i) the effect of the various treatments on the available phosphorus content, which may be felt both immediately and also on a long term basis. (ii) the stimulation of root growth especially by the amendment treatments by the divalent cations (Harris, 1968) and consequent enhancement in root biomass production contributing to a greater degree of root excretions capable of solubilising phosphorus. The effect of these plant factors and their interaction with soil is likely to be reflected on both available phosphorus status as well as on plant growth. Superimposed on these effects are the removal of phosphorus during crop growth. Since this removal of phosphorus is generally from the total available pool, the removal of phosphorus itself may stimulate the conversion of more unavailable to available forms.

A generalised picture emerges from an examination of the results from table 7(a) and 7(b) in that all amendment treatments from M_1 to M_5 have resulted in an enhanced available phosphorus status of the soil. This obviously indicates that in general, phosphorus solubilising factors due to addition of amendments by themselves, by enhanced root growth in consequence and the effect of the amendment through the plant together far exceeds the enhanced uptake of phosphorus by the crop under the various amendment treatments. That the growing of a leguminous crop enhances available phosphorus status is a generalised observation reported by many workers. Amendments such as lime, gypsum, $MgCO_3$, dolomite etc. in acid soils enhance available phosphorus status is a well tested possibility (Loganathan and Krishnamoorthy, 1977).

Application of higher levels of potassium has been found to increase available phosphorus status in the earlier two stages of crop growth. The initial effects due to potassium are to be mainly attributed to the neutral salt effect of added muriate of potash in increasing phosphorus availability.

Exchangeable potassium

All the plots have received potassium - some at lower dose and others at higher dose. In general it can be seen that, due to the growing of a crop of groundnut, a continuous depletion of exchangeable potassium occurs which shows a tendency to increase at harvest stage as seen in table 9(b). This may be attributed to the decreased demand by the crop and greater sloughed off tissue from the root at harvest stage.

Exchangeable calcium

In general, all amendment treatments containing calcium show an enhanced exchangeable calcium content in the soil. This effect is maximum in the case of treatment under gypsum and minimum in the case of treatment with $MgCO_3$ alone. However the exchangeable calcium content under gypsum treatment decrease at a faster rate than under $CaCO_3$ (lime treatment or dolomite treatment) (table 9(b)). This may partly be due to leaching of the more soluble $CaSO_4$ under gypsum treatment and the greater release with time of calcium from carbonate in other treatments.

Exchangeable magnesium

Exchangeable magnesium status of the soil steadily increases in treatments with $MgCO_3$(M_2 and M_5) and under dolomite (M_3)(table 10). In treatments which exclude magnesium such as M_1 and M_4 exchangeable magnesium steadily decreases. These results indicate that soil exchangeable magnesium levels in the experiment fields are below critical limits for crop growth and have more than adequately been taken care of in treatments M_2, M_3 and M_5.

Plant nitrogen

Table 11(a) and 11(b) present data on the nitrogen content of plants at various stages of growth. In general, there is a decreasing trend in the nitrogen content of haulms which is to be attributed to the dilution effect due to increased crop growth. Comparing the nitrogen content of plants under different treatments it can be noticed that application of various amendments as well as different levels of potassium have a significant effect on nitrogen content at both peg and pod forming stages. A perusal of table 6(a) and 6(b) presenting data on total nitrogen content of soil, shows that a general trend of decrease of total nitrogen with increasing stages of growth; However this appears to be less marked in plants receiving amendment treatments. This has already been discussed in detail as largely due to an enhanced excretion of symbiotically fixed nitrogen from the growing roots aswell as due to sloughed off root tissues into the surrounding soil medium. It has also been emphasised in this context that the greater demands on nitrogen for pod filling and peg formation stage are relied upon more on the symbiotic nitrogen fixation process which possibly takes place at an enhanced magnitude in view of the amendment treatments. It appears that the plant relies to a lesser degree on the soil nitrogen pool. The results on nitrogen status of the plants obtained thus confirms the broad inferences based on soil studies. In fact results support each other. The higher demand of nitrogen at peg forming and pod forming stages under amendment treatments is supported by the observed higher nitrogen content of kernels under such treatments (Table 17(a)).

However, at peg and pod forming stages higher levels of potassium in the soil appear to decrease the nitrogen content. This may partly be attributed to the greater succulence and dilution effects in view of the higher uptake of potassium. That higher uptake of potassium takes place in plants receiving higher doses of potassium is evident from table 13(a) and 13(b).

Plant phosphorus

Higher content of phosphorus was observed in the earlier stages of growth in respect of both amendment treatments and higher levels of potassium. These results indicate that uptake pattern of phosphorus, in general, is higher in the earlier stages of growth than in later stages. These results are generally in agreement with earlier observations of many workers.

Table 7(a) and 7(b) on available phosphorus status at various stages of growth indicate a higher content of available phosphorus under treatments with amendments and higher levels of potassium. This observed higher status of available phosphorus has already been explained as due to both the neutralising effects of soil acidity by amendments and the neutral salt effect of applied muriate of potash. This enhanced available phosphorus status in the soil under such treatments has possibly got reflected in the phosphorus status of plants growing therein.

Plant potassium

Table 13(a) and 13(b) present data on the potassium status of plants. Higher levels of potassium and the use of amendments appear to have increased the potassium content of plants in earlier stages. Divalent cations such as calcium and magnesium made available by the application of amendments might have exchanged part of the difficulty available potassium. Further it might have resulted in greater replacement of exchangeable

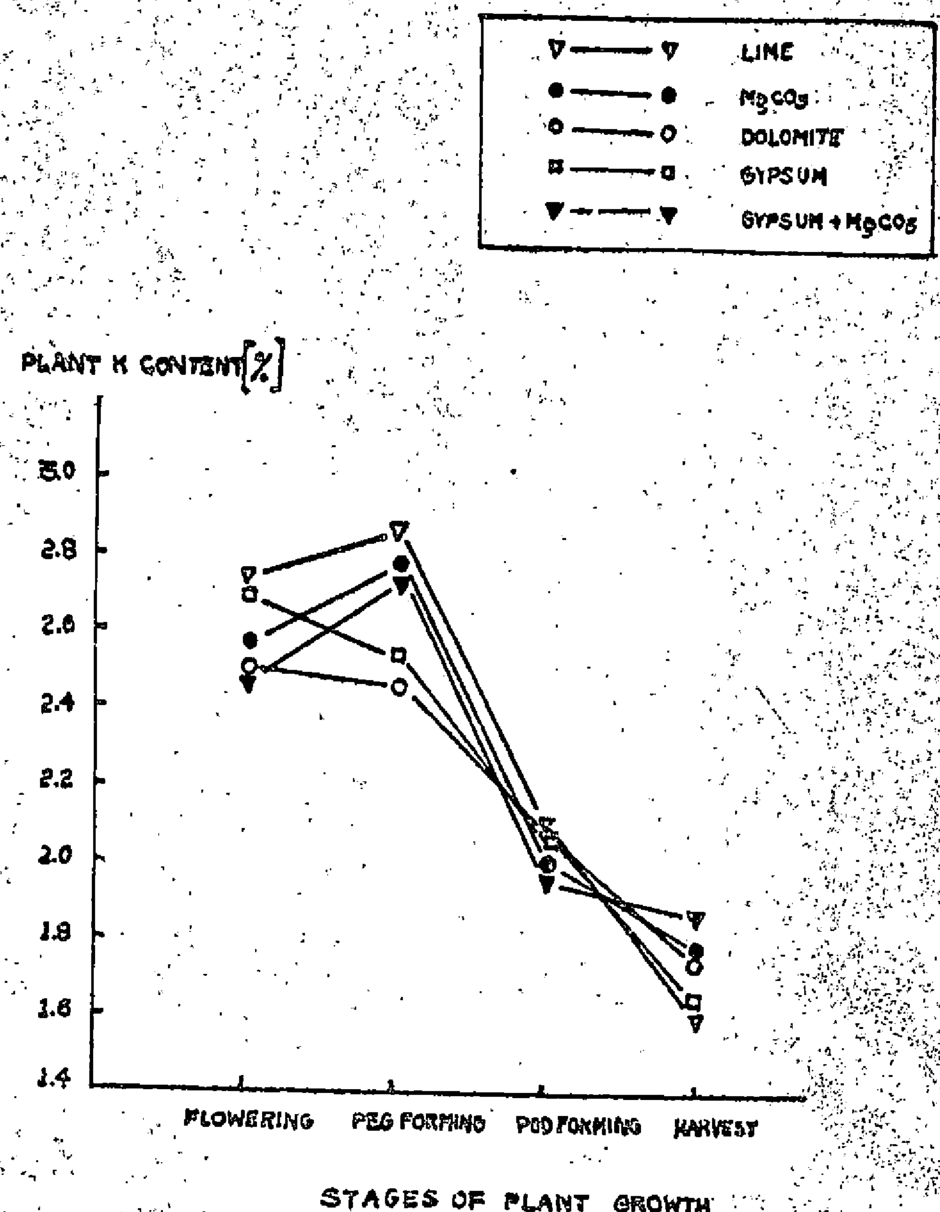


FIG. 10 POTASSIUM CONTENT OF PLANT AT DIFFERENT STAGES OF GROWTH.

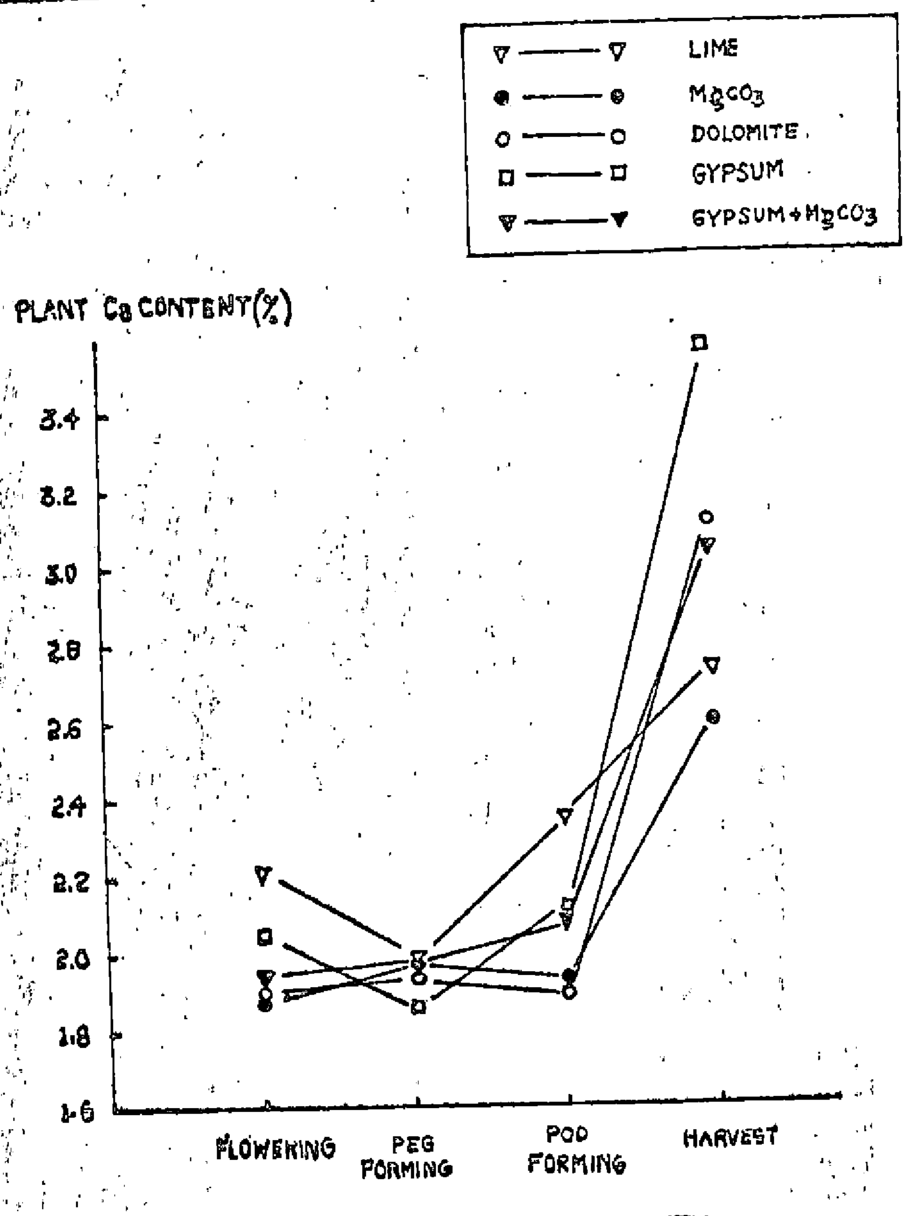


FIG.11. CALCIUM CONTENT OF PLANT AT DIFFERENT STAGES OF GROWTH

potassium for uptake by the plant. These results have been indicated in table 8(a) and 8(b) and discussed in detail. This enhanced availability of potassium has been reflected in the potassium content of plants in the earlier stages of growth. Later the dilution effects and the decreasing effects on soil available potassium due to amendments have possibly resulted in the tapering off of the initially registered higher potassium concentration. These results have been illustrated in Fig.10 . Similar results have been obtained by Dal and Laborayan (1977).

Plant calcium

At all the earlier stages as revealed by table 14(a) and 14(b) and Fig.11 the calcium content is observed to be higher under various amendments especially calciferic amendments. This is only to be expected and similar results have been recorded by other workers. However at peg forming stage the increased calcium demand for gynaphoric nutrition is possibly met by remobilization from the aerial parts of the plant which has a higher accumulated content of calcium. This is possibly the reason for the lower concentration of calcium observed in the aerial parts at peg formation stage.

Plant magnesium

Magnesium was found to be significantly higher as revealed by table 15(a) and 15(b) and Fig.12 in

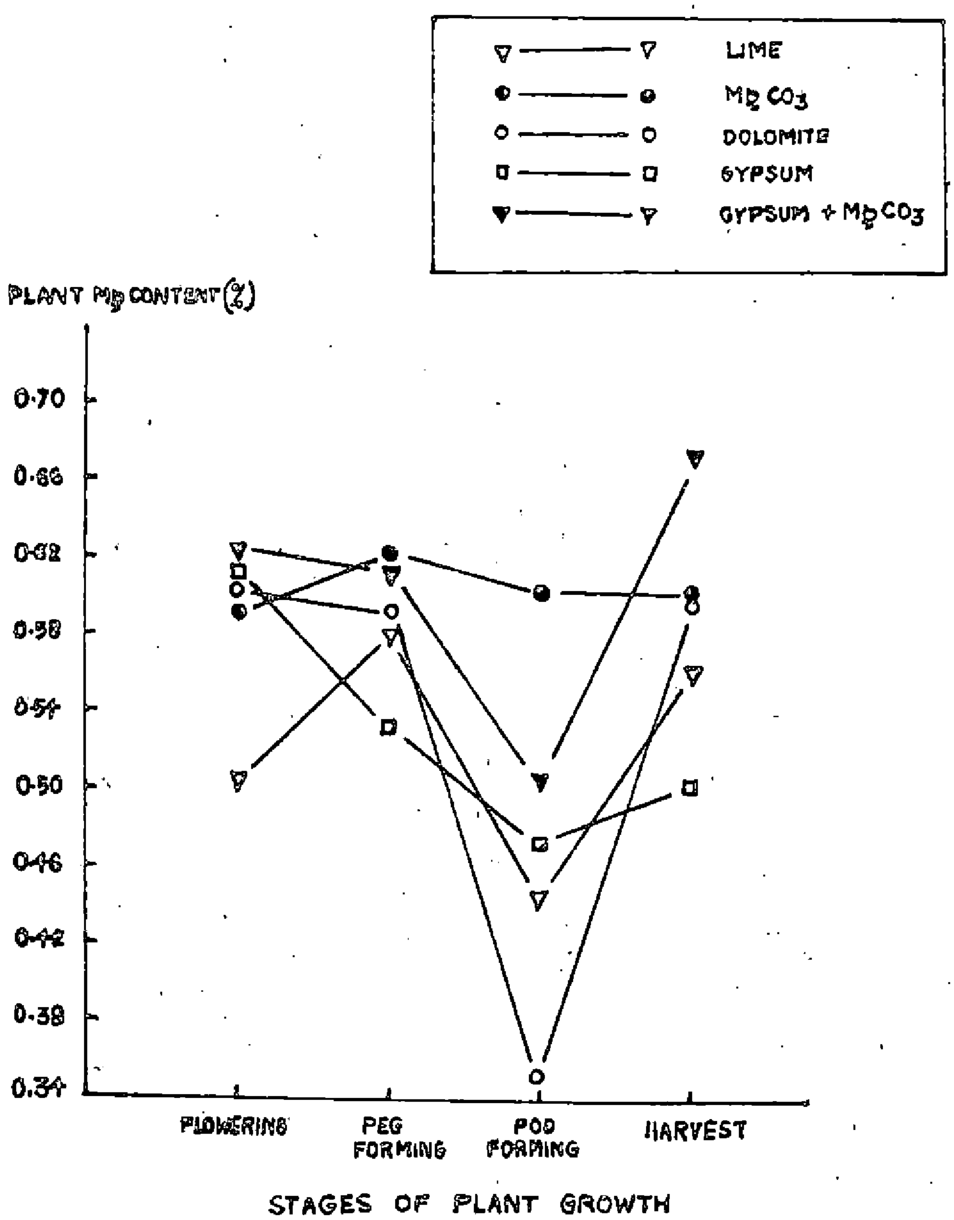


FIG. 12 MAGNESIUM CONTENT OF PLANT AT DIFFERENT STAGES OF GROWTH

amendment treatments receiving magnesium such as $MgCO_3$, dolomite and gypsum plus $MgCO_3$ when compared to lime or gypsum alone.

Plant sulphur

The sulphur content in plants was found to be higher for gypsum containing treatments such as M_4 and M_5 from peg formation stage onwards. This may be attributed to the increased and steady availability of sulphur from gypsum which is not observed for lime or $MgCO_3$ treatment.

Monovalent (K) to Divalent (Ca+Mg) cationic ratios

Table 19(a), 19(b) and 20(a), 20(b) present the ratios of monovalent to divalent cations (K/Ca+Mg) expressed as me/100 g of soil/ plant material respectively, at various sampling intervals representing four different stages of growth of the crop. A perusal of the results immediately reveals that, only at the pod forming stage, a pattern of interpretable result is discussed.

At this stage the ratio in the soil was minimum for dolomite application (treatment M_3). At the same time the ratio in the plant in the treatment M_3 was the highest revealing there by that during the period, immediately preceding the sampling of soil and plant material, considerable uptake of potassium has taken place as to increase the ratio in the plant and decrease the same in the soil. Dolomite application might have contributed to an increase in calcium and magnesium content of the soil, causing a decreased K/Ca+Mg ratio in the soil. This appears to be superimposed by an increased uptake of potassium which has caused a reduction in soil potassium. In other treatments and stages of the crop in the present study, significant trends in the ratio in plants and soil have not been observed. It appears that more critical and controlled experiments under pot culture conditions might be able to signify the differences to arrive at more meaningful conclusions.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A field experiment was conducted in the red loam lateritic soils of Vellayani using different carriers of calcium and magnesium and the combinations thereof with two levels of potassium and boron. The different carriers used were magnesite ($MgCO_3$) as a source of magnesium alone, lime ($CaCO_3$) and gypsum ($CaSO_4$) as two different sources of calcium, dolomite as a naturally combined source of calcium and magnesium and another treatment containing gypsum and magnesite. Care was taken to standardise the treatments with respect to the quantity of calcium and magnesium carried by each of them on an equivalent basis to enable comparisons and a critical analysis. Two levels of potassium namely 40 and 60 kg K/ha as well as two levels of boron namely zero and 10 kg B/ha as borax were also included.

Yield data, oil content, yield components etc. were observed. Detailed chemical studies at different stages were conducted. The salient findings are enumerated below and the conclusions highlighted.

I. <u>Yield attributes</u>

(i) Height of the plants: None of the main effects due to sources of calcium and magnesium or levels of potassium were significant with respect to the height of plant. Boron however had a depressing effect on height.

(ii) Number of branches: None of the main effects due to the carriers of calcium and magnesium and levels of potassium were significant. Boron had a depressing effect. The boron-potash interaction is however significant at flowering stage.

(iii) Dry weight of haulms: None of the main effects of sources of calcium and magnesium or levels of potassium or boron were significant. However the interaction effects between amendment treatments and levels of potassium were significant.

(iv) Number of pods per plant: The sources of calcium and magnesium had a significant effect on the number of pods. Maximum number of pods were observed under gypsum treatment (M_4 and M_5) and minimum under dolomite treatment - Levels of potassium had also a significant effect.

(v) 100 kernel weight: Sources of calcium and magnesium and boron had no effect on 100 kernel weight. Levels of potassium however had a significant influence, a higher rate in general increasing the 100 kernel weight.

II. <u>Yield of pods, shelling percentage, oil content etc.</u>

(vi) Yield of pods: Different sources of calcium and magnesium and levels of potassium had a significant effect on pod yield. Thus treatment gypsum (M_4) or gypsum plus magnesite (M_5) produced significantly higher yields than other carrier amendments. Higher level of potassium had a significant influence in increasing the yield. The highest pod yield was produced by the treatment combination M_5K_2 closely followed by M_5K_1.

(vii) Shelling percentage: The highest shelling percentage was recorded by amendment treatment carrying gypsum (M_4 and M_5). Magnesium had a slight effect in increasing the shelling percentage, though not statistically significant. Levels of potassium and boron had also some influence in increasing the shelling percentage.

(viii) Oil content: The main effects of carriers of calcium and magnesium as well as boron were found to be significant in enhancing oil yield. Amendments carrying both magnesium and calcium had significant effect in enhancing the oil yield. The influence of potassium on enhancing the oil yield was found to be dependent on the nature of the amendment. Thus the insoluble amendment dolomite carrying calcium and magnesium gave a higher oil content in presence of higher dose of potassium while the more soluble amendment gypsum together with magnesium carbonate gave a higher oil content with a lower dose of potassium. Boron application at the rate of 10 kg/ha significantly increased the oil content.

(ix) Oil yield: Combining the yield of pods with shelling percentage and percentage oil content, it is seen that the highest oil yield is obtained under amendment treatment M_5K_1 closely followed by M_4K_2 and M_5K_2.

(x) Economics of return: The maximum net return is obtained for the treatment M_5K_1. The higher net return being due to an improvement in the number of pods per plant, a higher shelling percentage and a higher oil content. This being contributed by calcium of the gypsum, calcium and magnesium of the amendment combination and magnesium of amendment combination respectively. This brings out the importance of calcium and magnesium nutrition of groundnut.

III. Nutrient status in plant and soil at different stages of growth.

(xi) Nitrogen: In general with increasing age of the plant, there is a decrease in total nitrogen status of the plant. This decrease is less marked in plants receiving amendment treatments. Comparison of the total nitrogen status of the soil reveals a general trend of either a steady increase or an alternate increase and decrease in treatments M_3, M_4 and M_5. This has been explained as due to exalted levels of symbiotic nitrogen fixation to meet the demands of nitrogen at pod filling stage.

(xii) Phosphorus: Higher content of phosphorus is observed in plants especially under amendment treatments and with higher dose of potassium. Soil studies also indicate a higher content of available phosphorus under such treatments. This has been explained as due to the neutralising effects of amendments on soil acidity and the neutral salt effect of muriate of potash.

(xiii) Monovalent (K) to Divalent (Ca+Mg) cationic ratios: An interpretable result was obtained only at pod forming stage. Here in dolomite treatment, the ratio in the soil found to be minimum and it is maximum in the plant when compared to other treatments. This is mainly due to the higher rate of potassium absorption by the plant at this stage.

The following important conclusions are drawn from the above study.

(i) Gypsum appears to be a better source of calcium than calcium carbonate in increasing the number of pods per plant, shelling percentage, higher yield of pods and a high 100 kernel weight.

(ii) Magnesium nutrition is essential for enhancing the oil content and there by the total oil yield per hectare of groundnut grown.

(iii) The less soluble carrier of both calcium and magnesium namely dolomite functions nearly as effectively as gypsum plus magnesium carbonate when a higher level of potassium is combined with it. Gypsum plus magnesium carbonate is able to do so at a lower level of potassium possibly in view of the greater solubility of calcium in gypsum or the contribution of sulphate as a nutrient to the crop. These results illustrate the need for maintaining the monovalent to divalent cationic ratios in the nutrition of the crop.

(iv) The effect of boron on yield is only marginal and appears to become operative at higher levels of potassium when it enhances the oil content.

These studies conducted under the monocrop system of groundnut is replicable under southern Kerala situations. However it has to be further refined under intercrop situations of groundnut along with cassava which is being recommended and adopted in southern Kerala, to widen the scope of the technology now evolved.

REFERENCES

REFERENCES

Adams, F. and Hartzog, D. 1979. Effect of a lime slurry in soil pH, exchangeable calcium and peanut yields. Peanut Science, 6(2): 73-76.

Allaway, W.H. and Thompson, J.F. 1966. Sulphur in nutrition of plants and animals. Soil Sci., 101: 240-247.

Anderson, G.D. 1970. Fertility studies on a sandy loam in semi arid Tanzania II. Effects of phosphorus, potassium and lime in yield of groundnut. Expt. Agric., 6: 213-222.

Ashrif, M.I. 1965. Effect of sulphur on groundnuts. Oleagineux, 20: 243-244.

Asokan, S. and Raj, D. 1974. Effect of sources and levels of boron application on groundnut. Madras Agric. J., 61(8): 467-471.

Basha, S.K.M. and Rao, G.R. 1981. Effect of phosphorus and potassium deficiency on keto and amino acid content of peanut leaves. Plant and Soil, 59(1): 159-162.

Bathla, R.N., Virmani, S.M. and Choudhury, M.L. 1978. Pattern of calcium and magnesium uptake in some varieties of groundnut (Arachis hypogea L.). J. Indian Soc. Soil Sci., 26(3): 290-296.

Beer, F.E. and Toth, S.J. 1948. Influence of calcium on availability of other soil cations. Soil Sci., 65: 69-74.

Bhuiya, Z.H. and Choudhury, S.V. 1974. Effect of N,P,K and K on the protein and oil content of groundnut grown in Brahmaputra flood plain soils. Indian J. Agric. Sci., 44(1): 751-754.

Blair, A.W., Prince, A.L. and Ensminger, L.E. 1949. Effect of magnesium application on crop yields and on percentage of calcium and magnesium oxides in plant material. Soil Sci., 48: 59-75.

*Blamey, F.P.C. and Chapman, J. 1979. Boron toxicity in spanish groundnuts. Agrochemophysica, 11(4): 57-59. (Abstr. Soils and Fert., 43(12): 1980).

Blamey, F.P.C. and Chapman, J. 1982. Soil amelioration effects on peanut growth, yield and quality. Plant and Soil, 65(3): 319-334.

Bolhuis, G.G. and Stubbs, R.W. 1955. The influence of calcium and other elements on the fructification of the peanut in connection with absorption capacity of its gynophores. Neth. J. Agric. Sci., 3: 220-236.

Brady, N.C. 1948. The effect of period of calcium supply and mobility of calcium in the plant on peanut fruit filling. Proc. Soil Sci. Soc. Amer., 12: 336-341.

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

Brar, N.S., Bajan Singh and Sekhon, G.S. 1980. Leaf analysis for monitoring the fertilizer requirements of peanuts. Communication in Soil Science and Plant Analysis, 11: 335-346.

Bray, R.H. and Kurtz, L.T. 1954. Determining total organic and available forms of phosphate in soils. Soil Sci., 59: 39-45.

Bromfield, A.R. 1973. Uptake of sulphur and other nutrients by groundnuts in Northern Nigeria. Exptl. Agric., 9: 55-58.

Bromfield, A.R. 1975. Effect of groundnut to rock phosphate-sulphur mixture on yield and nutrient uptake of groundnut in Northern Nigeria. Exptl. Agric., 11: 265-272.

Burkhart, L. and Collins, E.R. 1942. Mineral nutrients in peanut plant growth. Soil Sci. Soc. Amer. Proc., 6: 272-280.

Chahal, R.S. and Virmani, S.M. 1973. Preliminary report on relative absorption of calcium and sulphur by the roots and gynaphores of groundnut (Arachis hypogea L.). Indian J. Agric. Sci., 43(12): 1037-1040.

Chahal, R.S. and Sukhpalsingh 1979. Calcium and magnesium uptake in groundnut at various stages of its plant growth. Oleagineux, 34(10): 459-461.

Chokheysingh and Pathak, S.S. 1969. Groundnut responds to N,P and K. Fert. News, 14: 26-27.

Chopade, A.T. 1964. Effect of application of sulphur on the composition, uptake and yield of groundnut. Annals of Agricultural Research, 1960-1965.

Chopra, S.L. and Kanwar, J.S. 1966. Effect of sulphur fertilization on the chemical composition and nutrient uptake of legumes. J. Indian Soc. Soil Sci., 14: 69-76.

Chopra, S.L. and Kanwar, J.S. 1966. Availability of sulphur in the sandy loam soils of Ludhiana. Indian J. Agric. Sci., 36: 278-284.

Chopra, S.L. and Kanwar, J.S. 1976. Analytical Agricultural Chemistry. Kalyani Publishers, Ludhiana, 312 p.

Clarke, G.M. 1980. Comparing Biology, Statistics and Experimental Design. Edward Arnold Ltd., London, pp.188.

Colwell, W.E. and Baker, G.O. 1939. Borax for alfalfa in Northern Idaho. Betl. Crops, 23(3): 9-11.

Colwell, W.E., Brady, N.C. and Piland, J.R. 1945. Composition of peanut shells of filled and unfilled fruits as affected by fertilizer treatments. J. Amer. Soc. Agron., 37: 792-805.

*Dal, R.N. and Laborayam, M.M. 1967. Calcium sodium interaction in the pod development of peanuts. Experimenta, 23: 382.

Davis, F.L. 1951. Nutritional pattern of peanuts in South Eastern Albama. Bett. Crops Pl. Food, 35: 6-10.

Do, N.K. and Chatterjee, B.N. 1976. Effect of trace elements on growth and yield of groundnut in leached sandy loam soil. Indian J. Agron., 21(3): 209-216.

Dongale, J.H. and Zende, G.K. 1976. Response of groundnut to the application of manganese, boron and sulphur both in presence and absence of FYM through soil and foliar spray. Indian J. Agron., 21(4): 321-326.

Draftar, S.V., Naphade, K.T. and Padoley. 1969. Effect of soil application of sulphur on the chemical composition of groundnut crop. Tehlan Patrika, 1: 33-35.

*Eweida, M.H.T., Fayed, M.H., Eid, H.M. and Madkour, M.A. 1980. Effect of fertilizer elements on Agronomic characters and yield of some groundnut cultivars. Annals of Agricultural Sciences, Moshtohar. 12: 43-54. (Abstr. Soils and Fert., 44(1): 1981).

*Fageria, N.K. 1974. Uptake of potassium and its influence on growth and magnesium uptake by groundnut plants (Arachis hypogea L.). Biologia plantarum, 16(3): 210.214.

*Ferreira, M.E., Fornasieri, D., Vitti, G.C. and Marvulo, C. 1979. Study of rates and time of gypsum application to groundnuts (Arachis hypogea). Cientifica, 7(2): 235-240.

Fudge, B.R. 1946. Effect of application of calcium and magnesium upon the absorption of potassium by citrus. Citrus Indust., 27: 05-9 (Abstr. Soils and Fert., 19: 166, 1947).

Gilbert, F.A. 1951. The place of sulphur in plant nutrition. Bot. Rev., 17: 671-691.

Goldin, E. and Har-Tzook, A. 1966. The effect of fertilization on the vegetative and reproductive development of Virginia Bunch improved groundnut. Agron. Trop. Paris, 21: 17-20.

Greenwood, M. 1951. Fertilizer trials with groundnut in Northern Nigeria. Emp. J. Exp. Agric., 19: 225-241.

Greenwood, M. 1954. Sulphur deficiency in groundnuts in Northern Nigeria. Trans. 5th Int. Congr. Soil Sci., 3: 245-251.

Habeebullah, B. 1973. Studies on the influence of potassium and calcium on nutrient availability yield and chemical composition of groundnut (POL-1) in the alluvial and red soils of Tamil Nadu. M.Sc.(Ag.) Thesis submitted to and approved by Tamil Nadu Agricultural University, 1973.

Hall, M. 1975. Effect of phosphorus, potassium and calcium on peanuts at Mauke (Cook Islands). New Zealand J. Expt. Agric., 3(2): 117-120.

Hallock, D.L. and Garren, K.H. 1968. Pod break down, yield and grade of Virginia type peanuts as affected by calcium, magnesium and potassium sulphates. Agron. J., 68: 253-257.

Hallock, D.L. and Allison, A.H. 1981. Response to land plaster by Virginia type peanuts grown in Virginia during 1970 to 1979. Proc. Amer. Peanut Rese. Education Soc., 13(1): 53-59.

*Hanower, P. 1971. Effect of sulphur deficiency on some aspects of nitrogen metabolism in groundnut. Memoires ORSTOM, 51: 114 (Abstr. Soils and Fert., 43: 1980).

*Hanower, P. and Brzozowska, J. 1969. Effect of sulphur deficiency on protein composition in groundnut Agrochimica, 13: 129-135. (Abstr. Soils and Fert., 32: 405, 1969).

Harigopal, N. 1968. Boron deficiency in groundnut. Indian J. Agric. Sci., 38: 832-834.

*Harigopal, N. 1976. Physiological studies on groundnut plants on boron toxicity.5. Effect on boron and iron distribution. Turrialba. 26(3): 288-294.

Harigopal, N. and Rao, I.M. 1967. Agro-physiological studies on groundnut with boron toxicity. Andhra agric. J., 14: 12-14.

Harigopal, N. and Rao, I.M. 1968. Effect on boron toxicity on some leaf constituents in groundnut plants. Andhra agric. J., 15: 21-25.

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

Harris, H.C. 1955. Absorption of radioactive sulphur by the fruit system in comparison to the roots of peanuts. International Conference in the Peaceful uses of Atomic Energy, 12: 203-207.

Harris, H.C. 1968. Calcium and boron effects on Florida peanuts. Bull. Fla. agric. Exp. Stn., 723: 18.

Harris, H.C. and Gilman, R.L. 1957. Effect of boron on peanuts. Soil Sci., 84: 233-242.

Harris, H.C. and Brolman, J.B. 1966. Comparison of calcium and boron deficiency of the peanuts.I. Physiological and yield differences. Agron. J., 58: 97-99.

Hashimoto, T. and Okamoto, M. 1953. The magnesium nutrition of crops.II. Amount of calcium in soybean plant deficiency in magnesium. J. Sci. Soil Manure, Japan, 24: 231-234.

Hava, K. 1964. The effects of calcium and sulphur on yields of groundnuts grown on virgin granite derived soil. Rhod. J. agric., 2: 79-83.

Haynes, J.L. and Robbins, W.R. 1948. Calcium and boron as essential factors in the root environment. J. Amer. Soc. Agron., 40: 795-803.

Hill, W.E. and Morrill, L.G. 1974. Assessing boron needs for improving peanut yield and quality. Soil Sci. Soc. Amer. Proc., 38(5): 791-794.

Hill, W.E. and Morrill, L.G. 1975. Boron, calcium and potassium interaction in Spanish peanuts. Soil Sci. Soc. Amer. Proc., 39(1): 80-83.

Inanaga, S., Nagasaky, Y., Horiguchi, T. and Nishihara, T. 1979. Role of calcium in fruiting of groundnut. 1. Effect of calcium on fruit growth. Bull. Fac. Agric., Kagoshima University, 29: 133-142.

Jackson, M.L. 1973. Soil Chemical analysis. Hall of India Pvt. Ltd., 498 p.

Jacob, A. and Von Vexkull, H. 1960. Fertilizer use Nutrition and manuring of tropical crops. Potash Rev., 20: 1-60.

Jayadevan, R. and Sreedharan, C. 1976. Effect of nitrogen and phosphorus on "Asiriya Mwitunde" groundnut in Kerala. Agric. Res. J. Kerala, 13(2): 123-127.

Jordan, H.K. and Reisemauer, H.M. 1957. Sulphur and soil fertility. Soil (USDA) Year book of Agriculture.

Kampfer, M. and Zehler, E. 1967. The importance of the sulphate fertilizers for raising the yield and improving the quality of agricultural, horticultural and silvicultural crops. Potash Rev., 24: 1-62.

Kanwar, J.S. 1963. Investigations on sulphur in soils: Sulphur deficiency in groundnut soils of Samrala. Indian J. Agric. Sci., 33: 196-198.

Kartha, A.R. and Sethi, A.S. 1957. A cold percolation method for gravimetric estimation of oil in small quantities of oil seeds. Indian J. Agric. Sci., 27(2): 211-218.

Keisling, T.C., Hammons, R.O. and Walker, M.E. 1982. Peanut seed size and nutritional calcium requirement. J. Plant Nutr., 5(10): 1177-1185.

*Koter, M. 1964. Studies on the influence of boron on growth and development of plants. Roczn. Glebozn., 13: 185-211. (Abstr. Soils and Fert., 27: 318.

Lachover, D. 1965. Effect of calcium on edible groundnuts in irrigated conditions. Oleagineaux, 21: 83-89.

Laurence, R.C.N. and Gibbson, R.W. 1976. Changes in yield, protein and oil content and maturity of groundnut cultivars with the application of sulphur fertilizers and fungicides. J. Agric. Sci., 86(2): 245-250.

*Leveque, L.A. and Beley. 1960. Contribution to the study of mineral nutrition of groundnut. The effect of boron and manganese toxicity. Agron. trop. Paris, 14: 657-710.

*Lipscomb, R.W., Robertson, W.K. and Chapman, W.H. 1966. Fertilizing and spacing of peanuts. Proc. Soil Crop Sci. Soc. Fla., 25: 329-334. (Abstr. Soils and Fert., 30: 1967).

Loganathan, S. and Krishnamoorthy, K.K. 1977. Influence of calcium application on yield of groundnut. Madras agric. J., 64(5): 312-316.

Lund, Z.F. 1970. The effect of calcium and its relation to several cations in soybean root growth. Soil Sci. Soc. Amer. Proc., 34: 456-459.

Mani, N.S. and Ramamoorthy, G.V. 1969. A study of groundnut in India. Tehlan Patrika, 1: 1-10.

Mariakulandai, A. and Morachan, Y.B. 1965. Results of manurial trials in Madras State on oil seeds. Madras Agric. J., 52: 3-9.

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

Mishra, L.C. 1980. Effects of sulphur dioxide fumigation on groundnut (Arachis hypogea L.). Environmental and Exptl. Bot., 20(4): 397-400.

*Mizuno, S. 1961. Physiological studies on the fruiting of peanuts. 7. The effect of calcium deficiency in the rooting zone on growth, fruiting characteristics and chemical composition of the plant. Proc. Crop Sci. Soc. Japan, 30: 51-55. (Abstr. Soils and Fert., 25: 248, 1962).

*Mizuno, S. 1965. Studies on the effect of calcium on fructification in the peanut. Mem. 18. Agron. Ser. 6 Hyago Univ. Agric., 69. (Abstr. Fld. Crop Abstr., 20: 226, 1967).

Mohr, G.R. 1942. Plant symptoms of boron deficiency and the effects of borax on the yield and chemical composition of several crops. Soil Sci., 54: 55-65.

Morrill, L.G., Hill, W.E., Chrudimsky, W.W., Ashlock, L.O., Tripp, L.D., Trucker, B.B. and Weathrly, L. 1977. Boron requirements of spanish peanuts in Oklahoma: Effects on yield and quality and interaction with other nutrients. Report Agrl. Expt. Stn. Oklahoma State University, 99: 20.

Nadarajan, L. 1981. Role of sulphur and calcium in oil synthesis in groundnut (Arachis hypogea L.). using ^{35}S and ^{45}Ca. Dessertation submitted to and approved by Tamil Nadu Agricultural University, 1981.

Nair, K.S., Ramasamy, P.P. and Rani perumal 1970. Nutritional factors affecting nitrogen fixation in Arachis hypogea L. Madras agric. J., 56(6): 307-310.

Nair, K.S., Ramasamy, P.P. and Rani perumal. 1970. Studies on the causes of poor nodulation in groundnut in soils of Tamil Nadu. Madras agric.J., 58(1): 5-8.

Naphade, K.T. 1963. Study on the effect of sulphur application to the soil on the uptake of nutrients, composition and yield of groundnut. Annals of Agricultural Research 1960-1965, College of Agriculture, Nagpur.

Nye, P.H. 1952. Studies on the fertility of gold coast soils. Emp. J. Exp. Agric., 20: 47-55.

*Odhnoff, C. 1957. Boron deficiency and growth. Physiologie pla., 10: 984-1000.

Ofori, C.S. 1972. The effect of nitrogen and sulphur treatments on P absorption and yield of groundnuts on soils of sand stone origin in use of isotopes for study of fertilizer utilization by legume crops Proceedings of a jointly organised symposium of the International Atomic Energy Agency and F.A.O. of United Nations, Vienna, 1972. Technical report, 149: 183-194.

Ofori, C.S. 1973. The influence of nitrogen and sulphur on the absorption of fertilizer phosphorus and the yield of groundnut grown on soil of granitic origin. Oleagineux, 28(1): 21-23.

*Omeuti, J.O. and Oyenuga, V.A. 1970. Effect of P fertilizer on protein and essential components of the ash of groundnuts and cowpea. N. afr. J. Biol. appl. chem., 13: 14-19. (Abstr. Soils and Fert., 34: 115, 1971).

*Oram, D.A. 1958. Recent development in groundnut production with special reference to Africa. Part I. Fld. Crop Abstr., 11: 1.

Palaniappan, R. 1970. Influence of P and S on progressive changes in the availability of soil nutrients and uptake, yield and quality of groundnut (Var.TMV-7). M.Sc.(Ag.) dessertation submitted to and approved by Tamil Nadu Agricultural University, 1970.

Panikkar, M.R. 1961. Balanced fertilizer application for record groundnut yield. Fert. News., 6: 22-24.

Pathak, A.N. and Pathak, R.K. 1972. Effect of sulphur component of some fertilizers on groundnut (Arachis hypogea L. T-28). Indian J. Agric. Res., 6(1): 23-26.

Piggot, C.J. 1960. The effect of fertilizers on yield and quality of groundnuts in Sierra Leone. Emp. J. Exp. Agric., 28: 59-64.

Piland, J.R., Ireland, C.F. and Reisenauer. 1944. The importance of borax in legume seed production in the south. Soil Sci., 57: 75-84.

Pothiraj, K. 1972. Studies on the effect of calcium, boron and their interaction on the progressive changes of nutrients and their influence on yield, quality and composition of groundnut, variety TMV-10 in two red soils of Tamil Nadu. M.Sc.(Ag.) dessertation submitted to and approved by Tamil Nadu Agricultural University, 1972.

Powers, W.L. 1939. Influence of boron in Agriculture. Boron in relation to soil fertility in the Pacific North West. Soil Sci. Soc. Amer. Proc., 4: 290-296.

Powers, W.L. and Jordan, J.V. 1950. Boron in Oregon soils and plant nutrition. Soil Sci., 70: 99-107.

Purvis, E.R. 1939. The present status of boron in American agriculture. Soil Sci. Soc. Amer. Proc., 4: 316-321.

Rani perumal. 1972. Studies on the mode of rhizobial incorporation and its interaction with P, Mg and B on the availability. Uptake and yield and quality in groundnut (Arachis hypogea L.). M.Sc. (Ag.) Thesis submitted to and approved by Tamil Nadu Agricultural University, 1972.

Rathee, O.P. and Chahal, R.S. 1977. Effect of phosphorus and sulphur application on the yield and chemical composition of groundnut (Arachis hypogea L.) in Ambala soils. Haryana Agric. Univ. J. Res., 7(4): 173-177.

Reddy, S.C.S. and Patil, S.V. 1980. Effect of calcium and sulphur and certain minor nutrient elements on the growth, yield and quality of groundnut (Arachis hypogea L.) Oleagineux, 35(11): 507-510.

Robertson, W.K., Neller, J.R. and Bartlett, F.O. 1966. Peanut responses to calcium sources and micro-nutrients. Proc. Soil Crop Sci. Soc. Fla., 25: 335-343.

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

*Rotini, O.T. 1956. Boron fertilizing and its most important problems. Ann. Fac. Agr. Pisa., 17: 35-45 (Abstr. Soils and Fert., 20: 163, 1957).

Russel, C. 1966. The importance of sulphur as a plant nutrient in world crop production. Soil Sci., 101: 230-239.

Saini, J.S., Tripathi, H.P., Dwivedi, R.S. and Randhava, N.S. 1975. Effect of micronutrients on yield and quality of groundnut. J. Res. Punjab Agri. Univ., 12(3): 224-227.

Sankaran, N., Sennaian, P. and Morachan, Y.B. 1977. Effect of forms and levels of calcium and levels of boron on the uptake of nutrients and quality of groundnut. Madras agric. J., 64(6): 384-388.

Sanjeevaiah, B.S. 1969. Effect of micronutrients on groundnut. Mysore J. agric. Sci., 3: 83-85.

Satyanarayana, P. and Krishna rao, D.V. 1962. Investigations on the mineral nutrition of groundnut by the method of foliar diagonosis. Andhra agric. J., 9: 329-335.

Satyanarayana, T., Badanur, V.P. and Havanagi, G.V. 1975. Studies on the influence of calcium on ragi and groundnut crops. J. Indian Soc. Soil Sci., 23(1): 66-67.

Singh, A.P., Prasad, B. and Prasad, A.N. 1977. Sulphur, copper and molybdenum interrelationship in groundnut. Fert. Technol., 14(3): 214-216.

Slack, T.E. and Morrill, L.G. 1972. A comparison of large seeded (NC_2) and small seeded peanut cultivars as affected by levels of calcium added to the fruit zone. Soil Sci. Soc. Amer. Proc., 36: 87-90.

Smith, B.W. 1954. Arachis hypogea - reproductive efficiency. Amer. J. Bot., 41: 607-616.

Sreedharan, C. and George, C.M. 1968. Effect of calcium, potassium and magnesium on growth, yield and shelling percentage of groundnut in red loam soils of Kerala. Agric. Res. J. Kerala, 6: 74-78.

Stanford, G. and Howard, V.J. 1966. Sulphur requirements of sugar, fibre and oil crops. Soil Sci., 101: 297-306.

Steel, R.G. D. and Torrie, J.H. 1981. Principles and procedures of statistics. McGraw-Hill Book Co. Inc., New York, 634 p.

Strauss, J.L. and Grizzard, A.L. 1948. The effect of calcium, magnesium and potassium on peanut yields. Soil Sci. Soc. Amer. Proc., 12: 348-352.

*Strolier, E.W. 1966. The effect of boron nutrition on growing and protein and nucleic acid metabolism in peanut plants. Dissert. Abs. 27. No.6, 1697 B.

Subbiah, B.V., Singh, N. and Gupta, Y.P. 1970. Effect of sulphur fertilization on the chemical composition of groundnut and mustard. Indian J. Agron., 15: 24-27.

Subramanian, R.M., Manickam, T.S. and Krishnamoorthy, K.K. 1975. Studies on the effect of magnesium on the progressive changes of nutrients on groundnut (POL-1) in two red soils of Tamil Nadu. Madras agric. J., 62(9): 550-554.

Tajuddin, E. 1971. Effect of lime and magnesium on the yield and quality of groundnut in the acid soils of Kerala. Agric. Res. J. Kerala, 8: 89-92.

*Tella, R.De., Canecchiofilho, V. and Rocha, J.L.V. 1971. Response of groundnut to N, P and K with and without lime. Bragantia, 30: 39-47. (Abstr. Soils and Fert., 35(10): 1972).

*Trepachev, E.P. and Atrashkova, N.A. 1965. Effect of Mg and Ca on linseed. Soc. Soil Sci., 156: 65-71.

Veeraraghavan, P.G. and Madhavan Nair, K. 1966. Effect of lime and potash on the yield of groundnut in the red loam soils of Kerala State. Agric. Res. J. Kerala, 4: 17-23.

*Venema, K.C.W. 1962. Some notes regarding the function of sulphate anion in the metabolism of oil producing plants, especially oil palms. Potash Trop. agric., 5: 3-4.

Verma, V.K., Thakur, A. and Rai, V.K. 1973. A note on effect of sulphur sources on quality of groundnut. Indian J. Agron., 18(1): 105.

Virmani, S.M. 1973. Some edaphic factors affecting yield of groundnut in arid brown soils. Indian J. Agric. Sci., 43: 119-122.

Walker, M.E., Keisling, T.C. and Drexler, J.S. 1976. Responses of three peanut cultivars to gypsum. Agron. J., 68(3): 527-528.

Walker, M.E. and Csinos, A.S. 1980. Effect of gypsum on yield, grade and incidence of pod rot in five peanut cultivars. Peanut Science, 7(2): 109-113.

Walker, M.E., Gaines, T.P. and Henning, R.J. 1982. Foliar fertilization effects on yield, quality, nutrient uptake and vegetative characteristics of Florunner peanuts. Peanut Science, 9(2): 53-57.

Warrington, K. 1934. Studies in the absorption of calcium from nutrient solutions with special reference to the presence or absence of boron. Ann. Bot., 48: 743-776.

Wolt, J.D. and Adams, F. 1979. Critical levels of soil and nutrient solution calcium for vegetative growth and fruit development of Florunner peanuts. Soil Sci. Soc. Amer. J., 43(6): 1159-1164.

Yadahalli, Y.H., Redder, G.D. and Patil, S.V. 1970. Response of groundnut to major and minor elements in the red sandy soils of Badami. Mysore J. Agri. Sci., 4: 21.

York, E.T. 1952. Research points the way to higher levels of peanut production. Bett. Crops Pl. Food, 36: 7-8.

*York, E.T. and Reed, P.H. 1953. Nutrient deficiencies in peanuts and their influence on fruit production. 50th Proc. Assoc. Southern Agric. Workers, 51.

*Original not seen

APPENDICES

APPENDIX I

ABSTRACT OF ANOVA

Height at different stages

Source	df	Mean squares			
		Flowering	Peg forming	Pod forming	Harvest
Replication	2	1.5652	12.1608	78.0575	58.8466
M	4	0.3811	1.0575	17.1346	12.6227
K	1	1.0218	0.0244	9.0870	0.1815
B	1	4.9594*	169.1088*	172.1443*	111.1937 *
MK	4	0.7008	4.1607	2.7133	2.2738
MB	4	0.8109	10.5820	23.8895	15.4306
KB	1	0.1490	0.3039	0.0432	5.6059
MKB	4	0.3660	17.2562	26.9996	40.0592
Error	38	0.7205	9.2959	24.6788	26.6000

*Significant at 5 per cent level

APPENDIX II

ABSTRACT OF ANOVA

Number of branches at different stages

Source	df	Mean squares		
		1st stage	2nd stage	3rd stage
Replication	2	0.8935	2.6761	2.5579
M	4	0.7865	1.0440	1.1278
K	1	0.0427	0.9375	2.1206
B	1	3.9732*	5.6059*	4.2770*
MK	4	0.1387	0.6021	0.9075
MB	4	1.0418	0.6207	0.6213
KB	1	2.3364*	0.0375	0.7526
MKB	4	0.6971	1.1519	0.8193
Error	38	0.5417	1.2247	0.9274

*Significant at 5 per cent level

APPENDIX III

ABSTRACT OF ANOVA

Source	df	Mean squares			
		Dry weight of haulms	No.of pods per plant	100 kernel weight	Shelling percentage
Replication	2	13.7873*	6.4823	0.0932	0.0152
M	4	1.2056	74.3419*	2.6664	231.1800*
K	1	1.2615	150.2584*	7.2802*	0.2407*
B	1	0.0202	1.2470	3.3135	0.3840*
MK	4	1.3807*	58.5032*	7.4539*	0.0043
MB	4	1.9189	119.9718*	7.0855*	0.0094
KB	1	0.1927	132.7594*	0.7042	0.0059
MKB	4	0.4679	68.0196*	13.3970*	0.0140
Error	38	0.4927	9.4220	1.0804	0.0078

*Significant at 5 per cent level

APPENDIX IV

ABSTRACT OF ANOVA

Source	df	Mean squares		
		Pod yield	Oil content	Protein content
Replication	2	0.002375	11.6010	40.2791*
M	4	2.1998*	329.8792*	303.9048*
K	1	0.6615*	4.6760	2.0572
B	1	0.08170	72.0510*	0.0936
MK	4	0.40761*	87.3895*	17.1728
MB	4	0.15192	84.0458*	9.7927
KB	1	0.32267*	2.1094	0.2196
MKB	4	0.35060*	48.7396*	21.1519
Error	38	0.06240	8.4673	11.1269

*Significant at 5 per cent level

APPENDIX V

ABSTRACT OF ANOVA

Total nitrogen in soil at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.000045	0.00062	0.00008	0.001995*
M	4	0.0011*	0.0021*	0.0036*	0.002762*
K	1	0.00028	0.0015*	0.0000016	0.000015
B	1	0.000042	0.000027	0.00014	0.001215*
MK	4	0.00098*	0.0020*	0.00078	0.000185
MB	4	0.00060*	0.0015*	0.000023	0.001144*
KB	1	0.0020*	0.00011	0.0012	0.000735
MKB	4	0.0017*	0.00054	0.00019	0.000123
Error	38	0.00022	0.00034	0.00039	0.00029

*Significant at 5 per cent level

APPENDIX VI

ABSTRACT OF ANOVA

Available phosphorus at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	271.1551*	385.9098*	383.1974*	150.8456*
M	4	1178.1343*	1281.3871*	60.1403	94.5282
K	1	609.6094*	344.2094*	101.7382	57.3694
B	1	181.2039	54.8553	28.7180	4.0716
MK	4	567.2268*	65.7499	61.6519	7.0016
MB	4	737.1224*	723.0215*	49.8562	37.8646
KB	1	72.4460	542.1020*	19.3688	42.1849
MKB	4	398.8890*	790.9642*	138.3463*	196.9289
Error	38	51.2192	43.4996	29.9821	32.3760

*Significant at 5 per cent level

APPENDIX VII

ABSTRACT OF ANOVA

Exchangeable potassium at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.00035	0.00083*	0.00086*	0.00046
M	4	0.0027*	0.0032	0.00022	0.00066*
K	1	0.0013*	0.00088*	0.000027	0.0017*
B	1	0.0091*	0.0037*	0.00323*	0.0141*
MK	4	0.0047	0.0011*	0.00065*	0.00014*
MB	4	0.0025*	0.0016*	0.0011*	0.00052
KB	1	0.0013*	0.0012*	0.000060	0.00033
MKB	4	0.0056*	0.0030*	0.00065*	0.0024*
Error	38	0.00019	0.00016	0.00015	0.00020

*Significant at 5 per cent level

APPENDIX VIII

ABSTRACT OF ANOVA

Exchangeable calcium at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.0639*	0.0065	0.0034	0.0044
M	4	1.5619*	0.8838*	0.8206*	0.2991*
K	1	0.2319*	0.0163	0.0256	0.1927*
B	1	0.0034	0.0687*	0.0248	0.0052
MK	4	0.1821*	0.0222*	0.0798*	0.2078*
MB	4	0.1789*	0.0722*	0.0211*	0.1195*
KB	1	0.0220	0.2220*	0.2067*	0.2257*
MKB	4	0.2347*	0.0924*	0.1183*	0.0094*
Error	38	0.0058	0.0043	0.0072	0.0054

*Significant at 5 per cent level

APPENDIX IX

ABSTRACT OF ANOVA

Exchangeable magnesium in soil at different stages

		Mean squares			
Source	df	First stage	Second stage	Third stage	Fourth stage
Replication	2	0.00098	0.00073	0.00068	0.00041
M	4	0.0801*	0.1686*	0.2457*	0.1918*
K	1	0.0032	0.0012	0.0476*	0.0459*
B	1	0.00054	0.00028	0.00014	0.00024
MK	4	0.0036*	0.0113*	0.0285*	0.00798*
MB	4	0.0135*	0.0089*	0.0080*	0.0043*
KB	1	0.00011	0.0198*	0.00060	0.00641*
MKB	4	0.00067	0.0036	0.0319*	0.9516*
Error	38	0.0010	0.0021	0.00068	0.0011

*Significant at 5 per cent level

APPENDIX X

ABSTRACT OF ANOVA

Nitrogen content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.0420	0.1549	0.7161*	0.1018
M	4	0.2319	0.6562*	0.2805*	0.1888
K	1	0.1597	0.0610	0.2161	0.0132
B	1	0.000897	0.000000067	0.0625	0.0294
MK	4	0.3346*	0.1262	0.1010	0.3556*
MB	4	0.1126	0.5283*	0.0819	0.0552
KB	1	0.0597	0.0051	0.0013	0.0666
MKB	4	0.1427	0.0722	0.1228	0.3438*
Error	38	0.1010	0.0822	0.0917	0.1131

*Significant at 5 per cent level

APPENDIX XI

ABSTRACT OF ANOVA

Phosphorus content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.0708*	0.0386*	0.0316*	0.0052
M	4	0.0420	0.4847*	0.2656*	0.1245*
K	1	0.1904*	0.0252	0.0232	0.0064
B	1	0.3083*	0.1698*	0.1092*	0.0265
MK	4	0.1768*	0.1025*	0.2135*	0.0610*
MB	4	0.4387*	0.3487*	0.1151*	0.1417*
KB	1	0.0107	0.1431*	0.1972*	0.0008
MKB	4	0.0686*	0.2008*	0.0464*	0.0156
Error	38	0.0172	0.0112	0.0088	0.0087

*Significant at 5 per cent level

APPENDIX XII

ABSTRACT OF ANOVA

Potassium content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	1.1834*	4.4107*	4.5007*	0.2147
M	4	0.1671	0.3501*	0.0433	0.1412
K	1	0.1162	0.0194	0.00024	0.0851
B	1	0.7348*	1.9296*	0.0280	0.0317
MK	4	0.3429*	0.5898*	0.1081	0.4021*
MB	4	0.3412*	0.2120	0.0766	0.4049*
KB	1	0.0346	0.00067	0.3628	0.0187
MKB	4	0.4356*	0.1089	0.1406	0.3730*
Error	38	0.1036	0.1179	0.1359	0.1156

*Significant at 5 per cent level

APPENDIX XIII

ABSTRACT OF ANOVA

Calcium content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.9068*	0.3386*	0.1061	0.1038
M	4	0.2293*	0.0301	0.3683*	1.8754*
K	1	0.0037	0.3010*	0.0577	0.0191
B	1	0.0400	0.5472*	0.0022	1.1620
MK	4	0.1205	0.1923	0.0345	0.2046
MB	4	0.1122	0.2597*	0.3679*	0.2434
KB	1	0.2627*	0.2196	0.0082	0.8335
MKB	4	0.0551	0.0999	0.0137	0.6067
Error	38	0.0498	0.0352	0.0453	0.4031

*Significant at 5 per cent level

APPENDIX XIV

ABSTRACT OF ANOVA

Magnesium content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.0218	0.0335*	0.0033	0.0524
M	4	0.0273*	0.0167*	0.0977*	0.0477*
K	1	0.0558*	0.0107	0.0154*	0.0060
B	1	0.0054	0.0068	0.0482*	0.0785*
MK	4	0.0253*	0.0023	0.0266*	0.00099
MB	4	0.0078	0.0041	0.0265*	0.0971*
KB	1	0.0037	0.00067	0.0187*	0.1335*
MKB	4	0.0211*	0.0048	0.0132*	0.0146
Error	38	0.0076	0.0031	0.0015	0.0167

*Significant at 5 per cent level

APPENDIX XV

ABSTRACT OF ANOVA

Sulphur content of haulms at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.0021*	0.000252	0.0048*	0.00016
M	4	0.0138*	0.0131*	0.0052*	0.0088*
K	1	0.0017	0.00113	0.0015	0.00032
B	1	0.00000067	0.0042*	0.00006	0.01176*
MK	4	0.00320*	0.0021*	0.0045*	0.00039
MB	4	0.0082*	0.00513	0.0085*	0.00413*
KB	1	0.01120*	0.0081 *	0.00861*	0.0019
MKB	4	0.0030*	0.00092	0.00096	0.0039*
Error	38	0.00043	0.00052	0.00052	0.00050

*Significant at 5 per cent level

APPENDIX XVI

ABSTRACT OF ANOVA

N, P, K contents of kernel

Source	df	Mean squares		
		N	P	K
Replication	2	1.0305*	0.000485	0.0165
M	4	7.7700*	0.0107*	0.0210
K	1	0.0522	0.000735	0.0577*
B	1	0.2042	0.0138*	0.0056
MK	4	0.4406	0.0216*	0.0164
MB	4	0.2510	0.0200*	0.0087
KB	1	0.0055	0.000082	0.00017
MKB	4	0.5847	0.0171*	0.0128
Error	38	0.2848	0.00023	0.0137

*Significant at 5 per cent level

APPENDIX XVII

ABSTRACT OF ANOVA

Ca, Mg, S contents of kernel

Source	df	Mean squares		
		Ca	Mg	S
Replication	2	0.0012	0.00051	0.000087
M	4	0.2538*	0.1067*	0.0230*
K	1	0.0713*	0.0874*	0.0015
B	1	0.0285*	0.0037*	0.00043
MK	4	0.0549*	0.0087*	0.00093
MB	4	0.0709*	0.0189*	0.00114*
KB	1	0.1277*	0.0269*	0.00081
MKB	4	0.0319*	0.0024*	0.00014
Error	38	0.0039	0.00086	0.000396

*Significant at 5 per cent level

APPENDIX XVIII

ABSTRACT OF ANOVA

N, P, K contents of shell

Source	df	Mean squares N	Mean squares P	Mean squares K
Replication	2	0.0776	4340.00	0.0027
M	4	3.1358*	326072.50*	0.0427*
K	1	0.2298	299626.67*	0.095*
B	1	0.3925*	138240.00*	0.0129*
MK	4	0.2640*	491730.83*	0.0990*
MB	4	0.5840*	601035.83*	0.4757*
KB	1	0.1102	114406.67*	0.0256*
MKB	4	0.5524*	704927.50*	0.0715*
Error	38	0.0732	6171.5789	0.0023

*Significant at 5 per cent level

APPENDIX XIX

ABSTRACT OF ANOVA

Ca, Mg and S content of shell

Source	df	Mean square		
		Ca	Mg	S
Replication	2	0.0011	0.0046	0.00015
M	4	14.2381*	0.0998	0.0035*
K	1	0.0022	0.0047	0.00067
B	1	1.0989*	0.0170*	0.00024
MK	4	1.1353*	0.0450*	0.00034
MB	4	1.6045*	0.0032	0.00096
KB	1	0.5339*	0.00060	0.00131*
MKB	4	1.8125	0.0128*	0.00043
Error	38	0.0631	0.0017	0.00028

*Significant at 5 per cent level

APPENDIX XX

ABSTRACT OF ANOVA

K/Ca+Mg ratio in soil at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.00080	0.00056	0.00075	0.00086
M	4	0.0182*	0.110*	0.0093*	0.0354*
K	1	0.00006	0.0042*	0.00024	0.0089*
B	1	0.0101*	0.0035*	0.0022*	0.115*
MK	4	0.0108*	0.0052*	0.0067*	0.0234*
MB	4	0.0077*	0.00199*	0.0024*	0.0075*
KB	1	0.4027*	0.0123*	0.00034	0.0028
MKB	4	0.00796*	0.0164*	0.0042*	0.0062*
Error	38	0.00046	0.00035	0.00034	0.0007

*Significant at 5 per cent level

APPENDIX XXI

ABSTRACT OF ANOVA

K/Ca+Mg ratio in plant at different stages

Source	df	Mean squares			
		First stage	Second stage	Third stage	Fourth stage
Replication	2	0.9340*	1.5419*	0.7933*	0.0572
M	4	0.1827	0.1103*	0.0548	0.0610
K	1	0.1882	0.1643*	0.0020	0.0060
B	1	0.4753*	1.1261*	0.00074	0.0807
MK	4	0.2382	0.1360*	0.0312	0.0388
MB	4	0.1081	0.1502*	0.0944	0.0622
KB	1	0.0836	0.0749	0.0018	0.0167
MKB	4	0.0703	0.0478	0.0143	0.0327
Error	38	0.0919	0.0378	0.0421	0.0316

*Significant at 5 per cent level

EVALUATION OF THE ROLE OF ELEMENTS, Ca, Mg, S AND B IN THE NUTRITION OF GROUNDNUT WITH REFERENCE TO MONOVALENT (K) TO DIVALENT (Ca+Mg) CATIONIC RATIOS

BY

SURESHKUMAR P.

ABSTRACT OF A THESIS
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ABSTRACT

A field experiment was conducted using different carriers of calcium and magnesium, two levels of potassium and two levels of boron and the combinations thereof. The different carriers used were magnesite ($MgCO_3$) as a source of magnesium alone, lime ($CaCO_3$) and gypsum ($CaSO_4$) as two different sources of calcium, dolomite as a naturally combined source of calcium and magnesium and another treatment containing gypsum and magnesium carbonate. Care was taken to standardise the treatments with respect to the quantity of calcium and magnesium carried by each of them on an equivalent basis to enable comparisons and a critical analysis. Two levels of potassium (40 and 60 kg K/ha) as well as two levels of boron (0 and 10 kg/ha) as borax were included. Yield data, oil content, yield components etc. were observed. Detailed chemical studies at different stages of crop growth of both soil and plant samples were conducted. The salient findings are enumerated below and the conclusions highlighted.

None of the main effects due to amendment treatments or levels of potassium were significant with respect to height of the plant, number of branches and dry weight of haulms. Boron has a depressing effect on height and number of branches but has no effect on dry weight of

haulms. Gypsum treatment as well as higher level of potassium increased the number of pods per plant. Neither boron nor amendments have any effect on 100 kernel weight but potassium at higher level increased the 100 kernel weight.

Gypsum containing treatments as well as higher dose of potassium increased the yield significantly. Shelling percentage was also increased by gypsum. Here boron and levels of potassium had same effect. When magnesium and calcium were applied together, oil content was enhanced considerably. The rate of potassium to be applied was dependent on the amendment treatment. Oil yield was found to be highest for treatment M_5K_1. The maximum net return was obtained for the treatment M_5K_1.

At pod filling stage, exalted levels of symbiotic nitrogen fixation caused an alternate increasing and decreasing trend of soil nitrogen and there was a decreasing trend in plant nitrogen. The neutralising effect of amendments and neutral salt effect of muriate of potash increased the available phosphorus content of soil. The monovalent to divalent cationic ratio was found to be minimum in soil and maximum in plant under dolomite treatment only at pod forming stage. This is explained as due to higher potassium uptake by plant.

Thus, from the present study gypsum is found to be the better source of calcium in increasing yield. Magnesium is found to have a role in increasing oil content. Boron also enhances oil yield. The better effect of gypsum may be either due to greater solubility of calcium or due to the effect of anion sulphate as a nutrient.

These studies conducted under monocrop system of groundnut is replicable under southern Kerala situations. However it has to be further refined under intercrop situations of groundnut along with cassava which is being recommended and adopted in southern Kerala to widen the scope of the technology now evolved.