RESPONSE AND CHEMICAL COMPOSITION OF GROUNDNUT TO POTASH FERTILIZATION AT DIFFERENT LEVELS OF PHOSPHORUS

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ABSTRACT

RESPONSE AND CHEMICAL COMPOSITION OF GROUNDNUT TO POTASH FERTILIZATION AT DIFFERENT LEVELS OF PHOSPHORUS

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A field experiment was conducted using randomised blc design with four replications on sandyloam soil of Gujarat Agricultural University, Anand Campus, Anand in order to stuc the response of groundnut varieties T.G.-17 (V_1) and Junagadh (V_2) to phosphorus application viz., 50 kg P_2O_5/ha (P_1), 100 P_2O_5/ha (P_2) and 150 kg P_2O_5/ha (P_3) in presence (60 kg K_2O/h K_1) and absence of potassium (K_0) application with respect to yield, oil content and content of macro, secondary and micro-elements at various stages of plant growth as well as total uptake of NPK.

The variety T.G.-17 (V_1) produced maximum (2206.32 kg/ha) pod yield while variety J-11 (V_2) produced maximum (6113.36 kg/ha) haulm yield. The oil content was more in J-11 (V_2) but production of oil was more in T.G.-17 (V_1) (793.93 kg/ha). Variety J-11 (V_2) removed significantly greater amour of N (217.42 kg/ha), P_2O_5 (79.12 kg/ha) and K_2O (119.17 kg/ha as compared to variety T.G.-17 (V_1).

The concentration of all nutrients in haulm, except Ca, Fe, Mn and Zn declined with the advancement of plant growth. At maturity, the nutrient elements N, P, S, Zn and Ca were concentrated in kernel, whereas Mn was more in shell.

Different levels of phosphorus did not influence significantly pod and oil yields, however, the oil content was significantly increased by fertilization with higher dose of phosphorus. The crop yield (2046 kg pods/ha and 7722 kg haulm/ha) and the uptake of N (213.41 kg/ha), P_2O_5 (75.20 kg/ha) and K_2O (116.12 kg/ha) were maximum when 100 kg P_2O_5/ha was applied.

Application of potash did not affect significantly pod and haulm yields, oil content and oil yield as well as total uptake of N (207.64 kg/ha) and K_2O (113.94 kg/ha), while P_2O_5 uptake (74.60 kg/ha) was maximum in absence of K application.

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CERTIFICATE

This is to certify that the thesis entitled "Response and chemical composition of groundnut to potash fertilization at different levels of phosphorus" submitted by Shri [illegible] in partial fulfilment of the requirements for the degree of M.Sc.(Agri.) in Agricultural Chemistry and Soil Science of the Gujarat Agricultural University is a record of bonafide research work carriedout by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

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* * *

CHAPTER I

INTRODUCTION

Despite, India occupies a prominent position on the oilseed map of the world, both in area and production the country is experiencing scarcity of edible oil. The situation has provoked the administrators to launch a campaign to increase the production of oilseed crops per unit area and time.

Among the important oilseed crops grown in this country, groundnut (Arachis hypogaea L.) ranks first. Groundnut oil is an edible oil. Kernels are also eaten either raw, roasted or sweetened. They are rich in fat, protein and vitamin A. The deoiled cake is used as a fertilizer. Groundnut kernels and cakes are exported to foreign countries. The importance of this crop is further enhanced by its potentiality for fixing atmospheric nitrogen and storing it in the nodules. Thus, it being a commodity with an everincreasing demand on account of its manifold uses and as a source of much needed foreign exchange, play an important role in the agricultural and industrial economy of our country.

Gujarat stands first in respect to area (1.75 million hectares) and production (16.0 to 20.0 million tonnes) of groundnut (Shah, 1980). However, the average production of groundnut per hectare in Gujarat is considerably low as compared to other states of the country (Joshi and Vora, 1980). This is mainly because it is raised mostly as a rainfed *kharif* crop with limited area under irrigation. In order to increase the area and production of groundnut, farmers are being encouraged by the administrators to adopt and intensify its cultivation as a summer crop under irrigated condition in areas where the facilities exist.

Where other factors including moisture supply, are not limiting, fertilizers could be added to achieve the desired level of yield. Groundnut being a member of leguminouseae, it can make use of atmospheric nitrogen through its root nodules and therefore its requirement for nitrogen is very small. Phosphorus is next to nitrogen in India that needs renewing supply in the soil, as there is no natural recuperation of phosphorus in the soil by biological fixation or other natural agency. Phosphorus fertilisation is found to exert beneficial effect on yield contributing characters of groundnut such as the number and weight of pods per plant, number and dry weight of nodules and number of pegs (Jayadevan and Sreedharan, 1975). Phosphorus also influences the vigour of the plant and improves the quality of the crop and it promotes flowering, fruiting and aids in setting of kernels and is important for proper root development. Groundnut being rich in oil and protein, it may have relatively higher requirement for phosphorus.

Although the potash content of Gujarat soil is reported to be adequate by Mehta and Shah (1956), the soils of Gujarat has been classified by Ramammorthy and Bajaj (1969) in low category with respect to potassium availability. Kanwar (1970) has stre[illegible] the use of balanced fertilizer containing nitrogen, phosphorus and potassium in a strategy of intensive cropping with high yielding varieties. Potassium application may help in improving crop quality like colour, flavour and size of pods as well as oil content of groundnut. It may also help in improving the efficiency of applied phosphorus.

In recent years summer cultivation of groundnut is increasing day by day in Gujarat. Besides the coastal fringes of Saurashtra, considerable area has been brought under summer groundnut cultivation in the command areas of Kadana irrigation project. However, the information on the phosphorus requirement of the crop in presence and absence of potash is lacking.

These considerations prompted to undertake present investigation on the effect of graded doses of phosphorus with and without potash on different groundnut varieties with following objectives.

(i) To study the performance of high yielding varieties of groundnut with regard to yield and oil content when raised on goradu soils in command area of Kadana project.

(ii) to study the effect of phosphorus and potassium application on the mineral composition of grounenut varieties at different stages of growth and

(iii) to study the nutrients demand of different high yielding varieties of groundnut under the influence of different doses of phosphorus with and without potassium.

CHAPTER II

REVIEW OF LITERATURE

Groundnut being leguminous crop requires small quantity of nitrogen as a starter for boosting up the initial growth of the plant and later on it fixes atmospheric nitrogen for its growth and development. While the requirements of phosphorus and potassium are usually high and they are supplemental through phosphatic and potassic fertilizers respectively. The purpose of the review is to examine the research work done on various aspects, related to the effect of phosphorus and potassium application on yield and chemical composition of different varieties of crop , particularly groundnut. The literature reviewed is presented here under following heads.

(1) Effect on crop yield and oil content.

(2) Effect on chemical composition.

2.1 Effect on crop yield and oil content

2.1.1 Variety effect

In experiment with improved varieties of groundnut Marani *et al.* (1961) observed that with application of 50 kg N and 160 kg P_2O_5, groundnut variety Virginia bunch gave higher yield as compared to Spanish-33. While evaluating eighteen groundnut varieties for their oil and protein contents, Tripathi *et al.* (1972) reported that no single variety can be considered best for both oil and protein contents. The oil content was higher in bunch varieties than in semi-spreading or erect varieties. The oil content ranged from 45.74 to 50.05 per cent. Bajwa et al. (1966) also reported variation in oil content from 46.1 to 51.3 per cent in different groundnut varieties.

The effect of two fertility levels on the yield ers of different varieties of groundnut was studied by Dholaria and Joshi (1972). They obtained greater yield and genetic variability at higher fertility level. The heritability estimates of most of the characters were higher under high fertility conditions. Saini and Tripathi (1973) studied the yield and oil content of spreading and erect varieties of groundnut and reported that spreading variety (M-145) excelled the bunch variety (Faizpur-1-5) by a margin of 25.7, 61.1 and 20.4 per cent in yield during 1969, 1970 and 1971 respectively. These workers (1975) conducted an experiment for three years (1971 to 1973) to ascertain the effect of graded levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) on different varieties of groundnut and called upon the fact that the yield increase in M-13 was due to a larger number of mature pods per plant and the heavier kernels as compared to other varieties.

Rao et al. (1974) reported that Spanish, Valencia and Virginia varieties of groundnut differed significantly for dry matter production and pod yield. The Virginia type was the best in these attributes followed by Valencia and Spanish types. Venkatrama (1976) obtained the highest pod yields in variety AH-1192, during both *rabi* and *kharif* seasons, while variety TMV-2 and Pollachi-1 produced the maximum haulm yield in *rabi* and *kharif* seasons respectively. Whereas, variety AK-12-34 yielded higher amount of kernel as well as dry matter than PG-1 variety of groundnut as reported by Bhan (1977). While working with eleven varieties of groundnut, Bathla *et al.* (1977, 1978a, 1978b) obtained no definite trend in dry matter yield of different groundnut varieties at different stages of growth. At maturity stage, the highest pod yield was obtained from Spanish improved variety, while variety HG-10 gave the maximum straw yield.

Three groundnut varieties were tested at different phosphorus levels by Mishra (1977) and noted that Jyoti variety gave 1.53 and 1.70 q/ha more pod yields over exotic-1 and local varieties of groundnut respectively. Patil (1977) conducted field experiment with five groundnut varieties and reported that the variety TG-3 produced highest pod yield (4237 kg/ha) which was 4.7, 5.4, 29.4 and 30.6 per cent more than that of variety RS-12, TH-3-30, Spanish improved and Hippergi-2-14 respectively. The highest oil content of 49.09 per cent was also recorded in TG-3.

Schiller *et al.* (1978) obtained 50 per cent more yield of unshelled nuts from groundnut cultivar Tainan-9 than that of local cultivar in northern Thialand. The oil content ranged from 49.14 per cent in variety Tainan-9 to 51.76 per cent in variety Tainan-6. Pachpute (1981) noted that the pod yield of variety TG-17 (2540 kg/ha) was significantly higher as compared to varieties GAUG-1 and Junagadh-11. Conversely, significantly greater haulm yield was obtained from varieties GAUG-1 and Junagadh-11 (7805 and 7662 kg/ha respectively) than variety TG-17. The variety TG-17 contained significantly higher percentage of oil (52.47 per cent) as compared to variety GAUG-1 (50.04 per cent) and Junagadh-11 (49.42 per cent).

2.1.2 Phosphorus effect

Bouger (1949) observed significant decrease in the pod yield where phosphoric acid alone was used for manuring groundnut. Singh (1958) observed no significant difference in yield between application of 30 lb and 60 lb P_2O_5/ac. While Dalal and Natu (1940) found that increase in yield of pods per kg of P_2O_5 under three levels viz., 10, 20 and 30 kg/ha was 16.9, 11.1 and 17.1 kg respectively. Pathak and Verma (1964) obtained maximum pod yield when 20 kg N + 20 kg P_2O_5/ha was applied. Reddy and Rao (1965) reported that application of 20 kg P_2O_5/ha as superphosphate increased the yield of groundnut.

However, the yield did not increase with the increase in dose of phosphorus to 40 kg of P_2O_5/ha. Lachover and Ebercon (1966) also could not obtained the response of groundnut to super-phosphate over 600 kg/ha in Israel. Whereas a negligible response to 40 lb P_2O_5/ac over 20 lb P_2O_5/ac was noted by Puntamkar and Bathkal (1967).

Barrios et al. (1970) conducted ten fertilizer trials at seven sites in Venezuela with two varieties of black beans, observed a negative response of phosphorus and potash application to black beans with regard to yield. Similar observations were also noted by Omueti and Oyenuga (1971), while studying the effect of phosphorus application on groundnut grown on phosphorus deficient soil.

Response of groundnut to nitrogenous and phosphatic fertilizers was studied by Tripathi and Moolani (1971) and reported increase in yield from 1.65 to 2.9 t/ha at 20 kg N/ha over control (no nitrogen). Increase in the rate of applied P_2O_5 from 0 to 50 kg/ha was accompanied by linear increases in yields from 1.75 to 2.21 t/ha, further increase in the rate of applied P gave no additional yield.

From the experiment conducted at the Central Arid Zone Research Institute, Jodhpur, Bhan and Mishra (1971) observed that P application to groundnut crop contributes longer roots with more primary and secondary roots. They also opined that when the soil moisture was deficient, the crop fertilized with P had better ability to take up the available moisture than the crop fertilized with N. Soil application of 20 kg P_2O_5/ha to groundnut on Akola soils, significantly increased number and weight of pods per plant as well as yield of unshelled nuts and nonsignificantly increased shelling percentage (Dahatonde and Rahate, 1974).

Punnoose and George (1974) reported that application of P_2O_5 upto 75 kg/ha increased yield and oil content of groundnut cv. TMV-2 and further increase in phosphorus dose to 100 kg P_2O_5/ha depressed the yield. The highest yield of 2.19 t/ha was obtained with 10 kg N + 75 kg P_2O_5/ha. Jayadevan and Sreedharan (1975) also reported highest pod yield of 2.97 t/ha with 20 kg N + 75 kg P/ha.

Muralidharan et al. (1975) conducted a field trial at Vellayani with groundnut at four levels of phosphorus and three levels of molybdenum. Higher rate of phosphorus and molybdenum delayed flowering and reduced the percentage of pegs developing into mature pods.

Rao (1977) noted the highest pod yield and net profit when the crop was fertilized with 20 kg N + 40 kg P_2O_5/hectare in the kharif season under rainfed conditions. Sanchez and Owen (1978) reported that application of phosphorus significantly increased pod yields from 0.75 t with no phosphorus to

2.07 t with 150 kg P_2O_5/ha and 2.00 t with 200 kg P_2O_5/ha.

Faldu (1978) reported that application of phosphorus at 50 kg P_2O_5/ha gave significantly higher yield as compared to that at 25 kg P_2O_5/ha to groundnut crop.

Birajdar and Ingle (1979) investigated the N and P fertilizer requirement of groundnut on medium black cotton soils of Parbhani and concluded that the economic fertilizer dose for groundnut was 27 kg N + 54 kg P_2O_5/ha which gave 17.66 q/ha yield.

Bhatol (1981) observed that application of phosphorus at the rate of 25 kg P_2O_5/ha was significantly superior to 0 and 50 kg P_2O_5/ha in increasing groundnut yield. Phosphorus application increased the oil content significantly over control. The highest oil content of 50.55 per cent was observed at 50 kg P_2O_5/ha.

2.1.3 Potassium effect

On the basis of three years observations, Katarki and Banahatti (1965) reported that application of potassium sulphate at 100 and 200 lb K_2O/ac had adverse effect on yields during three years. But Hagin and Koyumjisky (1966) obtained significant increase in yield of groundnut in two out of twenty field experiments, by application of 160 kg K_2O/ha in soil having adequate supply of available potassium. Singh (1958) reported that potassium application at 60 lb K_2O/ac significantly increased the yield of groundnut.

Rajashekhara and Sanjeevaiah (1969) found that application of 16.8 kg K_2O/ha increased the yield to 13 per cent and the yield at a higher level (33.6 kg K_2O/ha) did not differ much. Acuna and Sanchez (1970) reported that application of potassium (K_2O) at 80 kg/ha increased kernel yield but had no significant effect on oil yield.

Govinda Iyer et al. (1970) reported that oil content was not significantly influenced by potassium application, however, the pod yield was increased significantly. Son et al. (1974) conducted an experiment with semi runner type groundnut on sandy loam soils and observed that vegetative growth of above ground parts decreased with increase in potassium level, while oil content of groundnut kernels remained unaffected. While working with virginia type groundnut grown on clay loam soil low in all plant nutrients except potassium, Hall (1975) found that potassium application along with P and Ca depressed the yields of shelled and unshelled nuts by 1.73 and 3.21 kg/plot respectively.

Sanchez and Owen (1976) conducted an experiment on groundnut with four levels of potash viz. 0, 40, 80 and 120 kg K_2O/ha and reported that application of K t[illegible] to increase the yield from 1.54 t/ha with no K to 1.[illegible] with 80 kg K_2O/ha or more.

2.1.4 P x K interaction effect

Satyanarayana and Krishna Rao (1962) observed increase in the oil content of groundnut due to application of phosphorus and potassium. Application of phosphorus and potassium fertilisers significantly affected grain yield of soybean (Miller et al., 1961). A multiple regression analysis showed that over 60 per cent of the variation in soybean yield was accounted from by the variation in the phosphorus and potassium. While Puntamkar and Bathkal (1967) observed that P_2O_5 and K_2O levels did not bring any significant differences in the pod yields, however, the dry matter production increased due to increase in N and P_2O_5 levels but not with K_2O levels. Similar results were also reported by Anderson (1970). Acuna and Sanchez (1970) showed that potassium increased the effectiveness of phosphorus application.

Fertilizer trials were conducted on bean (*Phaseolus vulgaris*) by Barrios et al. (1970) with fertilizer levels 0, 100 and 200 kg P_2O_5 and 0 and 70 kg K_2O/ha and found that application of phosphorus and potassium resulted in a negative response with respect to the seed yield of black bean.

Horodyski and Pieczka (1970) reported that responses to phosphorus and potassium application were related to respective levels of nutrient in the soil. Application of phosphorus and potassium at higher rates did not influence oil content and test weight of seeds. Tell *et al.* (1970) noted that phosphorus application markedly increased the yield while potassium application decreased the yield of groundnut.

The influence of P and K application to peas on leached chernozem soils were examined by Omel Chenkov (1970) and noted that application of P and PK increased the LAI, photosynthetic productivity, number of pods per plant and seed yields. Singh and Singh (1973) found that application of 60 kg P_2O_5 and 40 kg K_2O along with 15 to 20 kg N per hectare were sufficient for good crop growth and yield of groundnut.

In a field trial conducted to study the effect of different levels of phosphorus and potassium along with nitrogen to wet season groundnut on Brahmaputra flood plain soil, Bhuiya and Chowdhury (1974) found that phosphorus application (67.2 kg P/ha) increased oil content whereas potassium application had no effect on oil content.

Sanchez and Owen (1978) conducted an experiment with high levels of nitrogen, phosphorus and potassium on groundnut. Phosphorus significantly increased pod yield from 0.75 t/ha with no P to 2.07 t/ha with 150 kg P_2O_5/ha and 2.00 t/ha with 200 kg P_2O_5/ha. The potassium application increased yields from 1.54 t/ha with no K to 1.96 t/ha with 80 kg K_2O/ha or more. However, the differences in the yield due to potassium application were not significant.

Nadgouda *et al.* (1976) reported that pod yields were not influenced by applied phosphorus. While inclusion of 30 kg K_2O/ha increased the yield by 12.7 per cent over 30 kg N + 40 kg P_2O_5/ha.

2.2 Effect on chemical composition

2.2.1 Variety effect

The groundnut varieties differed in their nitrogen, phosphorus and potassium contents of pods and kernels as reported by Marani *et al.* (1961). Smith *et al.* (1962) also reported differences in protein content in different varieties of groundnut.

Cox *et al.* (1970) observed that total nitrogen content of haulm of virginia type peanut decreased linearly from 5 per cent at 3 weeks growth stage to 2 per cent at harvest stage. The phosphorus content also decreased linearly from 0.45 per cent at 3 weeks growth stage to 0.12 per cent at harvest stage, but potassium content increased during the first 6-8 weeks of growth and later on it decreased. The calcium content increased from 0.75 to 1.0 per cent during first four weeks of growth. The sulfur content remained near 0.2 per cent except for a sharp increase in mid-season. The manganese content varied with site, being apparently associated with soil pH and soil Mn content. The copper content increased to a maximum of 9 ppm at 5-6 weeks and then decreased to 5 ppm at harvest stage.

The zinc content increased to 20-40 ppm in the first week, thereafter it decreased to 10 ppm at harvest stage. The iron content tended to decrease upto 15 weeks and then it increased sharply until harvest. While magnesium content show a distinct pattern. Whereas in Tatu variety of groundnut, the total contents of N, K and Ca in above ground parts increased as the age advanced, while those of P and Mg increased only between 34 and 110 days and that of sulfur increased from 12 to 14 days and then decreased upto 110 days. The nitrogen content decreased from 4.36 per cent at 12 days growth to 3.1 per cent at 110 days growth. The calcium content increased from 1.3 per cent at 12 days growth to 1.74 per cent at 110 days growth and potassium content increased from 2.51 per cent at 12 days to 2.66 per cent at 34 days and then fell to 2.51 per cent at 110 days. Seed contained 5.43 per cent N, 0.56 per cent P, 0.75 per cent K, 0.13 per cent Ca, 0.30 per cent Mg and 0.25 per cent Sulfur (Sichmann et al., 1970).

Hallock et al. (1971) reported the distribution of nutrients in peanut varieties at maturity. Average phosphorus content of peanut plant parts varied from 0.12 to 0.36 per cent. The fruit contained 0.27 to 0.36 per cent phosphorus whereas the leaf contained 0.17 to 0.26 per cent. The average phosphorus content in the Spanish and Valencia type peanuts was higher than that of small seed Virginia type, while the large seeded Virginia type contained the least amount of phosphorus. A significant interaction was observed between varieties and phosphorus content of plant parts. The potassium content varied from 0.6 to 3.6 per cent in various plant parts of different types of peanut. [illegible]ed Virginia type peanuts were higher in potassium contents than small seeded Virginia, Spanish and Valencia types. A significant interaction occurred between varieties and potassium contents of various plant parts. The calcium content of stem was the highest and that of fruit was the least, irrespective of cultivars. The large seeded Virginia type peanuts contained higher calcium than small seeded Virginia, Spanish and Valencia types.

Walker (1973) observed that nitrogen content of leaves, stems, roots, hulls and seeds of Spanish and runner groundnut varieties were unaffected by rate of N, P and K. Seeds had the highest nitrogen content which was followed by leaves, roots, hulls and stems. Phosphorus content of various parts of groundnut plant was in the order of kernels > leaves > roots > stems > hulls, whereas potassium was in the order of leaves and stem > seeds > hulls. The magnesium content of various parts of groundnut plant was in the order of leaves > stem > seed and hulls.

Hallock and Martens (1974) tested six runner type and four bunch type groundnut cultivars without fertilisers. They sampled blades and petioles near maturity and reported that blades contained higher amount of P, Ca, B, Mn, Zn and Cu than the petioles. The content of potassium, calcium and magnesium were higher in cv. Avoca-11, Va-61-R and F.10-runner respectively.

Rao et al. (1974) reported that content and uptake of nitrogen and phosphorus differed significantly among three different groundnut groups viz. Virginia, Valencia and Spanish.

On desert soil, Bhan (1977) observed that nitrogen content in groundnut plant was higher during early stages, which decreased as the age of plant advanced. At harvest, the distribution of nitrogen was in the order of kernel > leaf > shell. Among varieties, the PG-1 variety contained higher nitrogen and phosphorus through out the growth period, with exception at 30 days, in leaf as well as in kernel and at harvest stage in shell and stem as compared to variety AK-12-24.

Eleven varieties of groundnut were tested by Bathla et al. (1976b). The peak period for the absorption of calcium was found to be between flowering and pegging stages for varieties C-501, Faizipur-1-5 and H.G.-6 and the accumulation was 39.4, 37.2 and 41.4 per cent of the total uptake respectively. The highest per cent accumulation of magnesium was noticed between grand growth and flowering stages for varieties C-501 and Exoitic-5.

Chahal and Sukhapal Singh (1979) observed that in the above ground parts, calcium and magnesium contents were maximum at 50 and 100 days of growth. The uptake of calcium and magnesium was highest at 40-60 days of growth. The calcium and magnesium contents in different plant parts were in the order of leaves > stem > shell > seeds.

2.2.2 Phosphorus effect

When phosphorus (56.90 kg/ha) was applied as ammonium phosphate to Natal groundnut, Bunting and Anderson (1960) observed depletion in nitrogen contents of groundnut leaf from 5.12 to 2.20 per cent, stem from 2.65 to 1.20 per cent and root from 2.44 to 1.35 per cent as the growth advanced from twentieth day to maturity. At maturity, kernels and shells contained 5.17 and 0.67 per cent nitrogen respectively. The highest P_2O_5 concentration was recorded in kernels followed by leaves and shoots. In the peak period of absolute vegetative growth (from 34 to 77 days) leaflets and stems contained 2.2 to 4.0 per cent K, which declined to about 1.7 per cent in leaves at maturity. The calcium content was 1.75 per cent in leaflets, 0.66 per cent in stems, 0.30 per cent in shells and 0.01 per cent in kernels. The magnesium content of leaflets and stems reduced after 34 days of growth. At harvest, the magnesium content was 0.43 per cent in leaflets, 0.60 per cent in stems, 0.29 per cent in roots and 0.22 per cent both in kernels and shells.

Experiment was conducted on soil low in available phosphorus to study the influence of graded levels of phosphorus (0, 300, 600 and 900 kg superphosphate per hectare) on chemical composition of groundnut by Lachover and Fbercon (1966). They revealed that phosphorus content in the leaves and roots of the groundnut plant showed significant positive correlation with the rate of phosphorus application at 15 days after emergence and in the lateral roots at 45 days after emergence. While studying the effect of phosphorus fertiliser on protein and chemical components of groundnut and cowpea, Fawusi and Oyenuga (1971) noted that phosphorus fertilization increased protein, P, K, Ca, Zn, Cl and Co contents while decreased Na and Cu contents of groundnut and cowpea seeds. The Fe content of cowpea was increased but that of groundnut was decreased by phosphorus fertilizers. The Mg, phytin and oxalate contents of cowpea and groundnut seeds were not affected by phosphorus fertilization.

Puntamkar and Bathkal (1967) observed that P_2O_5 content was found to increase with the development of plant which may be due to slow availability of P_2O_5 after application. Chahal and Ahluwalia (1977) studied the influence of P fertilization on zinc content and uptake under glass house condition and reported that highest amount of zinc was accumulated at 75 days of growth. Its concentration in shoot portion increased again at maturity. The phosphorus application showed an antagonistic effect on zinc uptake.

Georgiev (1977) observed that accumulation of N, P and K in above ground parts was most intense during the early flowering and pod formation periods. Applied P (137–270 kg P_2O_5/ha) had slightly increased phosphorus accumulation, but promoted more intensively the accumulation of nitrogen and potassium in the above ground parts as well as potassium in pods.

Rathee and Chahal (1977) studied the effect of applied P and S on yield and chemical composition of groundnut in Ambala soils. Application of phosphorus and sulphur significantly increased nitrogen content. The accumulation of P, S and N was higher in seeds than in haulm.

Singh and Khind (1976) studied critical limit of phosphorus in Ludhiana soils and reported that 16.6 kg per hectare of Olsen's extractable P is the critical limit. This was higher than the limit of 12.4 kg P/ha proposed by Olsen *et al.* (1954).

Groundnut showed linear yield response to applied P_2O_5 ~~at rates~~ upto 20, 15 and 10 ppm on soils of low, medium and high P_2O_5 contents respectively (Singh and Rana, 1979).

On medium black calcareous soils of Gujarat, Faldu (1976) observed that nitrogen, phosphorus, potash and magnesium contents were increased in kernels while calcium and sulphur decreased by phosphorus application. The sulphur content increased by super phosphate application. The iron content varied from 49.92 to 55.15 ppm in kernel and from 11.6 to 122.6 ppm in haulm. The manganese content varied from 10.03 to 13.19 ppm in kernel and 71.5 to 91.6 ppm in haulm. The zinc content varied from 10.94 to 12.74 ppm in kernel and 6.95 to 16.45 ppm in haulm. The copper content varied from 10.15 to 15.03 ppm in kernel and from 6.75 to 12 ppm in haulm with application of 25 kg N and 50 kg P_2O_5/ha.

Srinivasa (1979) observed that phosphorus application significantly increased grain phosphorus content from 0.303 per cent to 0.413 per cent and grain K content from 1.37 to 1.54 per cent in soybean. Bhatol (1981) studied phosphorus effect with different levels of nitrogen and zinc on groundnut variety GAUG-1 on loamy sand soil. The phosphorus was applied at 0, 25 and 50 kg P_2O_5/ha. The nitrogen content significantly increased in kernel and shell and that of magnesium was increased only in kernel by phosphorus application. While phosphorus, potassium, calcium and sulphur contents were not significantly influenced by levels of phosphorus.

2.2.3 Potassium effect

Effect on NPK manuring with liming on groundnut was studied by Nakagawa et al. (1966) and reported that application of potassium increased the P, K and Ca contents in leaves. The nitrogen content was increased by potassium in absence of calcium. The correlation observed between the yield and potassium content of leaves was positive and highly significant.

Puntamkar and Bathkal (1967) observed that application of potassium was found to increase the K_2O concentration of plant at all stages. Higher K_2O concentration was in leaf followed by seed and shoot.

Gillier and Gau Treau (1971) studied the response to graded levels of potassium (0, 30, 60 and 90 kg KCl/ha) raised on potassium deficient soils, and stated that phosphorus content decreased, while potassium content increased with increasing potassium levels.

Groundnut seedlings were grown for 55 days in nutrient solution containing six concentrations of potassium in the range of 51-512 μm. The potassium uptake followed michaelis-menten kinetics with a michelis constant of 0.06×10^{-3} M. The potassium content increased upto 200 μm K and thereafter, it remained more or less constant. The increases in potassium concentration of the nutrient solution decreased magnesium uptake (Fageria, 1974).

A pot experiment was conducted with 0 and 200 kg CaO/ha alone and in combination with four levels of potassium, viz. 0, 50, 100 and 150 kg/ha in the form of KCl by Habbebullah et al. (1977). The results revealed that the nitrogen content of the haulm was increased by application of potassium but in kernels it decreased. The potassium content increased in haulm and kernel due to potassium application.

Srinivasa (1979) observed that the potassic fertilizers increased leaf and grain K content significantly from 1.09 to 1.46 per cent in leaf and 1.26 to 1.66 per cent in grain respectively.

2.2.4 P x K interaction effect

A multiple regression analysis (Miller et al., 1961) showed that over 80 per cent of the variation in soybean yield was accounted for by the variation in the phosphorus and potassium contents of some plant parts. Application of P and K fertilisers significantly affected phosphorus and potassium contents of soybean plant.

Puntamkar and Bathkal (1967) observed that application of N, P and K together was found to be more effective in utilisation of N and P_2O_5 as compared to their single application. Application of P_2O_5 with N or alone was found to influence the uptake of N and P but the inclusion of K was found to decrease the uptake of P_2O_5.

Tang Van and Rolland (1973) measured the rate of P and K uptake by using continuous flow nutrient bath. The phosphorus concentration ranged from 0.05 to 1.5 ppm, potassium from 2 to 15 ppm and calcium from 0.5 to 8 ppm. The potassium application had no effect on the uptake of phosphorus but potassium uptake was increased by the presence of calcium.

CHAPTER III

MATERIALS AND METHODS

The present study was undertaken in order to know the influence of phosphorus and potassium on production and chemical composition of different groundnut varieties grown on goradu soil. Plant samples were collected at different growth stages from the field experiment conducted at the College Agronomy Farm by the Agronomy Department, B.A. College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during summer season of the year 1980.

Climate

Gujarat Agricultural University, Anand Campus, Anand, where the present study was undertaken, is situated at 22.62° north latitude and 73.00° east longitude and has an elevation of 46 metres above the mean sea level.

The meteorological data on an average monthly maximum and minimum temperatures, relative humidity, sunshine hours and rainfall recorded at the College Farm Observatory during the period under investigation i.e. from February, 1980 to June 1980 are given in Table 1.

Summer season commences in the second fortnight of February and ends by the middle of June. As to the summer, May is the hottest month of the year. The highest temperature

Table 1. Meteorological data for the period from February, 1960 to June, 1960.

Meteorological week	Date	Rainfall in mm	Mean temperature in °C		Relative humidity %	Sunshine (hr/day)
			Maximum	Minimum		
6th	5.2.60 to 11.2.60	-	27.6	9.3	40.0	10.5
7th	12.2.60 to 18.2.60	-	32.1	11.8	56.0	10.5
8th	19.2.60 to 25.2.60	-	33.6	14.4	67.0	10.8
9th	26.2.60 to 4.3.60	-	34.7	15.1	73.0	10.6
10th	5.3.60 to 11.3.60	-	31.5	12.1	60.0	10.4
11th	12.3.60 to 18.3.60	-	35.1	17.4	37.0	10.8
12th	19.3.60 to 25.3.60	-	36.7	19.1	57.0	10.7
13th	26.3.60 to 1.4.60	-	37.6	18.7	58.0	9.3
14th	2.4.60 to 8.4.60	-	38.4	20.2	44.0	10.8
15th	9.4.60 to 15.4.60	-	40.4	19.9	52.0	11.3
16th	16.4.60 to 22.4.60	-	40.7	22.6	61.0	10.1
17th	23.4.60 to 29.4.60	-	40.2	21.8	74.0	11.4
18th	30.4.60 to 6.5.60	-	41.8	24.4	75.0	11.0
19th	7.5.60 to 13.5.60	-	40.6	24.1	79.0	11.7
20th	11.5.60 to 20.5.60	-	40.6	25.4	76.0	11.7
21th	21.5.60 to 27.5.60	-	40.6	24.5	73.0	11.8
22nd	28.5.60 to 3.6.60	32.5	39.9	26.4	77.0	10.4
23rd	4.6.60 to 10.6.60	34.0	35.0	26.9	88.0	5.4
24th	11.6.60 to 17.6.60	1.5	36.5	27.3	86.0	7.2
25th	18.6.60 to 24.6.60	28.2	34.9	26.1	91.0	5.9
26th	25.6.60 to 1.7.60	65.0	30.6	25.6	96.0	2.1
	Total	161.2	-	-	-	-

Average annual rainfall 815 mm.

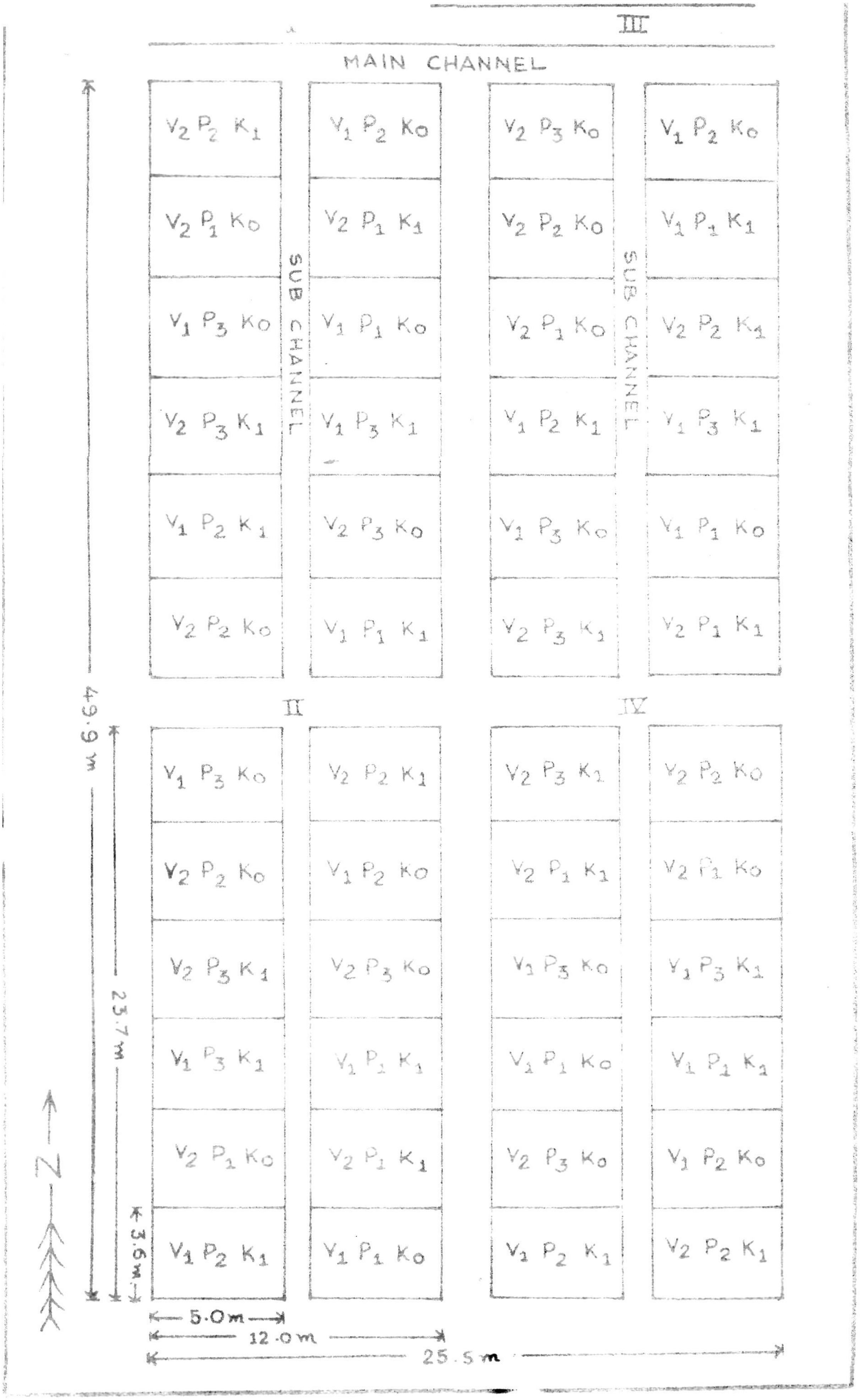
recorded was 41.6°C in the 16th standard meteorological week. Maximum sunshine hours were noticed in the 21st standard week. Rainfall was received during the 22nd and 23rd standard week. On an average weather was quite favourable for successful cultivation of groundnut.

<u>Soil</u>

The physico-chemical characteristics of the surface soil (0-15 cm depth) of the experimental field are presented in Table 2. The soil is of alluvial origin locally known as '<u>goradu</u>'. The soil is sandy loam in texture with slightly alkaline soil reaction. It is very deep, well drained and moderately retentive of soil moisture. Electrical conductivity being low suggests that the soil is free from salt hazards. The surface soil is low in organic carbon and total nitrogen content, moderate in available phosphorus and tended to be high in available potassium.

Table 2. Physico-chemical soil properties of the experimental field.

1.	Mechanical fractions (Piper, 1950):	
	i) Coarse sand (per cent)	0.55
	ii) Fine sand (per cent)	75.50
	iii) Silt (per cent)	15.60
	iv) Clay (per cent)	5.35
2.	Texture	Sandy loam
3.	pH (1:2.5 soil : water ratio) (Jackson, 1973)	7.65
4.	EC (1:2.5 soil : water ratio) (m mhos/cm at 25°C) (Jackson, 1973)	0.23


III
MAIN CHANNEL
$V_2 P_2 K_1$
$V_1 P_2 K_0$
$V_2 P_3 K_0$
$V_1 P_2 K_0$
$V_2 P_1 K_0$
$V_2 P_1 K_1$
$V_2 P_2 K_0$
$V_1 P_1 K_1$
$V_1 P_3 K_0$
$V_1 P_1 K_0$
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$V_2 P_3 K_1$
$V_2 P_1 K_1$
SUB CHANNEL
SUB CHANNEL
II
IV
$V_1 P_3 K_0$
$V_2 P_2 K_1$
$V_2 P_3 K_1$
$V_2 P_2 K_0$
$V_2 P_2 K_0$
$V_1 P_2 K_0$
$V_2 P_1 K_1$
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$V_1 P_2 K_0$
$V_1 P_2 K_1$
$V_1 P_1 K_0$
$V_1 P_2 K_1$
$V_2 P_2 K_1$
49.9 m
23.7 m
3.6 m
5.0 m
12.0 m
25.5 m
N

5.	Organic carbon (per cent) (Walkley and Black method; Jackson, 1973)	0.27
6.	Total nitrogen (per cent) (Kjeldhal's method; Jackson, 1973)	0.025
7.	Available P_2O_5 (kg/ha) (Olsen's method; Jackson, 1973)	42.90
8.	Available K_2O (kg/ha) (Neutral N NH_4OAc, Flame photometric method; Jackson, 1973)	336.00
9.	Cation exchange capacity (m eq/100 g soil; Jackson, 1973)	11.50
10.	Exchangeable calcium (m eq/100 g soil; Schwarzenbach and Biedermann, 1948)	6.00
11.	Exchangeable magnesium (m eq/100 g soil; Schwarzenbach and Biedermann, 1948)	3.60
12.	Heat soluble sulphur (ppm) (Williams and Steinberg, 1959)	12.00
13.	Available iron (ppm) (Lindsay and Norvell, 1969)	8.14
14.	Available manganese (ppm)(Lindsay and Norvell,1969)	15.36
15.	Available zinc (ppm) (Lindsay and Norvell, 1969)	0.80
16.	Available copper (ppm) (Lindsay and Norvell,1969)	0.36

__Experimental details__

1. Crop - Groundnut (*Arachis hypogaea*, L.)
2. Design - Randomized Block Design (Fig.1)
3. Number of replication - 4
4. Number of treatments - 12

5. Details of treatments - All possible combinations of A, B and C

A. Varieties (two): i) T.G.-17 (V_1)

ii) Junagadh-11(V_2)

B. Phosphorus levels(three): i) 50 kg P_2O_5/ha (P_1)

ii) 100 kg P_2O_5/ha (P_2)

iii) 150 kg P_2O_5/ha (P_3)

C. Potash levels (two): i) 0 kg K_2O/ha (K_0)

ii) 60 kg K_2O/ha (K_1)

Treatment combinations:

i) $V_1P_1K_0$	vii) $V_2P_1K_0$
ii) $V_1P_1K_1$	viii) $V_2P_1K_1$
iii) $V_1P_2K_0$	ix) $V_2P_2K_0$
iv) $V_1P_2K_1$	x) $V_2P_2K_1$
v) $V_1P_3K_0$	xi) $V_2P_3K_0$
vi) $V_1P_3K_1$	xii) $V_2P_3K_1$

6. Plot size - Gross: 3.60 m x 5.00 m

Net : 1.80 x 4.00 m

7. Spacing - 30 cm between rows

8. Seed rate - 125 kg/ha (kernel)

9. Date of sowing - 21.2.1980

10. Date of sampling - i) 4.4.1980 - Flowering stage

ii) 21.4.1980 - Pegging stage

iii) 23.6.1980 - Harvesting stage

11. Date of harvest - 23.6.1980

12. Number of irrigations - 13

Application of fertilisers

A recommended dose of nitrogen (20 kg N/ha) was applied in the form of di-ammonium phosphate to all the plots which also supplied 50 kg of P_2O_5/ha. Single superphosphate and muriate of potash were used as the sources of phosphorus and potash respectively to supply the remainder quantity of phosphorus and potassium as per treatment to the respective plot. The fertilisers were drilled below the seeds.

Cultural operations

Cultural operations were done as per the package of practices recommended for groundnut cultivation. Seeds were treated with cereson (2.5 g/kg of seeds) before sowing as a precautionary measures against the infection of diseases. The crop was sprayed with thiodan (2 ml/litre) and dusted with 10% DDT dust (25 kg/ha) twice as a preventive measures against the attack of insect pests. Crop was harvested at maturity from net plots and allowed to air dry in the field. The yield of pods and haulm were recorded separately. The pod yield was divided into kernel and shell by considering the ratio.

Collection and preparation of plant samples

The plant samples from each plot were collected randomly at three stages of growth viz. flowering, pegging and harvesting. The above ground plant parts only were sampled during first two growth stages i.e. flowering and pegging stage. While whole plant was collected as a sample by uprooting the plant at the maturity stage. The samples were brought to laboratory and washed thoroughly first with tap water and then with glass distilled water after removing the roots, and allowed to dry under well aerated shade. Air dried plants sample of matured crop were divided into three components namely; haulm, kernel and shell. The samples were oven dried at 65°–70°C till constant weight. Then they were powdered in a mechanical grinder having stainless still blade. All necessary precautions were taken to avoid contamination from extraneous sources while collecting as well as preparing the samples for analysis.

Plant analysis

Wet digestion procedure of Johnson and Ulrich, 1960 (diacid mixture 2:1, HNO_3:$HClO_4$) was employed for preparation of the acid extract of plant samples for determining macro, secondary and micronutrients except nitrogen. Estimation of N in different plant parts and oil contents in kernel were carried out separately. Details of methods used for determining the Macro and secondary elements in acid extract as well as for nitrogen and oil contents are presented in Table 3. The concentration of micronutrients, (Fe, Mn, Zn and Cu) in the plant extract were determined by using Atomic Absorption Spectrophotometer (Varian Techtron AA-120 model) as described by Brech (1966) and Isaac and Kerber (1971).

Table 3. Methods used for analysis of different elements.

Elements	Methods	Authors
Nitrogen	Macro-Kjeldhal's digestion method	Jackson (1973)
Phosphorus	Vanado molybdo phosphoric acid yellow colour method	Jackson (1973)
Potassium	Flame photometric method	Jackson (1973)
Calcium	Versenate titration method	Schwarzenbach and Biedermann (1948)
Magnesium	Versenate titration method	Schwarzenbach and Biedermann (1948)
Sulphur	Turbidimetric method	Chaudhary and Cornfield(1966)
Oil	Ether extraction	A.O.A.C.(1955)

Statistical analysis

The data of pod and haulm yields as well as oil content and nutrient concentrations were subjected to statistical analysis by following the methods of Snedecore and Cochran (1967).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present investigation undertaken to study the response of groundnut varieties raised on loamy sand soils of middle Gujarat to potash fertilization at different levels of phosphorus with respect to yield and chemical composition are presented and discussed in this chapter.

4.1 Yield

The pod and haulm yields of groundnut varieties as influenced by different levels of phosphorus with and without potassium are presented in Table 4.

4.1.1 Variety effect

The results revealed that the effect of varieties on yields of pod and haulm was highly significant (Table 4). The highest pod yield (2208.32 kg/ha) was recorded in variety V_1 as compared to V_2 (1845.48 kg/ha), the reverse was true for haulm yield. The results are in line with those obtained by Pachpute (1981). The genetic variations in groundnut varieties have been also reported by Saini and Tripathi (1973), Rao *et al.* (1974), Venkatrama (1976), Bhan (1977) and Bathla *et al.* (1977, 1978a and 1978b).

Table 4. Effect of phosphorus and potassium application on pod and straw yields as well as oil content and oil yield of different groundnut varieties.

(Mean value)

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)	Oil content (per cent)	Oil yield (kg/ha)
Phosphorus - P_1	2106.76	7010.38	48.80	730.90
P_2	2045.99	7722.16	49.55	725.00
P_3	1927.94	7201.35	50.36	693.82
S.Em. ±	77.92	237.36	0.283	29.67
C.D. 0.05	NS	NS	0.615	NS
C.V. %	15.39	13.00	2.28	16.56
Potash - K_0	2076.95	7310.14	49.32	733.65
K_1	1976.84	7312.46	49.82	699.49
S.Em. ±	63.61	193.75	0.231	24.22
C.D. 0.05	NS	NS	NS	NS
C.V. %	15.39	13.00	2.28	16.56
Variety - V_1	2208.32	6509.22	49.50	793.93
V_2	1845.46	8113.36	49.64	639.21
S.Em. ±	63.61	193.75	0.231	24.22
C.D. 0.05	183.10	557.91	NS	69.72
C.V. %	15.39	13.00	2.28	16.56

4.1.2 Phosphorus effect

Application of phosphorus did not affect significantly the pod and straw yields of groundnut. The maximum yield of pod was 2106.76 kg/ha by application of 50 kg P_2O_5/ha (P_1) and of straw 7722.16 kg/ha by application of 100 kg P_2O_5/ha (P_2). This indicates that application of P_2O_5 beyond 50 kg P_2O_5/ha in soils having medium available P_2O_5 (42.90 kg P_2O_5/ha) status will not be beneficial for pileing up the pod yield of groundnut. The maximum straw yield recorded in P_2 indicates that 100 kg P_2O_5/ha increased the nitrogen utilization efficiency which resulted in only the vegetative growth of a crop. While the highest level of P_2O_5 decreased the vegetative growth. The reason may be the imbalance of phosphorus with other nutrients such as nitrogen, zinc, etc. which were low to marginal initially and the availability of such nutrients might have reduced further due to high P_2O_5 addition. Singh and Rana (1979) observed that pod and straw yields had a linear response to phosphorus application upto 20 ppm on soils having low P_2O_5 content. In medium and high P soils, a significant response was observed upto 15 and 10 ppm P_2O_5 respectively.

4.1.3 Potassium effect

Application of potassium did not affect significantly the pod and straw yields of groundnut probably due to adequate available native K_2O (336 kg/ha) in the soil. The maximum yield of pod (2076.95 kg/ha) was recorded in absence of potassium (K_0) and of straw (7312.46 kg/ha) with addition of 60 kg K_2O/ha (K_1). Boon-Ampol and Chang (1974) observed depletion in groundnut yield with application of 150 kg K_2O/ha in dry year. Similar results were also reported by Son et al. (1974) and Hall (1975).

4.1.4 Interaction effect

All the first and second order interactions viz., VP, VK, PK and VPK were found to be nonsignificant for pod and straw yields of groundnut.

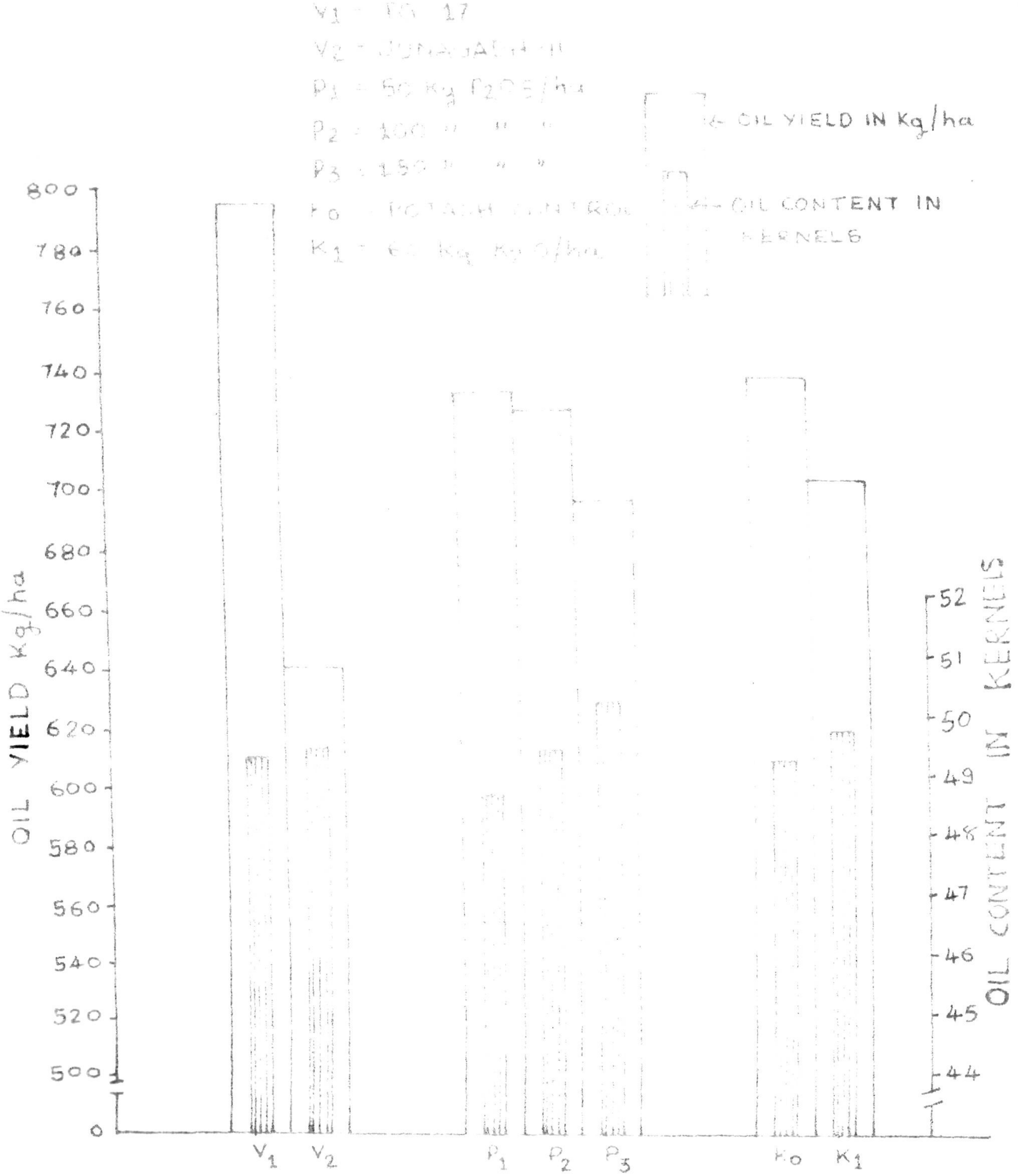
4.2 Oil content and oil yield

The data on oil content of groundnut varieties and their yield as affected by phosphorus and potassium levels are presented in Table 4 and Figure 2.

4.2.1 Variety effect

The oil content of variety V_2 (49.64 per cent) and variety V_1 (49.80 per cent) did not differ significantly. However, the computation of oil yield clearly indicated superiority of variety V_1 over V_2. The variety V_1 yielded 793.93 kg oil/ha as compared to 639.21 kg oil/ha by variety V_2. The significant increase in oil yield was mainly due to more pod yield of variety V_1 as compared to V_2. Such a small varietal differences in oil content were also reported by Bajwa et al. (1968), Saini and Tripathi (1973), Patil (1977) and Schiller et al. (1978).

FIG. 2: OIL YIELD IN Kg PER HECTARE AND OIL PERCENTAGE IN KERNELS AS INFLUENCED BY VARIETIES, LEVELS OF PHOSPHORUS AND POTASH



SCALE: 1 Cm = 20 Kg OIL
1 Cm = 1 PER CENT OIL CONTENT

4.2.2 Phosphorus effect

A perusal of the data in Table 4 revealed that application of 150 kg P_2O_5/ha (P_3) significantly increased the oil content over 50 kg P_2O_5/ha (P_1). There was a linear increase in oil content with higher levels of phosphorus. However, the oil yield was not found to vary significantly by application of phosphorus due to decrease in the production of pods with the increased phosphorus application. Meyer and Anderson (1952) reported that application of P increased the oil content of kernel. The beneficial effect of phosphorus application on oil content was also noted by Nijawan (1962), Acuna and Sanchez (1970), Jayadevan and Sreedharan (1975) and Faldu (1978).

4.2.3 Potassium effect

The oil content and oil yield were not found to vary significantly by application of potassium. However, the oil content increased with addition of potassium. Higher percentage of oil content was recorded under K_1 treatment (49.62 per cent) while the oil yield was the maximum (733.65 kg/ha) under treatment K_0. This could be attributed to decrease in yield of pods due to potassium application. Acuna and Sanchez (1970) also reported nonsignificant differences in oil production with potassium levels.

4.2.4 Interaction effect

All the interactions between varieties, phosphorus and potassium levels were found to be nonsignificant in their effect on oil content of groundnut and oil yield.

4.3 Content of nutrient elements

4.3.1 Nitrogen content

The analytical results regarding nitrogen content of different plant parts of groundnut at various stages of growth as affected by various treatments are presented in Table 5.

The nitrogen content of above ground plant parts of groundnut at flowering stage was 3.03 per cent which decreased to 2.03 per cent at pegging stage and 1.92 per cent at harvesting stage. The decrease in nitrogen content in haulm with advancement of plant growth can be attributed to dilution effect and translocation of nitrogen to the developing seeds (Bunting and Anderson, 1960; Marani *et al.*, 1961 and Puntamkar and Bathkal, 1967). At harvesting stage, nitrogen concentration was observed to be more in kernel (4.13 per cent) followed by heulm (1.92 per cent) and shell (1.04 per cent). Similar results were also recorded by Pachpute (1981).

4.3.1.1 Variety effect. The data given in Table 5 showed that the varietal differences in nitrogen content of heulm at flowering and pegging stages were significant, while at maturity, it was nonsignificant. The variety V_1 contained 3.18 and 2.25 per cent higher nitrogen than variety V_2 at flowering and pegging stages respectively. Whereas at harvesting stage, the kernel of variety V_2 contained significantly higher nitrogen (4.45 per cent) than V_1 (3.82 per cent). Similar varietal

Table 5. Nitrogen content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	2.95	2.00	1.64	3.95	1.02
P_2	2.96	2.00	1.93	4.09	1.03
P_3	3.16	2.06	2.00	4.36	1.05
S.Em. ±	0.011	0.006	0.019	0.019	0.007
C.D. 0.05	0.031	0.016	0.057	0.056	0.019
C.V. %	1.42	1.11	4.14	1.66	2.64
Potash - K_0	3.01	2.03	1.86	4.07	1.03
K_1	3.04	2.03	1.96	4.20	1.04
S.Em. ±	0.009	0.005	0.016	0.016	0.006
C.D. 0.05	NS	NS	0.047	0.046	NS
C.V. %	1.42	1.11	4.14	1.88	2.64
Variety - V_1	3.16	2.25	1.94	3.82	1.05
V_2	2.67	1.60	1.90	4.45	1.03
S.Em. ±	0.009	0.005	0.016	0.016	0.006
C.D. 0.05	0.025	0.013	NS	0.046	0.016
C.V. %	1.42	1.11	4.14	1.88	2.64

differences in nitrogen content of different plant parts of groundnut were also noted by Walkar (1973), Rao *et al*. (1974) and Bhan (1977). Pachpute (1981) has also observed differences in the nitrogen content under middle Gujarat conditions among three varieties of groundnut viz. GAUG-1, J-11 and T.G.-17.

4.3.1.2 Phosphorus effect. A perusal of the data presented in Table 5 indicated that the phosphorus application significantly increased the nitrogen content of haulm at all three stages of growth as well as in kernel and shell at harvest. A linear increase in the nitrogen content with the increase in the level of phosphorus could be attributed to the fact that when phosphorus is applied to legumes, it enhances the activity of rhizobia and increases the formation of root nodules which helps in fixing more of atmospheric nitrogen in root nodules (Yawalkar *et al*., 1977). Puntamkar and Bathkal (1967), Singh and Singh (1973) and many other workers have reported similar effect of P application on nitrogen content. The increase in N content of groundnut with P application might possibly be due to its role in protein synthesis (Meyer and Anderson, 1952).

4.3.1.3 Potassium effect. The analytical results presented in Table 5 revealed that the nitrogen content was significantly increased in groundnut kernel and haulm at harvesting stage only. While the nitrogen content in above ground plant parts at flowering and pegging stages and that in shell at harvesting stage remained practically the same due to potassium application. The nitrogen content in kernel was significantly increased from 4.07 to 4.20 per cent and in haulm at maturity from 1.66 to 1.96 per cent when crop was fertilized with potassium. This was possibly due to more efficient utilization of N and P_2O_5 on account of potassium fertilization (Puntamkar and Bathkal, 1967). These results also indicate that potassium helps in protein formation and improves the final product (Yawalker *et al.*, 1977). Walkar (1973) has observed the highest N content in seed followed by leaves, roots, hulls and stems due to addition of potassium.

4.3.1.4 Interaction effect. Both, at flowering and pegging stages all the first and second order interactions between groundnut varieties, phosphorus levels and potassium levels affected significantly the nitrogen content of above ground parts of groundnut plant excepting V x K interaction at flowering stage (Table 6 and 7). The treatment combination V_1P_3 yielded significantly higher nitrogen content at flowering (3.26 per cent) and pegging (2.31 per cent) stages as compared to that under other treatment combinations of groundnut varieties and phosphorus levels. Whereas the nitrogen contents of above ground plant parts at flowering and pegging stages under V_2P_2 were the lowest being 2.74 and 1.74 per cent respectively. Similarly, amongst the treatment combinations of P and K levels, P_3K_1 produced the maximum concentration of nitrogen in plant at both

Table 6. Interaction effect of VPK on nitrogen content in haulm at flowering stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	3.06	3.15	3.11	2.82	2.74	2.78	2.94	2.95
P_2	3.21	3.14	3.17	2.72	2.76	2.74	2.96	2.95
P_3	3.23	3.29	3.26	3.05	3.14	3.09	3.14	3.21
Mean	-	-	-	-	-	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.01	0.044
VPK	0.021	0.062

Table 7. Interaction effect of VPK on nitrogen content in haulm at pegging stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	2.17	2.16	2.16	1.94	1.71	1.83	2.06	1.95
P_2	2.21	2.31	2.26	1.73	1.75	1.74	1.97	2.03
P_3	2.30	2.33	2.31	1.80	1.67	1.84	2.05	2.10
Mean	2.23	2.27	-	1.82	1.76	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.006	0.023
VK	0.007	0.019
VPK	0.011	0.032

stages, while the minimum concentration was obtained under P_1K_0 treatment at flowering stage and under P_1K_1 at pegging stage. The interaction between variety and K levels affected significantly the nitrogen content at pegging stage, where in the content was the highest under treatment combination V_1K_1 and the least under V_2K_1. On the whole, the nitrogen content was the maximum under $V_1P_3K_1$ at both flowering and pegging stages, while that under treatment combination $V_2P_1K_0$ at flowering stage and under $V_2P_1K_1$ at pegging stage was the minimum. Puntamkar and Bathkal (1967) observed thatapplication of P and K together was found to be more effective in utilisation of N as compared to their lone application.

At maturity, the interaction effect of VP on haulm, VP, VK and PK on kernel and VP, PK and VPK on shell was significant with respect to nitrogen content. It was observed that the highest nitrogen content (2.04 per cent) was recorded at P_3 level in V_2 variety (Table 8), which was significantly more than rest of the combinations barring V_1P_2 and V_1P_3 in haulm. The data in Table 9 revealed that V_2P_3 combination gave maximum nitrogen concentration (4.63 per cent), which was significantly more than rest of the VP combinations in kernel. Smith et al. (1962) reported differences in nitrogen content in different varieties, due to VxP interaction effect.

Table 8. Interaction effect of VP on nitrogen content in haulm at harvesting stage of groundnut (per cent).

V \ P	P_1	P_2	P_3
V_1	1.83	2.03	1.97
V_2	1.84	1.82	2.04
S.Em. ±	0.028	C.D. 0.05	0.081

Table 9. Interaction effect of VPK on nitrogen content in kernel at harvesting stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	3.54	3.91	3.72	4.13	[illegible]	4.18	3.83	4.07
P_2	3.53	3.73	3.63	4.50	4.59	4.55	4.02	4.16
P_3	4.08	4.12	4.10	4.64	4.61	4.63	4.36	4.37
Mean	3.72	3.92	-	4.43	4.47	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.027	0.079
VK	0.022	0.064

Data relating to VxK interaction on nitrogen content of kernel indicated that the maximum (4.47 per cent) and minimum (3.72 per cent) nitrogen content were recorded under V_2K_1 and V_1K_0 treatment combinations respectively. Whereas the combination of P and K levels were found to differ significantly from each other with respect to nitrogen content except P_3K_0 and P_3K_1 combinations.

The interaction effect of VxP, PxK and VxPxK were significant on nitrogen content in shell (Table 10). The V_2P_1 combination recorded minimum nitrogen content (0.99 per cent) which was significantly less than rest of the VxP combinations. In case of PxK interaction, maximum nitrogen (1.07 per cent) was recorded under P_3K_1 combination, which was significantly higher than the rest except P_2K_0 combination. The $V_1P_2K_1$ combination recorded minimum nitrogen content (0.99 per cent), which differed significantly from the rest barring $V_2P_1K_0$ and $V_2P_1K_1$ combinations.

Table 10. Interaction effect of VPK on nitrogen content in shell at harvesting stage of groundnut (Per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	1.02	1.09	1.06	0.99	0.99	0.99	1.01	1.04
P_2	1.07	0.97	1.02	1.04	1.05	1.05	1.06	1.01
P_3	1.05	1.06	1.06	1.02	1.07	1.04	1.03	1.07
Mean	-	-	-	-	-	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.010	0.027
VPK	0.014	0.039

4.3.2 Phosphorus (P_2O_5) content

The results of P_2O_5 content of different plant parts of groundnut varieties at various stages of growth as influenced by phosphorus and potassium application are presented in Table 11.

The P_2O_5 content of vegetative part of groundnut at flowering stage was 1.16 per cent which decreased to 0.82 per cent at pegging stage and 0.79 per cent at harvesting stage. The decrease in phosphorus content of vegetative parts of groundnut with the advancement of crop growth could be attributed partly to dilution effect and partly to translocation of nutrient from vegetative parts to the reproductive parts (Bunting and Anderson, 1960).

At maturity, the average phosphorus contents in different parts of groundnut plant were 0.79, 0.92 and 0.21 per cent in haulm, kernel and shell respectively. These results are in line with those reported by Cox *et al*. (1970) and Bhan (1977).

4.3.2.1 Variety effect. The data given in Table 11 indicated that the effect of different varieties of groundnut on P_2O_5 content was significant in haulm at flowering stage and in haulm and kernel at harvesting stage. In case of haulm at flowering and harvesting stage phosphorus (P_2O_5) contents were 1.18 and 0.82 per cent respectively in variety V_2, which were significantly higher than those (1.13 and 0.76 per cent respectively) in variety V_2. However, the P_2O_5 content in kernel

Table 11. Phosphorus (P_2O_5) content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	1.07	0.79	0.77	0.91	0.16
P_2	1.16	0.82	0.79	0.90	0.21
P_3	1.23	0.84	0.81	0.94	0.23
S.Em. ±	0.007	0.007	0.006	0.005	0.004
C.D. 0.05	0.021	0.019	0.017	0.015	0.011
C.V. %	2.51	3.30	3.04	2.25	7.79
Potash - K_0	1.19	0.84	0.81	0.93	0.21
K_1	1.12	0.79	0.77	0.90	0.20
S.Em. ±	0.006	0.005	0.005	0.004	0.003
C.D. 0.05	0.017	0.016	0.014	0.012	0.009
C.V. %	2.51	3.30	3.04	2.25	7.79
Variety - V_1	1.13	0.82	0.76	0.96	0.20
V_2	1.16	0.81	0.82	0.88	0.21
S.Em. ±	0.006	0.005	0.005	0.004	0.003
C.D. 0.05	0.017	NS	0.014	0.012	NS
C.V. %	2.51	3.30	3.04	2.25	7.79

was significantly more in V_1 as compared to V_2. The varietal differences in phosphorus content of various components of plant at various stages of growth might be due to the fact that different varieties possessed different potentiality of nutrient absorption (Bathla *et al.*, 1977) and dry matter production. Pachpute (1981) also observed significant difference in P_2O_5 content of different varieties at flowering and harvesting stages.

4.3.2.2 Phosphorus effect. The results revealed that the P_2O_5 content in various parts of groundnut plant at different stages of growth was significantly affected by phosphate fertilization (Table 11). The phosphorus content was increased from 1.07 to 1.23 per cent at flowering stage, from 0.79 to 0.84 per cent at pegging stage and from 0.77 to 0.81 per cent, 0.91 to 0.94 per cent and 0.16 to 0.23 per cent in haulm, kernel and shell respectively at harvesting stage with the increase in level of P_2O_5 application from 50 kg/ha to 150 kg/ha. Consequently, the highest P_2O_5 content was observed under P_3 level at all the stages of growth which was significantly higher than the other two level viz. P_1 and P_2. However, the content decreased with the age of crop. The increased concentration in different plant parts might be due to increased root growth on account of P application. Similar findings were reported by Singh and Singh (1973).

4.3.2.3 Potassium effect. The data presented in Table 11 revealed that the P_2O_5 content of haulm at all the stages of plant growth was significantly influenced by K application. The P_2O_5 contents in above ground parts of plant were 1.19, 0.84 and 0.81 per cent at flowering, pegging and harvesting stages respectively in absence of K application, which was significantly reduced to 1.12, 0.79 and 0.77 per cent at respective stages of growth when 60 kg K_2O/ha was added to soil. The phosphorus contents in kernel (0.93 per cent) and shell (0.21 per cent) under K_0 level were significantly higher than P_2O_5 content (0.90 and 0.20 per cent respectively) under K_1 level. Such decline in phosphorus content due to potassium application was reported by Walker (1973) in groundnut.

4.3.2.4 Interaction effect. Both, at flowering and pegging stages all the first order interactions between groundnut varieties, phosphorus and potassium levels affected the phosphorus content in aerial parts of groundnut plant excepting VxK and PxK at flowering stage (Table 12 and 13). The plants under treatment V_2P_3 contained significantly higher phosphorus at flowering (1.27 per cent) and pegging (0.85 per cent) stages except V_1P_3 and V_2P_2 at pegging stage than that under other treatment combinations of variety and phosphorus levels. In case of PxK interaction at pegging stage, maximum phosphorus (0.86 per cent) was recorded under P_3K_0 treatment, which was

Table 12. Interaction effect of VP on phosphorus content (P_2O_5) in haulm at flowering stages of groundnut. (per cent).

V \ P	P_1	P_2	P_3
V_1	1.06	1.13	1.20
V_2	1.07	1.19	1.27

S.Em. ± 0.010 C.D. 0.05 0.029

Table 13. Interaction effect of VP, PK and VK on phosphorus (P_2O_5) content in haulm at pegging stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	0.81	0.82	0.82	0.77	0.75	0.76	0.79	0.79
P_2	0.84	0.77	0.80	0.88	0.79	0.83	0.86	0.78
P_3	0.85	0.81	0.83	0.90	0.80	0.85	0.88	0.81
Mean	0.84	0.80	-	0.85	0.78	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.010	0.027
VK	0.006	0.022

significantly higher than rest of the treatments except P_2K_0 combination, while amongst the combinations of variety and potassium levels the plants under treatment V_1K_0 and V_2K_0 contained significantly higher P_2O_5 than rest of the treatment combinations.

Data presented in Table 14 indicated significant effect of PxK interaction on P_2O_5 content of haulm at harvesting stage. Maximum P_2O_5 content (0.65 per cent) was recorded under P_3K_0 combination which was significantly superior to other combinations. Puntamkar and Bathkal (1967) observed that application of N, P and K together was found to be more effective in utilisation of P_2O_5 as compared to lone application.

Among different interactions V_1P_3, P_3K_0, V_1K_0 and $V_1P_3K_0$ combinations contained maximum P_2O_5, while V_2P_1, P_2K_1, V_2K_1 and $V_2P_1K_0$ contained the minimum P_2O_5 in kernel at harvesting stage (Table 15). Rao *et al.* (1979) reported that the effect of varieties x phosphorus levels was significant on grain yield but this interaction was nonsignificant with respect to phosphorus content in rice crop.

4.3.3 Potash content

The results of K_2O content of different parts of groundnut plant at various stages of growth as affected by different varieties and phosphorus as well as potassium levels are presented in Table 16.

Table 14. Interaction effect of PK on phosphorus (P_2O_5) content in haulm at harvesting stage of groundnut. (per cent).

K \ P	P_1	P_2	P_3
K_0	0.78	0.82	0.85
K_1	0.76	0.77	0.77

S.Em. ± 0.008 C.D. 0.05 0.024

Table 15. Interaction effect of VPK on phosphorus (P_2O_5) content in kernel at harvesting stage of groundnut. (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	0.96	0.95	0.96	0.83	0.89	0.86	0.91	0.92
P_2	0.97	0.90	0.93	0.89	0.84	0.86	0.93	0.87
P_3	0.99	0.95	0.97	0.95	0.86	0.91	0.97	0.91
Mean	0.98	0.93	-	0.89	0.86	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP and PK	0.007	0.021
VK	0.006	0.017
VPK	0.010	0.030

Table 16. Potash (K_2O) content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus – P_1	1.32	1.33	1.37	0.84	0.63
P_2	1.37	1.33	1.32	0.76	0.60
P_3	1.37	1.39	1.31	0.77	0.59
S.Em. ±	0.007	0.009	0.005	0.004	0.006
C.D. 0.05	0.020	0.027	0.014	0.013	0.016
C.V. %	2.09	2.78	1.50	2.25	4.21
Potash – K_0	1.33	1.34	1.32	0.75	0.59
K_1	1.37	1.36	1.35	0.84	0.62
S.Em. ±	0.006	0.006	0.004	0.004	0.005
C.D. 0.05	0.017	NS	0.012	0.010	0.015
C.V. %	2.09	2.78	1.50	2.25	4.21
Variety – V_1	1.36	1.41	1.36	0.80	0.63
V_2	1.35	1.28	1.31	0.79	0.56
S.Em. ±	0.006	0.006	0.004	0.004	0.005
C.D. 0.05	NS	0.022	0.012	0.010	0.015
C.V. %	2.09	2.78	1.50	2.25	4.21

Data relating to potash content did not vary much. The content in haulm decreased with the advancement of plant growth from flowering to harvesting stages probably due to dilution effect. The results were in accordance with those reported by Bunting and Anderson (1960), Marani et al. (1961) and Sichmann et al. (1970). The potash content was almost the same at flowering and pegging stages, but it decreased from pegging to harvesting stage. Among various parts of groundnut plant at harvesting stage, the potash content was maximum (1.33 per cent) in haulm followed by kernel (0.80 per cent) and shell (0.61 per cent). Similar results were also observed by Faldu (1978) and Pachpute (1981).

4.3.3.1 Variety effect. The data given in Table 16 showed that the differences in K_2O content were significant at pegging and maturity stages in all the plant parts studied. While such significant differences were not noticed during flowering stage (Table 16).

At flowering stage, potash content of haulm was 1.36 and 1.35 per cent in varieties V_1 and V_2 respectively. At pegging stage, V_1 contained significantly higher amount of potash (1.41 per cent) as compared to V_2 (1.28 per cent). The potassium (K_2O) contents at harvesting stage in haulm, kernel and shell of variety V_1 were 1.36, 0.80 and 0.63 per cent respectively which was significantly higher than thatof variety

V_2 (1.31, 0.79 and 0.56 per cent K_2O respectively). This is probably due to variation in dry matter production and differential ability of varieties for potassium absorption at different stages of growth (Bathla et al., 1978a).

Significant difference in potassium content among the groundnut cultivars were also recorded by Hallock et al. (1969, 1971) and Pechpute (1981) when similar plant parts were sampled at different dates.

4.3.3.2 Phosphorus effect. The phosphorus application significantly changed the potassium content of different plant parts at various growth stages of groundnut (Table 16). The data revealed that at flowering stage plants under treatment P_1 contained significantly less potassium (1.32 per cent K_2O) as compared to that under P_2 and P_3 levels of phosphorus (1.37 per cent K_2O). However, at pegging stage, the phosphorus treatments P_1 and P_2 being at par, were significantly inferior to P_3 in increasing potassium content of haulm. Thus, at flowering and pegging stages, there was increasing trend in potassium content due to increase in phosphorus application. The increase in potassium content of groundnut with P application might be due to balanced ratio of N and K in plant nutrition. The trend at harvesting stage was reverse as the contents of potassium in all parts of plant declined with increase in the dose of phosphorus. Walker (1973), Taldu (1978) and Bhatol

(1981) have reported greater concentration of K in haulm than in kernel of groundnut. The potassium contents in haulm, kernel and shell were 1.37, 0.84 and 0.63 per cent K_2O at P_1 level, which were significantly higher than at P_2 and P_3 levels in the respective plant parts. Contrary to this, Thornton (1964) reported significant increase in potassium content of kernel and fodder by P application.

4.3.3.3 Potassium effect. The influence of levels of potassium on potassium contents was significant at flowering and harvesting stages, while such effect was absent at pegging stage (Table 16). The results indicated that at flowering stage haulm contained 1.37 per cent K_2O under K_1 treatment which was significantly more than that (1.33 per cent K_2O) recorded under K_0. At maturity stage 1.35, 0.84 and 0.62 per cent K_2O recorded in haulm, kernel and shell at K_1 level indicated significantly higher amounts of potassium as compared to that (1.32, 0.75 and 0.59 per cent K_2O respectively) obtained under K_0. Similar findings were reported by Habbebullah *et al.* (1977), who observed that K application increased K content in haulm and kernel. Srinivasa (1979) reported that K content significantly increase in leaf and in grain of soybean by K application.

4.3.3.4 Interaction effect. Interaction effect between variety and phosphorus was found to be significant in respect to potash content at flowering stage. Data presented in Table 17 indicated that V_1P_2 combination recorded maximum (1.39 per cent) K_2O, which was significantly higher than the rest, except V_1P_3 and V_2P_3 combinations.

The interaction effect of all the factors were found to be significant for K_2O content at harvesting stage in all the parts except VP for haulm, PK for kernel and VP, VK and VPK for shell. Data revealed that K_2O content was significantly more under V_1K_1 combination as compared to V_2K_0 and V_2K_1 combinations (Table 16). The data relating to PK interaction indicated that P_1K_0 recorded maximum potassium (1.36 per cent), which was significantly more than the rest except P_1K_1 combination in haulm at harvesting stage. The VPK interaction indicated that $V_1P_1K_0$ combination was significantly superior to other combinations which contained 1.42 per cent K_2O, whereas minimum K_2O (1.24 per cent) content was recorded under $V_2P_2K_0$, which was significantly less than rest of the combinations.

The VP interaction was significant with respect to K_2O content of kernel (Table 19). The potassium content was maximum (0.66 per cent) under V_1P_1 combination which was significantly more than the rest of the treatment combinations. Among various combinations of VK interaction, V_1K_1 combination contained significantly higher potassium (0.86 per cent) than rest of the combinations. The combinations V_1K_0 and V_2K_0 were at par, while V_1K_1 and V_2K_1 differed significantly, indicating differential ability of varieties for utilizing applied potassium.

Table 17. Interaction effect of VP on potash (K_2O) content in haulm at flowering stage of groundnut (per cent).

V \ P	P_1	P_2	P_3
V_1	1.32	1.39	1.37
V_2	1.32	1.35	1.36

S.Em. ± 0.010   C.D. 0.05 0.029

Table 18. Interaction effect of VPK on potash (K_2O) content in haulm at harvesting stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	1.42	1.37	-	1.34	1.37	-	1.36	1.37
P_2	1.33	1.37	-	1.24	1.32	-	1.29	1.35
P_3	1.33	1.35	-	1.27	1.29	-	1.30	1.32
Mean	1.36	1.37	-	1.26	1.33	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VK	0.006	0.017
PK	0.007	0.020
VPK	0.010	0.029

Table 19. Interaction effect of VPK on potash (K_2O) content in kernel at harvesting stage of groundnut (per cent).

	V_1			V_2			Mean	
	K_0	K_1	Mean	K_0	K_1	Mean	K_0	K_1
P_1	0.84	0.92	0.88	0.76	0.85	0.80	-	-
P_2	0.71	0.86	0.79	0.75	0.79	0.77	-	-
P_3	0.70	0.81	0.75	0.77	0.81	0.79	-	-
Mean	0.75	0.86	-	0.76	0.82	-	-	-

Interaction	S.Em. ±	C.D. 0.05
VP	0.006	0.018
VK	0.005	0.015
VPK	0.009	0.026

Table 20. Interaction effect of PK on potash (K_2O) content in shell at harvesting stage of groundnut (per cent).

K \ P	P_1	P_2	P_3
K_0	0.63	0.57	0.59
K_1	0.64	0.62	0.59

S.Em. ± 0.009 C.D. 0.05 0.026

Among different combinations of VPK interaction, $V_1P_1K_1$ combination showed its superiority in potassium content of kernel over other combinations, which contained 0.92 per cent K_2O. Minimum potassium (0.70 per cent) content was recorded under $V_1P_3K_0$ combination which was at par with $V_1P_2K_0$, rest being significantly superior to these combinations.

The data relating to PK interaction for K_2O of shell indicated that P_2K_0 contained minimum (0.57 per cent) potassium, while P_1K_1 contained maximum (0.64 per cent). The differences among these combinations were significant in shell (Table 20). Puntamkar and Bathkal (1967) have also reported that application of PK was found to increase the K_2O content in plant.

4.3.4 Calcium content

The results of calcium content in different plant parts of groundnut varieties at various stages of growth as affected by various treatments are tabulated in Table 21.

The average calcium content in haulm was found to increase with the age of the plant. The contents in haulm were 1.23, 1.31 and 1.44 per cent at flowering, pegging and harvesting stages respectively. Similar trend of calcium content in groundnut has been reported by Eichmann *et al.*(1970).

At maturity, the calcium content in different parts of groundnut plant was in the order of haulm > shell > kernel. Similar trend was also noted by Baynes and Walmsley (1974).

Table 21. Calcium content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizer and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	1.25	1.33	1.49	0.22	0.51
P_2	1.23	1.31	1.44	0.23	0.53
P_3	1.20	1.29	1.40	0.25	0.55
S.Em. ±	0.005	0.004	0.007	0.005	0.008
C.D. 0.05	0.014	0.011	0.020	0.015	0.022
C.V. %	1.56	1.18	1.69	9.24	5.81
Potash - K_0	1.22	1.30	1.43	0.24	0.55
K_1	1.24	1.32	1.45	0.22	0.51
S.Em. ±	0.004	0.003	0.006	0.004	0.006
C.D. 0.05	0.011	0.009	0.016	0.013	0.016
C.V. %	1.58	1.18	1.69	9.24	5.81
Variety - V_1	1.22	1.26	1.42	0.24	0.51
V_2	1.24	1.33	1.46	0.22	0.55
S.Em. ±	0.004	0.003	0.006	0.004	0.006
C.D. 0.05	0.011	0.009	0.016	0.013	0.016
C.V. %	1.56	1.16	1.69	9.24	5.81

4.3.4.1 <u>Variety effect</u>. The data in Table 21 showed that the differences in calcium contents of groundnut plant parts at flowering, pegging and harvesting stages were significant due to different varieties of groundnut. Variety V_2 contained 1.24, 1.33 and 1.46 per cent calcium at flowering, pegging and harvesting stages respectively, which were significantly higher than that of variety V_1 at respective stages of growth. Variety V_1 contained significantly higher calcium (0.24 per cent) in kernel as compared to that of variety V_2 (0.22 per cent), while reverse was true for calcium content in shell. Hallock *et al*. (1969, 1971) observed significant variation in calcium content of different plant parts of various cultivars of peanut sampled on different dates. Rao *et al*. (1974) and Pachpute (1981) have reported differences in calcium content of groundnut plant due to varieties.

4.3.4.2 <u>Phosphorus effect</u>. The data presented in Table 21 revealed that the effect of phosphorus was significant on the calcium content of various parts of plant at different stages of growth. At flowering stage, the calcium concentration decreased with increasing rate of P_2O_5 application and difference between two subsequent levels of P_2O_5 was significant. Similar trend was also observed in case of haulm at pegging and harvesting stage. Contrary to this, the trend of calcium in kernel and shell increased with increasing the dose of phosphorus application. Foster and Russell (1956) showed that calcium absorption decreased with increasing the level of phosphorus and high lime may also reduce P absorption owing to the decreased availability of P associated with a high $HPO_4^{=}$: $H_2PO_4^-$ ratio in the soil solution at higher pH.

4.3.4.3 <u>Potassium effect</u>. The data given in Table 21 revealed that the calcium content of haulm was significantly influenced at all the stages due to potassium application. Calcium content in aerial parts of the plant was 1.24, 1.32, and 1.45 per cent at flowering, pegging and maturity stages in presence of potassium, which was significantly higher than the value recorded under control at respective stages, whereas calcium contents of kernel and shell were significantly decreased with potassium application. Habbebullah *et al.* (1977) observed that calcium content decreased with potassium application in kernel when calcium application was not given.

4.3.4.4 <u>Interaction effect</u>. The interaction effect on calcium content of groundnut plant at various stages of growth was found to be absent excepting the VxP interaction in haulm at harvesting stage.

The data in Table 22 revealed that V_2P_1 treatment combination yielded significantly higher calcium (1.50 per cent) content as compared to rest of the combinations except V_1P_1 which gave 1.46 per cent calcium. Minimum calcium (1.37

per cent) content was recorded under V_1P_3 combination which was significantly less than all other treatment combinations.

Table 22. Interaction effect of VP on calcium content in haulm at harvesting stage of groundnut (per cent).

V \ P	P_1	P_2	P_3
V_1	1.46	1.42	1.37
V_2	1.50	1.46	1.44

S.Em. ± 0.010 C.D. 0.05 0.026

4.3.5 Magnesium content

The results of magnesium content in various plant parts of groundnut at different stages of growth, as affected by varieties, phosphorus levels and potassium levels are presented in Table 23. The average magnesium content of haulm declined with the advancement of plant growth. The decrease in magnesium content was abrupt from flowering stage (1.66 per cent) to pegging stage (0.92 per cent), probably due to peak period of absolute vegetative growth of groundnut (Bunting and Anderson, 1960). At harvesting stage, the magnesium content of different parts of groundnut plant was in the order of haulm > shell > kernel. Similar results have been reported by Baynes and Walmsley (1974) and Habbebullah *et al.* (1977).

Table 23. Magnesium content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	1.61	0.86	0.82	0.22	0.23
P_2	1.68	0.92	0.85	0.23	0.24
P_3	1.69	0.98	0.88	0.25	0.25
S.Em. ±	0.013	0.010	0.014	0.005	0.004
C.D. 0.05	0.039	0.028	0.040	0.013	0.015
C.V. %	3.25	4.28	6.51	7.84	8.84
Potash - K_0	1.68	0.94	0.87	0.24	0.25
K_1	1.64	0.90	0.83	0.22	0.23
S.Em. ±	0.011	0.008	0.011	0.004	0.004
C.D. 0.05	0.032	0.023	0.033	0.011	0.012
C.V. %	3.25	4.28	6.51	7.84	8.84
Variety - V_1	1.63	0.92	0.83	0.23	0.25
V_2	1.69	0.93	0.87	0.24	0.22
S.Em. ±	0.011	0.008	0.011	0.004	0.004
C.D. 0.05	0.032	NS	0.033	NS	0.012
C.V. %	3.25	4.28	6.51	7.84	8.84

4.3.5.1 Variety effect. The data in Table 23 showed that the differences in magnesium content of haulm at flowering and harvesting stages were significant due to varieties of groundnut. Variety V_2 contained 1.69 and 0.67 per cent magnesium in haulm at flowering and harvesting stages respectively, which were significantly higher than that in variety V_1 at respective stages. While in case of shell at harvesting stage, variety V_2 had significantly lower magnesium (0.22 per cent) content as compared to V_1 variety. This could be attributed to its lower haulm and higher kernel and shell yields. Pachpute (1981) also reported significant differences in magnesium content in different varieties of groundnut at various growth stages.

4.3.5.2 Phosphorus effect. The magnesium content of various plant parts of groundnut were significantly influenced by phosphorus application (Table 23). The content under P_3 was significantly higher than that under P_1. The content under P_2 treatment was at par with P_3 excepting at pegging stage. Whereas it was found to be significantly superior at pegging stage. The maximum content of magnesium was 1.69, 0.96 and 0.66 per cent in haulm at flowering, pegging and maturity stages respectively under P_3 treatment. The corresponding minimum content was 1.61, 0.86 and 0.62 per cent at respective stages. The magnesium content (0.25 per cent) in both kernel and shell at harvest due to treatment P_3 was the highest whereas the magnesium content (0.22 per cent) in kernel and in shell (0.23 per cent) recorded under P_1 treatment were the lowest. Faldu (1976) has noted that phosphorus alone increased the magnesium content with successive increase in the dose, while in combination with N, the content declined.

4.3.5.3 Potassium effect. The magnesium contents in various plant parts of groundnut were significantly decreased at various growth stages on account of potassium. Magnesium contents in haulm at flowering, pegging and harvesting stages were 1.64, 0.90 and 0.63 per cent respectively under K_1 level, which were significantly lower than that (1.66, 0.94 and 0.67 per cent respectively) under control. The magnesium content also decreased from 0.24 to 0.22 per cent in kernel and from 0.25 to 0.23 per cent in shell due to potassium fertilisation. This might be due to antagonism between K and Mg in K-rich soils (Kanwar, 1976). Similar results are also reported by Habbebullah et al. (1977).

4.3.5.4 Interaction effect. All the interaction between varieties, phosphorus and potassium levels on magnesium content of different parts of groundnut plant at various stages of growth were found to be nonsignificant.

4.3.6 Sulphur content

The data on sulphur content of different plant parts of groundnut as affected by different varieties, phosphorus and potassium fertilizers are presented in Table 24. The sulphur

Table 24. Sulphur content in different plant parts of groundnut as influenced by phosphorus and potassium fertilisers and varieties (per cent on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	0.31	0.23	0.19	0.23	0.15
P_2	0.33	0.24	0.19	0.24	0.16
P_3	0.35	0.25	0.20	0.25	0.17
S.Em. ±	0.004	0.002	0.002	0.002	0.002
C.D. 0.05	0.011	0.005	0.005	0.006	0.006
C.V. %	4.51	3.14	3.33	3.72	5.17
Potash - K_0	0.33	0.24	0.19	0.24	0.16
K_1	0.33	0.24	0.20	0.24	0.16
S.Em. ±	0.003	0.002	0.001	0.001	0.002
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	4.51	3.14	3.33	3.72	5.17
Variety - V_1	0.33	0.24	0.20	0.24	0.16
V_2	0.33	0.24	0.19	0.23	0.16
S.Em. ±	0.003	0.002	0.003	0.002	0.002
C.D. 0.05	NS	NS	NS	0.005	NS
C.V. %	4.51	3.14	3.33	3.72	5.17

content of haulm decreased gradually from 0.33 per cent at flowering stage to 0.24 per cent at pegging stage and further to 0.19 per cent at maturity stage. Pachpute (1981) reported that the sulphur content of haulm decreased from 0.26 per cent at flowering stage to 0.22 per cent at pegging and 0.16 per cent at harvesting stage.

At harvesting stage, the average sulphur content of various plant parts of groundnut was in the order of kernel > haulm > shell. Similar trend was observed by Brom-Field (1973) and Pachpute (1981).

4.3.6.1 Variety effect. The sulphur content of different plant parts were not significantly influenced by varieties except the groundnut kernel. Sulphur content was practically equal in haulm of both the varieties at all three stages of growth. While in kernel at harvesting stage, variety V_2 contained significantly lower sulphur (0.23 per cent) as compared to that of variety V_1. Such variations in sulphur contents of groundnut varieties were also reported by Bathla *et al.* (1977).

4.3.6.2 Phosphorus effect. The data presented in Table 24 revealed that the effect of phosphorus application was significant on sulphur content of haulm at various growth stages as well as in kernel and shell at harvesting stage. The sulphur content in haulm, kernel and shell at various growth stages under phosphorus treatment P_3 was significantly higher than that under P_1 and P_2 treatments. The differences between later two treatments (P_1 and P_2) were also found to be significant at all the growth stages. This indicates that the sulphur content in plant increase with increase in the P levels probably due to increase P:S ratio (Shinde et al., 1979).

4.3.6.3 Potassium effect. The data in Table 24 revealed that application of potassium had no significant effect on sulphur content of different plant parts of groundnut at various stages of growth. The mean sulphur (0.33 per cent) content at flowering and (0.24 per cent) pegging stages remained unchanged with and without potassium fertilization. The sulphur content was 0.24 and 0.16 per cent in kernel and shell respectively under both K_0 and K_1 treatments.

4.3.6.4 Interaction effect. All the first and second order interactions viz., VP, VK, PK and VPK were found to be nonsignificant with respect to sulphur content of different parts of groundnut plant at various stages of growth.

4.3.7 Iron content

The results of iron content of groundnut plant parts at various stages of growth as influenced by varieties as well as phosphorus and potassium levels are presented in Table 25.

Table 25. Iron content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (ppm on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	63.90	77.65	64.29	70.73	74.97
P_2	63.67	75.22	62.64	66.73	73.19
P_3	60.06	71.63	61.66	66.28	72.96
S.Em. ±	1.353	1.020	1.413	0.909	1.212
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	6.46	22.26	6.79	5.25	6.56
Potash - K_0	60.33	75.43	62.76	66.67	73.33
K_1	64.76	74.23	63.75	69.62	74.06
S.Em. ±	1.091	0.633	1.154	0.742	0.990
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	6.48	22.26	6.79	5.25	6.56
Variety - V_1	62.99	75.73	63.60	69.47	73.04
V_2	62.11	73.93	62.93	69.02	74.36
S.Em. ±	1.091	0.633	1.154	0.742	0.990
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	6.46	22.26	6.79	5.25	6.56

The mean iron content of vegetative parts of groundnut plant decreased from 82.55 ppm at flowering stage to 74.83 ppm at pegging stage, but lateron it increased to 83.26 ppm at harvesting stage. Walmsley and Baynes (1978) reported that iron content in groundnut foliage was maximum at seven weeks of growth and minimum at harvest. While Pachpute (1981) observed maximum iron (115.60 ppm) content in haulm of groundnut at harvesting stage. The iron contents of different parts of groundnut plant at harvesting stage were in the order of haulm > shell > kernel.

4.3.7.1 Variety effect. The different varieties of groundnut did not differ significantly in iron content at all the stages of growth. The iron contents in haulm at flowering, pegging and harvesting stages as affected by varieties varied from 82.99 (V_1) to 82.11 (V_2) ppm, 75.73 (V_1) to 73.93 (V_2) ppm and 83.60 (V_1) to 82.93 (V_2) ppm respectively. At harvesting stage, variety V_1 contained 69.47 ppm iron in kernel which was higher than that of V_2 (69.02 ppm) whereas variety V_2 contained more iron 74.38 ppm than that of V_1 (73.04 ppm) in shell. This could be attributed to genetic variability for utilization efficiency of iron among the groundnut varieties (Hartzook et al., 1974).

4.3.7.2 Phosphorus effect. Iron content of different groundnut plant parts at various stages of growth decreased with the phosphorus application but the differences were not significant.

The decrease in iron content with increasing phosphorus levels were from 83.90 (P_1) to 60.08 (P_3) ppm at flowering stage and 77.65 (P_1) to 71.63 (P_3) ppm at pegging stage, while at harvesting stage, the reduction was from 64.29 (P_1) to 61.66 (P_3) ppm in haulm, 70.73 (P_1) to 66.28 (P_3) ppm in kernel and 74.97 (P_1) to 72.96 (P_3) ppm in shell. The depletion in iron content might be due to antagonism between phosphorus and iron. Such findings were reported by Faldu (1978) and Bhatol (1981).

4.3.7.3 <u>Potassium effect</u>. Iron content of haulm at flowering and pegging stages as well as different plant parts at harvesting stage did not differ significantly due to potassium application. Iron content at flowering stage increased from 60.33 to 64.78 ppm when potassium was added to soil, while it decreased from 75.43 to 74.23 ppm at pegging stage. At harvesting stage, potassium application (K_1) increased the iron content in haulm, kernel and shell. Aiyer (1948) reported a definite increase in the iron content of paddy straw in the absence of K.

4.3.7.4 <u>Interaction effect</u>. The effects of interactions between varieties, phosphorus and potassium levels on iron content of different parts of groundnut plant were found to be nonsignificant.

4.3.8 <u>Manganese content</u>

The data on manganese content of different parts of groundnut plant at various stages of growth as affected by different varieties, phosphorus and potassium levels are presented in Table 26.

Table 26. Manganese content in different plant parts of groundnut as influenced by phosphorus and potassium fertilisers and varieties (ppm on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus – P_1	51.52	49.83	30.43	16.90	42.23
P_2	54.05	51.52	31.25	17.74	42.23
P_3	55.74	56.59	32.67	18.58	43.07
S.Em. ±	2.109	1.906	1.612	1.761	1.502
C.D. 0.05	NS	5.492	NS	NS	NS
C.V. %	15.69	14.49	22.99	40.16	14.13
Potash – K_0	52.93	52.93	31.51	16.90	41.67
K_1	54.62	52.36	31.53	18.58	43.36
S.Em. ±	1.722	1.556	1.460	1.454	1.226
C.D. 0.05	ns	NS	NS	NS	NS
C.V. %	15.69	14.49	22.99	40.16	14.13
Variety – V_1	53.49	51.60	30.94	16.33	41.10
V_2	54.05	53.49	32.09	19.15	43.92
S.Em. ±	1.722	1.556	1.460	1.454	1.226
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	15.69	14.49	22.99	40.16	14.13

The average manganese content of above ground parts of groundnut at flowering and pegging stages were 53.77 and 52.64 ppm respectively, but it was greatly depressed to 31.52 ppm at harvesting stage. This indicates that the ratio between manganese absorption and growth of plant was more or less similar during vegetative growth period. The reduction in manganese concentration at harvesting stage might be due to translocation of the element to reproductive parts of the plant. The manganese content was more in shell (42.51 ppm) followed by haulm (31.52 ppm) and kernel (17.74 ppm). These results are in conformity with those reported by Walmsely and Baynes (1976).

4.3.8.1 Variety effect. The manganese content of haulm at flowering and pegging stages as well as different plant parts at harvesting stage were not significant in different varieties, however variety V_2 tended to contain higher manganese as compared to V_1 variety. The manganese content of variety V_2 was 54.05 ppm at flowering stage and 53.49 ppm at pegging stage, whereas at harvesting stage its content was 32.09 ppm in haulm, 19.15 ppm in kernel and 49.92 ppm in shell. Hallock et al. (1971) reported significant differences in manganese content of plant portions of groundnut cultivars in latter stages of growth.

4.3.8.2 Phosphorus effect. The manganese content was significantly increased by phosphorus application at pegging stage only, while at other growth stages itwas found to be nonsignificant. Manganese content at P_3 level was significantly higher than P_1 treatment, while P_1 and P_2 levels were at par as regards to manganese content at pegging stage. The manganese content was in the order of $P_3 > P_2 > P_1$ in all the plant parts at different stages of its growth. Bhatol (1981) reported nonsignificant differences in manganese content due to P application in groundnut.

4.3.8.3 Potassium effect. Manganese content of haulm at flowering and pegging stages as well as in different plant parts at harvesting stage were not significantly affected by potassium application. Manganese content increased from 31.51 to 31.53 ppm in haulm, 16.90 to 16.56 ppm in kernel and 41.67 to 43.36 ppm in shell due to K fertilization.

4.3.8.4 Interaction effect. All the first and second order interactions were found to be nonsignificant with respect to manganese content of different plant parts of groundnut at various growth stages.

4.3.9 Zinc content

The results of zinc content in various plant parts of groundnut varieties at different stages of growth, as affected by phosphorus and potassium fertilizers are presented in Table 27.

The average zinc content in haulm increased until the vegetative growth was in progress (upto pegging stage), but it decreased at maturity, probably due to translocation of

Table 27. Zinc content in different plant parts of groundnut as influenced by phosphorus and potassium fertilizers and varieties (ppm on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	24.86	27.61	20.06	22.53	11.20
P_2	23.55	27.32	19.92	21.66	10.77
P_3	22.39	26.16	19.33	21.66	10.63
S.Em. ±	0.320	0.364	0.419	0.331	0.304
C.D. 0.05	0.922	1.105	NS	NS	NS
C.V. %	5.43	5.66	6.47	6.04	11.21
Potash - K_0	23.35	27.13	19.67	21.90	10.77
K_1	23.64	26.93	19.67	22.00	10.96
S.Em. ±	0.261	0.313	0.342	0.270	0.249
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	5.43	5.66	6.47	6.04	11.21
Variety - V_1	23.65	26.84	19.46	21.61	10.96
V_2	23.55	27.22	20.01	22.29	10.77
S.Em. ±	0.264	0.313	0.342	0.270	0.249
C.D. 0.05	NS	NS	NS	NS	NS
C.V. %	5.43	5.66	6.47	6.04	11.21

zinc to reproductive parts, viz. the pod as observed by Chahal and Ahluwalia (1977). Shukla and Prasad (1979) found that zinc content in groundnut haulm decreased with the age of plant.

At harvesting stage, the zinc content of different parts of groundnut plant were in the order of kernel > haulm > shell. Similar trend was also reported by Walmsely and Baynes (1976) and Pachpute (1981).

4.3.9.1 Variety effect. The different varieties of groundnut did not differ significantly in zinc content at all the stages of growth. The zinc content in haulm at flowering, pegging and harvesting stages, as affected by varieties varied from 23.65 (V_1) to 23.55 (V_2) ppm, 26.64 (V_1) to 27.22 (V_2) ppm and 19.46 (V_1) to 20.01 (V_2) ppm respectively. Variety V_1 contained 21.61 and 10.96 ppm zinc while variety V_2 contained 22.29 and 10.77 ppm zinc in kernel and shell. Hallock *et al.* (1971) did not find significant differences in zinc content of different plant parts of peanut cultivars at maturity. Panchpute (1981) also reported that the T.G.-17 variety contained significantly higher zinc in haulm (16.70 ppm) and lower in kernel (20.30)ppm) and shell (11.10 ppm) as compared to varieties GAUG-1 and J-11.

4.3.9.2 Phosphorus effect. Phosphorus application had significant effect on zinc content at earlier stages of growth, i.e. at flowering and pegging, but at harvesting stage, they had nonsignificant effect on zinc content in haulm, kernel and shell. The data revealed that at flowering and pegging stages, P_3 contained significantly less zinc as compared to P_1 and P_2 levels of phosphorus. At harvesting stage, P_3 level contained less zinc 19.33, 21.66 and 10.63 ppm as compared to P_1 and P_2 levels of phosphorus in haulm, kernel and shell respectively. Many workers have reported that P immobilizes zinc and thereby reduces the content of zinc which is mainly due to formation of insoluble zinc phosphate (Brown <u>et al.</u>, 1970). Faldu (1976) and Bhatol (1981) have also reported decrease in zinc content in groundnut plant parts due to P fertilization.

4.3.9.3 <u>Potassium effect</u>. Zinc content of different groundnut plant parts at various growth stages were not significantly affected by potassium fertilizer. Zinc content was increased nonsignificantly by potassium fertilizer in all the plant parts at harvesting stage and flowering stage, while zinc content was decreased with K fertilization at pegging stage.

4.3.9.4 <u>Interaction effect</u>. All the first and second order interactions, viz. VP, VK, PK and VPK did not affect significantly zinc content of different parts of groundnut plant at various stages of growth.

4.3.10 <u>Copper content</u>

The data on copper content of groundnut plant parts at various stages of growth as affected by different varieties, phosphorus levels and potassium levels are presented in Table 28.

Table 28. [illegible] content in different plant parts of groundnut as influ[illegible] by phosphorus and potassium fertilisers and varieties (ppm on dry matter basis).

Treatment	Flowering stage (haulm)	Pegging stage (haulm)	Harvesting stage		
			Haulm	Kernel	Shell
Phosphorus - P_1	10.69	10.44	9.91	15.00	14.88
P_2	11.34	[illegible]	10.44	15.47	15.41
P_3	11.61	11.07	10.44	16.00	15.50
S.Em. ±	0.252	0.200	0.192	0.313	0.261
C.D. 0.05	NS	0.575	NS	NS	NS
C.V. %	8.92	7.53	7.50	8.09	7.37
Potash - K_0	11.67	10.95	10.65	15.55	15.60
K_1	10.89	10.29	9.86	15.43	14.92
S.Em. ±	0.205	0.163	0.157	0.256	0.229
C.D. 0.05	[illegible]	0.470	0.451	NS	0.661
C.V. %	[illegible]	7.53	7.50	8.09	7.37
Variety - V_1	11.13	10.53	9.64	14.23	13.52
V_2	11.43	10.71	10.69	16.75	16.99
S.Em. ±	0.205	0.163	0.157	0.256	0.229
C.D. 0.05	NS	[illegible]	0.451	0.736	0.661
C.V. %	8.92	7.53	7.50	8.09	7.37

The average copper content in haulm was found to decrease with the age of plant. The reduction in copper content was from 11.28 ppm at flowering stage to 10.62 ppm at pegging stage and further to 10.26 ppm at harvesting stage. Cox et al. (1970) and Walmsley and Baynes (1978) also pointed out that there was a decrease in the copper content of the groundnut foliage with the age of plant.

At harvesting stage, the copper contents of groundnut plant parts were in the order of kernel (15.49 ppm) > shell (15.26 ppm) > haulm (10.26 ppm).

4.3.10.1 Variety effect. The data presented in Table 28 showed that the differences in copper content at flowering and pegging stages were nonsignificant due to different varieties of groundnut. At harvesting stage, variety V_2 contained 10.69, 16.75 and 16.99 ppm copper in haulm, kernel and shell respectively which were significantly higher than those in respective plant parts of V_1 variety. Hallock et al. (1971) found higher copper content of virginia type of the Spanish and Valencia type peanuts.

4.3.10.2 Phosphorus effect. Copper content of different parts of groundnut plant at various growth stages were not significantly increased by the phosphorus fertilizer, except in haulm at pegging stage. Copper content (11.07 ppm) significantly increased at P_3 level over P_1 (10.44 ppm) and P_2 (10.35 ppm) level in haulm at pegging stage. Bhatol (1981) observed nonsignificant increase in copper content by phosphorus application.

4.3.10.3 Potassium effect. The data revealed that the copper contents of haulm at all the stages were significantly decreased by potassium (K_1) application and it was decreased from 11.67 to 10.69 ppm, 10.95 to 10.29 ppm and 10.65 to 9.86 ppm at flowering, pegging and harvesting stages respectively. At harvesting stage, copper content showed nonsignificant variation by potassium application in kernel. While in shell, copper content was significantly reduced from 15.60 to 14.92 ppm by potassium application over no application. Copper content decreased in all the groundnut plant parts at all the growth stages by potassium application.

4.3.10.4 Interaction effect. The interaction effect between VP, VK, PK and VPK were found to be nonsignificant on copper content of different plant parts except in kernel by VP interaction (Table 29).

Table 29. Interaction effect of VP on copper content in kernel at harvesting stage of groundnut (ppm).

V \ P	P_1	P_2	P_3
V_1	14.47	13.75	14.47
V_2	15.54	17.16	17.53

S.Em. ± 0.443 C.D. 0.05 1.274

A perusal of the data indicated that V_2P_3 combination contained significantly higher copper (17.53 ppm) in kernel as compared to rest of the combinations except V_2P_2 which contained 17.16 ppm copper. Copper content in kernel was significantly higher in V_2 variety than V_1 variety at P_2 and P_3 levels of phosphorus.

4.4 Uptake of major nutrients

Although, the percentage composition contributes greatly to the study of nutrient assimilation by plant, it is essential to determine total quantity of nutrient elements removed by the plant in order to know the nutritional needs of the crop which in turn provides the basis to work out the optimum fertilization rates. Hence, the total amount of major nutrients removed by the crop at harvesting stage under different treatments were worked out. The data are presented in Table 30.

4.4.1 Variety effect

Results pertaining to NPK uptake revealed that variety V_2 removed significantly more NPK as compared to variety V_1. The quantities of N, P_2O_5 and K_2O removed were 217.42, 79.12 and 119.17 kg/ha by variety V_2 and 193.96, 65.42 and 105.66 kg/ha by variety V_1 respectively. The differential uptake could be attributed to genetic variability in N fixation capacity as well as P and K utilization efficiency of a genotype. The variation in the yield potential

Table 30. Effect of phosphorus and potassium application on total uptake of NPK (kg/ha) by groundnut varieties.

Treatment	Nitrogen	Phosphorus (P_2O_5)	Potash (K_2O)
Phosphorus - P_1	193.91	69.19	112.96
P_2	213.41	75.20	116.12
P_3	209.75	72.42	108.20
S.Em. ±	5.055	2.023	3.276
C.D. 0.05	14.556	NS	NS
C.V. %	9.83	11.20	11.66
Potash - K_0	203.73	74.60	110.91
K_1	207.64	69.95	113.94
S.Em. ±	4.128	1.652	2.675
C.D. 0.05	NS	NS	NS
C.V. %	9.83	11.20	11.66
Variety - V_1	193.96	65.42	105.68
V_2	217.42	79.12	119.17
S.Em. ±	4.128	1.652	2.675
C.D. 0.05	11.665	4.757	7.702
C.V. %	9.83	11.20	11.66

and similar genotypic differences have also been reported by Panchpute (1961), while studying the NPK uptake behaviour of different cultivars of groundnut.

4.4.2 Phosphorus effect

The effect of phosphorus levels on total nitrogen uptake was significant. Whereas the phosphorus and potassium uptakes were not significantly influenced by various levels of phosphorus. The crop under phosphorus treatment P_2 removed maximum quantity of N (213.41 kg/ha), P_2O_5 (75.20 kg/ha) and K_2O (116.12 kg/ha). The higher uptake recorded under phosphorus level P_2 could be attributed to higher dry matter production under this treatment. Puntamkar and Bathkal (1967) reported increased uptake of both N and P due to phosphorus application. In the present investigation P uptake was not increased probably due to medium level of available soil phosphorus. The results with regards to effect of phosphorus application on the potassium uptake are in line with those reported by Bhatol (1961) under similar soil conditions.

4.4.3 Potassium effect

Potassium application did not produce significant effect on the uptake of N, P and K by groundnut crop. William and Weeks (1955) also reported that K fertilization did not affect P and K uptake of alfalfa. Though, results were nonsignificant, potash incorporation enhanced the uptake of N and K and depraved phosphorus u[illegible]. This might be due to decrease in the phosphorus content of different plant parts with K addition. These findings are in agreement with those reported by Puntamkar and Bathkal (1967).

4.4.4 Interaction effect

All the first and second order interactions were found to be nonsignificant with respect to total NPK uptake of groundnut at harv[illegible]e.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The present investigation was carried out on sandy loam soils of middle Gujarat at the College Agronomy Farm, Gujarat Agricultural University, Anand Campus, Anand to evaluate the effect of different levels of phosphorus in presence and absence of applied potash on yield, oil content and content of macro, secondary and micro-elements at various stages of plant growth as well as uptake of NPK at maturity by two groundnut varieties, J-11 and T.G.-17. The results obtained are summarized below.

5.1 Yield

The variety T.G.-17 (V_1) produced significantly higher pod yield (2206.32 kg/ha) than J-11 (V_2). Conversely, significantly greater haulm yield (8113.36 kg/ha) was obtained from V_2 than V_1. Neither the different levels of phosphorus nor the potash application produced significant effect on pod and haulm yields of groundnut.

5.2 Oil content and oil yield

Varietal differences in oil content were not significant, however, the total oil production under variety V_1 (793.93 kg/ha) was more than that under variety V_2 (639.21 kg/ha). Among different levels of phosphorus, P_3 recorded maximum oil content (50.36 per cent) which was significantly higher than that under P_1 and P_2 levels. The oil yield was not affected by different levels of P and K either alone or in combination.

5.3 Nutrients content

Nitrogen

The nitrogen content of vegetative parts of groundnut plant decreased with the advancement of plant growth. Variety V_1 contained significantly higher nitrogen at flowering and pegging stages in haulm as well as in the shell at maturity. While variety V_2 contained more nitrogen (4.45 per cent) in kernel at maturity stage. Application of phosphorus significantly increased the nitrogen content in different plant parts. Potash application significantly increased nitrogen content in haulm and kernel only at maturity.

Phosphorus

With the advancement of age, the phosphorus content decreased in the vegetative parts of plant. The phosphorus content was significantly more in V_2 at flowering and harvesting stages in case of haulm and kernel respectively as compared to V_1. With the increase in the phosphorus application at each level, there was significant increase in phosphorus content, while with the potash application it showed the reverse trend.

Potash

Potash content of haulm decreased as the growth advanced. Variety V_1 contained significantly more potash as compared to V_2 at all the growth stages in different plant parts except haulm at flowering stage. Phosphorus application at P_3 contained significantly more potash as compared to P_1 at flowering and pegging stages. At harvesting stage, haulm, kernel and shell contained significantly less potash under P_3 level as compared to P_1. Potassium fertilization increased potash content of all plant parts at various growth stages.

Calcium

The average calcium content of haulm increased with the age of the plant. Variety V_2 contained significantly more calcium in haulm at flowering (1.24 per cent), pegging (1.33 per cent) and maturity (1.46 per cent) stages. Similarly in shell of variety V_2 contained more Ca (0.55 per cent) than that of variety V_1. However, the trend was reverse in the case of kernel. Application of 150 kg P_2O_5/ha significantly decreased calcium content in haulm but potash application significantly increased calcium content in haulm at all the stages of growth. While reverse trend was obtained for calcium content in kernel and shell by P and K application.

Magnesium

The average magnesium content of haulm declined with the increase in plant growth. The magnesium content was significantly more in above ground plant parts of variety V_2 at flowering and harvesting stages, while V_1 variety contained significantly more magnesium in shell at maturity. Increase in phosphorus application increased the magnesium content while potash application decreased the content in all the plant parts at different growth stages.

Sulphur

The sulphur content of vegetative parts of groundnut plant declined gradually as the growth advanced. Varietal differences were nonsignificant for sulphur content at all the stages of growth except that in kernel at harvest. Phosphorus treatment P_3 significantly increased the sulphur content, while potash application could not produce significant effect on sulphur content of various plant parts during different periods of plant growth.

Iron

The mean iron content of vegetative parts of groundnut plant decreased from flowering to pegging stage, but it again increased at maturity stage. Genotype and different levels of phosphorus and potash application were found to be nonsignificant in their effect on iron content in various plant parts. However, phosphorus application tended to decrease iron content, while potash application tended to increase it in all the plant parts at various stages.

Manganese

The manganese content of vegetative parts of groundnut plant declined with the advancement of plant growth. Variety

V_2 contained higher manganese than V_1 in all the plant parts at different periods of growth. Application of P and K did not influence the manganese content in different parts of plant at various growth stages, but phosphorus at P_3 level produced significant effect on manganese content at pegging stage.

Zinc

The average zinc content of vegetative parts of groundnut plant increased from flowering to pegging stage and then it depressed at maturity stage. Varietal differences were found to be nonsignificant in zinc content. Phosphorus level P_3 significantly decreased zinc content, while potash application did not effect the zinc content of haulm at flowering and pegging stages. Application of P and K had nonsignificant effect on zinc content in different plant parts at maturity stage.

Copper

The average copper content decreased gradually as the growth advanced. Variety V_2 contained significantly higher copper than V_1 in different parts at maturity stage. Application of phosphorus at the rate of 150 kg P_2O_5/ha increased copper content in all the parts of groundnut plant, but was significant only at pegging stage. Application of potash significantly decreased copper content in all the parts of plant except in kernel.

5.4 Uptake of NPK

Variety V_2 removed significantly more NPK as compared to V_1. Nitrogen removal under P_2 treatment (213.41 kg/ha) was significantly higher than that (193.91 kg/ha) under P_1 level, whereas phosphorus and potash uptakes were nonsignificant. Potassium application did not produce significant effect on the uptake of NPK.

Conclusion

It can be concluded that the variety T.G.-17 (V_1) produced maximum (2206.32 kg/ha) pod yield and variety J-11 (V_2) produced maximum (6113.36 kg/ha) haulm yield. The oil content was more in J-11 (44.64 per cent) but the production of oil was more in T.G.-17 (793.93 kg/ha). Variety J-11 (V_2) removed significantly more amount of N (217.42 kg/ha), P_2O_5 (79.12 kg/ha) and K_2O (119.17 kg/ha) as compared to that by variety T.G.-17 (V_1).

The concentration of all nutrients in haulm, except Ca, Fe, Mn and Zn declined with the advancement of plant growth. At maturity, the nutrient elements N, P, S, Zn and Cu were concentrated in kernel, whereas Mn was more in shell.

Various levels of phosphorus application did not influence significantly pod and haulm yields as well as oil yield, but oil content was significantly increased with higher dose of phosphorus fertilisation. The uptake of N [illegible] maximum when phosphorus was applied at the rate of 100 kg P_2O_5[illegible]$_2$).

Application of potash did not affect significantly pod and haulm yields, oil content and oil yield as well as total uptake of NPK.

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