NUTRITIONAL REQUIREMENT OF THE SESAMUM VARIETY THILOTHAMA IN PARTIALLY SHADED UPLANDS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Nutritional requirement of the sesamum Var. Thilothama in partially shaded uplands" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Nutritional requirement of the Sesamum Var. Thilothama in partially shaded uplands" is a record of research work done independently by Smt. Girija devi, L. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Gingelly is one of the most ancient oil seed crops known to man. India occupies a prominent place in the oil seed map of the world with groundnut, rape seed, mustard and sesamum occupying the top ranking positions in acreage and production. Sesamum is an important edible oil seed crop cultivated extensively in India and stands next to groundnut in area. It also assumes importance as a source of protein and essential amino acids in human and livestock nutrition.

Research on sesamum appears to have been initiated only from the early twenties. Not much work on the agronomy of this crop seems to have been attempted in this country. A review of the research work on this crop revealed that only a fringe of the problems connected with its cultivation has been touched. The research works in most of the states have been confined only to evolving high yielding plant types by selection from the local or acclamatised varieties. As the sesamum crop is grown mostly as a catch crop in a number of states, it had not received the required attention.

The average productivity of the crop in Kerala is low (around 250 kg/ha) though the potential yields of this crop are estimated to be around 600-1000 kg/ha under dry land

and 1000-1200 kg/ha under irrigated conditions. The major constraints in the realisation of this high rate of production are considered to be low residual moisture level in the soil mainly leading to poor stand of the crop and the low soil fertility. By paying proper attention to agronomic practices it could be possible to step up the yields at least by about 5% if not more. Judicious thinning of the crop, systematic intercultivation and adequate manuring will increase the yield. As such, systematic trials on these aspects should be undertaken in the important sesamum growing tracts so that with in a few years, results of immediate value to the grower can be achieved and the present low level of yields can be stepped up.

Unless sesamum is adequately manured, its depressing effect on the succeeding crop is sure to be felt. Hence planned manurial-cum-rotational experiments have to be undertaken with a view to obviate such deleterious effect.

With this background the present investigation was undertaken to achieve the following broad objectives:

1. to study the nutritional requirements of sesamum var. Thilothama
2. to study the performance of the crop under partial shade.

3. to investigate the effect of fertilizer application on the yield and quality of produce.
4. to study the uptake of mineral nutrients under partial shade.
5. to study the economics of fertilizer application on sesamum production.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Experimental evidences on nitrogen, phosphorus and potash nutrition of sesamum are very meagre. However, the influence of these nutrients on the yield, oil content and protein content of other oil seed crops of the country has been studied well. A brief review of the work done in sesamum and related crops on the nutrition of these elements is presented hereunder.

Effect of applied nitrogen on plant growth

The effect of nitrogen on plant growth was studied by several workers.

Moursi et al (1966) reported that increased application of nitrogen resulted in increased dry matter production of leaves, stems and fruits in sesamum. Gopalakrishnan et al (1971) studied the nutrient uptake in sesamum and found that increasing fertilizer levels had a positive effect during early stages of crop growth, but fluctuations were noticed as the crop attained maturity. Bonsu (1977) pointed out that fertilizer nitrogen lowered plant height by 10% below the control in sesamum. Bonsu (1977) concluded that fertilizer nitrogen lowered shoot dry matter production in sesame. Rahman et al (1978) concluded that plant height increased with increased nitrogen application in sesame. Subramanian et al (1979) reported that nitrogen application increased the number of branches per plant in sesamum.

The dry matter production in mustard under irrigated conditions in a sandy loam soil low in nitrogen and poor in organic matter was not affected by nitrogen application (Maini et al, 1965). Nordestguard (1979) revealed that crude fat content in the dry matter declined from 33 to 30.4% and crude protein and chlorophyll increased in dry matter in the case of white mustard with the application of increased rates of nitrogen. Vir et al (1979) reported that in rainfed mustard, dry matter production increased upto 60 kg N/ha. Pal (1974) concluded that the dry matter production was maximum with 80 kg N/ha in sunflower.

Effect of applied nitrogen on yield attributes

Moursi et al (1966) pointed out that nitrogen application increased the number of fruits per plant in sesamum. Bonsu (1977) investigated the effect of fertilizer application on the growth, yield and yield components of sesame and found that fertilizer application did not significantly increase the number of podding nodes per plant, number of pods per plant nor the number of mature seeds per pod, though nitrogen tended to increase seed weight.

Rahman et al (1978) observed an increase in the number of heads with increased levels of nitrogen application in safflower and obtained maximum number of heads with the application of 40 kg nitrogen. According to Singh et al (1978) the number of pods per plant in mustard increased with increased levels of nitrogen application. Solanki et al (1979) studied the correlation and path-coefficient analysis in safflower and found that seed yield per plant was positively correlated with number of heads per plant.

Subramanian et al (1979) observed an increase in the number of capsules per plant in sesamum with increased levels of nitrogen application. Abdel Rahman et al (1980) studied the physiological response of sesame to nitrogen fertilizers and found that the highest number of effective capsules per plant was obtained with the application of 45 kg nitrogen.

Maity et al (1980) found that increased rates of nitrogen application resulted in an increased production of capsules per plant in mustard. According to Andhale and Kalbhor (1978), 1000 seed weight of sunflower increased with the increased application of nitrogen upto 75 kg/ha.

Effects of applied nitrogen on seed yield

Rai and Srivastava (1968) conducted manurial trials in sesamum in red loam soils and found that seed yield increased with nitrogen application and optimum level of nitrogen was found to be 22.5 kg/ha. Gaur and Trehan (1973) pointed out that under Rajasthan conditions highest yield was obtained with 30 kg N/ha applied half at sowing and the other half one month after sowing in the case of sesamum. Singh and Kaushal (1973) studied the effect of nitrogen on the yield of rainfed sesamum and found out that the yield of sesame seed increased with increase in the rate of nitrogen from 0 to 60 kg/ha. Gaur and Trehan (1973) pointed out that in sesamum, the seed yields were highest with 50 kg N/ha in Kharif season. Gowda (1974) reported that application of 40 kg N/ha gave the highest seed yields of 1.44 t/ha in sesamum crop. Singh and Kaushal (1975) studied the response of rainfed sesamum to fertilizer levels and found that application of 50 kg N/ha increased yields from 431 kg/ha to 617 kg/ha. Kasana and Chaudhary (1976) observed that seed yield increased with applied nitrogen and the optimum application rate was 20 kg N/ha in the case of groundnut crop. Popov et al (1976) reported that application of nitrogen at the two to three leaf stage of sesamum gave the highest average seed yields. According to

Choudhary (1977) pod yields of irrigated groundnut Cv. TMV-2 were higher with 20 kg N/ha than with 40 kg/ha. Gowda et al (1977) reported that application of 40 kg N/ha gave the highest seed yields in sesamum. Reddy (1977) pointed out that seed yields of the sunflower cultivars increased with increase in rates of applied nitrogen from 0 to 120 kg/ha. Aleshehenko (1978) pointed out that application of 60 kg N/ha along with phosphorus and potassium gave the highest average seed yields of 2.82 t/ha compared to 2.38 t/ha without fertilizer in the case of sunflower. Andhale and Kalbhor (1978) reported that yield components and seed yields of sunflower were increased with the increased application of nitrogen upto 75 kg/ha. Mehrotra et al (1978) studied the response of rainfed sesamum to nitrogen levels and found that average seed yields of sesame increased from 400-760 kg/ha with increase in rates of applied nitrogen from 0 to 30 kg/ha and further increase in yield with 45 kg N/ha was not significant.

Mukand Singh et al (1978) pointed out that average seed yields of raya varieties increased with the increased application of nitrogen. Nadgouda et al (1978) studied the response of groundnut to nitrogen in Bijapur district and found that application of 30 kg nitrogen alone or in combination with phosphorus and potassium increased pod yields by 28.8% and 39% compared to unfertilised controls. Salam et al (1978) reported that the response and productive efficiency of nitrogen decreased with increasing nitrogen rates in sunflower. According to Sanchez et al (1978), application of 20 kg nitrogen increased yields of pods of groundnut to 1.72 t/ha compared with 1.53 t/ha with no nitrogen, 1.67 t with 40 kg/ha nitrogen and 1.64 t/ha with 60 kg nitrogen.

Satyanarayana (1978) studied the effect of nitrogen on the yield of two gingelly varieties and found that highest seed yield was obtained with the application of 25 - 50 kg N/ha. Sennaiyan and Arunachalam (1978) studied the effect of nitrogen fertilizer on gingelly-TMV-3 grown under rainfed conditions in black loam soils and found that the seed yield was highest with 25 kg nitrogen. Singh et al (1979) observed an increase in seed yield with increased application of nitrogen in brown sarson. Arunachalam and Morachan (1979) found that application of 40 kg N/ha gave the highest average seed yield in safflower. Bhan (1979) reported that the yieldsof two mustard cultivars were greater with the increased application of nitrogen from 0 to 120 kg/ha. Bhosale et al (1979) studied the effect of graded levels of nitrogen on the yield of sunflower variety peredavik and found that average seed yields of sunflower increased from 0.73 to 1.26 t/ha with increase in rate of applied nitrogen from 0 to 50 kg/ha. However, further increase in yield with 78 kg N/ha was not significant. Bishnoi (1979) reported that average seed yields of raya increased from 1-1.7 to 1.37 - 2.32 t/ha by increasing the rates of nitrogen application from 30 to 90 kg/ha. Delgado et al (1979) pointed out that sesame responds positively to nitrogen. Appropriate rates are of the order of 200 kg urea/ha. Gangasran and Kinra (1979) studied the response of rai to nitrogen with and without phosphorus and potassium and found that seed yield increased with increased nitrogen application. Gowda et al (1979) indicated that the economical optimum nitrogen rate for sunflower hybrids was 60 kg/ha and further increase was not economical. Gowda and Gajanan (1979) made studies on the differential response of sunflower to nitrogen levels on red sandy loam soils and found that increasing rates of applied nitrogen from 0-90kg/ha increased seed yields of sunflower from 1.05 to 1.91 t/ha, further increases in nitrogen rates decreased yields. Kachapur (1979) reported that application of 40 kg nitrogen increased seed yields of niger. Kachapur et al (1979) observed an increase in the seed yield of niger from 225 kg to 405 kg/ha with the increased rate of application of nitrogen. Munoz (1979) studied the response of two species of rape to different levels of nitrogenous fertilizers and found that maximum yields were obtained with 200 units of nitrogen.

Sadanandan and Sasidhar (1979) studied the response of sesamum variety Kayamkulam-1 to fertilizer application and found that 30 kg nitrogen per ha was optimum for getting higher yield. Saran (1979) observed an increase in yield of rape with the increased application of nitrogen. Singh (1979) reported an yield increase in brown sarson with the increased application of nitrogen. Solanki et al (1979) found that the seed yield per plant in safflower was positively correlated with number of seeds per head, number ofheads per plant and 100 seed weight. Subramanian (1979) reported that application of 40, 60, 40 kg/ha of nitrogen, phosphoric acid and potash respectively increased seed yield of sunflower compared to no fertilizer application. According to Vir and Verma (1979) increasing the rates of nitrogen from 0 to 30 and 60 kg/ha increased the seed yield and yield components in mustard.

Studies conducted by Aulakh et al (1980) showed that the grain yield of both yellow mustard and white mustard increased with the increased level of application of nitrogen. Daulay and Singh (1980) indicated that seed yield of sunflower increased with the increased level of application of nitrogen. Maity et al (1980) found that application of 50 kg N/ha under rainfed conditions without irrigation significantly increased seed yields in mustard variety Varuna. Patel et al (1980) studied the response of mustard to different levels of nitrogen and found that mustard gave significantly higher seed yields with 50 kg applied N/ha than with 0-25 or 75 kg N/ha. Sheppard et al (1980) observed that rape responded to broadcast application of nitrogen with maximum seed yields at 100 kg N/ha independent of sowing date or banded fertilization. Yadava et al (1980) found that the seed yield per plant in 22 sesame cultivars was positively correlated with number of capsules, primary branches per plant and 1000 seed weight. Path Co-efficient analysis showed that capsules per plant, 1000 seed weight, number of days taken for 50% flowering and primary branches per plant had high direct effects on yield. Maiti (1981) reported that seed yields of 6 sesame cultivars were increased by increasing nitrogen rates from 0 to 80 - 120 kg/ha and yields were further increased by adding phosphorus and potassium along with nitrogen. The yields with nitrogen were increased due to an increase in the number of capsules per plant and the capsule size.

Effect of nitrogen on quality attributes

Oil content

Mitchell et al (1974) found that seed quality was significantly influenced by nitrogen application in the case of sesamum. Mitchell (1974) observed that increased nitrogen application reduced oil content of sesamum. Revenko (1977) observed that different combinations of nitrogen, phosphorus and potassium did not favour an increase in the oil content of sunflower. Vali et al (1978) studied the effect of different levels and methods of fertilizer application on rainfed groundnut and found that seed oil content was not affected by treatments. Highest profit per ha was obtained with application of 20 kg N/ha. Satyanarayana (1978) observed that oil yield of two sesamum cultivars were higher with the application of 25 kg N/ha. Bishnoi et al (1979) studied the oil yield and quality parameters of three raya varieties as influenced by nitrogen levels and found out that applied nitrogen decreased the oil content. Munoz (1979) observed an increase in the seed oil content of rape with the increased application of nitrogen. Singh et al (1979) studied the effect of nitrogen on oil content of brown sarson and found that oil content was increased by low rates of nitrogen but decreased by higher rates (48-60 kg N/ha).

Vir and Verma (1979) reported that increasing the rates of nitrogen from 0 to 30 kg and 60 kg/ha appɸied to mustard had no effect on seed oil contents. Aulakh et al (1980) studied the quality of mustard crops as influenced by nitrogen fertilizer and found that nitrogen had little effect on oil content of grain; but total oil production increased many fold.

Protein content

Bhuiya et al (1974) studied the effect of nitrogen on the protein content of groundnut grown in Brahmaputra - flood plain soil and found that nitrogen application increased the percentage of protein. Mitchell (1974) found that seed protein content was increased by increased nitrogen application. Mitchell et al (1974) studied the mineral composition and seed characteristic of sesame as affected by nitrogen nutrition and found that increased nitrogen application did affect seed quality significantly. Mitchell et al (1976) observed an increase in the concerntration of individual protein - amino acid with the increased level of application of nitrogen,in seed. Skalski (1978) reported that application of increased levels of nitrogen increased the protein content from 31.15 to 35.9% of the dry matter in white mustard. Diepenbrock (1979) studied the influence of nitrogen nutrition on qualitative characteristics of seeds of rape (*Brassica napus*) and found out that nitrogen fertilizer application decreased the lipid content during the main growth stages. Nitrogen nutrition significantly changed fatty acid composition only during the early stages of seed growth. At maturity, increased nitrogen application resulted in a trend towards higher contents of palmitic and linoleic acids but a lower oleic acid content. Aulakh et al (1980) indicated that protein content of mustard grain improved markedly with applied nitrogen.

Effect of nitrogen on the content and uptake of nutrients

Vir and Verma (1979) found that increasing the rates of nitrogen from 0 to 30 and 60 kg/ha to mustard increased seed nitrogen contents and uptake of total nitrogen. Aulakh *et al* (1980) noticed that nitrogen fertilizer significantly increased the concentration and uptake of nitrogen in mustard crop. Bhati and Rathor (1982) studied the response of Indian mustard to nitrogen fertilization and found that seed yield and uptake with 60 kg N/ha were higher than with 20-40 kg/ha. Bishnoi and Singh (1982) studied the effect of nitrogen levels on the nitrogen, phosphorus and potassium uptake of raya and observed that applied nitrogen increased the nitrogen and phosphorus contents and their uptake.

Reddy and Narayanan (1983) studied the concerntration of nitrogen in plant parts of sesame cultivars and observed that nutrient concentration in all vegetative plant parts increased until six weeks after sowing followed by a gradual decline towards maturity. Remobilisation of nitrogen occurred from leaf, stem and root to the pods during the reproductive phase. The nutrient concentration in the leaves were higher than the reported critical concentration throughout the growth period, indicating that nutrient status of the crop was more than sufficient. Reddy et al (1983) found that nitrogen uptake of groundnut crop was maximum with the application of 10 kg nitrogen applied as basal dressing and remaining 20 kg nitrogen applied 30 days after sowing.

Effect of applied phosphorus on plant growth

Ramirez et al (1975) found that placement of phosphorus increased plant height in sesamum. Rahman et al (1978) observed that plant height increased with the increased levels of phosphorus in safflower. Sirry et al (1979) studied the effect of phosphorus fertilizer on the growth and nutrient content of sesame plant and found that increased rate of phosphorus application increased height of plants in sesamum. Rahman et al (1978) reported that number of branches per plant in safflower increased with the increased level of application of phosphorus. The dry matter production in mustard under irrigated conditions in a sandy loam soil, low in nitrogen and poor in organic matter was not affected by phosphorus application in combination with nitrogen and potash (Maini et al, 1965). Moursi et al (1966) studied the growth and chemical composition of sesame in sand culture with different concentrations of phosphorus in nutrient solution and found that increasing level of phosphorus increased the dry matter of leaves, stems and fruits. Gopalakrishnan et al (1971) studied the nutrient uptake in sesamum and found that fertilizer levels had a positive effect on dry matter during early stages of crop growth, but fluctuations were noticed as the crop attained maturity. Pal (1979) noticed that dry matter production was highest with 80 kg P_2O_5 in sunflower. Vir and Verma (1979) observed that application of phosphorus at the rate of 30 kg/ha increased the dry matter production in rainfed mustard.

Effect of phosphorus on yield attributes

Bonsu (1977) investigated the effect of fertilizer application on the growth, yield and yield components of sesame and found that fertilizer application did not significantly increase the number of podding nodes per plant, number of pods per plant nor the number of seeds per pod. Rahman et al (1978) found that number of heads in safflower increased with increased level of application of phosphorus and obtained maximum number of heads with the application of 30 lb P_2O_5/ha. Solanki et al (1979) studied the correlation and path coefficient analysis in safflower and found that seed yield per plant was positively correlated with number of heads per plant.

Effect of applied phosphorus on seed yield

Rai and Srivastawa (1968) made manurial trials in sesamum on red loam soils and found that there was not much response to phosphorus application with respect to seed yield. Gaur and Trehan (1974) pointed out that the seed yields were highest with 50 kg P_2O_5/ha in kharif season in case of sesamum. Gowda (1974) found that application of 20 kg P_2O_5/ha gave the highest seed yields of 1.44 t/ha in sesamum. Singh and Kaushal (1975) studied the response of rainfed sesamum to fertilizer levels and found that application of 50 kg P_2O_5/ha along with nitrogen increased yields from 431 kg/ha to 617 kg/ha. Popov et al (1976) observed that application of phosphorus along with nitrogen at the two to three leaf stage of sesamum gave the highest average seed yields. According to Choudhary (1977), pod yields of irrigated groundnut Cv. TMV-2 were higher with 60 kg P_2O_5/ha than with 30 kg P_2O_5. Application of 20 kg P_2O_5/ha along with nitrogen and potash gave highest seed yields in sesamum (Gowda et al 1977). Mishra (1977) studied the response of groundnut varieties to various levels of phosphorus and found that highest pod yield was obtained with the application of kg/ha. Aleshehenko (1978) found that application of 60 kg phosphorus gave the highest average seed yields of 2.82 t/ha in sesamum. According to Nadgouda et al (1978) groundnut crop showed little response to applied phosphorus. Sanchez et al (1978) found that application of phosphorus in groundnut increased pod yields from 0.75 t with no phosphorus to 2.7 t with 150 kg P_2O_5 and 2 t with 200 kg. Sennaiyan and Arunachalam pointed out that application of 25 kg P_2O_5 to gingelly TMV-3 gave the highest seed yield. According to Arunachalam and Morachan(1979) sunflower crop showed no response to the application of 20-40 kg P_2O_5. Shosale et al (1979) reported that application of 0-7 kg P_2O_5/ha gave yields 1.04 t - 1.08 t/ha. Gangasaran and Kinra (1979) pointed out that application of phosphorus along with nitrogen and potassium was profitable in the case of rai(*Brassica juncea*). According to Gowda et al (1970) the economical optimum rate of phosphorus was 60 kg P_2O_5/ha which gave a yield of 1.63 t/ha and further increases in fertilizer were not economical in the case of sunflower hybrids. Average seed yield of niger was found to increase with the application of phosphorus at the rate of 40 kg P_2O_5/ha (Kachapur, 1979). Kachapur et al (1979) reported that seed yield of 405 kg/ha was obtained with 60 kg P_2O_5 in niger compared to 225 kg without fertilizer. Munoz (1979) studied the response of two species of rape to different levels of phosphorus fertilizer and found that maximum yields were obtained with 100 units of posphorus per hectare.

According to Sadanandan and Sasidhar (1979) the seed yields of sesamum variety Kayamkulam-I grown in the red loam soils were not significantly affected by the application of phosphorus at the rate of 0-55 kg/ha.

Subramanian (1979) reported that application of phosphorus at the rate of 60 kg P_2O_5/ha increased seed yield of sunflower. Patel et al (1980) found that mustard gave significantly higher seed yields with 50 kg P_2O_5/ha than with 0-25 or 75 kg P_2O_5/ha.

Maiti (1981) pointed out that seed yields of six sesame cultivars were increased by the application of phosphorus at the rate of 40 kg P_2O_5/ha.

Shelke and Khuspe (1981) studied the phosphorus - yield relationship in summer groundnut and found that the response of summer groundnut to applied phosphorus was quadratic and was expressed by Y (predicted pod yield)= $23.28 + 8.5\,p - 4.00\,p^2$. Maximum predicted yield was 2.78 t/ha with 18.55 kg P_2O_5/ha.

Effect of phosphorus on quality attributes

Oil content

Bhuiya et al (1974) studied the effect of phosphorus on the oil content of groundnut grown in Brahmaputra flood - plain soil and found that phosphorus application increased percentage of oil. Mitchell (1974) found that phosphorus had no effect on oil content in sesamum. According to Mitchell et al (1974) phosphorus had no effect on the seed quality of sesamum. Mishra (1977) studied the response of groundnut to various levels of phosphorus and found that by the application of 90 kg P_2O_5/ha, seed oil content can be increased. Revenko (1977) noticed that different combinations of phosphorus, nitrogen and potassium did not favour an increase in the oil content of sunflower. Vali et al (1978) studied the effect of different levels and methods of fertilizer application on rainfed groundnut and found that seed oil content was not affected by treatments. Highest profit per ha was obtained with application of 40 kg P_2O_5/ha. Munoz (1979) observed that phosphorus application had no effect on the oil content of rape.

Protein content

Bhuiya et al (1974) studied the effect of phosphorus on the protein content of groundnut grown in the Brahmaputra flood plain soil and found that phosphorus application increased the percentage of protein. According to Mitchell et al (1974), phosphorus had no effect on the seed quality of sesame. Based on the studies conducted by Mitchell et al (1976) on the protein and free amino acid composition of sesame meal, it was found that phosphorus nutrition did not affect amino acid composition.

Effect of phosphorus on the content and uptake of nutrients

Vir and Verma (1979) studied the effect of phosphorus fertilization on nitrogen and phosphorus content and their uptake in rainfed mustard and found that application of P_2O_5 at the rate of 30 kg/ha increased seed phosphorus content and uptake of nitrogen and phosphorus in seed and recovery of the applied phosphorus. Joao et al (1981) found that the highest rate of application of phosphorus significantly increase phosphorus content of the seeds.

Effect of applied potash on plant growth

Rahman et al (1978) in a field trial in safflower found that plant height increased with increased potash application. Satyanarayana et al (1978) observed that the height of plants was not affected by the application of 30 and 60 kg K_2O/ha in two sesamum varieties C 1036 and T 12 in sandy loam soil under irrigated conditions. Rao (1979) found that the number of branches was not influenced by applied potash in irrigated groundnut TMV-2. The dry matter production in mustard under irrigated conditions in a sandy loam soil low in nitrogen and poor in organic matter was not affected by potash application alone or in combination with nitrogen and phosphorus (Maini et al, 1965). Positive effect between dry matter production and increasing levels of potash fertilizers was obtained by Gopalakrishnan et al (1971) in TMV-3 sesamum during the early stages of crop growth, but fluctuations were noticed as the crop attained maturity. Rao (1979) observed increase in dry matter production with higher levels of potash in irrigated groundnut TMV-2.

Effect of applied potash on the yield attributes

Satyanarayana (1978) reported that potash application failed to produce any effect on the number of capsules per plant in unirrigated sesamum varieties, C 1036 and T12. Also the correlation worked out between number of capsules per plant and yield did not give any significant relation with seed yield. Rao (1979) observed that number of capsules per plant increased with higher levels of potash in groundnut. Satyanarayana (1978) has shown that 1000 grain weight was not influenced by potash application in sesamum. The correlation coefficient between test weight and seed yield showed no relation in his study. Rao (1979) reported increase in test weight of groundnut, TMV-2 with higher levels of applied potash.

Effect of applied potash on seed yield

Eventhough the level of potash in the soil was very low, Brady and Colewell (1945) could not get any yield increase in peanuts due to application of potash.

Singh et al (1960) could not get any effect on the yield of sesamum by applied potassium.

Application of potash alone or in combination with nitrogen or phosphorus failed to give any effect on grain yield of mustard in a sandy loam soil poor in nitrogen or organic matter (Maini et al 1965).

Menon and Unnithan (1965) got highly significant and consistent increase in yield during three seasons in sesamum variety, Onattukara local due to potash application in the sandy loam soils of Kayamkulam which was very low in available potassium. It was found that addition of potash alone at 15 to 30 lb/ac had given an increased yield of 20.93 kg and 37.82 kg/ac respectively over no manure. Gopalakrishnan et al (1971) obtained 16.3% higher yield in sesamum bythe lowest fertilizer level over no fertilizer, but further increase of fertilizer tended to decrease the yield. Sivappa and Raj (1971) observed a decrease in seed yield per plant from 102.05 g to 82.75 g when potash was increased from 0 to 30 kg K_2O/ha in TMV-3 sesamum under irrigated conditions in red sandy loam of Coimbatore. They attributed the reason to fairly good availability of potash in the soil. A slight increase, in yield due to potash applicatio was observed by Gupta and Das (1973) in rape seed. In Jabalpur, yield of sesamum was decreased by the application of 25 kg K_2O/ha (Singh and Kaushal, 1975). In another study by Mitchell et al (1976) significant increase in seed yield was obtained by increasing the supply of nitrogen, phosphorus or potassium to sesamum. In a spacing cum fertilizer response study with TMV-3 sesamum during 1972-73 under rainfed conditions, fertilizer application failed to produce any response to yield (Arunachalam and Sennaiyan, 1977). Gowda and Krishnamurthy (1977) got slight increase in yield due to applied potassium in variety_ spacing-cum-fertilizer trial. Satyanarayana (1978) in a fertilizer cum varietal trial with C 1036 and T-12 sesamum in the sandy loam soils of Tirupati under irrigated conditions obtained increased seed and oil yield with increase in applied potassium at lower levels of nitrogen and spacing.

In another study by Rao (1979), application of 40 and 80 kg K_2O/ha to groundnut TMV-2 gave 19.3% and 24.9% increased yield over control.

Sadanandan and Sasidhar (1979) in a fertilizer study with sesamum variety Kayamkulam-1 in the red loam soils of Vellayani observed that application of 0-45 kg K_2O/ha did not affect the seed yields.

<u>Effect of applied potash on quality attributes</u>

<u>Oil content</u>

Brady and Colwell (1945) reported that the oil content of large seeded type peanut was not affected by potash application. Singh <u>et al</u> (1960) found that the seed oil content of sesamum variety Agra local was improved by applied potassium. Maini <u>et al</u> (1965) reported that oil content of mustard was not affected by potash application. In another study by Gupta and Das (1973) the oil content of rape seed was not found to be affected by applied potash. Application of potash at 44.8 kg/ha increased the oil content over no potash and the response was found to be greater in the presence of phosphorus in groundnut grown in the flood plain soils of Bangladesh (Bhuiya and Choudhary, 1974). Increased levels of potash tended to reduce the oil content of sesamum in a pot culture study (Mitchell et al 1974). Gupta and Friend (1975) obtained increased oil content in white mustard with higher levels of potash in a pot culture study. Stoyanova et al (1975) obtained increased oil content due to applied potassium in sunflower seeds. Revenko (1977) noticed that different combinations of nitrogen, phosphorus and potassium did not favour an increase in the oil content of sunflower.

Protein content

Quilantan - Villareal (1969) observed a decrease in protein content by potash application in sesamum. Similar results were obtained by Bhuiya and Choudhary (1974) in groundnut. The protein content was found to decrease when the applied potassium was increased from zero to 44.8 kg/ha in this study. Mitchell et (1974) in a sand culture study observed an increase in protein content coupled with a decrease in oil content due to applied potash in sesamum. From a similar study with sesamum the same authors in 1976 concluded that application of potash increased the individual protein amino acids in the seed meal of sesamum due to increase in protein concentration. Potash deficiency resulted in the accumulation of free amino acids coupled with a decrease in protein content suggesting potash is required for the proper utilisation of amino acids in protein synthesis.

Effect of applied potash on the content and uptake of nutrients

Habeebullah et al (1977) from a pot culture study in red and alluvial soils demonstrated that the nitrogen content of haulm was increased and that of kernel was decreased when potash was applied between 0 and 100 kg/ha in sesamum. However, the results were not statistically significant, but the highest level of potassium increased the nitrogen content of haulm. Hebeebullah et al (1977) based on a pot culture study reported that potash application recorded higher phosphorus content in haulm and kernel in sesamum when applied at 0,50,100 and 150 kg/h The uptake of nitrogen was found to be increased with applied potash at 0,40,80 kg K_2O/ha in irrigated groundnut, variety TMV-2 (Rao, 1979). The uptake of phosphorus in irrigated groundnut var. TMV-2 was found to be enhanced when potash was applied at 0,40 and 80 kg K_2O/ha during rabi 1977-78 and kharif 1978 (Rao, 1979). Rao (1979) also reported increased uptake of potash in irrigated groundnut variety TMV-2 under the influence of potash. Reddy and Narayanan (1983) studied the concerntration of potash in plant parts of sesamum and found that the nutrient concentration in all vegetative plant parts increased until 6 weeks after sowing followed by a gradual decline towards maturity. Remobilisation of nutrients occurred from leaf, stem and root to the pods during the reproductive phase. The nutrient concentration in the leaves were higher than the reported critical concentration throughout the growth period, indicating that the nutrient status of the crop was more than sufficient. Reddy _et al_ (1983) indicated that uptake of potash in groundnut was maximum when it was applied basally at the rate of 40 kg/ha in 1980 and 25 kg/ha in the year 1981.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken with the objective of studying the nutritional requirement of sesamum var. Thilothama under conditions of partial shade and also to investigate the effect of nitrogen, phosphorus and potash on the growth, yield, quality, chemical composition and uptake of mineral nutrients.

1. Materials

1.1. Experimental site: The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani. The College is located at 8°N latitude and at an altitude of 29M above mean sea level.

1.2. Soil: The soil of the experimental area is red loam with the following physico - chemical properties. Data on the analysis of the soil before starting the experiment are given below.

A. Mechanical composition

Coarse sand	(%)	..	13.70
Fine sand	(%)	..	33.40
Silt	(%)	..	28.00
Clay	(%)	..	24.90

B. Chemical composition

p^H	.. 5.3
Total Nitrogen	.. 0.077%
Available P_2O_5	.. 43.49 kg/ha
Available K_2O	.. 40.00 kg/ha

1.3. Cropping history of the field

The experimental area was lying fallow for three months prior to the present investigation and before that it was under a bulk crop of Guinea grass.

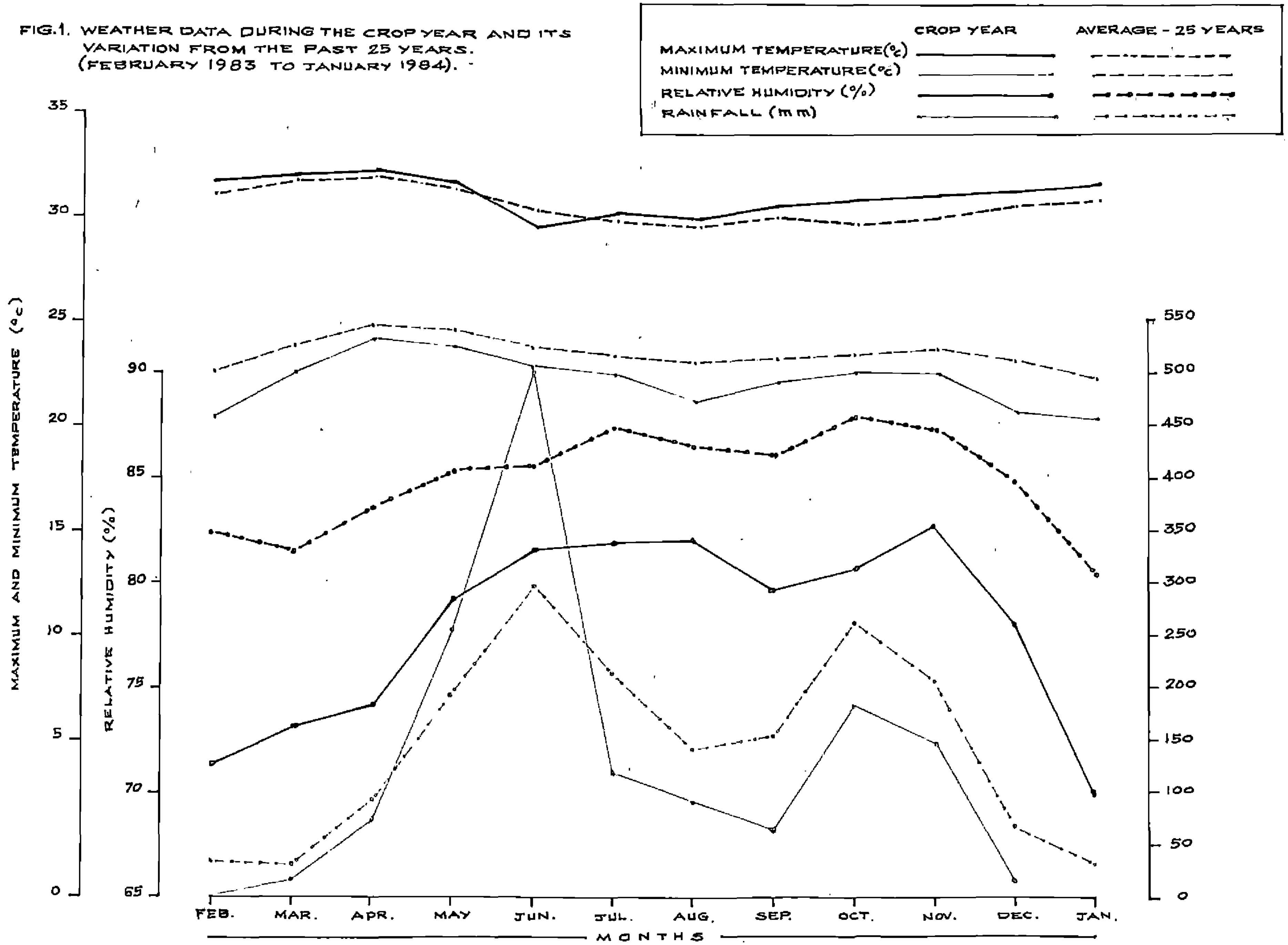
1.4. Season: The experiment was conducted during kharif season of the year 1982-83.

1.5. Weather conditions: Data on maximum temperature, rainfall and relative humidity during the entire crop season were collected from the meteorological observatory of the Instructional Farm and presented as weekly averages in Appendix I and in Fig. I.

In general the weather conditions were favourable for the satisfactory growth of the crop.

1.6. Variety: The variety used for the study was Thilothama. It is a cross between PT-58-35 and Kayamkulam-I. This variety matures in about 75-80 days. The average yield is about 250-300 kg/ha. The seeds were obtained from the Rice Research Station, Kayamkulam.

FIG.1. WEATHER DATA DURING THE CROP YEAR AND ITS VARIATION FROM THE PAST 25 YEARS. (FEBRUARY 1983 TO JANUARY 1984).



1.7. Fertilizers: Fertilizers with the following analysis were used for the experiment.

Urea	.. 46 percent N
Super phosphate	.. 16 percent P_2O_5
Muriate of potash	.. 60 percent K_2O

2. Methods

2.1. Details of treatments

The treatments consisted of factorial combinations of three levels of Nitrogen, three levels of phosphorus and three levels of potash.

Levels of nitrogen

n_0 - 0 kg N/ha

n_1 - 20 kg N/ha

n_2 - 40 kg N/ha

Levels of phosphorus

p_0 - 0 kg P_2O_5/ha

p_1 - 15 kg P_2O_5/ha

p_2 - 30 kg P_2O_5/ha

Levels of potash

k_0 - 0 kg K_2O/ha

k_1 - 20 kg K_2O/ha

k_2 - 40 kg K_2O/ha

2.2. Design and layout

The experiment was laid out in a 3^3 factorial design

FIG. 1. WEATHER DATA DURING THE CROP YEAR AND ITS VARIATION FROM THE PAST 25 YEARS. (FEBRUARY 1983 TO JANUARY 1984).

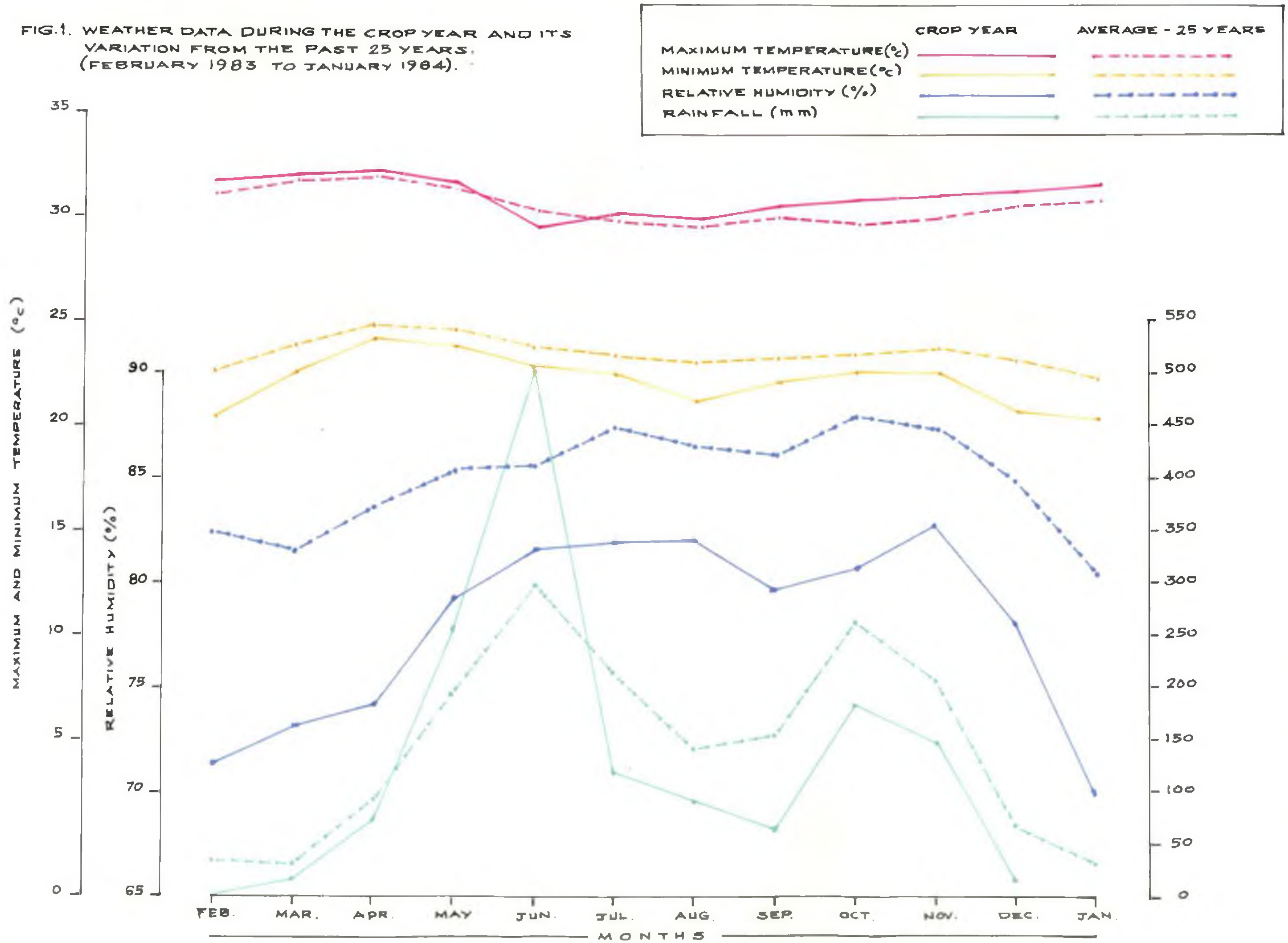


FIG. 2. LAY-OUT PLAN. CONFOUNDED FACTORIAL EXPERIMENT.

N

Replication										Block
REPLICATION - I	$n_0p_2k_1$	$n_0p_0k_0$	$n_2p_0k_1$	$n_2p_1k_0$	$n_1p_1k_1$	$n_1p_0k_2$	$n_2p_2k_2$	$n_1p_2k_0$	$n_0p_1k_2$	BLOCK 1·1
	$n_0p_2k_2$	$n_2p_0k_2$	$n_1p_2k_1$	$n_2p_2k_0$	$n_2p_1k_1$	$n_0p_0k_1$	$n_0p_1k_0$	$n_1p_1k_2$	$n_1p_0k_0$	BLOCK 1·2
	$n_2p_2k_1$	$n_1p_1k_0$	$n_0p_2k_0$	$n_2p_1k_2$	$n_1p_2k_2$	$n_0p_1k_1$	$n_1p_0k_1$	$n_0p_0k_2$	$n_2p_0k_0$	BLOCK 1·3
REPLICATION - II	$n_1p_2k_2$	$n_2p_1k_1$	$n_0p_0k_0$	$n_2p_0k_2$	$n_0p_1k_2$	$n_1p_0k_1$	$n_1p_1k_0$	$n_0p_2k_1$	$n_2p_2k_0$	BLOCK 2·1
	$n_0p_1k_1$	$n_2p_0k_1$	$n_1p_0k_0$	$n_1p_2k_1$	$n_0p_2k_0$	$n_0p_0k_2$	$n_2p_1k_0$	$n_1p_1k_2$	$n_2p_2k_2$	BLOCK 2·2
	$n_0p_1k_0$	$n_2p_0k_0$	$n_1p_2k_0$	$n_1p_0k_2$	$n_1p_1k_1$	$n_0p_0k_1$	$n_2p_1k_2$	$n_2p_2k_1$	$n_0p_2k_2$	BLOCK 2·3

NET PLOT SIZE - 2·6 X 4·6 M. GROSS SIZE OF PLOT 3X5 M.

TREATMENTS.

LEVELS OF NITROGEN	LEVELS OF PHOSPHORUS	LEVELS OF POTASSIUM
n_0 - 0 kg N/ha.	p_1 - 0 kg P_2O_5/ha	k_1 - 0 kg K_2O/ha
n_1 - 20 " "	p_2 - 15 " " "	k_2 - 20 " "
n_2 - 40 " "	p_3 - 30 " " "	k_3 - 40 " "

with two replications. The crop was raised in shade under the fully grown coconut garden. The higher order interaction NPK and NP^2K^2 were partially confounded in replication I and II respectively. The allocation of various treatments to different plots was done using random numbers. The layout plan is shown in Fig.2. The details of layout are furnished below.

Gross plot size	.. 5 x 3 M
Spacing	.. 20 x 20 cm
Border rows	.. 2
Net plot size	.. 4.6 x 2.6 M
Total number of plots	.. 54
Number of blocks per-replication	.. 3
Replications	.. 2

For chemical analysis studies, one row was selected after leaving two border rows on the three metre side and again one border row was left in the inner side. Two plants were left in the sampling row as border for subsequent sample collection.

2.3. Field culture

2.3.1. Preparation of main field

The experimental plot was dug twice, stubbles removed, clods broken and the field was laid out into blocks and plots.

2.3.2. Fertilizer application

The treatments were arranged in the plots according to random numbers. Fertilizer applications were made as per the various treatments. Nitrogen as urea, phosphorus as superphosphate and potash as muriate of potash were applied to different plots in appropriate quantities according to the treatment schedule. Basal dose was applied one day prior to sowing and top dressing was done 35 days after sowing.

2.3.3. Seeds and sowing

The seeds were dibbled in lines at a spacing of 20 x 20 cm.

2.3.4. After cultivation

Thinning and intercultural operations were done 15 days after sowing. The second interculture and weeding were done 25 days after sowing.

2.3.5. Plant protection

BHC 10% was applied to control the leaf and pod caterpillar during the flowering period.

2.3.6. Harvesting

The crop was ready for harvest in 81 days after sowing. Harvesting was done by pulling out the plants. Then the root portion was cut and the plants were bundled and stacked for 3 to 5 days. Later the bundles were spread in the sun and beaten with sticks to break the capsules. Drying and threshing were continued for three days more.

3. Observations recorded

The following observations were recorded.

3.1. Growth characters

1. Height of plants
2. Number of leaves per plant
3. Number of branches/plant and time of branching.
4. Number of nodes/plant
5. Leaf Area Index
6. Dry matter production.

3.2. Yield and yield components

1. Time of flowering
2. Number of capsules/plant
3. Weight of capsules/plant
4. Percentage of capsule set
5. Number of seeds/capsule
6. Seed weight/plant
7. 1000 seed weight
8. Seed yield
9. Haulm yield
10. Shelling percentage
11. Harvest Index.

3.3. Chemical Analysis

3.3.1. Quality characteristics

1. Protein content of seeds
2. Oil content
3. Oil yield.

3.4. Plant Analysis

Plant components were analysed for the nutrients on 30th day after sowing (flowering), 60th day (cessation of flowering) and at harvest.

3.4.1. Nitrogen content in different components

i. Percentage of nitrogen in seeds
ii. Percentage of nitrogen in haulm

3.4.2. Phosphorus content in different components

i. Percentage of phosphorus in seeds
ii. Percentage of phosphorus in haulm

3.4.3. Potash content in different components

i. Percentage of potash in seeds
ii. Percentage of potash in haulm

3.4.4. Uptake of nitrogen by different components

i. Uptake of nitrogen by seeds
ii. Uptake of nitrogen by haulm
iii. Total uptake of nitrogen by the plant.

3.4.5. Uptake of phosphorus by different components

i. Uptake of phosphorus by seeds
ii. Uptake of phosphorus by haulm
iii. Total uptake of phosphorus by the plant.

4. Sampling procedure

Observations on the growth characters like height, number of branches, number of pods per plant etc. were taken from 12 plants from each plot at flowering (30th day), at cessation of flowering (60th day) and at harvest. Twelve rows were selected at random after eleminating the border rows and one plant from each row was selected at random asthe observational plant. For chemical analysis studies five plants were uprooted at a stretch from the 3rd row after eliminating two border rows from the three metre long side of the plots. These plants were used for determining the dry matter production and for chemical analusis at flowering and at cessation of flowering. At harvest, five out of the twelve observational plants were used for dry matter estimation and chemical analysis.

5. Details of observation

5.1. Height of plants

Twelve plants from each plot were selected at random and tagged. The height of the plants from the ground level to the growing tip was measured in centimetres and the average height per plant was worked out and recorded. Observations were recorded on the same plants at the three growth stages, namely 30th day, 60th day and at harvest.

5.2. Number of leaves

The number of leaves of the observational plants were recorded at 30th day, 60th day and at harvest, and the average number of leaves per plant was then worked out and recorded.

5.3. Number of branches

The number of primary branches seen on each of the twelve observational plants were counted and the average number per plant was worked out and recorded.

5.4. Number of nodes

The number of nodes seen on each of the twelve observational plants were counted and the average number per plant was worked out and recorded.

5.5. Number of pods per plant

Number of pods per plant was recorded at harvest on the sample plants and the average was worked out.

5.6. Number of days taken for flowering

The number of days taken for flowering was observed and recorded for all the observational plants and the average number of days taken for flowering was then calculated and recorded.

5.7. Total dry weight of plants

Five sample plants uprooted at 30th and 60th day after sowing were used for the determination of dry weight.

At harvest, the observational plants were used for the dry weight estimation. The samples were dried in a hot air oven at a temperature of 70°C for three days and then dry weights were recorded. At harvest, pods were separated from the plants. The pods were also separated into seed and shell after drying and their air dry and oven dry weights were determined separately. For calculating the total dry weight at harvest, the weight of pods was added to the weight of stem and leaves.

5.8. Dry weight of seeds

At harvest, pods from the sample plants were collected and they were separated into seeds and shell after drying and the dry weight recorded.

5.9. Dry weight of stover

This was recorded from the dry weight of the sample plants after separating the seeds at harvest.

5.10. Weight of capsules/plant

Total dry weight of capsules produced by the five observational plants was recorded and the mean weight per plant calculated.

5.11. Number of capsules per plant

Total number of capsules produced by the five observational plants at harvest was counted and the average worked out.

5.12. Number of seeds/capsule

Total number of seeds in each capsule was counted and the average per capsule worked out.

5.13. Seed weight/plant

Seeds from five sample plants of each plot were separated and the dry weight recorded after oven drying at 70 ± 10°C till a constant weight was obtained. From this average seed weight per plant was worked out.

5.14. 1000 grain weight

From the produce obtained from the ten observational plants, 200 seeds were counted and their weights recorded after oven drying. Test weight was expressed as 1000 seed weight in grams.

5.15. Seed yield

Crop was harvested from the net plots, threshed, winnowed and cleaned. Grains were sundried and weight recorded. Yield was estimated in kg/ha. The yield of observational plants was also added to the net plot yield.

5.16. Haulm yield

Air dry weight of the plants from the net plots after separating the seeds was recorded. Air dry weight of haulm of the observational plants was also added to the net plot weight to get the haulm yield. Haulm yield was estimated in kg/ha.

5.17. Shelling percentage

Shelling percentage was calculated from the dry weight of grain and dry weight of pods of the observational plants as follows.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds} \times 100}{\text{Dry weight of pods}}$$

5.18. Harvest Index

Harvest Index was calculated as follows

$$\text{Harvest Index} = \frac{\text{Y econ}}{\text{Y biol}}$$ where

Y econ = Dry weight of grains

Y biol = Total dry weight of plants (excluding roots)

The five observational plants selected for chemical analysis at harvest were used for calculating the harvest index.

6. Chemical analysis

Plant samples collected for recording dry weight at 30th day and 60th day of sowing were used for chemical analysis studies. At harvest, the observational plants were used for chemical analysis. At harvest, the sample plants were separated into seeds and haulm and analysed separately. The different components were oven dried to constant weight and powdered for the estimation of total nitrogen, total phosphorus and total potash contents.

6.1. Total Nitrogen content

Total nitrogen was estimated by modified micro-kjeldahl method as given by Jackson (1967)

6.2. Uptake of nitrogen

This was calculated from the nitrogen content of the plant and the total dry weight of the sample plants for the three stages of growth. At harvest, the uptake by the haulm and grains were added to get the total uptake. The uptake values were presented in kg/ha.

6.3. Total phosphorus content

Phosphorus content was estimated colorimetrically (Jackson, 1967) after wet digestion of the sample using 2:1 mixture of nitric acid and perchloric acid and developing colour by the vanado-molybdo-phosphoric yellow colour method and read in spectronic 20.

6.4. Uptake of phosphorus

This was estimated from the phosphorus content and the dry weight of the components. Uptake by haulm and grains were added to get the total uptake at harvest.

6.5. Total potash content

Total potash content in plant was estimated by flame photometric method, after wet digestion of the sample using di-acid mixture.

6.6. Uptake of potash

This was calculated from the potash content and the dry weight of the compoents. Uptake by grain and stover were added to get the total plant uptake at harvest.

6.7. Oil content

Oil content of oven dry seeds was estimated by Soxhlet extraction using petroleum ether of boiling point 60-80°C. (Chopra and Kanwar, 1976)

6.8. Oil yield

This was calculated from the oil content and the total dry weight of seeds.

6.9. Protein content

The percentage of protein was calculated from the percentage of nitrogen using the factor 6.25 (Simpson *et al* 1965).

6.10. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The soil samples collected were analysed for total nitrogen, available phosphorus and available potash contents. Total nitrogen content was estimated by the modified micro-kjeldahl method. Available phosphorus content was estimated by Bray's method (Jackson, 1967) and available potash by amonium acetate method (Jackson, 1967).

7. Statistical analysis

Data on yield, yield attributes, growth characters and those on chemical analysis were analysed by employing the technique of analysis of variance for partially confounded 3^3 factorial experiment and significance was tested by F - test (Cochran and Cox, 1965).

RESULTS

RESULTS

The results of the study on NPK nutrition of sesamum are presented below.

A. <u>Growth characters</u>

1. <u>Height of plants</u>

The data on the mean height of plants are presented in Table 1 and the analysis of variance in Appendix II.

It is seen that increasing levels of nitrogen increased the height of plants at all stages of growth, especially at 60th day after sowing and at harvest. The difference between the two levels, viz. 20 and 40 kg N/ha was significant only at 60th day after sowing although a trend of slight increase was shown at other stages.

Phosphorus did not show any significant influence on the height at any of the stages.

Application of potassium at the rate of 20 kg/ha increased the height of plants significantly over the control plants. But further increase in the rate to 40 kg/ha showed a slight decrease in the height of plants at all the stages of growth.

Table 1. Effect of various levels of N,P and K nutrition on height of plants at different stages

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean p or k	n_0	n_1	n_2	Mean p or k	n_0	n_1	n_2	Mean p or k
P_0	10.36	11.81	11.34	11.17	39.06	47.83	48.84	45.24	68.94	75.90	76.83	73.89
P_1	11.48	11.55	12.15	11.72	43.78	48.71	55.51	49.33	73.60	74.90	82.99	77.16
P_2	10.84	11.06	14.13	12.01	40.74	48.97	35.92	48.54	69.03	80.62	85.33	78.52
K_0	10.30	10.06	9.91	10.09	34.35	44.78	47.35	42.16	66.00	72.50	75.34	71.28
K_1	11.72	12.16	13.70	12.53	45.30	53.81	57.24	52.12	73.42	81.69	84.44	79.85
K_2	10.66	12.19	14.01	12.28	43.94	46.91	55.67	48.84	72.15	77.22	85.37	78.24
Mean (N)	10.89	11.47	12.54		41.12	48.50	53.42		70.52	77.17	81.71	
	P0	P1	P2		P0	P1	P2		P0	P1	P2	
K_0	8.73	9.77	11.77	10.09	35.91	46.78	43.80	42.16	69.67	72.07	72.10	71.28
K_1	12.66	12.82	12.11	12.53	54.31	50.18	51.85	52.12	79.48	80.59	79.49	79.85
K_2	12.12	12.58	12.16	12.28	45.51	51.03	49.98	48.84	72.52	78.83	83.38	78.24

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	1.880	4.616	6.519
(ii) NP, NK or PK combination	3.257	7.995	11.2912

The various treatment combinations did not show any profound influence on the height of plants at any of the growth stages.

2. Number of leaves per plant

The number of leaves recorded at different stages of observation are presented in Table 2 and their analysis of variance in Appendix II.

The number of leaves produced at the first and last stages was not significantly influenced by the application of nitrogen though the number increased slightly during the above two stages. At the second stage of observation a significant increase in the number of leaves produced was observed; but with no difference between 20 and 40 kg N/ha.

Phosphorus application did not show any significant difference in the number of leaves produced by the plant at any of the growth stages. Application of phosphorus beyond 15 kg/ha showed a slight decrease in the number of leaves produced during the second and last stages of crop growth.

Although increasing levels of potassium increased the number of leaves at all stages, significant increase was observed only at the 30th day after sowing.

Table 2. Effect of various levels of N, P and K nutrition on number of leaves at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean p or K	n_0	n_1	n_2	Mean P or K
P_0	8.69	9.34	9.17	9.07	14.77	15.70	17.06	15.84	23.84	23.38	25.10	24.11
P_1	9.17	9.51	9.58	9.42	15.58	16.38	17.75	16.57	24.97	22.56	26.34	24.62
P_2	9.14	9.05	9.99	9.39	15.21	17.92	18.42	17.19	21.89	25.66	26.01	24.52
K_0	8.92	8.84	8.51	8.75	14.69	16.01	15.96	15.55	22.85	23.43	24.63	23.64
K_1	9.10	9.65	10.33	9.69	15.40	17.20	18.04	16.88	23.56	23.69	25.91	24.39
K_2	8.98	9.42	9.91	9.44	15.48	16.81	19.25	17.18	24.29	24.49	26.91	25.23
Mean (N)	9.00	9.30	9.58		15.19	16.67	17.74		23.57	23.87	25.82	
	PO	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	8.13	8.88	9.25		14.59	15.51	16.55		24.88	23.12	22.91	
K_1	9.76	9.77	9.55		16.48	17.88	16.27		24.45	25.03	23.67	
K_2	9.31	9.62	9.38		16.46	16.31	18.74		22.99	25.72	26.98	

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.480	1.689	3.733
(ii) NP, NK or PK combination	0.832	2.925	6.466

None of the interaction effects was found to be significant.

3. Number of branches per plant

The number of branches recorded at 60th day and at harvest are given in Table 3 and the analysis of variance in Appendix III.

The data revealed that there was significant effect of applied nitrogen on the number of branches produced per plant. There was a marked increase in the number of branches produced by an application of 40 kg N/ha over the level of 20 kg N/ha.

Phosphorus and potash application could not produce any significant favourable influence on the number of branches per plant. Instead, both of them produced a depressing effect on this character when application rate of phosphorus and potash exceeded from 15 to 30 kg/ha and 20 to 40 kg/ha respectively.

Interaction effect was also not found to be significant.

Table 3. Effect of various levels of N, P and K nutrition on number of branches at different stages.

	60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.76	1.83	2.13	1.91	2.11	2.11	2.50	2.24
P_1	2.32	2.08	2.97	2.45	2.68	2.41	3.12	2.74
P_2	1.79	2.23	2.45	2.16	1.91	2.55	2.81	2.43
K_0	1.89	1.80	2.30	1.99	2.27	2.22	2.64	2.38
K_1	2.23	2.29	2.54	2.35	2.44	2.34	2.73	2.51
K_2	1.75	2.05	2.72	2.17	1.98	2.51	2.07	2.52
Mean (N)	1.96	2.05	2.52		2.23	2.36	2.81	
	P_0	P_1	P_2		P_0	P_1	P_2	
K_0	1.62	2.44	1.93	1.99	2.05	2.82	2.26	2.38
K_1	2.09	2.69	2.27	2.35	2.12	2.97	2.43	2.51
K_2	2.01	2.23	2.27	2.17	2.54	2.43	2.60	2.52

CD for comparison of means

	60th day	Harvest
(i) N, P or K	0.457	0.402
(ii) NP, NK or PK	0.792	0.697

4. Number of nodes per plant

Data on number of nodes per plant at three stages of observation are presented in Table 4 and analysis of variance in Appendix III.

It was found that nitrogen application increased the number of nodes per plant at all stages of observation, but significant influence was obtained only on 60th day after sowing. The levels of 20 kg and 40 kg N/ha were on per as far as this character was concerned.

Phosphorus had no significant influence on the number of nodes per plant at any stage of observation.

However, significant increase in the number of nodes per plant was observed with the application of potash on 30th day after sowing. But no difference was observed between 20 an 40 kg K_2O/ha.

None of the interaction effects were found to be significant.

5. Leaf area per plant

The data on leaf area per plant recorded at the harvest stage are presented in Table 4 (a) andthe analysis of variance in Appendix III.

Application of nitrogen significantly influenced the leaf area per plant at harvest. The highest dose of

Table 4. Effect of various levels of N, P and K on number of nodes at different stages

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	4.34	4.67	4.58	4.53	7.38	7.85	8.53	7.92	11.92	11.70	12.55	12.05
P_1	4.58	4.75	4.79	4.71	7.79	8.19	8.9	8.29	12.49	11.27	13.17	12.31
P_2	4.57	4.52	4.99	4.69	7.61	8.96	9.17	8.58	10.95	12.83	13.01	12.26
K_0	4.46	4.42	4.25	4.37	7.34	9.01	7.96	7.77	11.43	11.71	12.32	11.82
K_1	4.55	4.82	5.16	4.84	7.70	8.60	9.01	8.44	11.78	11.85	12.96	12.20
K_2	4.49	4.71	4.95	4.72	7.74	8.40	9.62	8.88	12.15	12.23	13.46	12.61
Mean (N)	4.50	4.65	4.79		7.59	8.33	8.86		11.79	11.93	12.91	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	4.66	4.44	4.62	4.37	7.30	7.78	8.23	7.77	12.44	11.56	11.46	11.82
K_1	4.88	4.88	4.77	4.84	8.24	8.94	8.13	8.44	12.22	12.52	11.84	12.20
K_2	4.65	4.81	4.69	4.72	8.23	8.15	9.37	8.88	11.50	12.85	13.49	12.61

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.240	0.852	1.864
(ii) NP, NK or PK combination	0.416	1.476	3.228

Table 4 (a) Leaf Area at harvest

Levels of Phosphorus of Potash	Levels of nitrogen or phosphorus			
	n0	n_1	n_2	Mean P or K
P_0	141.75	132.41	153.85	142.67
P_1	135.45	136.04	198.53	156.68
P_2	131.21	133.05	194.61	152.95
K_0	137.00	133.32	175.97	148.76
K_1	132.67	134.781	182.17	149.88
K_2	138.74	133.39	188.84	153.66
	P_0	P_1	P_2	
K_0	134.74	155.51	156.04	148.76
K_1	146.80	156.92	145.90	149.88
K_2	146.47	157.59	156.91	153.66

CD for comparison among N, P or K = 8.88

CD for NP, NK, PK combination = 15.38

nitrogen recorded the maximum leaf area.

Phosphorus application also had significant influence on the leaf area and the highest value was recorded with the application of 15 kg P_2O_5/ha. Application of phosphorus beyond 15 kg showed a depressing trend on the leaf area of plants.

Potash application did not produce any significant influence on this character.

Among the various interactions only NP combination expressed significant influence recording the highest value with n_2p_1 followed by n_1p_2.

6. <u>Dry matter production</u>

Data on dry matter (kg/ha) produced at different stages of observation are presented in Table 5 and the analysis of variance in Appendix VIII.

Application of nitrogen increased the dry matter production significantly and the highest production of dry matter was recorded with the highest level of nitrogen at all stages of the growth of the plant.

Increasing levels of phosphorus also increased the dry matter production significantly at all the stages of growth. The highest production of dry matter was recorded

Table 5. Effect of various levels of N, P and K nutrition on drymatter Production at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	164.02	176.07	202.08	180.73	952.91	1122.95	1230.25	1102.04	1017.00	1102.65	1068.03	1062.56
P_1	175.14	198.30	240.79	204.74	951.21	1204.38	1435.11	1196.90	1034.46	1077.83	1238.99	1117.09
P_2	189.61	228.22	231.09	216.31	959.81	1249.24	1385.74	1198.26	1080.60	1133.19	1200.38	1128.06
K_0	160.41	185.14	218.62	188.06	949.32	1135.98	1274.27	1119.86	1013.53	1145.88	1127.39	1095.60
K_1	176.06	199.57	224.95	200.19	955.71	1216.55	1362.15	1178.14	1034.72	1102.22	1183.11	1106.69
K_2	192.29	217.88	230.40	213.52	958.90	1224.04	1414.68	1199.21	1053.82	1065.56	1196.90	1105.43
Mean (N)	176.26	200.87	224.65		954.64	1192.19	1350.37		1034.02	1104.55	1169.13	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	165.99	190.12	208.06	198.06	1039.02	1152.19	1168.36	1119.86	1075.93	1106.95	1104.31	1095.60
K_1	182.93	203.76	213.89	200.19	1114.26	1230.49	1189.66	1178.14	1043.99	1142.31	1133.76	1106.69
K_2	193.24	220.35	226.97	213.52	1152.84	1208.01	1236.78	1199.21	1067.76	1102.42	1146.10	1105.43

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	5.101	11.073	31.769
(ii) NP, NK or PK	8.836	19.179	55.023

by the highest level of phosphorus application at 30th day of sowing. But there was no difference between 15 kg/ha and 30 kg/ha of applied phosphorus in the later stages with respect to the dry matter production.

Potassium application also exerted significant influence on dry matter production. Increasing levels of potassium application increased the dry matter produced only upto the 2nd stage, but increasing the level further to 40 kg K_2O/ha showed a slight decline in dry matter production during the 3rd stage.

Among the various interactions, NP, NK, NPK, NPK^2 and NP^2K produced significant influence on the production of dry matter in the first stage of observation.

In the 2nd stage of observation the interactions, NP, NK, PK, NPK^2, NP^2K and NP^2K^2 showed significant influence on the dry matter production of the crop.

The interactions NP, NK and NPK^2 showed significant influence in the harvest stage of the crop. Among the various NP interactions n_2p_2 recorded the highest value and n_2k_2 recorded the highest value among the NK interactions.

B. Yield and yield attributes

1. Number of capsules per plant

Data on the number of capsules per plant at harvest are presented in Table 6 and the analysis of variance in Appendix V.

Table 6. Number of capsules per plant.

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	10.00	11.16	12.16	11.11
P_1	10.66	11.16	12.33	11.38
P_2	11.16	10.5	12.16	11.27
K_0	10.83	10.83	12.50	11.38
K_1	10.83	11.66	13.00	11.66
K_2	10.66	10.33	11.16	10.72
Mean (N)	10.61	10.94	12.22	
	P_0	P_1	P_2	
K_0	11.66	10.83	11.66	11.38
K_1	11.33	12.16	11.50	11.66
K_2	11.16	10.33	10.66	10.72

CD for comparison among N, P or K = 1.155

CD for NP, NK, PK combination = 2.000

The number of capsules produced by the plant increased significantly with increase in the levels of nitrogen. Significant difference was observed between the levels 20 and 40 kg N/ha.

The number of capsules per plant was seen not affected by the application of phosphorus and potash. However, there was an increasing trend with increasing levels of phosphorus and potash upto 15 kg/ha and 20 kg/ha respectively while further increase to 30 kg/ha and 40 kg/ha revealed a depressing trend in the number of capsules.

None of the interactions was found to be significant.

2. <u>Weight of capsules per plant</u>

The data on the weight of capsules per plant are presented in Table 7 and the analysis of variance in Appendix V.

Increasing levels of nitrogen increased the weight of capsules per plant. However, this increase was not significant.

Application of phosphorus and potassium increased the weight of capsules per plant upto 15 kg/ha and 20 kg/ha respectively and only a slight decrease was observed with a further increase to 30 kg/ha and 40 kg/ha each respectively.

Table 7. Weight of capsules (g) per plant

Levels of phosphorus or potash	Levels of Nitrogen or Phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	6.61	6.81	7.21	6.88
P_1	6.75	7.29	7.77	7.27
P_2	7.05	6.55	7.19	6.93
K_0	7.07	6.66	7.64	7.12
K_1	6.80	7.00	7.36	7.06
K_2	6.78	6.76	7.18	6.91
Mean (N)	6.81	6.88	7.39	
	P_0	P_1	P_2	
K_0	6.89	7.28	7.19	7.12
K_1	6.87	7.39	6.91	7.06
K_2	6.87	7.15	6.69	6.91

CD for comparison among N, P or K = 0.507

CD for NP, NK, PK combination = 0.878

The effect of the treatment combination NPK was found to be significant.

3. Number of seeds per capsule

The data on number of seeds per capsule are given in Table 8 and the analysis of variance in Appendix V.

The number of seeds per capsule is found to be increased significantly with the increase in the level of nitrogen application.

Application of phosphorus also increased the number of seeds per capsule upto 15 kg/ha while a slight decrease was observed when it was increased to 30 kg/ha.

Potash application also produced significant results. Among the various treatment combinations NP interaction was found to be significant. The highest value was obtained with n_2p_1 combination which was on par with n_2p_0, n_2p_2 and n_0p_1 combinations. n_0p_0 combination recorded the lowest value.

4. Seed weight per plant

The data on the weight of seeds per plant are presented in Table 9 and the analysis of variance in Appendix IV.

Nitrogen application produced significant influence on the seed weight per plant and the highest value was recorded with the highest dose of nitrogen.

Table 8. Number of seeds per capsule

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	35.98	37.01	40.78	37.92
P_1	39.87	39.53	41.55	40.32
P_2	36.22	39.63	40.36	38.74
K_0	36.93	37.12	40.74	38.27
K_1	37.39	38.58	40.89	38.96
K_2	37.76	40.46	41.06	39.76
Mean (N)	37.36	38.73	40.90	
	P_0	P_1	P_2	
K_0	37.11	39.21	38.48	38.27
K_1	37.63	41.08	38.15	38.96
K_2	39.03	40.66	39.6	39.76

CD for comparison among N, P or K = 1.080

CD for NP, NK, PK combination = 1.872

Table 9. Seed weight (g) per plant

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	0.56	0.57	0.87	0.66
P_1	0.62	0.71	1.14	0.82
P_2	0.72	0.73	0.84	0.77
K_0	0.74	0.58	1.13	0.82
K_1	0.56	0.57	0.94	0.74
K_2	0.59	0.71	0.79	0.70
Mean (N)	0.63	0.67	0.95	
	P_0	P_1	P_2	
K_0	0.72	0.76	0.96	0.82
K_1	0.66	0.83	0.73	0.74
K_2	0.61	0.87	0.60	0.70

CD for comparison among N, P or K = 0.126

CD for NP, NK, PK combination = 0.218

Phosphorus and potash application did not produce any significant influence on seed weight and among the interactions NK interaction produced significant effect and the highest value was obtained by the treatment n_2k_0 which was on par with n_2k_1 combination. The value recorded a declining trend in the order n_1k_2, n_1k_0, n_0k_1, n_1k_1, n_0k_0 and finally n_0k_2.

5. <u>1000 seed weight</u>

The data on 1000 seed weight recorded at harvest are presented in Table 10 and the analysis of variance in Appendix IV.

Application of nitrogen significantly increased the 1000 seed weight and the highest value was recorded with the highest level of nitrogen application.

Phosphorus application also increased the 1000 seed weight significantly. However, application of phosphorus beyond 15 kg/ha had a depressing effect on 1000 seed weight.

Potash application also produced significant effect on 1000 seed weight. However, there was no difference between 20 and 40 kg K_2O/ha in this character.

Among the various interactions NP interaction produced significant influence on 1000 seed weight. Among this n_2p_1 was superior followed by n_1p_1 and n_1p_2 combinations.

Table 10. 1000 seed weight (g)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	2.32	2.45	2.45	2.40
P_1	2.41	2.46	2.51	2.46
P_2	2.41	2.46	2.45	2.44
K_0	2.30	2.41	2.43	2.38
K_1	2.40	2.46	2.50	2.45
K_2	2.44	2.50	2.49	2.48
Mean (N)	2.38	2.46	2.47	
	P_0	P_1	P_2	
K_0	2.33	2.41	2.41	2.38
K_1	2.42	2.49	2.45	2.45
K_2	2.46	2.50	2.47	2.48

CD for comparison among N, P or K = 0.026

CD for NP, NK, PK combination = 0.045

6. Seed yield

The data on seed yield are presented in Table 11 and the analysis of variance in Appendix IV.

Nitrogen application produced significant increase in seed yield. Increasing levels of nitrogen increased seed yield upto 40 kg N/ha. However, the difference between 20 kg N and 40 kg N per hectare was not significant.

Application of phosphorus also produced significant increase in seed yield. But phosphorus application beyond 15 kg/ha produced a slight depression in seed yield.

Potash was not found to increase yield significantly. However, application of potash upto 20 kg/ha produced an increase in seed yield, while application beyond 20 kg K_2O/ha produced a slight decline in the yield of seed.

Among the various interactions, the treatment combinations NPK, NP^2K and NP^2K^2 were found to be significant.

7. Stover yield

The data on stover yield are presented in Table 12 and the analysis of variance in Appendix VI.

The yield of stover was significantly influenced by the increased levels of nitrogen.

Phosphorus application also produced significant yield increase. However, there was no difference between

Table 11. Seed yield (kg/ha)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	303.00	320.00	354.83	325.94
P_1	320.33	340.16	382.00	347.60
P_2	314.50	332.83	366.50	337.94
K_0	315.66	317.00	375.00	335.88
K_1	319.66	337.16	360.16	339.00
K_2	302.50	338.83	368.16	336.50
Mean (N)	312.61	331.00	367.77	
	P_0	P_1	P_2	
K_0	327.50	345.16	336.83	335.88
K_1	323.83	352.83	331.00	339.00
K_2	326.50	344.50	346.00	336.50

CD for comparison among N, P or K = 12.834

CD for NP, NK, PK combination = 22.228

Table 12. Haulm yield (kg/ha)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	893.47	977.23	901.68	924.13
P_1	896.68	927.87	1075.63	966.73
P_2	921.49	1000.33	1045.72	989.18
K_0	889.89	1009.27	958.18	952.44
K_1	920.12	916.44	1047.95	961.50
K_2	901.66	979.73	1016.89	966.09
Mean (N)	903.89	968.48	1007.68	
	P_0	P_1	P_2	
K_0	938.31	956.66	962.36	952.44
K_1	904.39	991.06	1002.83	961.50
K_2	929.69	952.46	1002.36	966.09

CD for comparison among N, P or K = 35.478

CD for NP, NK, PK combination = 61.448

15 kg and 30 kg phosphorus per hectare. But the highest stover yield was recorded by the highest levels of phosphorus.

Potash application did not produce any significant yield increase, but increasing levels of potassium tended to increase the stover yield and the maximum stover yield was recorded by the highest level of potassium.

The treatment combinations NP and NK were found to be significant. n_2p_1 recorded the highest value but was on par with n_2p_2.

Among NK combinations, the highest value was obtained with n_2k_1 combination, but was on par with n_2k_2 and n_1k_0.

8. <u>Shelling percentage</u>

The data on shelling percentage recorded at harvest are given in Table 13 and the analysis of variance in Appendix VI

Nitrogen significantly influenced the shelling percentage, but there was no difference between 20 and 40 kg N/ha.

Application of phosphorus and potassium did not give any significant result and increasing the levels of these nutrients beyond 15 kg/ha and 20 kg/ha respectively showed a slight decline in the value of shelling percentage.

The interaction effect was also not found to be significant.

Table 13. Shelling percentage

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	66.61	68.78	68.91	68.10
P_1	68.50	68.72	69.31	68.85
P_2	67.77	68.04	69.65	68.49
K_0	67.46	68.27	69.39	68.37
K_1	67.94	68.73	69.28	68.65
K_2	67.49	68.54	69.20	68.41
Mean (N)	67.63	68.51	69.29	
	P_0	P_1	P_2	
K_0	67.81	69.09	68.22	68.37
K_1	68.41	68.84	68.71	68.65
K_2	68.09	68.61	68.53	68.41

CD for comparison among N, P or K = 0.873

CD for NP, NK, PK combination = 1.513

9. <u>Harvest index</u>

The data on harvest index are given in Table 14 and the analysis of variance in Appendix VI.

The harvest index was significantly influenced by nitrogen application, the highest value being recorded by the highest level of nitrogen.

Phosphorus and potash application did not produce any significant influence on harvest index.

NP and NK combinations produced significant influence on harvest index of the crop. n_2p_0 combination recorded the highest value of 0.39 followed by n_1p_1 but were on par with n_1p_1 and n_0p_1 combinations.

Among the various NK interactions, n_2k_0 recorded the highest value of 0.38, but was on par with n_0k_1, n_1k_2, n_2k_2 and n_2k_1 combinations.

C. <u>Quality attributes</u>

1. <u>Oil content</u>

The data on oil content at harvest are given in Table 15 and the analysis of variance in Appendix VII.

Although there was significant increase in oil content with applied nitrogen the difference between 20 and 40 kg N/ha was not significant.

Phosphorus application did not produce any significant increase in oil content. Increasing levels of phosphorus

Table 14. Harvest Index

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	0.34	0.33	0.39	0.35
P_1	0.36	0.37	0.36	0.36
P_2	0.34	0.33	0.35	0.34
K_0	0.34	0.33	0.38	0.35
K_1	0.35	0.32	0.37	0.35
K_2	0.34	0.37	0.35	0.36
Mean (N)	0.35	0.34	0.37	
	P_0	P_1	P_2	
K_0	0.35	0.36	0.35	0.35
K_1	0.36	0.36	0.33	0.35
K_2	0.35	0.37	0.35	0.36

CD for comparison among N, P or K = 0.018

CD for NP, NK PK combination = 0.031

Table 15. Oil Content (%)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	49.85	51.09	51.28	50.74
P_1	50.69	51.11	51.85	51.22
P_2	50.39	50.88	51.26	50.74
K_0	50.15	50.83	51.12	50.69
K_1	50.43	51.01	51.57	51.00
K_2	50.36	50.95	51.69	50.99
Mean (N)	50.31	50.93	51.46	
	P_0	P_1	P_2	
K_0	50.34	50.50	50.89	50.69
K_1	51.25	50.86	51.26	51.00
K_2	50.64	50.86	51.49	50.99

CD for comparison among N, P or K = 0.566

CD for NP, NK, PK combination = 0.980

increased the oil content upto 15 kg, while there was a decrease in the oil content when phosphorus application was increased to 30 kg.

Potash also showed no significant influence on oil content. Here also increasing the levels of potash increased the oil content upto 20 kg/ha, whereas the oil content decreased when potash application was increased to 40 kg/ha.

None of the interactions was significant.

2. Protein content

The data on protein content of seeds recorded at harvest are presented in Table 16 and the analysis of variance in Appendix VII.

Application of nitrogen was found to increase the protein content of seeds significantly and highest protein content was recorded by the highest level of nitrogen.

Protein content of seed was found to be increased significantly with the increased level of phosphorus application and the highest protein content was recorded by the highest level of phosphorus.

Potash application did not produce any significant influence on the protein content of seeds. However, increasing the levels of potassium increased the protein content upto 20 kg and further increase in potassium level decreased the protein content slightly.

Table 16. Protein content of seeds (%)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	17.83	19.19	20.26	19.09
P_1	18.74	19.83	20.77	19.78
P_2	19.48	19.73	21.24	20.15
K_0	18.65	19.49	20.46	19.53
K_1	18.53	19.53	20.97	19.68
K_2	18.88	19.73	20.84	19.82
Mean (N)	18.69	19.58	20.76	
	P_0	P_1	P_2	
K_0	18.85	19.56	20.19	19.53
K_1	19.05	19.96	20.01	19.68
K_2	19.38	19.82	20.25	19.82

CD for comparison among N, P or K = 0.228

CD for NP, NK, PK combination = 0.395

Among the various interactions NP, NPK^2 and NP^2K were found to be significant. n_2p_2 combination was found to be superior to all other treatments. This was followed by n_2p_1 and then by n_2p_0. The lowest value was recorded by n_0p_0.

3. Oil Yield

The data on oil yield recorded at harvest are presented in Table 17 and the analysis of variance in Appendix VII.

The data showed that there was significant difference in the oil yield of grains with different levels of nitrogen giving the highest value for the highest level of nitrogen.

Phosphorus application also produced significant increase in oil yield. However, phosphorus application beyond 15 kg showed a slight decline in oil yield.

Potash application did not produce any significant effect on oil yield of grains.

The treatment combinations NPK and NP^2K produced significant effect on oil yield.

D. Analysis of plant samples

1. Total nitrogen content in different plant parts

1.1. Nitrogen content of stover

The data on the nitrogen content of stover are presented in Table 18 and the analysis of variance in Appendix IX.

Table 17. Oil Yield (kg/ha)

Levels of phosphorus or potash	Levels of nitrogen or phosphorus			
	n_0	n_1	n_2	Mean P or K
P_0	15257.96	16177.55	18186.50	16540.67
P_1	15941.80	17386.66	19591.45	17639.97
P_2	15620.45	17016.61	19002.55	17213.20
K_0	15265.40	17272.66	18983.11	17173.73
K_1	15459.11	16122.22	19181.02	16920.78
K_2	16095.70	17185.95	18616.37	17299.34
Mean (N)				
	P_0	P_1	P_2	
K_0	16792.86	17445.00	17283.31	17173.73
K_1	16291.35	17947.18	16523.82	16920.78
K_2	16537.80	17527.73	17832.48	17299.34

CD for comparison among N, P or K = 713.318

CD for NP, NK, PK combination =1235.467

Table 18. Effect of various levels of N,P and K nutrition on nitrogen content of plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.12	1.20	1.32	1.21	1.82	2.09	2.56	2.16	1.31	1.68	2.17	1.72
P_1	1.18	1.27	1.46	1.30	1.89	2.22	2.78	2.30	1.39	1.70	2.28	1.79
P_2	1.17	1.34	1.51	1.34	1.88	2.21	2.89	2.32	1.52	1.71	2.45	1.89
K_0	1.13	1.18	1.35	1.22	1.85	2.16	2.56	2.19	1.22	1.64	2.15	1.67
K_1	1.19	1.26	1.42	1.29	1.88	2.15	2.83	2.29	1.52	1.77	2.33	1.87
K_2	1.15	1.37	1.52	1.35	1.86	2.21	2.84	2.30	1.49	1.67	2.41	1.86
Mean (N)	1.15	1.27	1.43		1.86	2.17	2.74		1.41	1.69	2.30	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	1.15	1.26	1.26	1.22	1.96	2.25	2.35	2.19	1.55	1.68	1.77	1.67
K_1	1.21	1.29	1.37	1.29	2.17	2.36	2.32	2.29	1.85	1.82	1.95	1.87
K_2	1.28	1.36	1.39	1.35	2.33	2.27	2.30	2.30	1.75	1.87	1.96	1.86

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.032	0.087	0.128
(ii) NP, NK or PK combination	0.057	0.151	0.222

Nitrogen content of stover increased significantly with increasing levels of applied nitrogen at all the stages of growth.

Phosphorus and potash application also increased the nitrogen content of stover significantly.

Among the various interactions, NP, NK, NPK, NPK^2 were significant at the first stage of observation. Among the NP interactions, n_2p_2 was superior, but was on par with n_2p_1. The lowest value was recorded by the treatment n_0p_0. Among the NK interactions n_2k_2 was superior to all other combinations followed by n_2k_1 which was on par with n_1k_2. The treatment n_0k_0 recorded the lowest value which was on per with n_1k_0 and n_0k_2.

The treatment combinations PK and NP^2K were significant at the 2nd stage of observation. Among the PK interactions p_1k_1 was superior and p_0k_0 recorded the lowest value.

In the 3rd stage of observation the combinations NP^2K and NP^2K^2 alone were significant.

1.2. <u>Nitrogen content of seeds</u>

The data on the nitrogen content of seeds are presented in Table 21 and the analysis of variance in Appendix IX.

Nitrogen application significantly influenced the

Table 21. Effect of various levels of N, P and K nutrition on nitrogen, phosphorus potassium content of grains at harvest.

	Nitrogen content (%)				Phosphorus content (%)				Potassium content (%)			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	2.85	3.07	3.24	3.05	0.46	0.46	0.47	0.46	0.49	0.50	0.50	0.50
P_1	3.00	3.17	3.32	3.16	0.49	0.49	0.51	0.50	0.49	0.49	0.51	0.50
P_2	3.11	3.15	3.39	3.22	0.57	0.58	0.58	0.58	0.49	0.50	0.51	0.50
K_0	2.98	3.12	3.27	3.12	0.50	0.51	0.51	0.51	0.46	0.47	0.48	0.47
K_1	2.96	3.12	3.35	3.15	0.51	0.51	0.52	0.51	0.49	0.49	0.51	0.50
K_2	3.02	3.16	3.34	3.17	0.51	0.51	0.53	0.52	0.52	0.53	0.55	0.53
Mean (N)	2.99	3.13	3.32		0.51	0.51	0.52		0.49	0.50	0.51	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	3.01	3.12	3.23	3.12	0.46	0.49	0.57	0.51	0.47	0.46	0.47	0.47
K_1	3.05	3.19	3.20	3.15	0.46	0.50	0.58	0.51	0.49	0.50	0.50	0.50
K_2	3.10	3.17	3.24	3.17	0.47	0.50	0.58	0.52	0.53	0.53	0.53	0.53

CD for comparison of means

	Nitrogen	Phosphorus	Potassium
(i) N, P or K	0.036	0.004	0.005
(ii) NP, NK or PK combination	0.062	0.007	0.009

nitrogen content of grain and the highest value was recorded by the highest level of nitrogen at all the stages.

Phosphorus application also increased the nitrogen content of grains significantly, but there was no difference between 15 and 30 kg P_2O_5/ha during the 3rd stage.

Potassium also significantly influenced the nitrogen content of grain. Increasing levels of potassium increased the nitrogen content of grains.

Among the interactions NP and NPK^2 produced significant effect on the nitrogen content of grains. n_2p_2 recorded the highest value followed by n_2p_1, n_2p_0 and n_1p_1. However, n_1p_1 was on par with n_1p_2 and n_0p_2. The lowest value was recorded by the treatment combination n_0p_0.

2. <u>Uptake of nitrogen by different plant parts</u>

2.1. <u>Uptake of nitrogen by stover</u>

The data on the uptake of nitrogen by stover are presented in Table 22 and the analysis of variance in Appendix XII.

Nitrogen application significantly influenced the nitrogen uptake at all the stages and the highest amount of uptake was seen with the highest level of nitrogen.

Nitrogen uptake was increased significantly with the application of phosphorus. During the 2nd and 3rd stages, increasing the level of phosphorus from 15 kg to 30 kg/ha

Table 22. Effect of various levels of N, P and K nutrition on uptake of nitrogen by plants at different stages

	30th day after sowing				60th day after sowing				Harvest			
P	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.84	2.14	2.68	2.22	17.34	23.65	31.53	24.17	13.34	18.30	23.10	18.24
P_1	2.07	2.54	3.52	2.71	17.93	26.76	40.03	28.24	14.08	18.31	28.30	20.23
P_2	2.22	3.06	3.48	2.92	18.01	27.56	39.97	28.51	16.10	19.42	29.41	21.64
K_0	1.81	2.20	2.97	2.33	17.54	24.77	32.78	25.03	12.04	18.73	24.25	18.34
K_1	2.10	2.54	3.21	2.62	17.93	26.19	38.57	27.51	15.72	19.51	27.55	20.93
K_2	2.21	2.30	3.51	2.91	17.81	24.02	40.18	28.34	15.75	17.80	28.99	20.85
Mean (N)	2.04	2.58	3.23		17.76	25.99	37.18		14.50	18.68	26.93	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	1.81	2.20	2.97	2.33	20.64	26.35	28.10	25.03	16.69	18.46	19.86	18.34
K_1	2.10	2.54	3.21	2.62	24.45	29.93	28.31	27.51	19.34	21.28	22.16	20.93
K_2	2.21	2.99	3.51	2.91	27.43	28.44	29.14	28.34	18.70	20.95	22.90	20.85

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.103	1.047	1.645
(ii) NP, NK or PK combination	0.178	1.813	2.850

made no significant difference in the nitrogen uptake of stover.

Applied potassium also produced significant effect on the nitrogen uptake by stover at all the stages. But there was no difference between 20 and 40 kg/ha of potash during the 3rd stage of observation.

NP, NK and NPK combinations produced significant effect on the nitrogen uptake by stover during the first stage of observation. Among the NP combinations n_2p_1 recorded the highest value but was on par with n_2p_2, n_1p_2 and n_2p_0. The lowest value was recorded by the combination n_0p_0.

Among the various NK interactions the highest value was recorded by n_2k_2 combination followed by n_2k_1 and then by n_2k_0. The lowest value was obtained with n_0k_0 combination.

NP, NK, PK, NP^2K and NP^2K^2 interactions made significant influence on the nitrogen uptake by stover during the 2nd stage of the crop.

However, none of the interactions were significant during the 3rd stage.

2.2. Nitrogen uptake by seeds

The data on the uptake of nitrogen by seeds are presented in Table 25 and the analysis of variance in Appendix XV.

Table 25. Effect of various levels of N, P and K nutrition on uptake of nitrogen, phosphorus and potash by grains at harvest.

	Nitrogen uptake				Phosphorus uptake				Potassium uptake			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	7.26	8.25	9.66	8.39	1.16	1.24	1.40	1.27	1.26	1.33	1.50	1.36
P_1	8.07	9.06	10.69	9.27	1.32	1.41	1.64	1.45	1.32	1.40	1.65	1.46
P_2	8.23	8.83	10.46	9.17	1.50	1.62	1.78	1.63	1.30	1.40	1.58	1.43
K_0	7.59	8.87	10.13	8.86	1.27	1.46	1.57	1.43	1.17	1.33	1.47	1.32
K_1	7.86	8.32	10.58	8.92	1.34	1.35	1.64	1.44	1.30	1.31	1.60	1.40
K_2	8.12	8.95	10.11	9.06	1.37	1.46	1.60	1.47	1.41	1.50	1.66	1.52
Mean (N)	7.85	8.71	10.27		1.33	1.42	1.60		1.29	1.38	1.58	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	8.33	9.09	9.15	8.86	1.27	1.43	1.60	1.43	1.29	1.34	1.33	1.32
K_1	8.30	9.54	8.92	8.92	1.25	1.49	1.60	1.44	1.34	1.48	1.39	1.40
K_2	8.54	9.19	9.45	9.06	1.28	1.45	1.69	1.47	1.46	1.55	1.56	1.52

CD for comparison of means

	Nitrogen	Phosphorus	Potassium
(i) N, P or K	0.364	0.055	0.058
(ii) NP, NK or PK combination	0.630	0.097	0.010

Nitrogen application significantly influenced the nitrogen uptake of grains at the harvest stage. The highest nitrogen uptake value was recorded by the highest level of nitrogen.

Phosphorus application also significantly influenced the nitrogen uptake by grains. However, increasing the levels of phosphorus from 15 to 30 kg/ha showed a slight decline in the uptake of nitrogen by grains.

Potassium did not significantly influence the nitrogen uptake by grains. However, there was slight increase in nitrogen uptake with increasing levels of potash application.

Among the various interactions NPK, NP^2K and NP^2K^2 were significant.

2.3. <u>Total uptake of nitrogen</u>

The data on the total uptake of nitrogen are furnished in Table 26 and the analysis of variance in Appendix XVI.

Nitrogen significantly increased the nitrogen uptake at all stages of growth. Total uptake of nitrogen was highest with the highest level of nitrogen.

Table 26. Effect of various levels of N, P and K nutrition on total uptake of nitrogen by plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.84	2.14	2.68	2.22	17.34	23.65	31.53	24.17	20.54	28.32	32.76	27.22
P_1	2.07	2.54	3.52	2.71	17.93	26.76	40.03	28.24	22.14	27.36	38.98	29.50
P_2	2.22	3.06	3.48	2.92	18.01	27.56	39.97	28.51	24.32	28.25	39.87	30.82
K_0	1.81	2.20	2.97	2.33	17.54	24.77	32.78	25.03	19.63	27.59	34.37	27.20
K_1	2.10	2.54	3.21	2.62	17.93	26.19	28.57	27.51	23.57	29.59	38.13	30.43
K_2	2.21	2.30	3.51	2.91	17.81	24.02	40.18	28.34	23.87	26.75	39.10	29.91
Mean (N)	2.04	2.58	3.23		17.76	25.99	37.18		22.36	27.38	37.20	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	1.81	2.20	2.97	3.33	20.64	26.35	28.10	25.03	25.02	27.56	29.01	27.20
K_1	2.10	2.54	3.21	2.62	24.45	29.93	28.31	27.51	29.41	30.81	31.08	30.43
K_2	2.21	2.99	3.51	2.91	27.43	28.44	29.14	28.34	27.24	30.13	32.35	29.91

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.103	1.047	1.969
(ii) NP, NK or PK combination	0.178	1.813	3.410

There was significant increase in the uptake of nitrogen with the application of phosphorus at all the stages. But increasing the level of phosphorus from 15 to 30 kg/ha could not make any difference in the uptake of nitrogen during the last two stages.

Potash application also produced significant influence. Here also increasing the level to 40 kg from 20 kg/ha showed a slight decrease in the uptake of nitrogen during the 3rd stage.

NP, NK and NPK combinations were significant during the first stage. NP, NK,PK, NP^2K and NP^2K^2 were significant during the 2nd stage.

However, during the 3rd stage, only NP combination was significant. n_2p_2 recorded the highest value followed by n_2p_1 but were on par with each other.

3. <u>Total phosphorus content in different plant parts</u>

3.1. <u>Phosphorus content of stover</u>

The data on phosphorus content of stover are furnished in Table 19 and the analysis of variance in Appendix X.

Phosphorus content of stover was significantly influenced by nitrogen application during the first and last stages.

Table 19. Effect of various levels of N,P and K nutrition on phosphorus content of plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	0.11	0.12	0.13	0.12	0.16	0.26	0.15	0.19	0.11	0.12	0.14	0.12
P_1	0.15	0.16	0.18	0.16	0.20	0.26	0.25	0.24	0.16	0.23	0.24	0.21
P_2	0.25	0.29	0.30	0.28	0.40	0.43	0.46	0.43	0.30	0.40	0.43	0.37
K_0	0.17	0.20	0.19	0.19	0.24	0.37	0.27	0.30	0.18	0.24	0.26	0.22
K_1	0.16	0.19	0.21	0.18	0.26	0.29	0.30	0.28	0.20	0.25	0.28	0.24
K_2	0.17	0.18	0.20	0.19	0.27	0.28	0.29	0.28	0.19	0.26	0.26	0.24
Mean (N)	0.17	0.19	0.20		0.26	0.31	0.29		0.19	0.25	0.27	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.12	0.15	0.29	0.19	0.26	0.23	0.40	0.30	0.11	0.19	0.37	0.22
K_1	0.12	0.17	0.26	0.18	0.16	0.25	0.44	0.28	0.14	0.23	0.37	0.24
K_2	0.12	0.16	0.28	0.19	0.15	0.24	0.45	0.28	0.13	0.21	0.38	0.24

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P, or K	0.007	0.056	0.011
(ii) NP, NK or PK combination	0.013	0.097	0.019

Application of phosphorus significantly influenced the phosphorus content of stover at all stages of crop growth and increasing the levels of phosphorus application increased the phosphorus content of stover.

Potash application did not influence the phosphorus content of stover at any stage and it was observed that increasing the rate of potash beyond 20 kg K_2O/ha showed a slight decrease in the phosphorus content of stover.

Among the interactions NP, NK, PK, NP^2K and NP^2K^2 were significant during the first stage of the crop.

NPK alone was significant during the 2nd stage and the combinations NPK^2, NP^2K and NP^2K^2 were significant during the 3rd stage.

3.2. <u>Phosphorus content of seeds</u>

The data on phosphorus content of seeds are furnished in Table 21 and the analysis of variance in Appendix X.

Nitrogen significantly influenced the phosphorus content of seeds at harvest stage.

Application of phosphorus and potash also significantly influenced the phosphorus content of seeds at the harvest stage.

Among the various interactions studied, NP, NK, PK, NPK, NPK^2 and NP^2K^2 were significant.

4. Uptake of phosphorus by different plant parts

4.1. Uptake of phosphorus by stover

The data on uptake of phosphorus are presented in Table 23 and the analysis of variance in Appendix XIII.

Nitrogen significantly influenced the uptake of phosphorus by stover and increasing the levels of nitrogen increased the phosphorus uptake.

Application of phosphorus also made significant influence on the phosphorus uptake and the highest uptake value was obtained with the highest level of phosphorus.

Potash application also made significant influence on the phosphorus uptake by stover at all the stages. But increasing the level of application beyond 20 kg K_2O/ha did not produce any significant difference in the uptake value.

NP, NK, PK and NPK interactions made significant influence on phosphorus uptake in the first stage. All of the interactions were significant on 60th day after sowing.

The interactions NP^2K and NP^2K^2 alone were significant at the harvest stage.

4.2 Phosphorus uptake by seeds

The data on phosphorus uptake by seeds are presented in Table 25 and the analysis of variance in Appendix XV.

Nitrogen significantly influenced the phosphorus

Table 23. Effect of various levels of N, P and K nutrition on phosphorus uptake by plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	0.18	0.21	0.25	0.21	1.56	1.73	1.83	1.71	1.15	1.15	1.48	1.32
P_1	9.26	0.32	0.42	0.33	1.94	3.11	3.68	2.91	1.23	2.49	2.94	2.35
P_2	0.47	0.95	0.70	0.61	3.84	5.32	6.38	5.18	3.12	4.50	5.11	4.25
K_0	0.28	0.40	0.43	0.37	2.30	3.20	3.51	2.99	1.80	2.70	2.93	2.75
K_1	0.28	0.39	0.47	0.38	2.45	3.58	4.17	3.40	2.08	2.81	3.38	2.76
K_2	0.35	0.39	0.48	0.41	2.60	3.39	4.22	3.40	2.01	2.82	3.22	2.68
Mean (N)	0.30	0.39	0.46		2.45	3.39	3.96		1.96	2.77	3.17	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.20	0.30	0.61	0.37	1.65	2.63	4.71	2.99	1.22	2.11	4.10	2.75
K_1	0.22	0.35	0.57	0.38	1.75	3.15	5.29	3.40	1.41	2.61	4.25	2.76
K_2	0.22	0.35	0.64	0.41	1.73	2.95	5.53	3.40	1.33	2.33	4.39	2.68

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.017	0.121	0.130
(ii) NP, NK or PK combination	0.030	0.209	0.225

uptake by grains and the highest uptake value was recorded by the highest level of nitrogen.

Application of phosphorus also made significant influence on the uptake of phosphorus by grains and here also the highest value was obtained with the highest level of phosphorus.

Potassium application had no significant effect on the phosphorus uptake of seeds.

Among the interactions only NP^2K was significant.

4.3. Total uptake of phosphorus

The data on total uptake of phosphorus are presented in Table 27 and the analysis of variance in Appendix XVII.

Nitrogen significantly influenced the total uptake of phosphorus at all the stages.

Phosphorus uptake was increased significantly with applied phosphorus and the highest uptake value was recorded with the highest level of phosphorus.

Potash application also got significant influence on the total phosphorus uptake but increasing the level of potash further to 40 kg/ha showed no difference in the total uptake of phosphorus as compared to 20 kg K_2O/ha during the 2nd and 3rd stages respectively.

Among the various interactions NP, NK, PK and NPK were significant in the first stage of the crop.

All of the interactions were significant during the 2nd stage of the crop.

Table 27. Effect of various levels of N, P and K nutrition on total uptake of phosphorus by plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	0.18	0.21	0.25	0.21	1.56	1.73	1.83	1.71	2.31	2.57	2.88	2.59
P_1	0.26	0.32	0.42	0.33	1.94	3.11	3.68	2.91	2.61	3.90	4.58	3.69
P_2	0.47	0.95	0.70	0.61	3.84	5.32	6.38	5.18	4.29	5.95	6.89	5.71
K_0	0.28	0.40	0.43	0.37	2.30	3.20	3.51	2.99	2.91	3.99	4.50	3.80
K_1	0.28	0.39	0.47	0.38	2.45	3.58	4.17	3.40	3.09	4.16	5.02	4.09
K_2	0.35	0.39	0.48	0.41	2.60	3.39	4.22	3.40	3.21	4.27	4.82	4.10
Mean (N)	0.30	0.39	0.46		2.45	3.39	3.96		3.07	4.14	4.78	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.20	0.30	0.61	0.37	1.65	2.63	4.71	2.99	2.49	3.54	5.37	3.80
K_1	0.22	0.35	0.57	0.38	1.75	3.15	5.29	3.40	2.65	3.93	5.69	4.09
K_2	0.22	0.35	0.64	0.41	1.73	2.95	5.53	3.40	2.62	3.61	6.08	4.10

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.017	0.121	0.246
(ii) NP, NK or PK combination	0.030	0.209	0.426

However, during the 3rd stage the interactions NP and NPK^2 alone were significant.

5. Total potassium content in different plant parts

5.1. Potassium content of stover

The data on potassium content of stover are presented in Table 20 and the analysis of variance in Appendix XI.

Nitrogen and phosphorus did not produce any significant influence on the potassium content of stover. Potassium content of stover increased significantly with increasing levels of applied potassium. Among the various interactions only the interaction NP^2K was significant during the 2nd stage.

5.2. Potassium content of seeds

The data on potassium content of seeds are presented in Table 21 and the analysis of variance in Appendix XI.

Nitrogen significantly influenced the potassium content of seeds. Potassium content was not affected by phosphorus application at any of the stages. Applied potassium significantly increased the potassium content of seeds. The interaction NP^2K alone was significant.

6. Potassium uptake by different plant parts

6.1. Uptake of potassium by stover

The data on uptake of potassium by stover are presented in Table 24 and the analysis of variance in Appendix XIV.

Nitrogen significantly influenced the uptake of potassium on 60th day after sowing and at harvest stage. Applied

Table 20. Effect of various levels of N, P and K nutrition on potassium content of plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	0.88	0.99	0.88	0.91	1.32	1.34	1.33	1.33	0.93	1.13	1.14	1.07
P_1	0.73	0.92	0.69	0.78	1.25	1.18	1.35	1.26	0.98	0.93	1.12	1.01
P_2	0.86	0.88	0.82	0.85	1.27	1.29	1.41	1.32	1.01	0.99	1.18	1.06
K_0	0.38	0.66	0.33	0.46	0.56	0.55	0.71	0.61	0.41	0.48	0.52	0.47
K_1	0.57	0.70	0.80	0.69	1.49	1.42	1.47	1.46	1.09	1.08	1.35	1.17
K_2	1.52	1.43	1.26	1.40	1.79	1.84	1.91	1.85	1.48	1.49	1.57	1.49
Mean (N)	0.82	0.93	0.80		1.28	1.27	1.36		0.97	1.02	1.15	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.56	0.37	0.43	0.46	0.63	0.58	0.61	0.61	0.49	0.44	0.48	0.47
K_1	0.74	0.57	0.76	0.69	1.52	1.31	1.54	1.46	1.23	1.08	1.21	1.17
K_2	0.14	1.40	1.36	1.40	1.85	1.89	1.81	1.85	1.48	1.51	1.49	1.49

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.206	0.144	0.172
(ii) NP, NK or PK combination	0.356	0.249	0.299

Table 24. Effect of various levels of N, P and K nutrition on the uptake of potash by plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.46	1.80	1.74	1.66	12.61	15.62	16.50	14.91	9.56	12.16	12.21	11.31
P_1	1.36	1.92	1.64	1.64	11.95	14.10	19.75	15.29	10.15	10.62	14.08	11.62
P_2	1.71	2.03	1.90	1.88	12.18	16.23	19.88	16.09	10.71	11.26	14.26	12.08
K_0	0.60	1.20	0.63	0.81	5.34	6.19	9.00	6.84	4.19	6.28	5.88	5.45
K_1	0.99	1.42	1.77	1.39	14.24	17.27	19.96	17.15	11.31	11.88	15.79	12.99
K_2	2.93	3.13	2.88	2.98	17.16	22.55	27.16	22.29	14.92	15.88	18.88	16.56
Mean (N)	1.51	1.92	1.76		12.25	15.34	18.71		10.14	11.35	13.52	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.85	0.69	0.89	0.81	6.53	6.60	7.30	6.84	5.32	5.67	5.35	5.45
K_1	1.36	1.16	1.66	1.39	16.90	16.30	18.24	17.15	12.88	12.39	13.72	12.99
K_2	2.78	3.08	3.08	2.98	21.20	22.90	22.60	22.29	15.74	16.79	17.16	16.56

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.395	1.777	1.985
(ii) NP, NK or PK Combination	0.684	3.077	3.438

Phosphorus did not affect the uptake of potassium. Potassium significantly influenced the potassium uptake by stover at all stages of growth. Potassium uptake was significantly increased with increasing levels of potassium. None of the interactions was found to be significant regarding the uptake of potassium.

6.2. <u>Potassium uptake by seeds</u>

The data on potassium uptake by seeds are presented in Table 25 and the analysis of variance in Appendix XV.

Nitrogen significantly influenced the potassium uptake by grains. Potassium uptake was significantly influenced by the applied phosphorus. Applied potassium significantly increased the potassium uptake by grains.

Among the interactions NP^2K and NP^2K^2 were significant.

6.3. <u>Total uptake of potassium</u>

The data on total uptake of potassium are presented in Table 28 and the analysis of variance in Appendix XVIII.

Total uptake of potassium was significantly influenced by nitrogen application on 60th day after sowing and at harvest. There was no significant influence on the potash uptake by the application of phosphorus. However the total uptake of potash was significantly increased with applied potassium at all the stages of growth.

None of the interactions was found to be significant for the total uptake of potassium.

Table 28. Effect of various levels of N, P and K nutrition on total uptake of potash by plants at different stages.

	30th day after sowing				60th day after sowing				Harvest			
	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K	n_0	n_1	n_2	Mean P or K
P_0	1.46	1.80	1.74	1.66	12.61	15.62	16.50	14.91	10.81	13.49	13.71	12.67
P_1	1.36	1.92	1.64	1.64	11.95	14.10	19.75	15.29	11.47	12.02	14.73	13.07
P_2	1.71	2.03	1.90	1.88	12.18	16.23	19.88	16.09	12.01	12.66	15.84	13.50
K_0	0.60	1.20	0.63	0.81	5.34	6.19	9.00	6.84	5.35	7.61	17.34	6.77
K_1	0.99	1.42	1.77	1.39	14.24	17.27	19.96	17.15	12.62	13.19	17.39	14.39
K_2	2.93	3.13	2.88	2.98	17.16	22.55	27.16	22.29	16.32	17.38	20.55	18.08
Mean (N)	1.51	1.92	1.76		12.25	15.34	18.71		11.43	12.72	15.09	
	P_0	P_1	P_2		P_0	P_1	P_2		P_0	P_1	P_2	
K_0	0.85	0.69	0.89	0.81	6.53	6.60	7.30	6.84	6.61	7.02	6.68	6.77
K_1	1.36	1.16	1.66	1.39	16.90	16.30	18.24	17.15	14.21	13.87	15.11	14.39
K_2	2.78	3.08	3.08	2.98	21.20	22.90	22.60	22.29	17.2	18.34	18.72	18.08

CD for comparison of means

	30th day	60th day	Harvest
(i) N, P or K	0.395	1.777	2.001
(ii) NP, NK or PK combination	0.684	3.077	3.466

Soil Analysis

7.1. Total nitrogen content of the soil after the experiment

The data on total nitrogen in soil after the harvest are furnished in Table 29 and the analysis of variance in Appendix XIX.

It is seen that application of nitrogen, phosphorus and potash could not make any significant influence on the nitrogen content of soil after the harvest of the crop.

Among the interactions the higher values of soil nitrogen were recorded by n_0p_2, p_0k_0 and p_2k_2.

7.2. Available phosphorus content of soil after the experiment

The data on the available phosphorus content of soil after the harvest are presented in Table 29 and the analysis of variance in Appendix XIX.

The data revealed that there was no significant difference in the available phosphorus content of soil due to various levels of phosphorus or potash.

Among the various interactions n_0p_0, n_0k_1, and p_1k_0 recorded comparatively higher values of available phosphorus contents.

7.3. Available potassium content of soil after the experiment

The values on the available potassium content of soil after harvest are given in Table 29 and the analysis of variance in Appendix XIX.

It is seen that the different levels of nitrogen did not make any significant difference in the available

Table 29. Effect of various levels of N, P and K on nitrogen, Phosphorus and potassium content of the soil after the experiment

	Nitrogen content				Phosphorus				Potassium content			
	n_0	N_1	N_2	Mean P or K	N_0	n_1	n_2	Mean P or K	n_0	N_1	n_2	Mean P or K
P_0	0.05	0.05	0.05	0.05	43.59	41.37	42.11	42.11	40.32	44.80	44.05	43.06
P_1	0.04	0.05	0.05	0.05	42.98	41.17	42.18	42.11	44.80	45.55	45.44	45.30
P_2	0.06	0.04	0.05	0.05	41.17	41.97	41.77	41.64	45.55	47.04	47.79	46.79
K_0	0.05	0.05	0.05	0.05	42.38	41.97	42.38	42.24	39.57	43.31	41.81	41.56
K_1	0.05	0.04	0.05	0.05	43.18	41.77	42.58	42.51	41.07	44.05	44.05	43.06
K_2	0.05	0.05	0.05	0.05	42.18	40.76	40.36	41.09	50.03	50.03	51.52	50.52
Mean (N)	0.05	0.05	0.05		42.58	41.50	41.77					
	P_0	P_1	P_2									
K_0	0.06	0.05	0.05		42.38	43.59	40.76	38.08	42.56	44.05	41.56	
K_1	0.05	0.04	0.04		42.78	42.58	42.18	41.81	42.56	44.80	43.06	
K_2	0.05	0.05	0.06		41.17	40.16	41.97	49.28	50.77	51.52	50.52	

CD for comparision of mean among N = 0.003
CD for comparison of means among NP, NK or PK combination = 0.005

CD for comparison among P = 1.972
CD for comparison among NP, NK or PK combination = 3.415

CD for comparison among K = 2.719
CD for comparision among NP, NK or PK combination = 4.710

potassium content of soil. However, the different levels of phosphorus and potassium could increase the available potassium content of soil.

Among the various NP interactions the highest quantity of available potassium was shown by n_2p_2. Among NK and PK interactions n_2k_2 and P_2K_2 **have** recorded the highest content of available potassium.

7.4. <u>Organic carbon content of soil after the experiment</u>

The organic carbon content of soil after the harvest are furnished in Table 30 and the analysis of variance in Appendix XX.

The data revealed that there was no significant difference in the organic carbon content of soil due to either different levels of nitrogen or phosphorus. However, the different levels of potassium could make significant difference in the organic carbon content of soil.

8. <u>Economics of nitrogen, phosphorus and potassium applicatio</u>

The economics of nitrogen, phosphorus and potassium application presented in Table 31 revealed that the combined application of 40 kg N, 15 kg P_2O_5 and 20 kg K_2O/ha ($N_2P_1K_1$) gave the highest net profit (Rs. 1520) followed by 40 kg N, 15 kg P_2O_5 and 0 kg K_2O/ha (Rs. 610). The increase in net

TABLE 30 Effect of various levels of N, P and K on organic carbon content of the soil after the experiment.

Levels of Phosphorus of Potash	LEVELS OF NITROGEN OR PHOSPHORUS			
	n_0	n_1	n_2	Mean P or K
P_0	0.499	0.502	0.488	0.496
P_1	0.528	0.486	0.514	0.509
P_2	0.471	0.498	0.494	0.488
K_0	0.503	0.483	0.451	0.479
K_1	0.488	0.494	0.515	0.499
K_2	0.506	0.510	0.529	0.515
Mean (N)	0.499	0.495	0.498	
	P_0	P_1	P_2	
K_0	0.492	0.490	0.455	
K_1	0.476	0.508	0.513	
K_2	0.520	0.530	0.495	

Marginal CD = 0.028

Combination CD = 0.048

profit by the application of $N_2P_1K_1$ over control was Rs. 1070. Hence it can be stated that $N_2P_1K_1$ is the best combination of nitrogen, phosphorus and potassium to obtain maximum profit.

From these results, it can be concluded that a combination of 40 kg N, 15 kg P_2O_5 and 20 kg K_2O/ha is the most advantageous fertilizer dose for sesamum var *Thilothama* in the red loam soils of Vellayani.

DISCUSSION

DISCUSSION

An investigation was carried out at the Agricultural College and Research Institute, Vellayani to find out the influence of nutrient combinations on sesamum crop in order to ascertain the best combination of nutrients.

Data were recorded on height of plants, number of leaves per plant, number of branches per plant, number of nodes per plant, leaf area per plant and dry matter production. Also the data were recorded on the yield components and yield such as number of capsules per plant, weight of capsules per plant, number of seeds per capsule, seed weight per plant, test weight of seed, seed yield, stover yield, shelling percentage and harvest index. The data were obtained on quality attributes such as oil content, protein content and oil yield.

The data obtained on various characters mentioned above are discussed hereunder.

A. Growth characters

1. Height of plants

Significant increase in the height of plant was observed at the 60th day after sowing due to nitrogen application at 40 kg N/ha over 20 kg N/ha. The role of nitrogen being the development of vegetative parts, it is quite natural that increasing levels of nitrogen increased the height of plants. Rahman et al (1978) reported increased plant height with higher levels of nitrogen application.

While the application of phosphorus did not influence the height of plants, potash application could influence the height favourably upto 15 kg/ha, beyond which it exerted a slight depressing effect. The effect of phosphorus is not generally seen on the vegetative development and therefore it failed to produce significant influence on the height of plants. Regarding the influence of potash, in many of the early studies contradictory reports were being revealed. While Rahman et al (1978) reported increased plant height with increased potash application, Satyanarayana et al (1978) observed that the height of the plant was not affected by the application of 30 and 60 kg potash per ha. In the present study also the effects of potash was evident on this aspect only upto 15 kg K_2O/ha.

2. Number of leaves per plant

It was found that the number of leaves produced during the initial stage was not influenced by the application of nitrogen, whereas at the later stages there was significant increase in the number of leaves. When the plants could put-forth enough number of roots to absorb the applied nitrogen in sufficient quantities, it could increase the number of leaves per plant.

It was seen that phosphorus could not produce any favourable influence on the height of plant. In the same way it could not affect the number of leaves per plant too. Potash influenced the number of leaves only upto 15 kg K_2O/ha. However, this influence of potash was observed only at 30th day after sowing.

3. Number of branches per plant

While nitrogen significantly increased the number of branches per plant at the highest level of application, phosphorus and potash could not produce any favourable influence on this character. Instead, they depressed this character when applied beyond 15 kg each per ha. The favourable influence of nitrogen on the number of branches was recognised universally as the role of nitrogen is to improve the vegetative growth of plant. Subramanian *et al* (1979) observed increased number of branches per plant in sesamum with the increased level of application of nitrogen. The results of the present investigation are also in agreement with the above findings. It is seen that potash was able to increase the height of plant only upto 15 kg/ha, but with out much effect on the number of branches. It appears that the extent of deficiency required for the induction of response in branching with applied potash may be much higher than that required for increasing the height of plants.

4. Number of nodes per plant

As in the case of number of leaves per plant, the number of nodes per plant was also significantly influenced by the nitrogen application. Here also significant influence was observed only on 60th day after sowing. The reasons projected for the number of leaves are applicable in this case also.

While phosphorus did not influence the number of nodes per plant, significant influence was brought out by the application of potash especially at the 30th day after sowing. It is seen that phosphorus could not produce any improvement on any of the vegetative characters and as such it is but natural that it could not exert any influence on the number of nodes per plant also. The favourable influence of potash was observed on the important vegetative characters like height and number of leaves per plant.

5. Leaf Area per plant

Among the three nutrients tried only nitrogen and phosphorus could increase the leaf area significantly. However, in the case of phosphorus a depressing trend was observed when applied beyond 15 kg P_2O_5/ha. The role of nitrogen in increasing the leaf area is universally recognised and that is why, in the present study also the highest leaf area was obtained with the highest level of nitrogen tried. In the case of nitrogen and phosphorus not only their main effects were significant, but many of their interactions were also found to be significant. Among the NP interactions the n_2p_1 (40 kg N and 15 kg P_2O_5/ha) recorded the highest value of leaf area per plant.

6. Dry matter production

It is seen that the application of nitrogen increased the dry matter production significantly and the highest production was recorded with the highest level of nitrogen at all stages. From the data presented in Table 4 it was observed that nitrogen effected increase in all the vegetative characters like height, number of leaves per plant, number of branches per plant and total leaf area per plant. Therefore it is but natural that nitrogen could produce increased dry matter with incremental doses of nitrogen. Moursi et al (1966), Pal (1979) and Vir et al (1979) reported increased dry matter with increased nitrogen levels in different oil seed crops including sesamum.

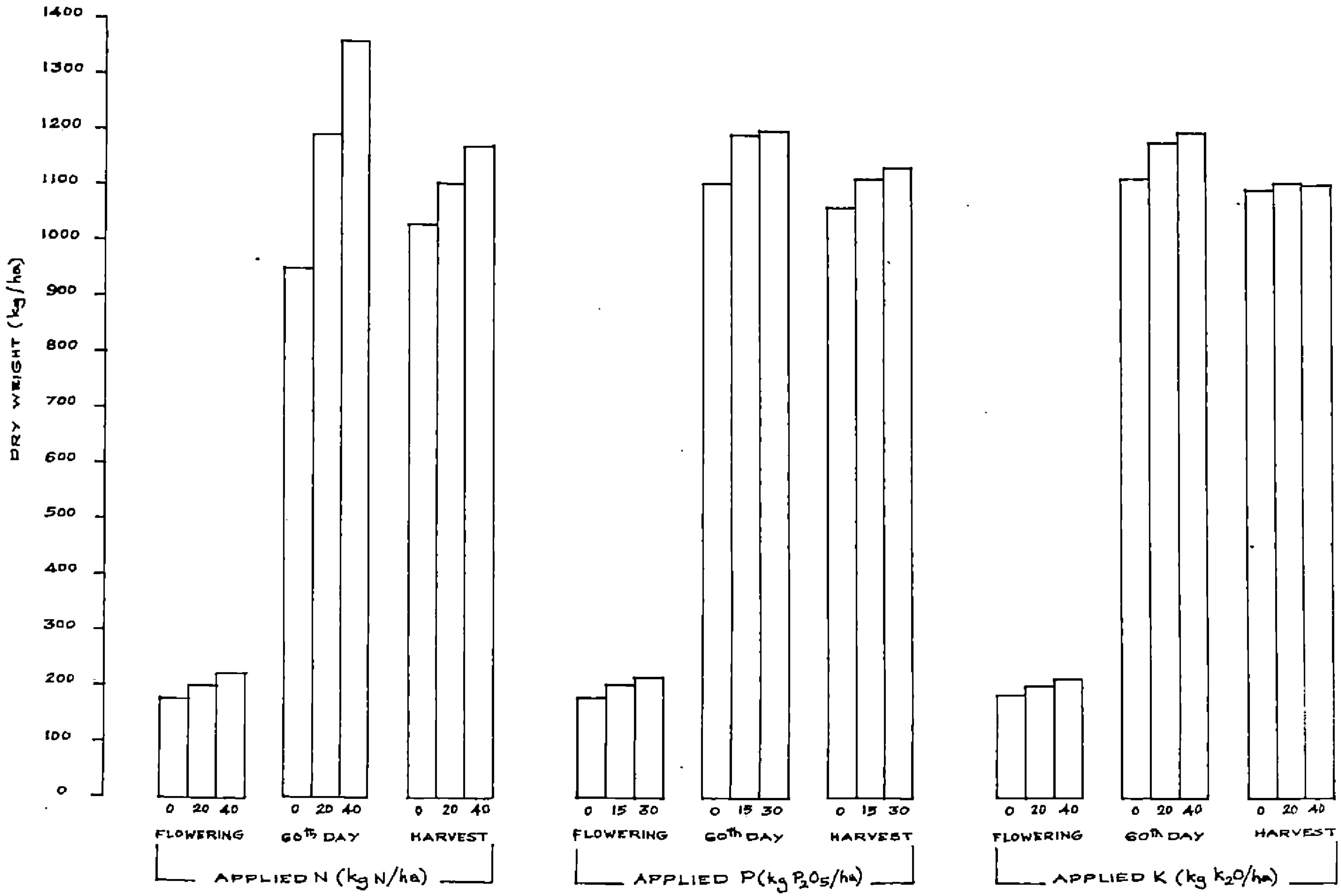
It is seen that phosphorus and potash could also increase the dry matter production. However, the response was seen only upto 15 kg each per hectare. Moursi et al (1966), Gopalakrishnan et al (1971) and Pal (1979) could bring out data showing that phosphorus could favourably influence the total dry matter production in plants. Positive effect of potash on dry matter production was brought out by Maini et al (1965), Gopalakrishnan et al (1971) and Rao (1979).

B. Yield and Yield attributes

1. Number of capsules per plant

Increasing levels of nitrogen increased the number of capsules per plant significantly. However, phosphorus and

FIG. 3. EFFECT OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON TOTAL DRYMATTER PRODUCTION (kg/ha) OF SESAMUM.



Potash did not influence the number of capsules per plant although an increasing trend was observed upto 15 kg/ha.

Gowda and Krishnamurthy (1977) pointed out that the number of capsules is an important yield contributing character in sesamum. Moursi et al (1966) pointed out that nitrogen application increased the number of fruits per plant in sesamum. Bonsu (1977), Maiti et al (1980) and Subramanian et al (1979) in sesamum, Rahman et al (1978) in safflower, Singh et al (1978) in mustard also reported increased number of capsules per plant with incremental doses of nitrogen.

However, Satyanarayana (1978) reported that potash application failed to produce any effect on the number of capsules per plant. This is in agreement with the findings of the present investigation also.

2. Weight of capsules per plant

The data presented in Table 6 revealed that the different levels of nitrogen increased the weight of capsules per plant although the increase was not significant. It is already evident that nitrogen could influence the number of capsules per plant (Table -7). When the number of capsules per plant was increased due to incremental doses of nitrogen, there should have increased weight of capsules per plant also.

Application of phosphorus and potash also increased the weight of capsules per plant but only upto 15 kg/ha, beyond which slight decrease was observed. The data on the number of capsules per plant also revealed positive effect of phosphorus and potash only upto 15 kg/ha.

3. <u>Number of seeds per capsule</u>

There was significant increase in the number of seeds per capsule with incremental levels of nitrogen application. It is seen from the data (Table 8) that the highest level of nitrogen could produce an average number of forty seeds per capsule. The data on the uptake of nitrogen (Table 26) revealed that the highest nitrogen uptake was seen with the highest level of nitrogen. This higher amount of nitrogen uptake would have been responsible for better filling of the capsules with more number of seeds, there by contributing to higher weight of capsules per plant.

As in the case of weight of capsules, the phosphorus levels could increase the number of seeds per capsule only upto 15 kg P_2O_5/ha beyond which a slight decrease was observed. Potash also could increase the number of seeds per capsule.

Among the various interactions, the NP interactions were found to be significant. While the interaction n_2p_1 produced the highest value, the lowest value was recorded by n_0p_0.

4. Weight of seed per plant

The data on the weight of seeds per plant (Table 9) revealed that the levels of nitrogen could produce significant influence on the weight of seed per plant and the highest value of 0.95 g/plant was recorded with the highest level of nitrogen. It is seen that the higher uptake of nitrogen in the treatment having the highest level of nitrogen could produce more number of seeds per capsule which means more weight of seeds per capsule. The data on the number of capsules per plant also revealed the fact that higher levels of nitrogen could increase number of capsules per plant. Thus these two factors viz. more number of seeds per capsule and more number of capsules per plant contributed to increased weight of seeds per plant.

However, phosphorus and potash could not produce any significant influence on this character. Although phosphorus could increase the number of seeds per capsule upto 15 kg P_2O_5/ha, it could not significantly influence the number of capsules per plant (Table 9). Moreover, there appeared a depressing trend beyond 15 kg P_2O_5/ha. Similar results have been obtained in the case of potash also. Therefore phosphorus and potash did not produce any significant influence on the weight of seed per plant.

5. 1000 seed weight

In the case of 1000 seed weight, only nitrogen could significantly increase this character. The highest level of 40 kg N/ha produced an average 1000 seed weight of 2.47 gram.

The higher amount of nitrogen absorbed by the plant would have been utilized not only for increasing the number of seeds per capsule but also for increasing in size of seeds by proper filling of the grains. The experiment conducted at Jalgaon under the All India Co-ordinated Research Project on oil seeds also revealed that higher levels of nitrogen could increase the 1000 seed weight in sesamum (Anon, 1974).

The behaviour of phosphorus and potash was similar to that in the case of number of capsules per plant and number of seeds per capsule and as such they could not produce positive influence on 1000 seed weight. Satyanarayana (1978) has shown that 1000 seed weight was not influenced by potash application.

6. Seed yield

The data on seed yield presented in Table 11 revealed that nitrogen application produced significant increase in seed yield. The highest seed yield of 367.77 kg/ha was produced by 40 kg N/ha.

The data on various yield attributes like number of capsules per plant (Table 6) weight of capsules per plant (Table 7), number of seeds per capsule (Table 8), weight of seeds per plant (Table 9) and 1000 seed weight (Table 10) revealed the favourable role of nitrogen in increasing the above yield attributes. Therefore it is quite natural that the seed yield which is a final expression of all the yield attributing characters has been increased with incremental doses of nitrogen. This role of nitrogen in increasing the seed yield of sesamum has been studied by several workers and the favourable effect reported abundantly in literature(Rao and Srivastava, (1968); Gaur and Trehan (1973); Singh and Kaushal (1973 and 1975); Gowda (1974); Gowda et al (1977), Mehrotra et al (1978); Satyanarayana (1978) and Sennaiyan and Arunachalam (1978). In an experiment conducted at Jalgaon under the All India Co-ordinated Research Project on Oil seeds, there was linear response to nitrogen upto the highest level of 60 kg N/ha (Anon, 1974).

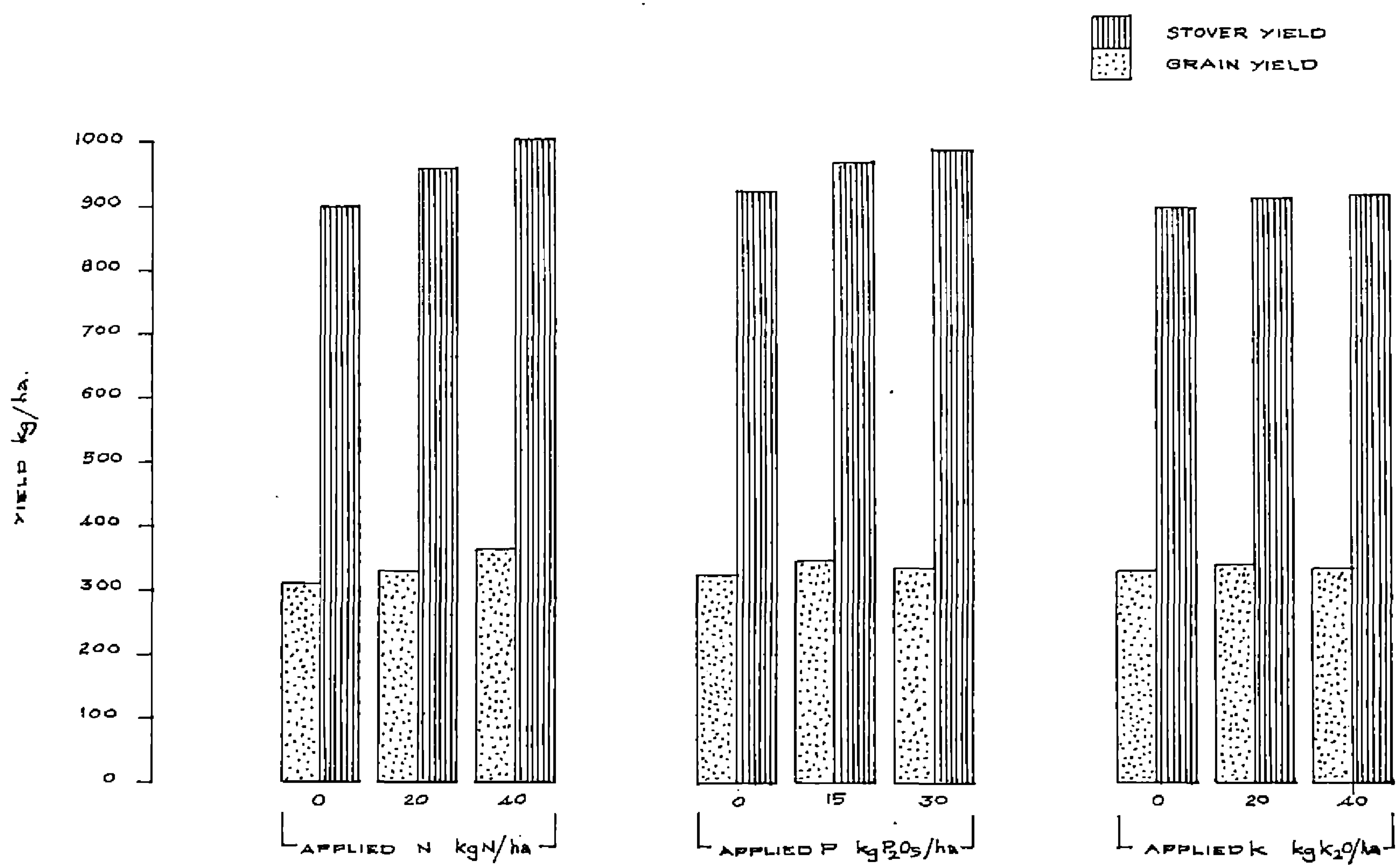
Although phosphorus could increase the seed yield significantly, potash could not prove its superiority in increasing the seed yield. On the contrary potash application beyond 15 kg K_2O/ha produced a slight decline in yield. Unlike potash phosphorus could increase the number of seeds per capsule thereby helped to increase the seed yield per plot. As potash did not support any of the yield attributing characters it is but natural that potash could not increase the grain yield significantly. Positive effects of phosphorus in increasing seed yield in sesamum has been projected by many workers like Gowda (1974); Singh and Kaushal (1975); Popov et al (1976) and Maiti (1981). The non_ responsive nature of potash has also been reported by many workers. According to Arunachalam and Sennaiyan (1977) fertilizer application failed to produce any response to yield in TMV-3 sesamum. Similarly Sadanandan and Sasidhar (1979) in a fertilizer trial with sesamum variety Kayamkulam-1 in the red loam soils of Vellayani observed that application of 0-45 kg K_2O/ha did not affect the seed yield. Similar effects of potash have been reported by workers like Brady and Colwell (1945) and Maini et al (1965). Singh and Kaushal (1973) even reported a decrease in the seed yield of rainfed sesamum with increase in rate of potash from 0-60 kg/ha.

7. Stover yield

It is seen that there was significant increase in the yield of stover with increasing levels of nitrogen (Table 12). Phosphorus also could increase the stover yield upto 15 kg P_2O_5/ha beyond which the response was not significant although the highest stover yield was recorded with the highest level of phosphorus. However, potash application did not produce any significant yield increase.

Nitrogen is well known for its influence on Vegetative growth (Moursi et al (1966); Gopalakrishnan et al (1971); Rahman et al (1978); Subramanian et al (1979); Vir et al (1979 and Pal (1979). Therefore in the present study also the higher levels of nitrogen had increased the vegetative parts of the plant body and thereby increased the stover yield.

FIG. 4. EFFECTS OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON GRAIN AND STOVER YIELD OF SESAMUM.



The data on the uptake of nitrogen (Table 26) revealed that the highest uptake of nitrogen was in the plot receiving the highest level of nitrogen. This enhanced rate of nitrogen would have been responsible for the increased vegetative growth. It is seen that all the vegetative characters like dry weight of plants, number of leaves per plant and number of branches per plant were increased due to increased nitrogen levels thereby contributing to higher amount of stover yield.

The higher levels of phosphorus also enhanced the nitrogen uptake (Table 26) especially during the initial stage. This enhanced uptake of nitrogen would have been responsible for the increased stover yield.

Although potash application did not significantly produce any increase in stover yield; increasing levels of potassium tended to increase the stover yield.

8. <u>Shelling percentage</u>

Although nitrogen could significantly influence the shelling percentage, there was no difference between 20 and 40 kg N/ha. Phosphorus and potash did not influence the shelling percentage. The positive effect of nitrogen on shelling percentage was reflected on the seed yield also. As the degree of improvement in this character is very much limited even nitrogen could not give a linear response with higher levels of nitrogen. Similar effect of nitrogen was also reported by workers like Rogers (1948), Brady (1948), Reed and Brady (1947).

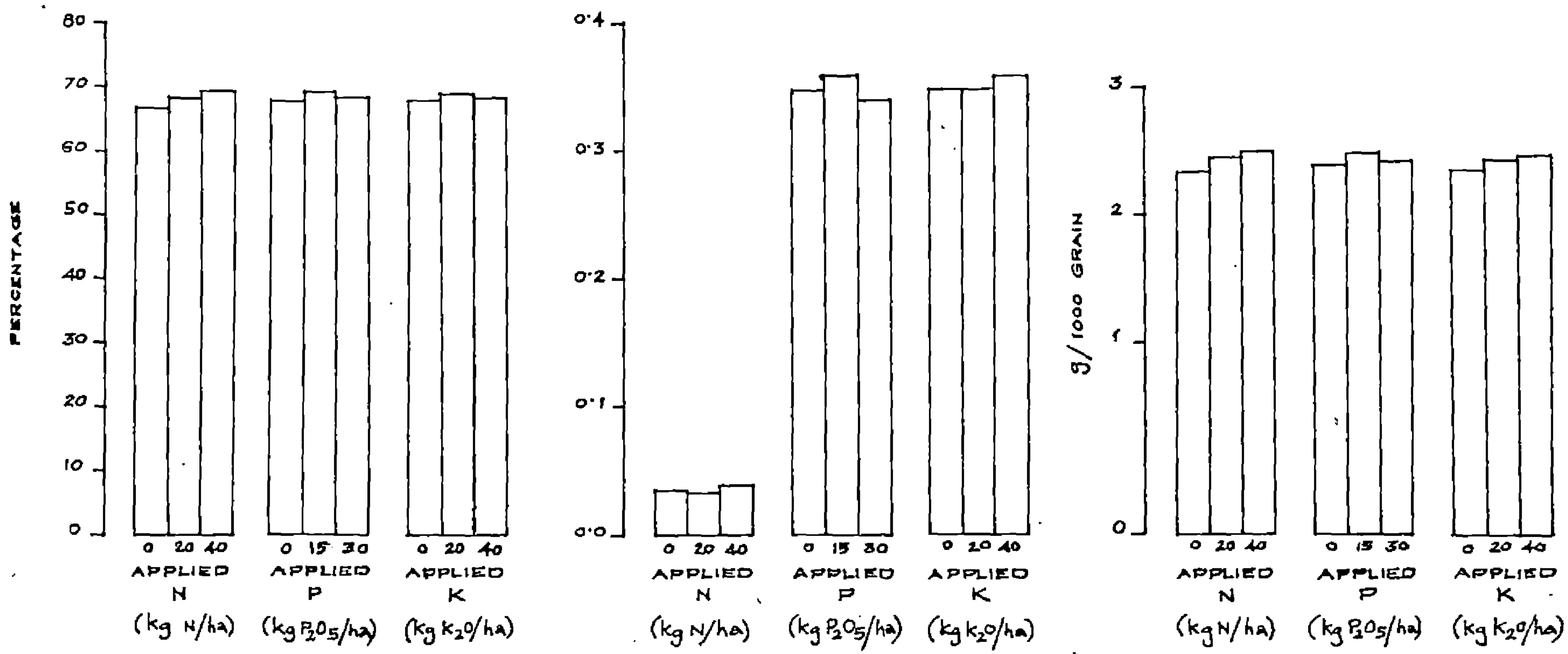
As phosphorus and potash are not directly involved in the filling up of the grains they did not give any significant increase in the shelling percentage.

9. Harvest index

Harvest index is defined as the ratio of economic yield to biological yield. In the present study it is seen that the nitrogen levels increased the harvest index values with the result that the highest value was recorded by the highest nitrogen level. Applied nitrogen significantly increased most of the yield attributing characters like number of capsules per plant, weight of capsules per plant, number of seeds per capsule, 1000 seed weight and seed yield. Along with this the vegetative characters were also increased with increasing levels of nitrogen. However, the role of nitrogen was selective in the sense that the vegetative attributes were improved only to the extent to contribute substantially to the productive attributes so as to get a higher harvest index value.

Unlike nitrogen, phosphorus and potash did not produce any significant influence on harvest index. This is quite natural because phosphorus and potash could not significantly influence many of the productive attributes like number of capsules per plant, weight of seeds per plant and on the

FIG. 5. EFFECT OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON SHELLING PERCENTAGE, HARVEST INDEX AND TEST WEIGHT OF SEEDS OF SESAMUM.



other productive characters like number of seeds per capsule and 1000 seed weight they had influence only upto 1$ kg each/ha beyohd which depressive effects were noticed in some cases.

C. Quality attributes

1. Oil content

It is seen from the data on oil content (Table 15) that nitrogen could significantly influence the oil content only upto 20 kg/ha since the difference in oil content between 20 and 40 kg N/ha was not significant. Satyanarayana (1978) observed that oil yield of two sesamum cultivars were higher with the application of 25 kg N/ha. The result of the present study is in agreement with the findings of Singh et al (1979) in brown Sarson that oil content was increased by low rates of nitrogen application, but decreased with the higher rates (48-60 kg N/ha).

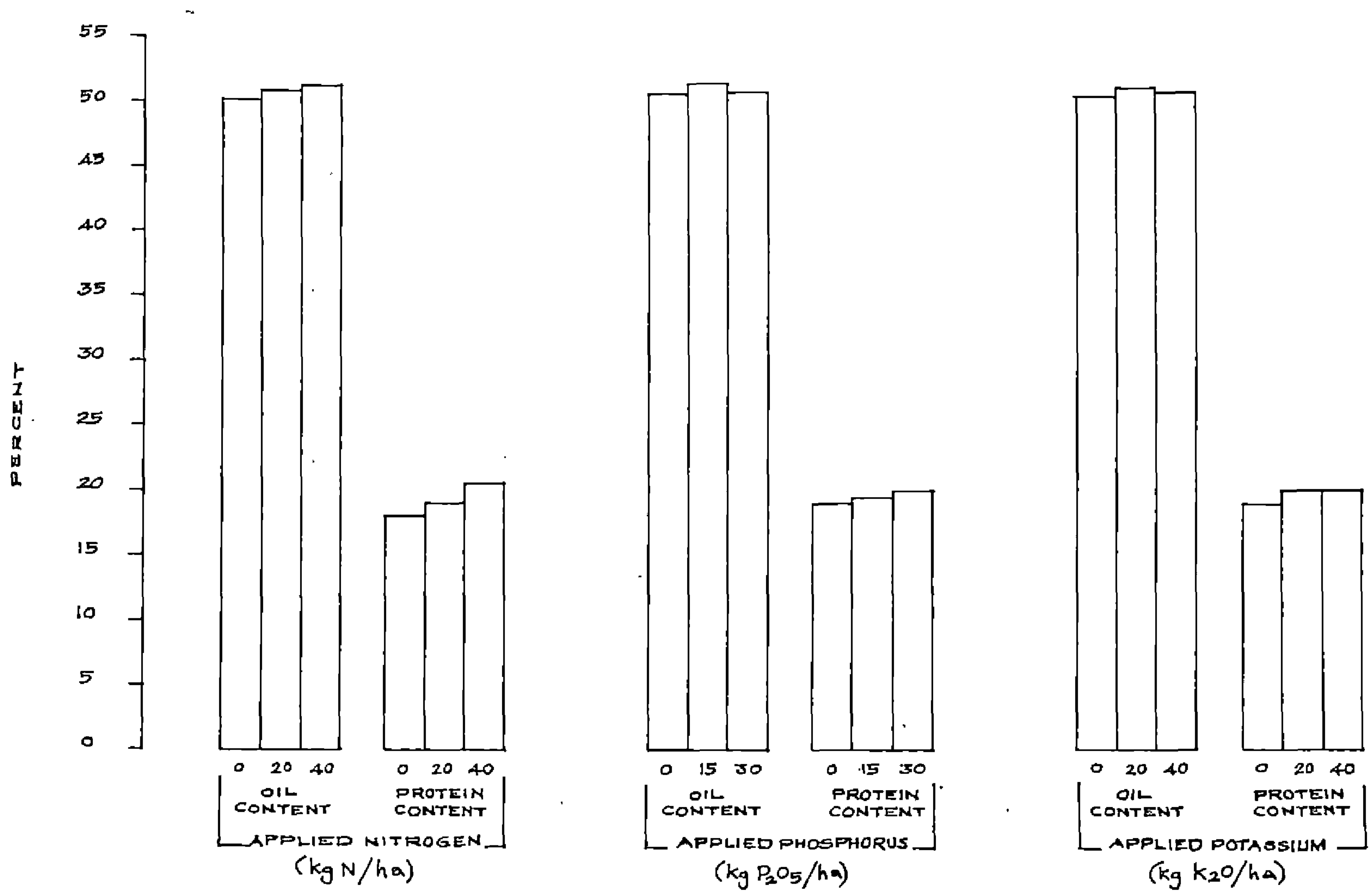
The observation that phosphorus did not produce any significant increase in oil content is in agreement with the findings of several workers in different oil seed crops. For example Mitchell et al (1974) observed that phosphorus had no effect on the seed quality of sesamum. According to Revenko (1977), different combinations of phosphorus, nitrogen and potash did not favour an increase in oil content of sunflower. Munoz (1979) observed that phosphorus application had no effect on the oil content of rape.

As in the case of phosphorus potash also could not significantly influence the oil content of sesamum. This observation is also quite in agreement with the findings of several workers. Brady Colwell (1945) reported that the oil content of large seeded type peanut was not affected by potash application. Maini et al (1965) in mustard and Gupta and Das (1973) in rape seed reported that in both crops the oil content was not affected by the application of potash. The result of the present study that at higher levels of potash application there was a reduction in the oil content is also in agreement with the findings of Mitchell et al (1974) that increased levels of potash tended to reduce the oil content of sesamum in a pot culture study.

2. Protein content

The data presented in Table 16 revealed that the protein content of seed was significantly increased with increasing levels of nitrogen and the highest value was recorded by the highest level of nitrogen. It is seen that the nitrogen content of seed (Table 21) and total uptake of nitrogen by seed (Table 26) were increased with incremental doses of nitrogen. As nitrogen is an integral part of protein it is quite natural that increased uptake of nitrogen by the seed increased the total protein

FIG.6. EFFECT OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON OIL AND PROTEIN CONTENT OF SESAMUM.



content of grains in the present study. The result of the present study is in agreement with the findings of several workers like Bhuiya et al (1974); Mitchell (1974), Mitchell et al (1974); Mitchell et al (1976) and Skalski (1978).

Phosphorus also increased the protein content of seed significantly and here again the hibest value of protein was recorded by the highest level of phosphorus. The data on Table 21 and Table 25 revealed that the content and uptake of phosphorus by grains were higher with incremental doses of phosphorus. This increased uptake of phosphorus would have been responsible for the significant increase in protein content of grains. The percentage of protein in groundnut was found to be increased with incremental level of phosphorus by Bhuiya et al (1978).

Contrary to the effects of nitrogen and phosphorus, potash could not produce any significant influence on the protein content of seeds. Moreover, at higher levels it tended to reduce the protein content. Quilantan - Villareal (1969) observed a decrease in protein content by potash application in sesamum. Similar results were obtained by Bhuiya and Chowdhary (1974) in groundnut. The protein content was found to decrease when the applied potash was increased from zero to 44.8 kg/ha in that study.

3. Oil yield

Result of the present study revealed that the total oil yield was significantly influenced by the different levels of nitrogen and the highest oil yield was obtained in the treatment containing the highest level of nitrogen. The data on the oil content (Table 15) and the seed yield (Table 11) clearly broughtout the significant influence of nitrogen in increasing the oil content as well as the seed yield of sesamum. Thus the higher seed yield coupled with higher percentage of oil has been responsible for the significantly higher oil yield with increasing levels of nitrogen.

The data on oil content (Table 15) revealed that although phosphorus could not produce any significant increase in oil content of grain, increasing levels of phosphorus increased the oil content upto 15 kg P_2O_5/ha. The seed yield also has been increased with higher levels of phosphorus. All these factors could have helped to produce higher oil yield upto 15 kg P_2O_5/ha.

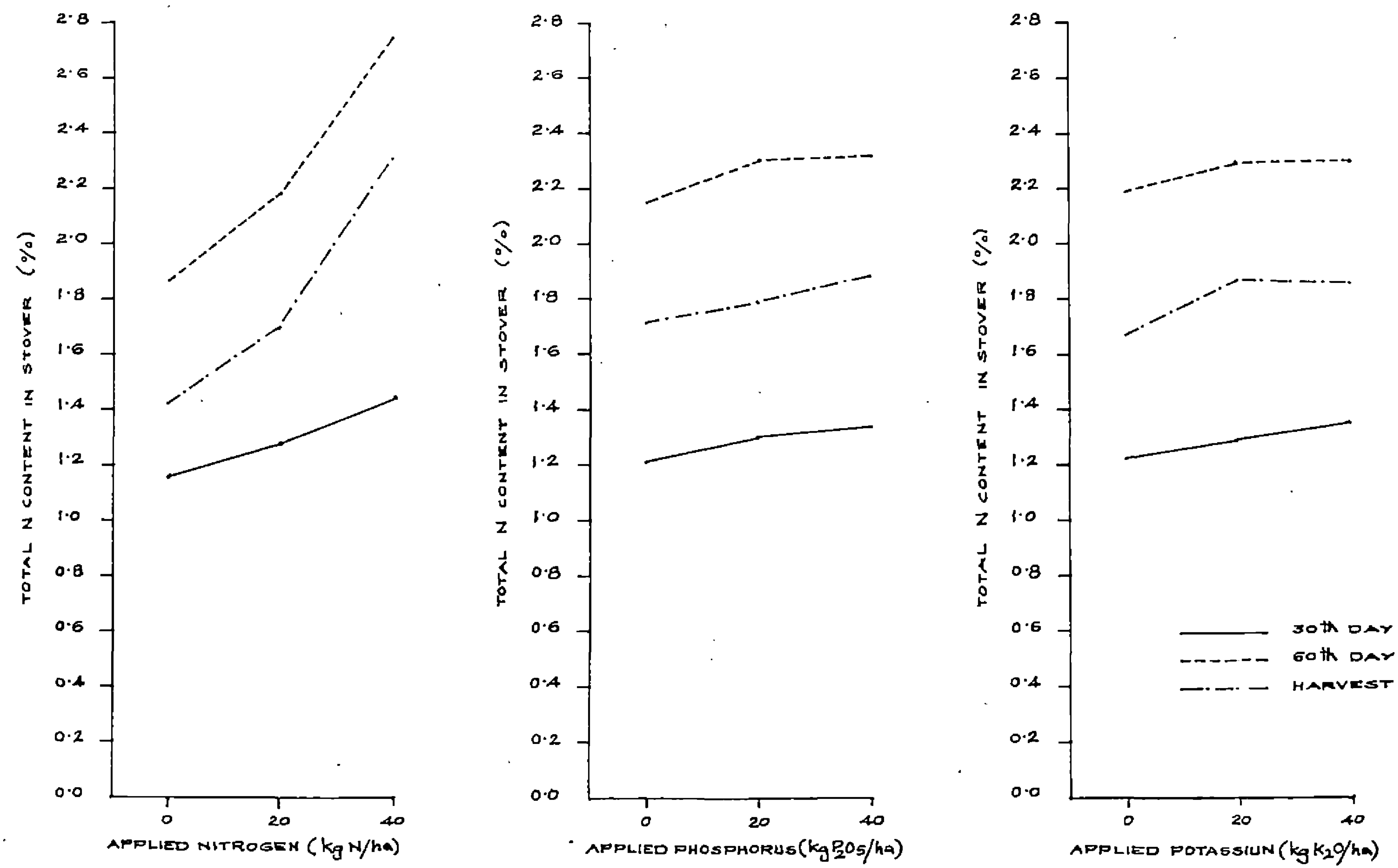
As potash could neither increase the seed yield nor the oil content, it failed to produce significantly higher oil yield with increasing levels of potash.

D. Analysis of plant samples

1. Nitrogen content and uptake by stover

It was observed that nitrogen content of stover was significantly higher with increasing levels of nitrogen (Table 18). The same trend has been reflected in the nitrogen uptake by stover also. Nitrogen uptake studies in other

FIG. 7. NITROGEN CONTENT OF SESAMUM STOVER AS INFLUENCED BY DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM.



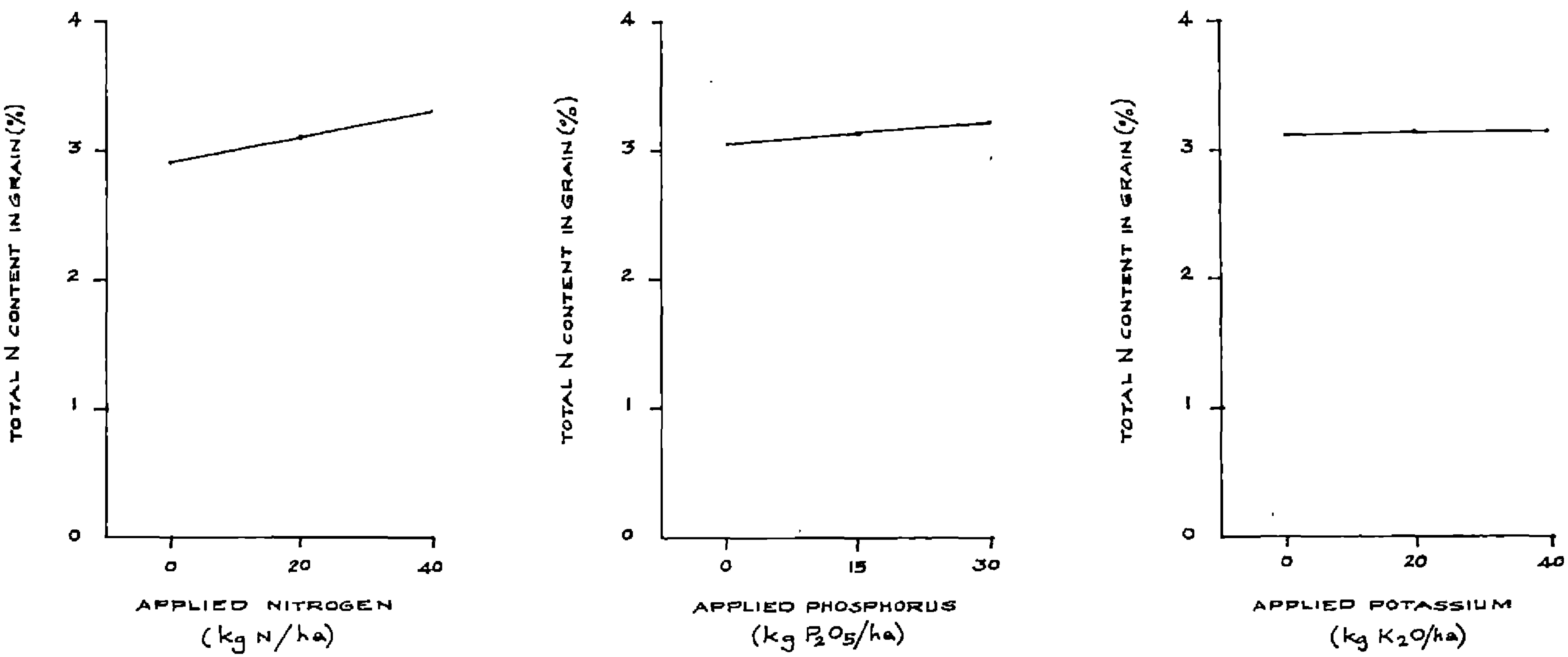
oil seed crops also revealed the significance of nitrogen levels on the nitrogen uptake. Aulakh et al (1980) reported the same trend in the mustard crop. Bishnoi and Kanwar (1982) reported that the contents of nitrogen and phosphorus and their uptake were increased with increasing levels of nitrogen in raya. In groundnut crop, Reddy et al (1977) found that the uptake of nitrogen was maximum when nitrogen was applied at 10 kg as basal dressing and the remaining 20 kg as top dressing 30 days after sowing.

Phosphorus and potash application also increased the nitrogen content of stover significantly. Similar trends were reported by other workers also. Habee bullah et al (1977) found that the nitrogen content of haulm was increased when potash was applied between zero and 100 kg/ha in sesamum. Phosphorus and potash application also increased the nitrogen uptake by stover in the present study. The uptake of nitrogen was found to be increased with applied potash at 0, 40 and 80 kg potash per hectare in irrigated groundnut var. TMV 2 (Rao, 1979).

2. Nitrogen content and uptake by seed

As in the case of stover the nitrogen content of grain also was significantly influenced by the levels of nitrogen, phosphorus and potash (Table 21). Similar trend has been reported by several workers in other crops also. Vir and Verma (1979) found that increasing the rate of nitrogen from

FIG. 8. NITROGEN CONTENT OF SESAMUM SEEDS AS INFLUENCED BY DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM.



0 to 30 and 60 kg/ha increased the seed nitrogen content in mustard. Vir and Verma (1979) while studying the effect of phosphorus on nitrogen content reported that the nitrogen content of seed increased with higher levels of phosphorus.

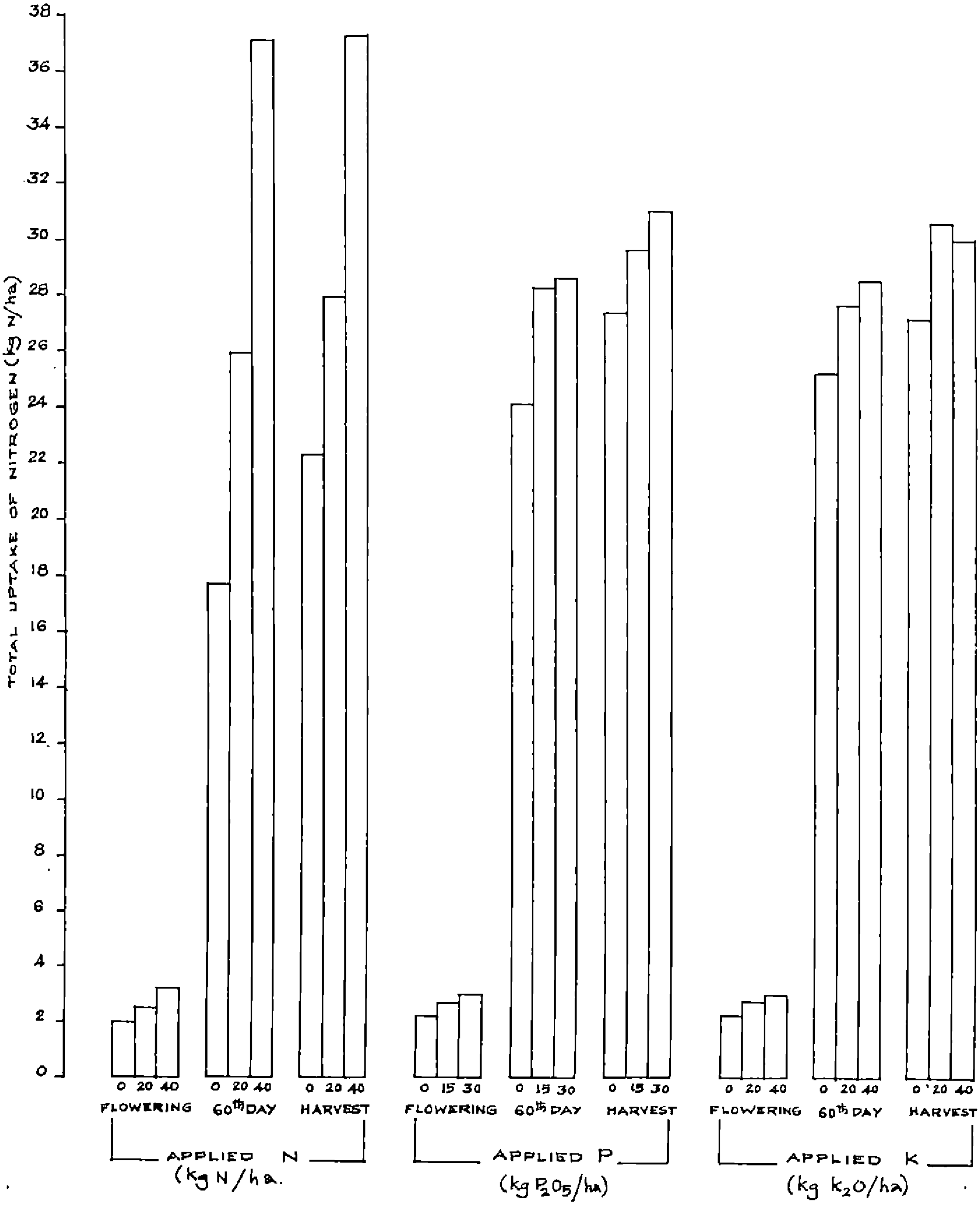
While nitrogen and phosphorus increased the uptake of nitrogen, different levels of potash did not significantly influence the uptake of nitrogen by the seed.

Bhati and Rathor (1982) while studying the response of Indian mustard to nitrogen fertilization found that the yield and uptake of nitrogen with 60 kg N/ha were higher than with 20-40 kg N/ha. According to Bishnoi and Kanwar Singh (1982) the applied nitrogen increased the nitrogen uptake in raya. Vir and Verma (1979) reported that application of phosphorus at 30 kg/ha increased the uptake of nitrogen in rainfed mustard.

Total uptake of nitrogen

It is seen that there was significant increase in the total uptake of nitrogen with increasing levels of nitrogen and the total uptake of nitrogen was the highest with the highest level of nitrogen. There was significant increase in the uptake of nitrogen with the application of different levels of phosphorus and potash also. The data on the nitrogen content and uptake of nitrogen by the stover and seed revealed that the different levels of nitrogen and phosphorus significantly increased these values. This increasing trend in the

FIG. 9. EFFECT OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF NITROGEN IN SESAMUM.

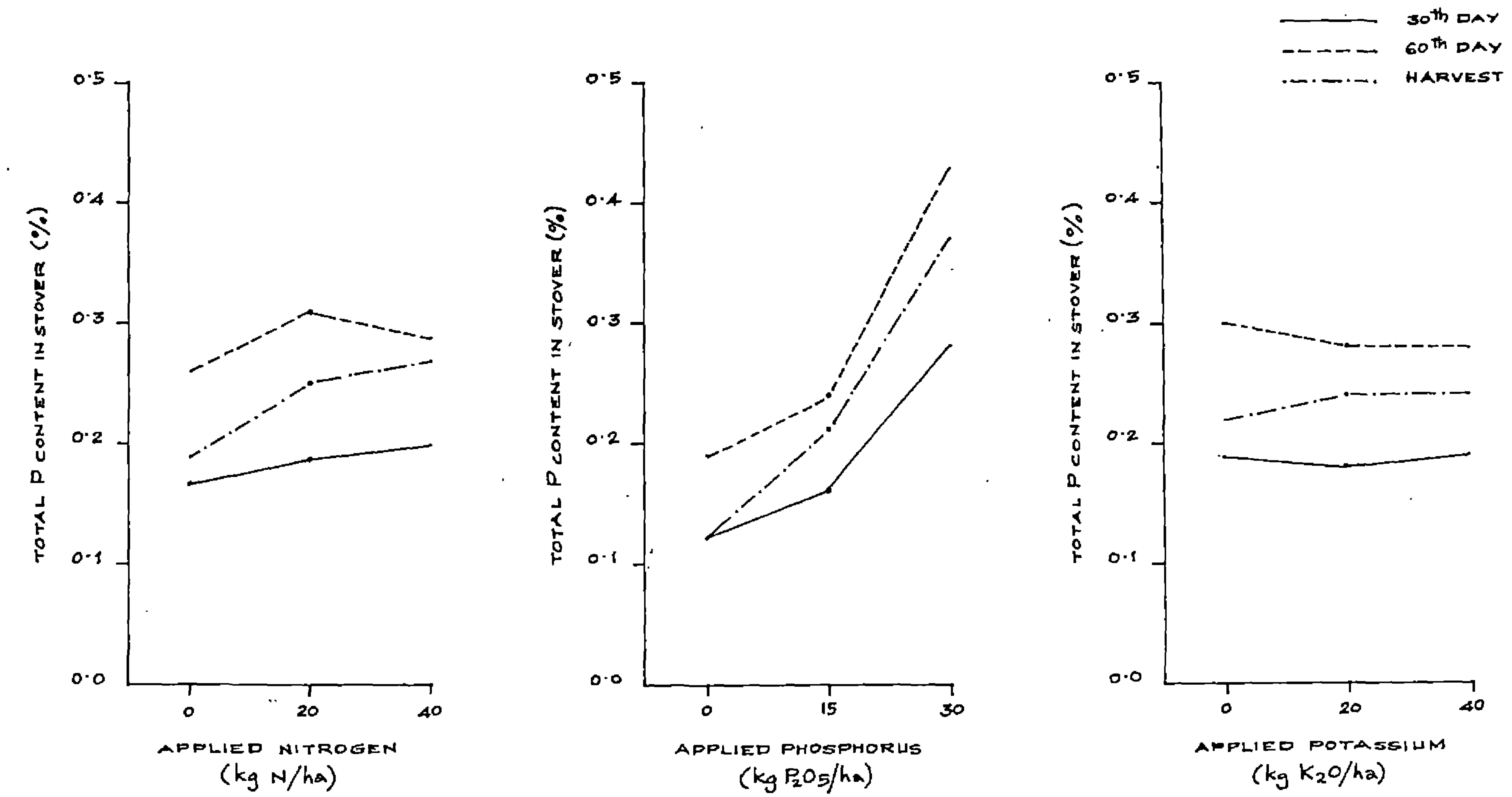


uptake of nitrogen by the stover and grain has been reflected in the total uptake of nitrogen also. Although potash could increase the content and uptake of nitrogen by stover it could not enhance the nitrogen uptake by grains, eventhough the nitrogen content of grains was also increased. However, in the total uptake of nitrogen together by grains and stover there was significant influence by the potash nutrient. This reveals the possibility that the nitrogen uptake by stover due to potash levels could have been more powerful to make the combined uptake of N due to potash being significant.

Phosphorus content and uptake by stover

While nitrogen and phosphorus significantly increased the phosphorus content of stover, potash application did not influence content of phosphorus in stover at any growth stage. Moreover potash levels beyond 15 kg K_2O/ha showed a slight decrease in phosphorus content of stover. Bishnoi and Kanwar Singh (1982) observed increased nitrogen and phosphorus contents of raya with increase in nitrogen levels. Increase in phosphorus content with higher rate of phosphorus application was reported by Nakagawa et al (1981). Although potash could not make significant increase in the phosphorus content of stover the uptake of phosphorus was influenced by potash levels. However, the application of potash beyond 15 kg K_2O/ha did not produce any significant influence on the uptake of phosphrous.

FIG.10. PHOSPHORUS CONTENT OF SESAMUM STOVER AS INFLUENCED BY DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM.



Phosphorus content and uptake by seed

It is seen that the phosphorus content of seed was significantly influenced by the different levels of nutrients tried in the experiment at the harvest stage. While the different levels of nitrogen and phosphorus significantly influenced the uptake of phosphorus by seed, potash application did not make any significant influence on this character. This clearly indicates that the rate of phosphorus content of seed due to higher levels of potash was not sufficient enough to make substantial increase in the uptake of this nutrient.

Total uptake of phosphorus

It is seen that the different levels of nitrogen significantly influenced the total phosphorus uptake at all stages. When the phosphorus content and uptake of stover and grain were significantly influenced by the increased rate of nitrogen application it is but natural that the total uptake of phosphorus was also favourably influenced by the different levels of nitrogen application.

In the case of phosphorus also the trend was very similar to that of nitrogen. When phosphorus was applied or higher levels, the content of phosphorus both in haulm and grain was increased with the result that the total uptake of phosphorus was also found to be high with higher levels of phosphorus application.

Regarding potassium application, the favourable effect was curtailed beyond 15 kg K_2O/ha and as such there was no

FIG. 11. PHOSPHORUS CONTENT OF SESAMUM SEEDS AS INFLUENCED BY DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM.

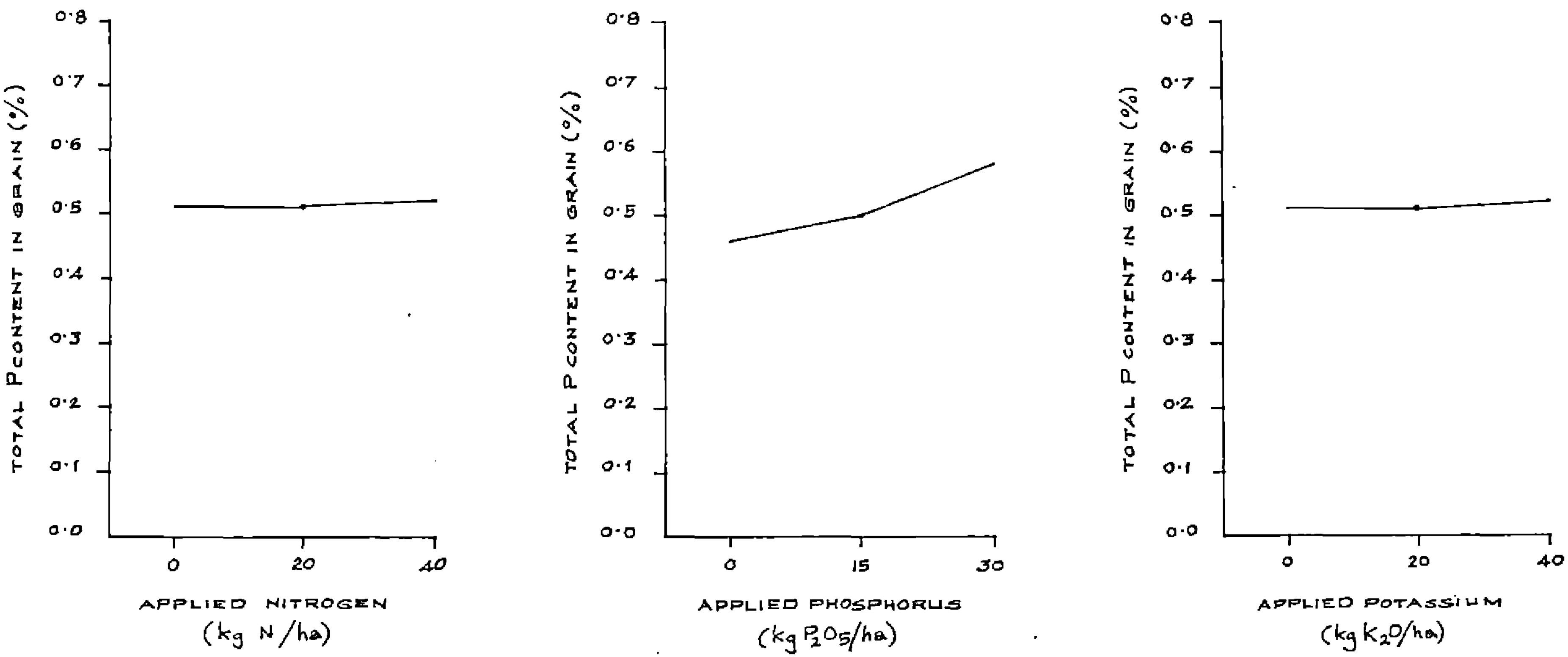
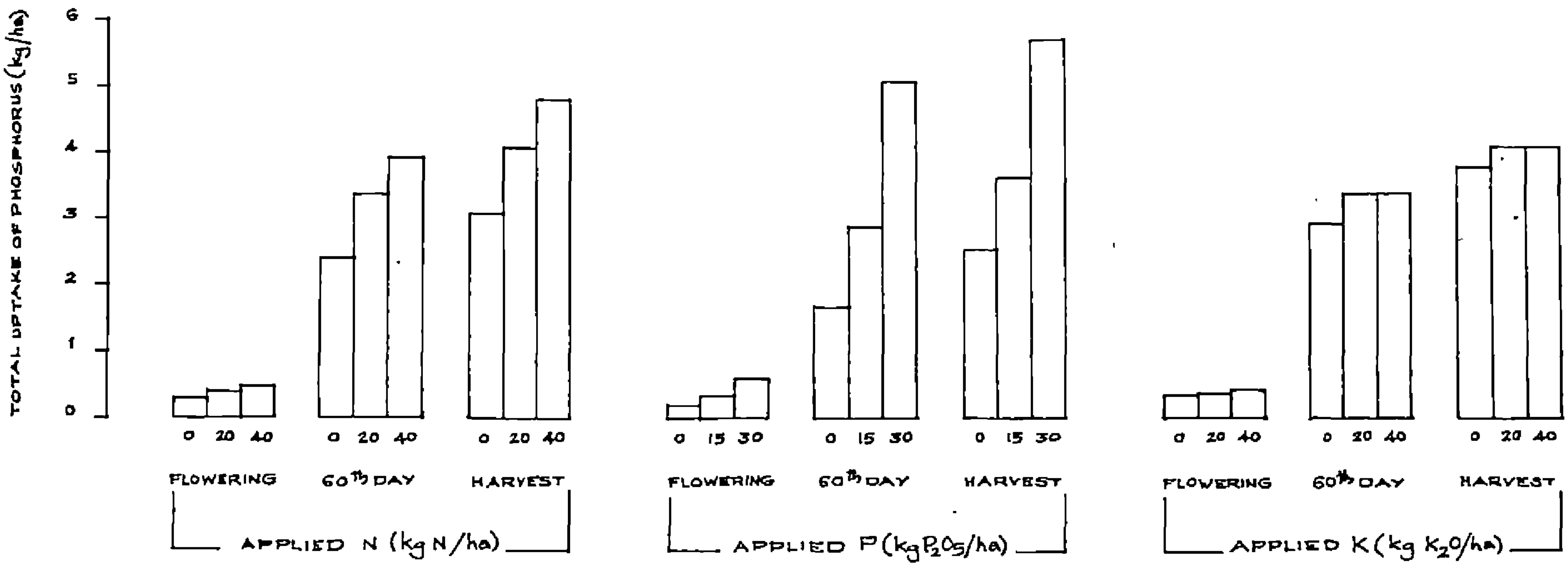


FIG.12. EFFECT OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF PHOSPHORUS IN SESAMUM.



difference between 15 kg K_2O/ha and 30 kg K_2O/ha regarding the total phosphorus uptake. The very same trend was seen in the content and uptake of phosphorus both by stover and grain which was reflected in the total uptake of phosphorus also.

Potassium content and uptake by stover

The data revealed that the different levels of nitrogen and phosphorus did not produce any significant effect on the potassium content of stover. However, increasing levels of potassium significantly increased the potassium content of stover.

Although the content of potassium in stover was not influenced by the different levels of nitrogen, the uptake of potassium was significantly influenced by the levels of potassium especially at 60th day and at harvest. However, applied phosphorus did not influence the uptake of potassium. As nitrogen was in favour of higher amount of vegetative growth, although the content of potassium was not influenced by the level of nitrogen, the comparatively large quantity of vegetative growth could significantly increase the total quantity of potassium present in stover. Phosphorus did not influence the potassium content of stover. The different levels of potash could increase the uptake of potassium by stover at all stages of growth. Rao(1979) reported increased uptake of potash in irrigated groundnut under the influence of potash.

Potassium content and uptake of seed

While nitrogen and potassium significantly influenced the potassium content of seeds, phosphorus failed to influence the potassium content. When the plant was supplied with higher levels of potassium it is but natural that plants would absorb higher amount of potassium which will be reflected on the percentage content of nutrient in the seed. As phosphorus failed to produce any significant influence on the content of potassium in stover, the same trend was seen in the potassium content of seed also.

In the case of uptake of potassium by seed, all the nutrients viz. nitrogen, phosphorus and potassium significantly influenced its uptake. As nitrogen and potassium levels significantly increased the grain content of potassium, they could increase the potash uptake also. However, the effect of phosphorus in this regard was found to be contradictory to its effect on the potassium content of seed.

Total uptake of potassium

Total uptake of potassium is the reflection of the average influence of various nutrients on the uptake of potassium by stover and grains. As nitrogen and potassium could significantly increase the potassium uptake both by stover and grain, the total uptake of potassium was also favourably influenced by the different levels of nitrogen and potash. However, phosphorus faile to make any significant influence on the total uptake of potassium. It is seen that phosphorus did not influence the uptake of potassium by stover although it increased the uptake of potassium by grain. As the stover yield is comparatively higher than

FIG. 13 POTASSIUM CONTENT OF SESAMUM SEEDS AS INFLUENCED BY DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM.

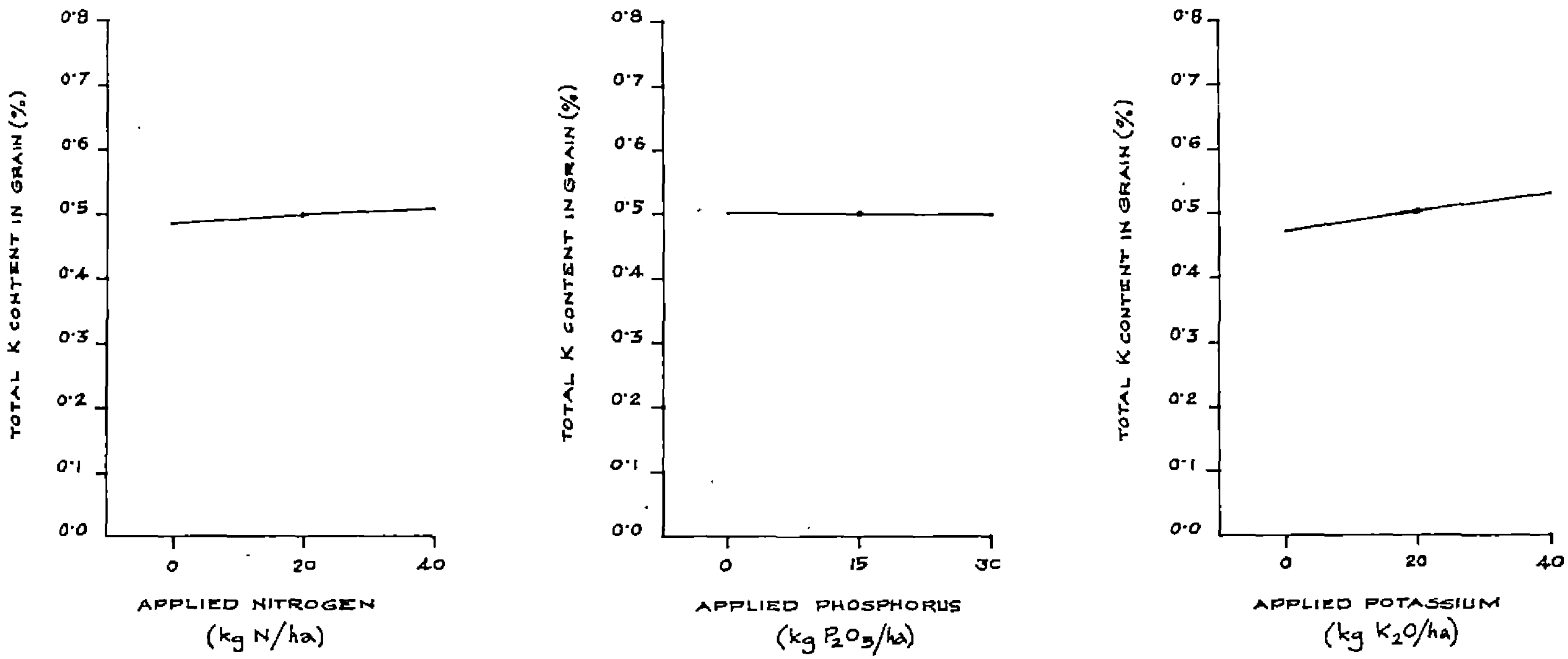
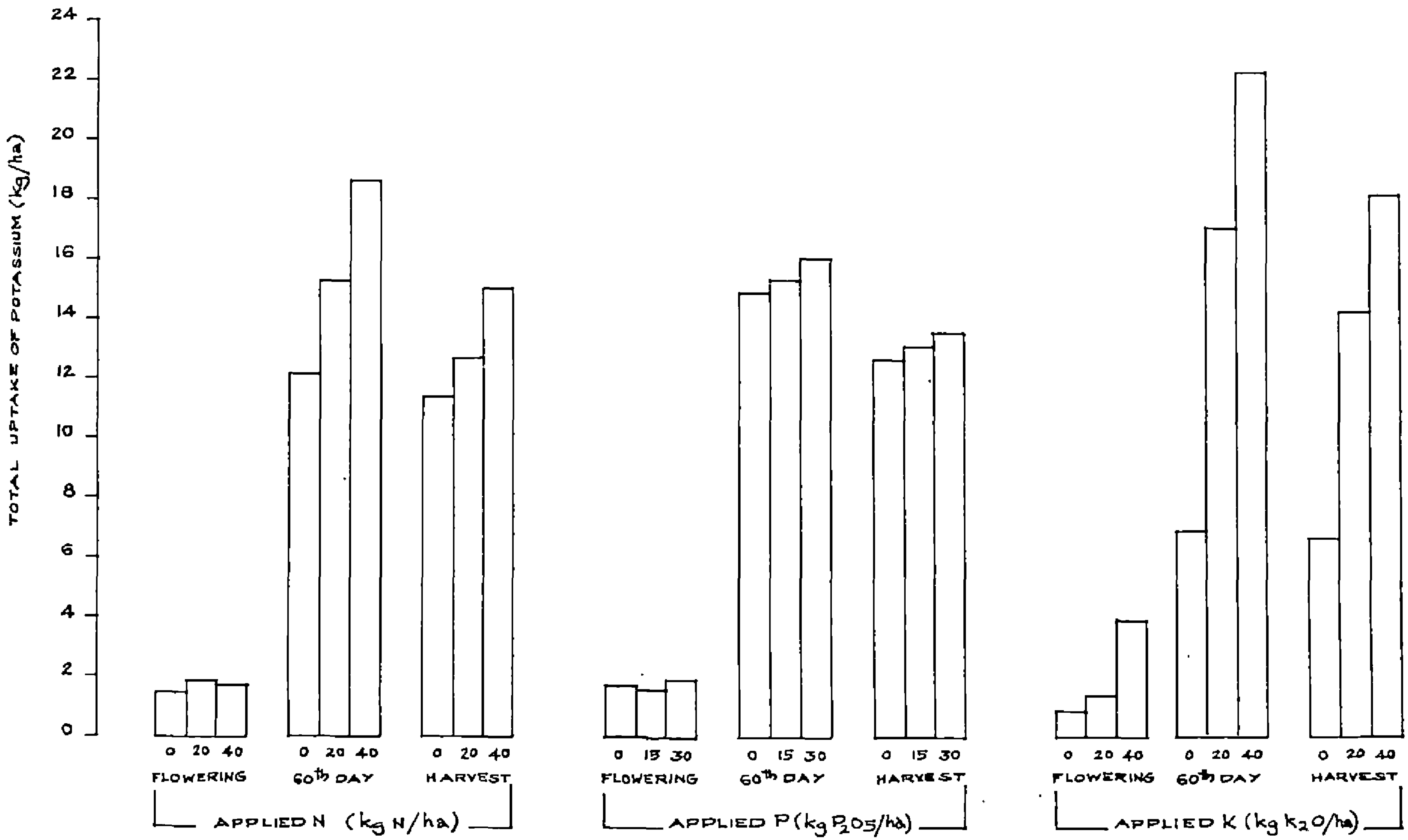


FIG. 14. EFFECT OF DIFFERENT LEVELS OF APPLIED NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF POTASSIUM IN SESAMUM.



grain yield in sesamum, phosphorus could not influence the total uptake of potassium because of this fact.

SUMMARY

SUMMARY

A field study on the effects of nitrogen,,phosphorus and potash application on the growth, yield, quality, chemical composition and uptake of mineral nutrients by sesamum was undertaken in the red loam soils of Vellayani. The experiment was laid out in the last week of August, 1983, in a 3^3 factorial experiment confounding NPK in replication 1 and NP^2K^2 in replication 2. The treatments consisted of three levels of nitrogen (0, 20 and 40 kg N/ha), three levels of phosphorus (0, 15 and 30 kg P_2O_5/ha) and three levels of potassium (0, 20 and 40 kg K_2O/ha).

Observations on the growth characters were taken on the 30th day (flowering), 60th day (cessation of flowering) and at harvest. The chemical composition of the plant at these stages was also determined. At harvest stage the grains were also analysed. The crop was harvested after 85 days and the yield was recorded. The results of the study are summarised below.

Nitrogen significantly influenced the growth of the plant at all the stages of growth. Height of plant, number of leaves per plant, number of nodes per plant, leaf area per plant, and dry matter production were increased significantly upto 40 kg N/ha, but the difference between 20 kg and 40 kg N/ha was found only in the 2nd stage of observation, although there was a slight increase in all the above characters in the other stages.

Nitrogen application significantly influenced the yield and most of the yield attributing characters eventhough weight of capsules per plant was not affected. Number of capsules per plant, number of seeds per capsule, seed weight per plant, 1000 seed weight, stover yield and harvest index were significantly increased upto 40 kg N/ha and the seed yield and shelling percentage only upto 20 kg N/ha, eventhough an increase in the value upto 40 kg N/ha was noted.

In the case of oil content of seeds there was significant influence of applied nitrogen but no difference was noted between 20 and 40 kg N/ha. There was significant influence for applied nitrogen upto 40 kg/ha for protein content.

Nitrogen content of stover and grain was increased significantly at all stages of the crop. Similarly the total uptake of nitrogen by stover and grains was also increased significantly with the application of nitrogen.

Phosphorus content of stover and grain as well as the total uptake of phosphorus by stover and grain was also influenced significantly by the applied nitrogen.

Nitrogen did not influence the content of potassium in stover, but it significantly influenced the content of potassium in grains. Nitrogen significantly influenced the uptake of potassium on 60th day after sowing and at harvest stage. Also uptake of potassium by seed was significantly influenced by nitrogen.

Application of phosphorus has not influenced the growth characters like height of plant, number of leaves per plant, number of branches per plant and number of nodes per plant. Leaf area per plant at harvest and dry matter production at all the stages were significantly influenced by the application of phosphorus. However, there was no difference between 15 and 30 kg P_2O_5/ha and moreover increasing the level of phosphorus from 15 to 30 kg P_2O_5/ha showed a slight decline in the characters like number of leaves produced per plant as well as the number of branches produced. Among the yield and yield attributing characters phosphorus influenced only the seed yield, haulm yield and 1000 seed weight.

Phosphorus application did not produce any significant influence on oil content, but influenced the protein content of seed significantly. Also, the oil yield was found to be increased significantly by the application of phosphorus.

There was significant increase in the content and total uptake of nitrogen by the stover and grains due to different levels of phosphorus. But there was no difference between 15 and 30 kg P_2O_5/ha in the last two stages. Phosphorus application significantly influenced the phosphorus content of grain and stover. Total uptake also was increased significantly with the application of phosphorus and the highest uptake value was recorded with the highest level of phosphorus.

Application of phosphorus did not produce any significant influence on the potassium content of stover and grain. There was no significant influence on the potash uptake also by the application of phosphorus.

Potash did not produce any significant influence on the characters like height, number of leaves, number of branches and leaf area per plant. However significant influence was observed in the case of dry matter production, but increasing the level from 15 to 30 kg K_2O/ha showed a declining trend.

Among the yield and yield attributing characters, only number of seeds per capsule and 1000 seed weight were influenced by potash application significantly. Also increasing the level of potash beyond 20 kg K_2O/ha showed a slight depressing effect on all the characters.

Potash application did not produce any significant influence on the quality characters like protein content, oil content and oil yield.

Potash application significantly influenced the nitrogen content of stover and grain. Total uptake of nitrogen by the crop was increased significantly by the application of potash, but increasing the level beyond 20 kg K_2O/ha could not make any difference in the uptake.

Application of potash did not produce any significant influence on the phosphorus content of stover, but influenced the Phosphorus content of grains significantly. Potash application also significantly influenced the total uptake of Phorphorus by the crop.

Applied Potassium significantly influenced the Potassium content of seeds and stover. Total uptake of Potash was significantly increased with applied Potassium at all the stages of growth.

The work revealed that the yield performance of Sesamum Var. Thilothama under partially shaded upland situation was comparable with the average yield of the crop reported in Package of practices Recommendations-82.

When the economics of Fertilizer application was taken in to consideration, maximum net profit of Rs.1070/ was obtained with the application of 40KgN, 15Kg $P_2 O_5$, and 20Kg K_2O/ha. Therefore it can be concluded that a combination of 40Kg N, 15Kg P_2O_5 and 20Kg K_2O/ha is the most advantageous fertilizer dose for Sesamum Var. Thilothama in the partially shaded uplands of Vellayani.

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APPENDICES

APPENDIX - I

Weather data during the crop year and its variation from the past 25 years

(Feb. 1983 to Jan. 1984)

MONTHS	Maximum temperature °C			Minimum temperature °C			Rainfall (mm)			Relative humidity		
	Crop year	Average for 25 years	Variation	Crop year	Average for 25 years	Variation	Crop year	Average for 25 years	variation	Crop year	Average for 25 years	variation
February	31.76	31.35	+ 0.41	20.67	22.78	-2.11	-	35.20	-35.20	71.20	82.49	-9.29
March	32.43	32.16	+ 0.27	22.62	23.97	-1.35	16.5	34.34	-17.84	73.06	81.62	-8.62
April	32.97	32.21	+ 0.76	24.20	24.96	-0.76	73.0	94.27	-21.27	74.12	83.54	-9.42
May	32.21	31.77	+ 0.44	23.73	24.87	-1.14	254.0	193.31	+60.69	79.17	85.27	-6.10
June	29.65	30.46	- 0.75	22.77	23.89	-1.12	500.5	299.01	+201.49	81.52	85.57	-4.05
July	30.16	29.73	+ 0.43	22.51	23.44	-0.93	120.0	217.08	-99.08	81.82	87.43	-5.61
August	30.05	29.77	+ 0.28	21.25	23.21	-1.96	91.0	143.82	-52.82	81.75	86.30	-4.35
September	30.48	30.09	+ 0.39	22.12	23.29	-1.17	66.0	156.75	-90.75	79.65	86.12	-6.47
October	30.99	29.70	+ 1.29	22.50	23.69	-1.19	181.5	266.97	-85.47	80.64	87.68	-7.04
November	31.03	29.95	+ 1.08	22.36	23.77	-1.41	149.0	209.85	-66.85	82.40	87.24	-4.84
December	31.30	30.62	+ 0.68	20.70	23.19	-2.49	19.5	69.44	-49.94	78.02	84.78	-6.76
January	31.58	30.91	+ 0.67	20.54	22.41	-1.87	-	33.55	-33.55	68.90	80.28	-10.38

Positive sign (+) shows increase over the average data and negative sign (-) the decrease.

Appendix - II

Analysis of variance for height of plants and number of leaves

Source	df	Mean squares					
		Height of plants			Number of leaves		
		30th day	60th day	Harvest	30th day	60th day	Harvest
Block	5	11.32	65.32	16.32	6.65	5.18	24.51
N	2	12.55	681.39	569.58**	1.53	29.65 *	26.80
P	2	3.32	84.75	95.24	0.70	8.13	1.34
K	2	32.44*	463.11*	373.47*	4.23*	13.46	11.46
NP	4	5.90	23.23	59.61	0.54	1.70	15.57
NK	4	5.50	26.72	15.93	1.16	3.22	0.67
PK	4	6.12	91.10	48.75	0.75	6.68	16.70
$NPK^{@}$	2	3.43	85.86	70.12	0.49	1.35	8.51
NPK^{2}	2	8.63	34.70	85.96	0.62	2.62	1.46
$NP^{2}K$	2	0.71	55.69	98.56	0.52	7.40	14.22
$NP^{2}K^{2@}$	2	0.16	140.56*	336.13*	0.74	10.31	24.71
error	22	7.40	44.59	88.92	0.48	5.97	29.17

@ confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - III

Analysis of variance for number of nodes, branches of plant and leaf area per plant.

Source	df	MEAN SQUARES					
		Number of Nodes			Number of branches		Leaf area
		30th day	60th day	Harvest	60th day	Harvest	Harvest
Block	5	1.29	8.55	6.18	0.68	0.39	1.40
N	2	0.38	7.35*	6.72	1.64*	1.66*	81.71**
P	2	0.16	0.95	0.32	1.34	1.15	5.75**
K	2	1.06**	3.41	2.82	0.57	0.11	0.72
NP	4	0.14	0.42	3.93	0.28	0.34	8.85**
NK	4	0.29	0.83	0.17	0.21	0.32	0.58
PK	4	0.19	1.64	4.17	0.19	0.47	1.20
NPK@	2	0.12	0.29	2.13	0.07	0.030	0.12
NPK^2	2	0.16	0.09	0.37	0.19	0.0063	0.68
NP^2K@	2	0.13	1.98	3.55	0.85	0.25	0.02
NP^2K^2	2	0.18	2.58	6.11	0.14	0.31	0.14
Error	22	0.12	1.52	7.27	0.44	0.34	

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - IV

Analysis of variance table for seed weight, 1000 seed weight and seed yield

Source	df	Mean squares		
		Seed weight (g/plant)	1000 seed weight	Seed yield (kg/ha)
Block	5	0.067	0.0017	300.51
N	2	0.56**	0.045**	14202.35
P	2	0.11	0.016**	2099.85
K	2	0.067	0.045**	48.91
NP	4	0.071	0.0050*	53.21
NK	4	0.10*	0.0030	826.01
PK	4	0.084	0.0029	222.19
$NPK^{@}$	2	0.057	0.0013	1176.26
NPK^2	2	0.082	0.0012	460.02
NP^2K	2	0.031	0.00065	1435.13
$NP^2K^{2@}$	2	0.0014	0.00016	1057.44
error	22	0.033	0.0014	344.63

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - V

Analysis of variance table for number of capsules per plant, weight of capsule per plant and number of seeds per capsule.

Source	df	Mean square		
		Number of capsules per plant	Weight of capsule per plant	Number of seeds per capsule
Block	5	3.45	0.44	2.48
N	2	3.01*	1.83	57.40*
P	2	0.35	0.83	26.54*
K	2	4.24	0.22	10.13*
NP	4	1.32	0.48	8.62*
NK	4	2.13	0.22	3.95
PK	4	1.63	0.13	2.51
NPK@	2	2.11	1.61	5.20
NPK^2	2	0.24	0.67	1.00
NP^2K	2	0.80	0.60	1.85
NP^2K^2@	2	1.93	0.22	0.51
error	22	2.80	0.54	2.44

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - VI

Analysis of variance table for haulm yield, shelling percentage and harvest index

Source	df	Mean squares		
		Haulm yield (kg/ha)	Shelling percentage	Harvest index
Block	5	3097.20	0.50	0.00099
N	2	49442.00**	12.44**	0.0030*
P	2	19652.70**	2.50	0.0015
K	2	868.68	0.41	0.00025
NP	4	20942.37**	2.37	0.0025*
NK	4	13246.40**	0.20	0.0028*
PK	4	3462.07	0.42	0.0030
NPK@	2	1618.09	2.08	0.00057
NPK^2	2	7044.09	0.43	0.00053
NP^2K@	2	467.00	0.89	0.0013
NP^2K^2	2	141.74	0.72	0.00085
error	22	2633.58	1.59	0.00069

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - VII

Analysis of variance table for oil content, protein content and oil yield

Source	df	Mean squares		
		Oil content (%)	Protein content (%)	Oil yield (kg/ha)
Block	5	2.06	0.39	754777.70
N	2	5.99*	9.43**	50595080.20**
P	2	1.37	5.18**	5528672.45**
K	2	0.54	0.36	669189.20
NP	4	0.48	0.54**	231586.17
NK	4	0.08	0.17	1709027.72
PK	4	0.77	0.21	1367064.45
NPK@	2	0.76	0.23	4126889.71*
NPK^2	2	0.04	0.43*	1759680.00
NP^2K	2	1.53	0.35*	4521916.30*
NP^2K^2@	2	0.59	0.07	2502643.06
error	22	0.67	0.11	1064612.91

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - VIII

Analysis of variance table for drymatter production (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	427.04	2120.91	1815.21
N	2	10542.29**	714144.41**	82200.87**
P	2	5930.01**	54779.56**	22151.24**
K	2	2920.74**	30410.62**	663.14
NP	4	800.58**	19260.20**	16195.27**
NK	4	213.81*	7116.57**	9800.07**
PK	4	76.91	3399.55**	3320.73
NPK@	2	1028.42**	6.94	3648.48
NPK^2	2	197.35*	14026.08**	7092.03**
NP^2K	2	264.24**	11845.15**	1788.15
NP^2K^2@	2	7.77	2649.02**	1387.94
error	22	54.45	256.56	2211.66

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - IX

Analysis of variance table for nitrogen content (%) of plants at different stages

Source	df	Mean squares			
		30th day	60th day	Harvest	
				Seeds	Stover
Block	5	0.005	0.03	0.01	0.21
N	2	0.34**	3.60**	0.05**	0.70**
P	2	0.07**	0.15**	0.13**	0.14*
K	2	0.07**	0.06*	0.01*	0.23**
NP	4	0.01*	0.03	0.014**	0.03
NK	4	0.01**	0.04	0.004	0.04
PK	4	0.002	0.08**	0.005	0.01
NPK@	2	0.01**	0.02	0.006	0.02
NPK^2	2	0.01**	0.01	0.01*	0.02
NP^2K@	2	0.003	0.07**	0.009	0.11*
NP^2K^2	2	0.002	0.04	0.002	0.10*
error	22	0.002	0.02	0.003	0.03

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - X

Analysis of variance table for phosphorus content (%) of plants at different stages

Source	df	Mean squares 30th day	60th day	Harvest Seeds	Harvest Stover
Block	5	0.0001	0.005	0.00007	0.001
N	2	0.01**	0.01	0.0009**	0.03**
P	2	0.13**	0.29**	0.06**	0.29**
K	2	0.00008	0.001	0.0004**	0.002**
NP	4	0.0005**	0.008	0.0001*	0.005**
NK	4	0.001**	0.01	0.0001**	0.0003
$NPK^{@}$	2	0.00007	0.02*	0.0002**	0.0003
NPK^2	2	0.0003	0.01	0.0003**	0.006**
NP^2K	2	0.0006**	0.01	0.00005	0.001*
$NP^2K2^{@}$	2	0.0005*	0.002	0.00003**	0.002**
error	22	0.0001	0.007	0.00004	0.0002

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XI

Analysis of variance table for potassium content (%) of plants at different stages

Source	df	Mean squares 30th day	60th day	Harvest Seeds	Harvest Stover
Block	5	0.17	0.08	0.00008	0.05
N	2	0.09	0.05	0.002**	0.14
P	2	0.08	0.03	0.0001	0.02
K	2	4.40**	7.26**	0.020**	4.92**
NP	4	0.01	0.02	0.0001	0.03
NK	4	0.15	0.02	0.00007	0.02
PK	4	0.02	0.04	0.00007	0.02
NPK@	2	0.02	0.006	0.00000009	0.05
NPK^2	2	0.006	0.05	0.0001	0.05
NP^2K	2	0.01	0.55	0.0002*	0.08
NP^2K^2@	2	0.01	0.01	0.00004	0.19
error	22	0.09	0.04	0.00006	0.06

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XII

Analysis of variance table for nitrogen uptake (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.02	5.99	21.79
N	2	6.33**	709.61**	720.16**
P	2	2.34**	106.35**	52.42**
K	2	1.51**	53.83**	39.04**
NP	4	0.26**	31.82**	15.21
NK	4	0.07*	22.57**	14.13
PK	4	0.01	18.46**	0.85
$NPK^@$	2	0.23**	2.10	0.60
NPK^2	2	0.01	6.09	6.84
NP^2K	2	0.01	13.95**	13.95**
$NP^2K^{2@}$	2	0.01	10.32*	9.18
error	22	0.02	2.29	5.66

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XIII

Analysis of variance table for phosphorus uptake (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.001	0.11	0.09
N	2	0.11**	10.52**	6.86**
P	2	0.73**	55.93**	39.66**
K	2	0.01**	0.96**	0.38**
NP	4	0.01**	2.04**	1.12**
NK	4	0.004**	0.19**	0.04
PK	4	0.004**	0.26**	0.09
$NPK^{@}$	2	0.004**	0.33**	0.03
NPK^2	2	0.002	0.28**	0.82
NP^2K	2	0.002	0.48**	0.14**
$NP^2K^{2@}$	2	0.001	0.31**	0.23*
error	22	0.001	0.03	0.04

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XIV

Analysis of variance table for potash uptake (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.77	10.28	5.53
N	2	0.77	187.87**	52.73**
P	2	0.31	6.60	2.66
K	2	22.70**	1113.92**	579.71**
NP	4	0.04	11.42	5.31
NK	4	0.47	16.81	8.01
PK	4	0.16	2.63	1.77
NPK@	2	0.20	0.89	14.91
NPK^2	2	0.15	14.96	9.52
NP^2K@	2	0.002	17.84	5.54
NP^2K^2	2	0.07	1.70	3.05
error	22	0.32	6.60	8.24

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XV

Analysis of variance table for nitrogen, phosphorus and potash uptake (kg/ha by grains at harvest

Source	df	Mean squares		
		Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)
Block	5	0.31	0.61	0.007
N	2	27.02**	0.36**	0.38**
P	2	4.21**	0.60**	0.04**
K	2	0.19	0.0075	0.18**
NP	4	0.10	0.0044	0.004
NK	4	0.69	0.018	0.013
PK	4	0.33	0.008	0.005
$NPK^{@}$	2	1.40*	0.017	0.021
NPK^2	2	0.54	0.006	0.015
NP^2K	2	1.59**	0.031*	0.042**
$NP^2K^{2@}$	2	1.06*	0.017	0.025*
error	22	0.28	0.006	0.007

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XVI

Analysis of variance table for total nitrogen (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.02	5.99	13.24
N	2	6.33**	1709.61**	1011.30**
P	2	2.34**	106.35**	59.47**
K	2	1.51**	53.83**	54.27**
NP	4	0.26**	31.82**	26.74*
NK	4	0.07*	22.57**	14.83
PK	4	0.01	18.46**	4.64
NPK@	2	0.23**	2.10	1.16
NPK^2	2	0.01	6.09	8.45
NP^2K	2	0.01	13.95**	18.57
NP^2K^2@	2	0.01	10.32*	24.95
error	22	0.02	2.29	8.10

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XVII

Analysis of variance table for total phosphorus uptake (kg/ha at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.001	0.11	0.37
N	2	0.11**	10.52**	13.46**
P	2	0.73**	55.93**	45.20**
K	2	0.01**	0.96**	0.53*
NP	4	0.01**	2.04**	1.73**
NK	4	0.004**	0.19**	0.074
PK	4	0.004**	0.26**	0.27
$NPK^@$	2	0.005**	0.33**	0.08
NPK^2	2	0.002	0.28**	1.14**
NP^2K	2	0.002	0.48**	0.13
$NP^2K^{2@}$	2	0.001	0.31**	0.24
error	22	0.001	0.03**	0.13

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XVIII

Analysis of variance table for total potassium uptake (kg/ha) at different stages

Source	df	Mean squares		
		30th day	60th day	Harvest
Block	5	0.77	10.28	5.27
N	2	0.77	187.87**	62.09**
P	2	0.31	6.60	3.11
K	2	22.70**	1113.92**	599.57**
NP	4	0.04	11.42	5.48
NK	4	0.47	16.81	8.36
PK	4	0.16	2.63	1.67
$NPK^{@}$	2	0.20	0.89	8.71
NPK^2	2	0.15	14.96	5.66
NP^2K	2	0.002	17.84	14.41
$NP^2K^{2@}$	2	0.07	1.70	3.52
error	22	0.32	6.60	8.38

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XIX

Analysis of variance table for nitrogen, phosphorus and potash content of the soil after the experiment

Source	df	Mean squares		
		Nitrogen content	Phosphorus content	Potassium content
Block	5	0.00005	26.28*	35.46
N	2	0.0001*	5.65	30.11
P	2	0.0002**	1.33	63.56*
K	2	0.0002**	10.12	414 .79**
NP	4	0.0001**	5.12	6.69
NK	4	0.00003	1.58	6.69
PK	4	0.0001**	8.13	8.36
$NPK^{@}$	2	0.00005	2.82	5.20
NPK^2	2	0.0002**	1.66	13.28
NP^2K	2	0.0002**	2.96	23.42
$NP^2K^{2@}$	2	0.00005	9.28	18.58
error	22	0.00002	8.18	15.48

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

Appendix - XX

Analysis of variance for organic carbon content of the soil (%) after the experiment

Source	df	Mean squares Organic carbon
Block	5	0.01**
N	2	0.00007
P	2	0.002
K	2	0.006
NP	4	0.002
NK	4	0.003
PK	4	0.002
NPK@	2	0.001
NPK^2	2	0.002
NP^2K	2	0.003
NP^2K^2@	2	0.003
error	22	0.002

@ Confounded effects

* Significant at 0.05 level

** Significant at 0.01 level

NUTRITIONAL REQUIREMENT OF THE SESAMUM VARIETY THILOTHAMA IN PARTIALLY SHADED UPLANDS

By

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ABSTRACT OF A THESIS
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ABSTRACT

An experiment was conducted in the red loam soils of the Instructional Farm, College of Agriculture, Vellayani during 1983 to study the effects of three levels of nitrogen (0, 20 and 40 kg N/ha), three levels of phosphorus (0, 15 and 30 kg P_2O_5/ha) and three levels of potassium (0, 20 and 40 kg K_2O/ha) on the growth, yield, oil and protein content and chemical composition and uptake of mineral nutrients of sesamum. The field trial was laid out as a 3^3 factorial experiment confounding NPK in replication - 1 and NP^2K^2 in replication - 2.

The study revealed that applied nitrogen affected most of the growth, yield and yield attributing characters, oil and protein content and the content and uptake of mineral elements. Height of plants, number of leaves, number of branches, dry matter production etc. increased upto 40 kg N/ha. All the yield and yield attributing characters increased significantly upto 40 kg N/ha except shelling percentage and seed yield which were also showed an increasing trend upto 40 kg/ha. Significant influence on oil and protein content of the crop was also noted, but there was no difference between 20 and 40 kg N/ha in the case of oil content. Applied nitrogen significantly influenced the nitrogen content of stover and grain at all the stages. Similarly, the total uptake of nitrogen by stover and

grains was also increased significantly with the application of nitrogen. Phosphorus content of grain and stover as well as the total uptake was also influenced significantly by the applied nitrogen. Potassium content of grains as well as the uptake of potassium was influenced significantly by the application of nitrogen.

Applied phosphorus failed to influence most of the growth characters, yield and yield attributes and quality attributes. The content and uptake of nitrogen and phosphorus were significantly influenced by the application of phosphorus, while the applied phosphorus did not influence the content and uptake of potash by the crop.

Among the growth characters, potash application produced significant influence on the dry matter production only. Increasing the level of potash from 15 to 30 kg K_2O/ha showed a declining trend in the yield attributing characters like number of seeds per capsule and 1000 seed weight. Also potash application did not produce any significant influence on the quality characters like protein content, oil content and oil yield. Application of potash significantly influenced the nitrogen and potassium content of stover and grain. Total uptake of nitrogen and potash were also increased significantly while increasing the level to 40 kg K_2O/ha showed a declining trend in the uptake of nitrogen by the crop. Phosphorus content of the stover was not influenced significantly by the application of Potash, while the Phosphorus content of grains and total uptake of Phosphorus by the crop were significantly influenced by applied Potash.

The work also revealed that yield performance of Sesamum Var. Thilothama under partially shaded upland conditions, was comparable with the average yeild of the crop reported in the Package of Practices Recommendations-82.

From the economics of Fertilizer application worked out, it can be concluded that a combination of 40KgN, 15Kg P_2O_5 and 20Kg K_2 O/ha is the most advantageous Fertilizer dose for Seamum Var. Thilothama in the partially shaded red loam Soils of Vellayani.