NUTRITIONAL REQUIREMENT OF PRE-RELEASE SESAMUM CULTURE 42-1 IN GARDEN LAND

By

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THESIS

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D E C L A R A T I O N

I hereby declare that this thesis entitled "Nutritional requirement of pre-release sesamum culture 42-1 in garden land" 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 title of any other University or Society.

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Vellayani,
21 - 3 - 1987.

C E R T I F I C A T E

Certified that this thesis, entitled "Nutritional requirement of pre-release sesamum culture 42-1 in garden land" is a record of research work done independently by Sri. P. Raveendran Nair under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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P. RAVEENDRAN NAIR.

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INTRODUCTION

INTRODUCTION

India is spending a good deal of foreign exchange for the import of edible oil. The production of oilseed will have to be increased manifold to put an end to this drain on foreign exchange resources. By the end of 2000 A.D. we need to produce 26 million tonnes of oilseeds for our internal consumption. The per capita consumption of oil as recommended by F.A.O. is 18 g. But due to the low production, the availability is only 13.7 g per day. In order to maintain the minimum requirement the present production will have to be atleast doubled.

India is the largest producer of oilseeds and we rank first in the production of groundnut and sesamum and second in rape seed and mustard. In India oilseeds are cultivated in an area of 17.88 million hectares with a production of 12.23 million tonnes (1983-84), accounting for 10% of the total area under cultivated crop.

Among the oilseeds, sesamum (Sesamum indicum L) occupies a major share and nearly a quarter of world's production of sesamum is from India. It is a crop of great antiquity and is widely grown in tropical and subtropical regions of Asia, Africa, South and North America. In India sesamum is grown in an area of 21.82 lakh hectares with an

annual production of 6.18 lakh tonnes. Uttar Pradesh is the largest producer of sesamum, contributing 28.7% of the area and 20% of the production. This is an ancient crop and is a rich source of oil, protein, minerals and essential aminoacids in human and animal nutrition.

In Kerala sesamum occupies an area of 14,000 hectares with an annual production of 3600 tonnes. The average production in the State is 270 kg/ha while in India it is 180 kg/ha (1983-84). The potential production of the crop is estimated to be about 600 to 1000 kg/ha under dry land and 1000 to 1200 kg/ha under irrigated condition. Yield as high as 2000 kg/ha has been recorded in Yugoslavia. The main reason for the low production is poor fertility status of land coupled with unfavourable climatic conditions, low residual soil moisture and use of local varieties.

Sesamum is mainly cultivated as a catch crop in summer rice fallows in Kerala. Onattukara tracts comprising of Karthikapally and Mavelikkara taluks of Alleppey District and Karunagapally taluk of Quilon District are famous for its cultivation and local varieties are mainly grown in these areas. But with the introduction of high yielding varieties appreciable area is brought under garden lands for its cultivation. Kerala Agricultural University has now released two

improved varieties namely, 'Soma' and 'Soorya' which have been found to step up the production of sesamum. Of the two varieties 'Soorya' or ACV-2 (formerly known as Culture 42-1) is found best suited to the garden lands of southern districts particularly for Trivandrum. This is a pureline selection from the West Bengal variety and is recommended to grow mainly in North East Monsoon Season (Semi Rabi - Aug.-Dec.) under garden land condition. This is a multi-loculed, short duration variety and is tolerant to leaf spot disease. Considering the fact that high yielding varieties require more nutrients, it was thought worthwhile to evaluate the response of the Culture 42-1 (Soorya or ACV-2) to different levels of nitrogen, phosphorus and potash under garden land situation. So the present investigation was undertaken with the following objectives:-

1. To standardise the N, P and K requirement of prerelease sesamum culture (now released as Soorya or ACV-2) for gardenland
2. To study the pattern of nutritional uptake by the culture 42-1
3. To study the changes in quality and quantity of oil content as influenced by the nutrient
4. To workout the economics of sesamum production.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In Kerala sesamum is mainly grown as a catch crop in summer rice fallows and as a garden land crop in semi rabi season (August-December). The nutritional requirement of sesamum under garden land situation has not been studied in detail and as such the research finding in this aspect is meagre in the State. Therefore a brief resume of work done in sesamum and related crops are furnished hereunder.

Effect of Nitrogen on Plant Growth.

The effect of nitrogen in plant growth has been studied by many workers. Moursi and Abdel Gawad (1966) reported that dry matter production of stem, leaves and fruit in sesamum was increased by increased application of nitrogen. Rahman et al. (1978) conducted fertilizer trials on sesamum and revealed that plant height increased with increased levels of nitrogen. Subramonian et al. (1979) observed the number of branches per plant in sesamum was increased by nitrogen application. Gosh and Sen (1980) found that N and P increased the plant height and yield attributes on sesamum.

Maini et al. (1965) pointed out that the dry matter production in mustard under irrigated condition in a sandy loam soil low in nitrogen and poor in organic matter was not

affected by nitrogen application. Bhishnoi and Kanwar Singh (1979) reported that nitrogen increased dry matter production significantly in raya. The dry matter production of rainfed mustard increased significantly up to 60 kg N/ha (Vir and Verma, 1979). Pal (1979) found that the dry matter production in sunflower was maximum with 80 kg N/ha. Daulay and Singh (1980) observed a linear increase in dry matter of sunflower with an increase in the level of nitrogen. Singh and Ahuja (1984) noticed an increase in dry matter yield, nuts and kernel oil in groundnut with an increase in the level of nitrogen.

Effect of Nitrogen on Yield Attributes.

Nitrogen as a major nutrient play an important part in yield and yield attributes of sesamum. Mourei and Abdel Gawad (1966) found that the number of fruits per plant in sesamum increased by nitrogen application. Bonsu (1977) reported that fertilizer application did not significantly increase the number of podding nodes per plant, number of pods per plant nor the number of mature seed per pod, though nitrogen tended to increase seed weight in sesame. Andhale and Kalbhor (1978) found that 1000 seed weight of sunflower increased with increased application of nitrogen up to 75 kg/ha. Surajbhan (1979) observed that application of nitrogen delayed

flower initiation and maturity in mustard under Gangetic alluvium of Uttar Pradesh. Subramonian et al. (1979) observed an increase in the number of capsule per plant in sesamum with increase in the level of nitrogen application. Abdel Rahman et al. (1980) studied the physiological response of sesame to nitrogen fertilizer and found that highest number of effective capsule per plant was obtained with the application of 45 kg nitrogen. Gosh and Sen (1980) observed that nitrogen and phosphorus fertilization to the tune of 90 kg N/ha and 30 kg P_2O_5/ha were found to be beneficial in increasing the number of capsule, weight of 1000 seed, plant height and finally the yield of sesamum. Maity et al. (1980) reported that increased rate of nitrogen application resulted in an increase in production of capsule per plant in mustard. Dan (1982) found that the growth, yield components and pod yield of groundnut was increased by applied nitrogen. Girija Devi (1985) found that the number of capsules produced by sesamum plant increased significantly with increase in levels of nitrogen.

Effect of Nitrogen on Seed Yield.

Rai and Srivasthava (1968) in a manurial trial in sesamum in red loam soils, found that seed yield increased

with nitrogen application and optimum level of nitrogen was found to be 22.5 kg/ha. Gaur and Terhan (1973) reported that under Rajasthan conditions highest yield was obtained with 30 kg N/ha applied half at sowing and other half one month after sowing in sesamum. Gaur and Terhan (1973) found that the seed yield in sesamum was highest with 50 kg N/ha in Kharif season. Gowda (1974) reported that application of 40 kg N/ha gave the highest yield of 1.44 t/ha in summer sesamum. Singh and Kaushal (1975) studied the effect of nitrogen on the yield of rainfed sesame and found that, seed yield increased with increase in the rate of nitrogen from zero to 60 kg/ha. In an experiment in sesamum Singh and Kaushal (1975) observed that application of 50 kg N/ha increased the yield from 431 kg per hectare to 617 kg per hectare under rainfed condition. Kasane and Chaudhary (1976) observed that seed yield increased with applied nitrogen and optimum application rate was 20 kg N/ha in the case of groundnut crop. Popov et al. (1976) reported that application of nitrogen at two to three leaf stage of sesamum gave the highest average seed yield. Gaur (1976) in a trial with sesame found that application of 50 kg N + 50 kg P_2O_5 + 25 kg K_2O /ha increased the seed yield to 600 kg/ha from 161 kg/ha for no NPK application. Gowda et al. (1977) reported that application of 40 kg N/ha gave the highest seed yield in sesamum. Reddy (1977) pointed

out that seed yield of sunflower cultivars increased with increase in rate of applied nitrogen from zero to 120 kg/ha. Aleshchenko (1978) observed that application of 60 kg N/ha along with phosphorus and potassium gave the highest average seed yield of 2.82 t/ha compared to 2.38 t/ha without fertilizer in the case of sunflower. Andhale and Kalbhor (1978) found that yield components and seed yield of sunflower were increased with increased application of nitrogen up to 75 kg/ha. The response of rainfed sesamum to nitrogen level was studied by Mehrotra et al. (1978) and found that average seed yield of sesamum increased from 400 - 760 kg/ha with increase in the rate of applied nitrogen from zero to 30 kg/ha and further increase in yield with 45 kg N/ha was not significant. According to Choudhary (1979) pod yield of irrigated Co TMV-2 was higher with 20 kg N/ha than with 40 kg/ha.

Nadgouda et al. (1978) studied the response of groundnut to nitrogen in Bijapur district and found that application of 30 kg N alone or in combination with phosphorus and potassium increased pod yield by 28.8% to 39% compared with unfertilized controls. Salam et al. (1978) found that response and production efficiency of nitrogen decreased with increasing nitrogen rates in sunflower. Mukand Singh et al. (1978) reported that average seed yield of raya varieties increased

with increased levels of nitrogen. According to Sanchez et al. (1978) application of 20 kg N/ha increased yield of pods of groundnut to 1.72 t/ha, compared with 1.53 t/ha with no nitrogen; 1.67 t/ha with 40 kg N and 1.64 t/ha with 60 kg nitrogen.

Arunachalam and Sennaiyan (1977) studied the effect of fertiliser nitrogen on gingelly cultivar TMV-3 grown under rainfed conditions in black loam soil and found that the seed yield was higher with 25 kg N/ha. Satyanarayana (1978) while studying the effect of nitrogen on yield of two gingelly varieties 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 condition in black loam soil and found that the seed yield was highest with 25 kg nitrogen. Dalgado et al. (1978) pointed out that sesame responds positively to nitrogen and appropriate rate was 200 kg urea/ha. Arunachalam and Morachan (1979) found that application of 40 kg N/ha gave the highest average seed yield in sunflower. Bhan (1979) reported that the yields of two mustard cultivars were greater with the increased application of nitrogen from zero to 120 kg/ha. According to Bhosale et al. (1979) the effect of graded levels of nitrogen on the

yield of sunflower variety 'peredovik' increased from 0.73 to 1.26 t/ha with increase in the rate of applied nitrogen from zero to 50 kg/ha. However, further increase in yield with 78 kg N/ha was not significant. Gangaseran and Kiura (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 and Gajananan (1979) conducted studies on the differential response of sunflower to nitrogen levels on red sandy loan soil and found that increasing rate of applied nitrogen from zero to 90 kg/ha increased seed yield of sunflower from 1.05 to 1.91 t/ha; further increase of N rate decreased yields. Kachapur et al. (1979) observed that application of 40 kg N increased seed yield of nigar from 225 to 405 kg/ha with increased rate of N application. Munoz (1979) studied the response of two species of rape to different levels of nitrogenous fertilizer and found that maximum yield was obtained with 200 units of nitrogen.

Sadanandan and Saeidhar (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. Surajbhan (1979) reported that application of nitrogen increased grain yield of mustard. Saran and Dee (1979) observed an increase in yield of rape with increased

application of nitrogen. Solanki (1979) found that the seed yield per plant in safflower was positively correlated with number of seed per head, number of head per plant and 1000 seed weight. Subramonian et al. (1979) reported that application of 40, 60 and 40 kg of nitrogen, phosphoric acid and potash respectively increased seed yield of sunflower compared to no fertilizer application. Vir and Verma (1979) concluded that increasing the rates of nitrogen from zero to 30 and 60 kg/ha increased the seed yield and yield components in mustard. Gosh and Sen (1980) observed that seed yield of sesamum was increased by nitrogen application.

According to Aulakh et al. (1980) the grain yield of both yellow and white mustard increased with the increased level of nitrogen application. Doulay and Singh (1980) indicated that seed yield of sunflower increased with increased level of nitrogen application. Maity et al. (1980) reported that application 50 kg N/ha under rainfed condition without irrigation significantly increased seed yield 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 yield with 50 kg applied N/ha than with zero to 25 or 75 kg N/ha.

Yadava et al. (1980) found that the seed yield per plant in 22 sesame cultivars was positively correlated with number of capsules, primary branches from plant and 1000 seed weight. Path coefficient analysis showed that capsule per plant, 1000 seed weight, number of days required for 50% flowering and primary branches per plant had high direct effect on yield. Maiti et al. (1981) found that yield of 6 sesame cultivars was increased by increasing nitrogen rates from zero to 80 - 120 kg/ha and yield was further increased by adding phosphorus and potassium along with nitrogen. Mane (1983) reported that grain yield of safflower (Carthamus tintoris) was significantly increased with increased level of N. Girija Devi (1985) also found that nitrogen application produced significant increase in seed yield. Jalaludeenkutty (1985) noticed significant increase in seed yield due to nitrogen and phosphorus application.

Effect of Nitrogen on Quality attributes.

Oil Content.

Ramaswamy et al. (1974) observed that nitrogen application increased the oil content significantly up to 50 kg/ha and higher doses decreased the oil content. Michell et al. (1974) observed that seed quality of sesamum was significantly influenced by nitrogen application. Satyanarayana (1978)

found that oil yield of two sesame cultivars were higher with the application of 25 kg N/ha. Munos (1979) noticed an increase in seed oil content of rape with increased application of nitrogen. Vir and Verma (1979) reported that increased rate of nitrogen from zero to 30 kg and 60 kg/ha to mustard had no effect on seed oil content. Singh and Yusuf (1979) studied the effect of nitrogen on oil content of brown sarson and found that oil content was increased by low rate of nitrogen but decreased by higher rates (48 -60 kg N/ha). Mane (1983) reported that the oil and protein content of safflower increased with increase in level of N up to 100 kg N/ha. Girija Devi (1985) reported that there was significant increase in oil content with applied nitrogen. Jalaludeenkutty (1985) also reported that there was significant increase in oil content due to applied nitrogen.

Protein Content.

According to Bhuiya and Chowdhary (1974) in Bramaputra flood plain soil the nitrogen application increased the porcentage of protein in groundnut. Michell et al. (1976) studied the mineral composition and seed characteristics of sesamum as affected by nitrogen nutrition and found that seed protein was increased by nitrogen application. Michell (1976)

observed an increase in N and K nutrition increased the seed concentration of individual protein amino acid with increased levels of applied nitrogen in sesamum seed. Dopenbrook (1979) studied the influence of nitrogen nutrition on qualitative characteristics of seeds of rape (Brassica napus) and found that nitrogen fertilisation decreased lipid content during the main growth stage and further studies indicated that nitrogen nutrition significantly changed fatty acid composition during early stages of seed growth. At maturity nitrogen application resulted in a higher content of palmetic and linolic acid but a low olic acid content. Aulakh et al. (1980) found that protein content of mustard grains improved with nitrogen application. Shelke and Khurpe (1981) found that increased level of nitrogen increased the protein content from 31.5 to 39.9% in white mustard. Singh and Ahuja (1984) reported that nitrogen application increased crude protein content in groundnut. According to Girija Devi (1985) nitrogen application increased the protein content of sesame seed and high protein content was recorded by highest level of nitrogen.

Effect of Nitrogen on the Content and Uptake of Nutrients.

Vir and Verma (1979) reported that increasing the rate of nitrogen application from zero to 30 and 60 kg/ha to mustard

increased seed nitrogen content and uptake of total nitrogen. Bishnoi and Kanwar Singh (1979) studied the effect of nitrogen levels on the nitrogen, phosphorus and potash uptake of raya and found out that applied nitrogen increased the nitrogen and phosphorus content and their uptake. Aulakh et al. (1980) found that nitrogen application significantly influenced the concentration and uptake (kg/ha) of nitrogen in mustard. According to Reddy and Narayanan (1983) the concentration of nitrogen in plant parts of sesamum cultivars and the nutrient concentration in all vegetative plant parts increased until six weeks after sowing followed by gradual decrease towards maturity. Remobilization of nitrogen occurs from leaf, stem and root to the pods during the reproductive phase. The nutrient concentration in the leaves was 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) studied the nitrogen uptake of groundnut crop and it was maximum with the application of 10 kg nitrogen as basal dressing and the remaining 20 kg nitrogen applied 30 days after planting. Girija Devi (1985) reported that nitrogen application significantly influenced the nitrogen content and uptake at all stage of growth both in stover and grain and the highest amount of uptake was seen with

highest level of nitrogen. Total nitrogen was highest with the highest level of nitrogen. Jalaludeenkutty (1985) also reported that the uptake was influenced by nitrogen application at all stages of growth.

Effect of Phosphorus on Plant Growth.

Experimental evidences show that phosphorus has also a major role in 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 increased levels of phosphorus in safflower. Rahman et al. (1978) also indicated that the number of branches per plant in safflower increased with increased levels of phosphorus. According to Sirry et al. (1979) increase in the rate of phosphorus application increased height of plant in sesamum.

Mourad and Abdel-Gawad (1966) observed that the growth and chemical composition in sand culture with different combinations of phosphorus increased the dry matter of leaves, stems and fruit of sesamum plants. Ramirez et al. (1975) reported that application of 30 kg P_2O_5/ha placed along with seed 2, 4 and 6 cm below it increased the dry matter of sesame. Pal (1979) observed that dry matter production was highest with 80 kg P_2O_5/ha in sunflower. Wiedenhofen and Camacaro (1975) reported that phosphorus applied in band 2 to 4 cm

below seed increased height and dry matter of sesame. Vir and Verma (1979) observed that application of phosphorus at the rate of 30 kg/ha increased the dry matter production on rainfed mustard. Daulay and Singh (1980) noticed a linear increase in dry matter production with an increase in phosphorus level. Girija Devi (1985) reported that there was significant influence of phosphorus in leaf area and dry matter production. Jalaludeenkutty (1985) also reported that P and K along with N had a positive effect on dry weight of plant.

Effect of Phosphorus on Yield Attributes.

Rahman et al. (1978) found that number of head of safflower increased with increased level of application of phosphorus and obtained maximum heads with the application of 30 kg P_2O_5/ha. Sanchez and Owen (1978) reported that application of 0, 50, 100, 150 and 200 kg P_2O_5/ha along with N and K increased pod yield in groundnut from 0.75 t to 2.07 t/ha with 150 kg P_2O_5. Singh and Kalra (1983) observed a remarkable influence of phosphorus on yield potential of groundnut. With every increase in P level the yield of pod increased linearly. Girija Devi (1985) reported that there was significant influence for P on weight of pod per plant, number of seed

per plant, 1000 seed weight and finally the seed yield of sesamum. Jalaludeenkutty (1985) also noticed significant influence with P on 1000 seed weight of sesamum.

Effect of Phosphorus on Seed Yield.

Rai and Srivastava (1968) conducted nutrient trials in sesamum on red loam soil and found that there was not much response to phosphorus application with respect to seed yield. Gaur and Trehan (1973) found that seed yield was higher with 50 kg P_2O_5/ha in Kharif season in sesamum. Gowda (1974) pointed out that seed yield was highest with 20 kg P_2O_5/ha (1.44 t/ha). Singh and Kaushal (1975) studied the response of rainfed sesamum to fertiliser levels and found that application of 50 kg P_2O_5/ha along with nitrogen increased yield from 431 kg/ha to 617 kg/ha. Popov et al. (1976) found that application of phosphorus along with nitrogen at two or three leaf stage of sesamum gave highest average seed yield. Choudhary (1979) noticed that pod yield of irrigated groundnut TMV-2 was higher with 60 kg P_2O_5/ha than with 30 kg P_2O_5/ha.

Gowda et al. (1977) observed that application of P_2O_5 @ 20 kg/ha along with nitrogen and potash gave the highest seed yield of 1.44 t/ha in sesame. Aleshchenko (1978) noticed that application of 60 kg phosphorus gave the highest average seed

yield of 2.82 t/ha in sesamum. Sanchez and Owen (1978) found that application of phosphorus in groundnut increased pod yield 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 (1978) pointed out that application of 25 kg P_2O_5/ha to gingelly variety TMV-3 gave highest yield. According to Arunachalam and Morachan (1979) sunflower crop showed no response to the application of 20 - 40 kg P_2O_5. Gangasaran and Kinra (1979) reported that application of phosphorus along with nitrogen and potassium was profitable in the case of rai (Brassica juncea). Kachapur et al. (1979) reported that average seed yield of 405 kg/ha was obtained with 60 kg phosphorus in nigar compared to 22.5 kg without fertilizer. Munoz (1979) studied the response of five species of rape to different levels of phosphorus fertilizer and found that maximum yield was obtained with 100 unit phosphorus per hectare. Sadanandan and Sasidhar (1979) reported that seed yield of sesamum variety Kayamkulam-1 grown in red loam soil was significantly affected by phosphorus application at the rate of 0 - 55 kg/ha. Subramanian et al (1979) found that application of phosphorus at the rate of 60 kg/ha increased seed yield of sunflower. Patel et al. (1980) observed that mustard gave significantly higher seed yield with 50 kg P_2O_5/ha. Maiti et al. (1981) pointed out that seed yield of six sesamum cultivars was increased by

the application of phosphorus at the rate of 40 kg/ha. Shelke and Khurpe (1981) found that the phosphorus yield relationship in summer groundnut to applied phosphorus was quadratic and was expressed by y (predicted pot yield) = $23.38 + 8.5p - 4xp^2$. Maximum predicted yield was 2.75 t/ha with 18.55 kg P_2O_5/ha. Zaiddi and Khan (1981) reported that application of 72 kg urea, 183 kg super phosphate and 165 kg nitrophos/ha gave seed yield of 81, 106 and 175 respectively in sesame. Friederich et al. (1983) observed that application of diammonium phosphate increased seed yield in sunflower. Girija Devi (1985) pointed out that application of phosphorus significantly increased the seed yield.

Effect of Phosphorus on Quality Attributes.

Oil Content.

Singh et al. (1960) reported that application of P_2O_5 and K_2O increased the oil content significantly over control in sesamum. Bhuiya and Chowdhury (1974) studied the effect of N, P, K and S on protein and oil content of groundnut in Brahmaputra flood plain soil and found that oil content of kernel increased with P application. Revenko (1977) studied the different combination of phosphorus, nitrogen and potash and reported that these nutrients did not favour an increase

in the oil content of sunflower. Satyanarayana (1978) observed an increase in oil content due to applied phosphorus in sesame. Choudhary and Paturde (1980) in a field experiment with sunflower found that phosphorus application increased seed oil content and oil yield. Friederich (1983) in a field trial in sunflower found that applied diammonium phosphate did not affect the oil content. Jalaludeenkutty (1985) in an experiment reported that N, P and K significantly influenced the oil content of sesamum.

Protein Content.

Bhuiya and Chowdhary (1974) conducted an experiment to study the effect of N, P, K and S on the protein and oil content of groundnut in Brahmaputra flood plain soil and found that phosphorus application increased protein content. Singh and Ahuja (1984) reported that P application increased the protein content of groundnut. Girija Devi (1985) in a nutritional trial in Thilothama variety of sesamum found that protein content of seed was increased significantly with increased level of phosphorus application. Similarly Jalaludeenkutty (1985) also reported that P and K significantly increased the protein content of sesamum.

Effect of phosphorus on the Content and Uptake Studies

Ramirez et al. (1975) reported that P uptake was highest when the P was placed 2 or 4 cm below the seed. Regression coefficient calculated for P uptake and dry weight was significant indicating the effect of P on the growth components. Sirry et al. (1979) reported that high P level increased P content of whole plant parts and K content of leaves. Vir and Verma (1979) conducted trials on 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. Jose and Reddy (1981) found that high rate of application of phosphorus significantly increased the P content of rape seed. Girija Devi (1989) reported that phosphorus uptake was increased significantly with applied phosphorus and the highest uptake was recorded with highest level of phosphorus. Phosphorus application significantly influenced the P content of both stover and seed in sesamum. Jalaludeenkutty (1985) reported that the main effect of P and K and their interaction were found to have significant influence in plant P content at 40 days after sowing. The highest P uptake was observed at the harvest stage in $N_2P_2K_2$ combinations (30 kg N, 15 kg P_2O_5 and 30 kg K_2O /ha).

Effect of Potassium on Plant Growth.

Rahman et al. (1978) conducted experiment on safflower and reported that plant height increased with increased potash application. Rao (1979) observed increase in dry matter production with higher levels of potash in groundnut TMV-2. Balamurugan and Venkatesan (1983) in an experiment on Co-1 variety of sesamum found that added potash had significant effect on both primary and secondary branches in summer sown crop at Bhavanisagar.

Positive effect between dry matter production and increasing levels of NPK fertilizer was obtained by Gopalakrishnan et al. (1971) in TMV-3 sesamum during the early stages of growth but fluctuations were noticed as the crop attained maturity.

Aipe (1981) reported that potassium significantly influenced the growth of the plant at all stages of growth in sesamum. Height of the plant, dry weight of seed and stover and total dry matter production increased significantly. Girija Devi (1985) reported that potash had significant influence on dry matter production up to 30 kg K_2O /ha in sesamum. Jalaludeenkutty (1985) also reported that potassium had a significant influence in sesamum on the total dry matter production.

Effect of Potassium on Yield Attributes.

Menon and Unnithan (1965) studied the response of sesamum to NPK in Kerala and reported that K is beneficial to the crop. Application of 30 lb of K_2O /acre mixed with 30 lb of N and 15 lb of P_2O_5 gave maximum yield. Rao (1979) observed that the number of capsules per plant increased with higher level of potash in groundnut. He also reported that the seed test weight of groundnut TMV-2 increased with high level of potash. Dan (1982) observed that the growth, yield components and pod yield were increased by applying N, P and K. Balamurugan and Venkatesan (1983) reported that the number of capsule per plant was increased with the addition of K in Bhavaninagar on summer crop of sesamum. Girija Devi (1985) reported that K significantly increased the number of seed per plant and 1000 seed weight in sesamum.

Effect of Potassium on Seed Yield.

Menon and Unnithan (1965) got highly significant and consistant increase in yield during three seasons in sesamum variety Onattukara local due to potash application in sandy loam soils of Kayamkulam. It is seen that addition of potash alone at 16.84 to 33.68 kg/ha had given an yield of 51.09 kg and 93.41 kg/ha respectively over the control. Gupta and

Das (1973) observed a slight increase in yield due to potash application in rape seed. Singh and Kaushal (1975) in a field trial on sesamum found that the yield of sesamum was decreased by application of 25 kg K_2O /ha along with nitrogen at the rate of 50 kg/ha and P_2O_5 at 50 kg/ha. Mitchell (1976) noticed an increase in yield of sesamum with nitrogen, phosphorus and potash. According Gowda et al (1977) an increase in yield due to applied potassium was obtained in a variety-spacing cum fertilizer trial on sesamum. Satyanarayana (1978) found that an increase in seed yield and oil yield with increased application of potassium and low level of nitrogen and spacing in C-1036 and T-12 sesamum varieties.

Rao (1979) studied the effect of potassium, calcium and magnesium on growth and yield of irrigated groundnut TMV-2 and found that application of 40 and 80 kg K_2O /ha gave 19.3% and 24.9% increased yield over control. Balamurugan and Venkatesan (1983) reported that K application had remarkable influence on seed yield of sesamum at Bavanimagar.

Aipe (1981) reported that potassium significantly influenced the yield and most of the yield attributing characters like 1000 grain weight, straw yield and grain yield.

Girija Devi (1985) in a study in Thilothama variety of sesamum observed the K application significantly influenced the number of capsule per plant and 1000 seed weight.

Effect of Potassium on Quality Attributes.

Oil Content.

Singh et al. (1960) found that the seed oil content of sesamum variety was improved by applied potassium. Bhuiya and Choudhary (1974) reported that application of 44.8 kg K_2O /ha increased oil content over no potash and response was found to be greater in the presence of phosphorus in groundnut, grown in the flood plain of Bangladesh. Gupta and Friend (1975) obtained increased oil content in white mustard with high level of potash in pot culture study. Stoyanova et al. (1975) obtained increased oil content due to applied potassium in sunflower. Revenko (1977) noticed that different combinations of nitrogen, phosphorus and potash did not favour an increase in oil content of sunflower. Satyanarayana (1978) reported that K application increased the oil content of sesamum. Balamurugan and Venkatesan (1983) in a field trial at Bavanisagar on sesamum found that application of 30 kg K_2O and 12.5 kg $MnSO_4$ was best for increasing seed yield and oil content. Aipe (1984) reported that K application significantly increased the oil content of sesamum up to 30 kg K_2O/ha.

Protein content.

Bhuiya and Chowdhary (1974) reported that the protein content of groundnut seed was increased when applied potassium was increased from zero to 44.8 kg/ha. Michell et al. (1974) in sand culture study observed that an increase in protein content coupled with decrease in oil content due to applied potash in sesamum. In a similar study the same author concluded that application of potash increased the individual protein amino acid in the seed meal of sesamum due to increase in protein concentration. Potash deficiency resulted in the accumulation of free amino acid correlated with decrease in protein content; suggesting the requirement of potash for proper utilization of amino acid in protein synthesis.

Effect of Potassium on the Content and Uptake.

Habeebullah et al. (1977) conducted pot culture experiment in red and alluvial soil and found that nitrogen content of haulm was increased and that of kernel decreased when potash was applied between zero and 100 kg/ha in sesame. Eventhough it was not statistically significant, the highest level of potash increased the nitrogen content of haulm. He also reported that potash application recorded higher phosphorus content in haulm and kernel in sesamum when applied at 0, 50, 100 and 150 kg/ha. The uptake of nitrogen

and phosphorus was found to increase with applied potash at 0, 40, 80 kg/ha in irrigated variety TMV-2 (Rao, 1979). Reddy and Narayan (1983) studied the concentration of potash in plant parts of sesamum and found that nutrient concentration in all vegetative plant parts increased up to six weeks after sowing, after which there was a gradual decrease towards maturity. Remobilization of nutrients occurred from leaf, stem and root to the pod 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) observed that uptake of potash in groundnut was maximum when it was applied basal at the rate of 40 kg/ha in 1980 and 25 kg during 1981.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out with the main objective of standardising the NPK requirement of pre-release sesamum Culture 42-1 (Soorya or ACV-2) in garden land and to study the pattern of nutrient uptake by the culture. It was also aimed at to study the changes in the quality and quantity of oil content as influenced by the nutrients and also to work out the economics of sesamum production.

MATERIALS

Experiment Site:

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, Trivandrum. The Farm is located at 8^{0} N latitude and at an altitude of 29 m above mean sea level.

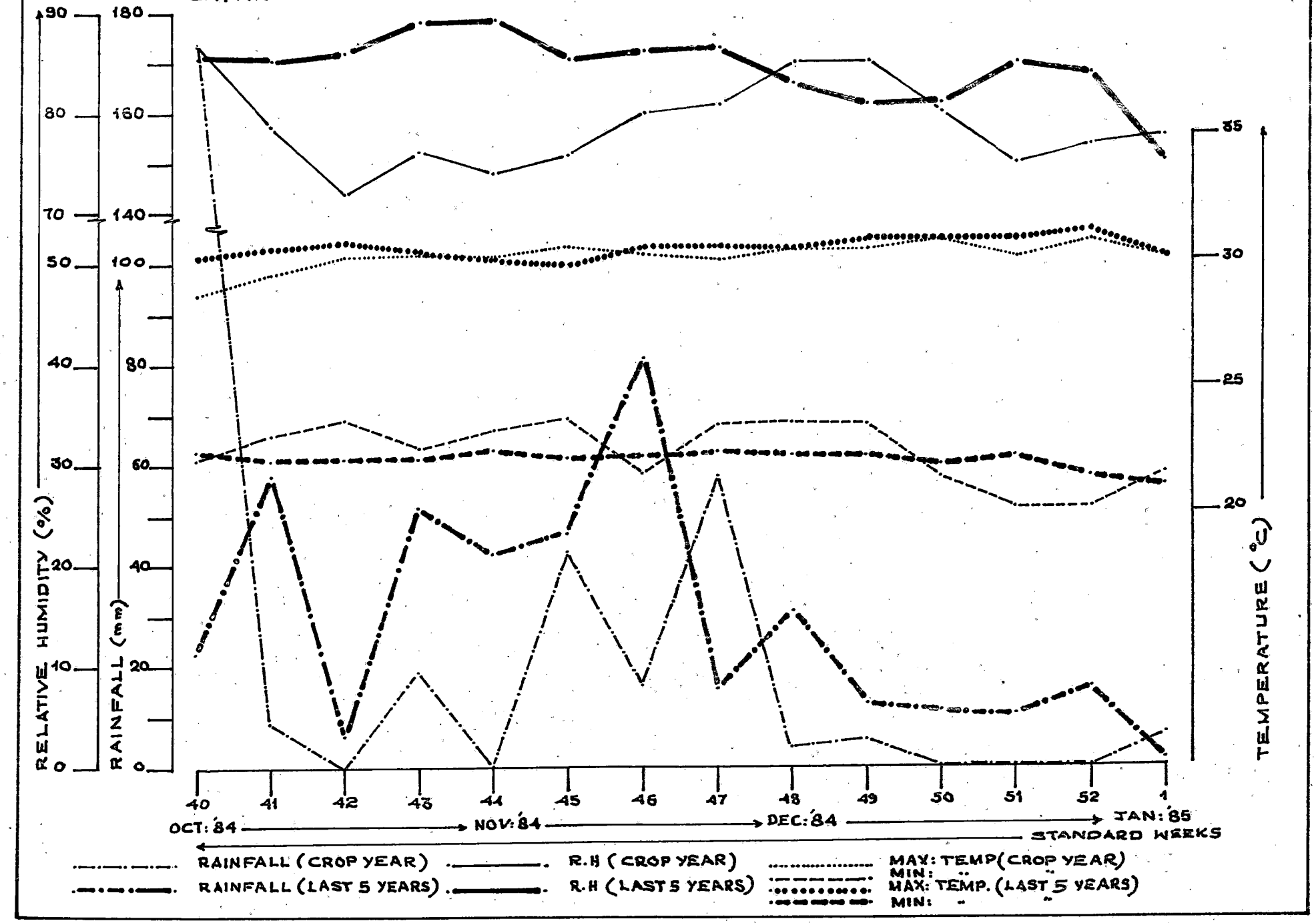
1.2. Soil

The soil of the experimental site was red loam with the following chemical properties.

A. Mechanical Composition

Coarse sand (percentage)	13.60
Fine sand	33.15
Silt	27.86
Clay	25.39

FIG. 1. WEATHER DATA DURING THE CROP YEAR (1984) AND FOR THE LAST FIVE YEARS (1979 - '84)



B. Chemical Properties

pH	5.3
Total nitrogen	0.017%
Available P_2O_5	39.45 kg/ha
Available K_2O	40.12 kg/ha

1.3. Cropping History of the Site

The experiment site was lying fallow for three months prior to the present study.

1.4. Season

The experiment was conducted during semi rabi season 1984. The crop was sown on 9th October 1984 and harvested on 5th January 1985.

1.5. Climatic Condition

The data on weather conditions such as maximum and minimum temperatures, rainfall and relative humidity were collected from the meteorological observatory of the Instructional Farm, Vellayani and are presented as weekly average in Appendix I. The weather conditions were favourable for the growth of the plant. The weekly average and daily maximum and minimum temperatures, showed only a little fluctuation. The range of maximum temperature for the entire

period was 28.4 to 30.9°C and the same for minimum temperature was 20.2 to 23.9°C. The range of relative humidity was from 72.4 to 87.6%. The crop received 9.6 mm rain during the first week after sowing and frequent rain was received during subsequent weeks. Life saving irrigation was done during the 3rd week of October and 1st week of November.

1.6. Variety

The variety selected for the study was a high yielding culture 42-1 (Sooriya or ACV-2) evolved at the College of Agriculture, Vellayani. It is a pure line selection from a West Bengal variety and is a straight growing plant with dark green stem and leaves. It is a short duration crop, maturing in 82 to 87 days and is a multiloculed and multipoded one. The average yield is 350 kg/ha and the seeds are ash in colour. This variety is mostly suited to upland situation and gives better yield than the varieties 'Philothoma' and 'Soma'.

1.7. Fertilizers

Chemical fertilizers such as urea, super phosphate and muriate of potash were used for the experiment and percentage nutrient content of the fertilizer was as follows:-

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

2. METHODS

The treatment consisted of 4 levels of Nitrogen, 4 levels of Phosphorus and 4 levels of Potash.

Levels of Nitrogen

n_1	10 kg N/ha
n_2	30 kg N/ha
n_3	50 kg N/ha
n_4	70 kg N/ha

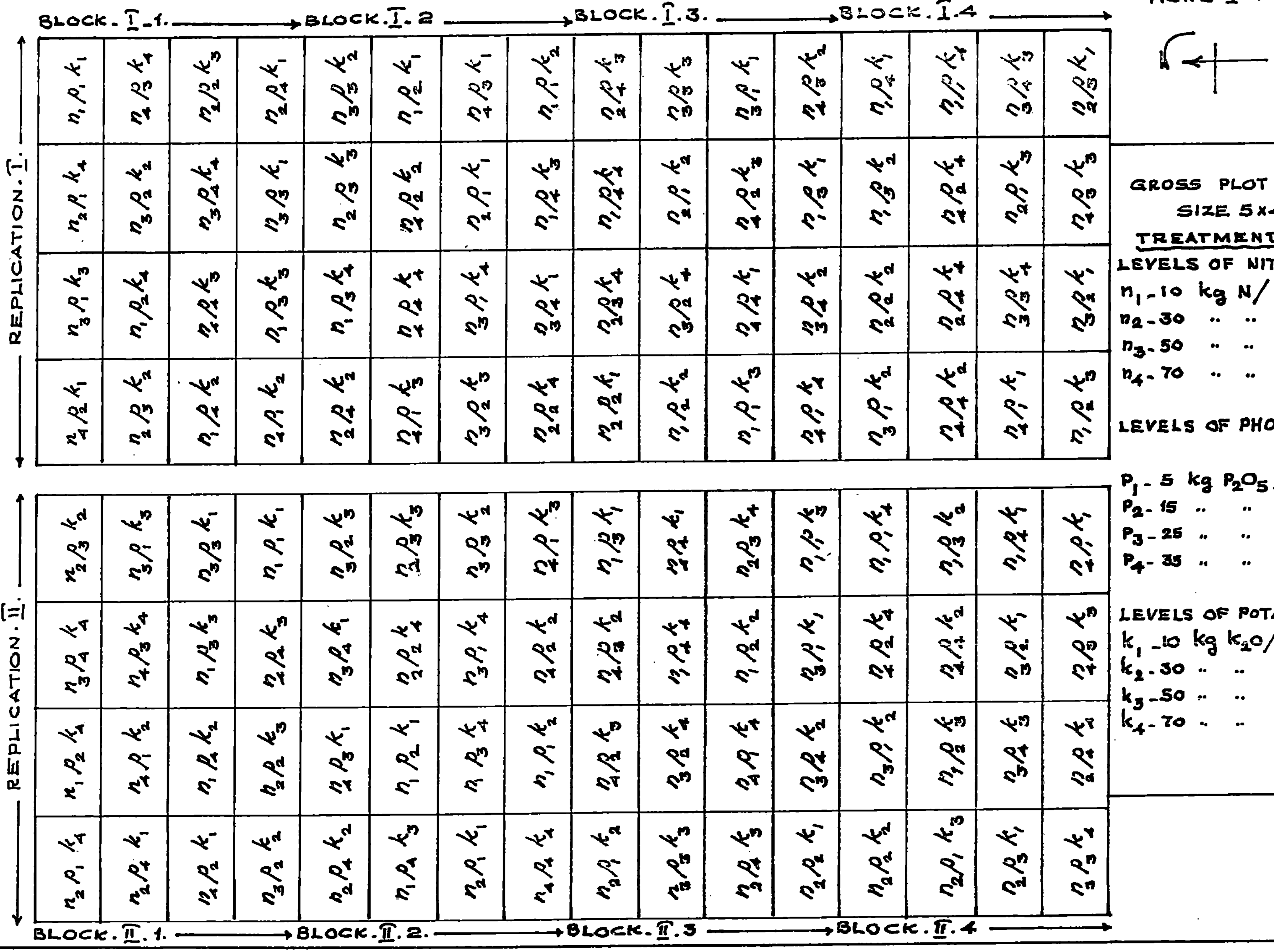
Levels of Phosphorus

p_1	5 kg P_2O_5/ha
p_2	15 kg P_2O_5/ha
p_3	25 kg P_2O_5/ha
p_4	35 kg P_2O_5/ha

Levels of Potash

k_1	10 kg K_2O/ha
k_2	30 kg K_2O/ha
k_3	50 kg K_2O/ha
k_4	70 kg K_2O/ha

FIG. 2. LAY OUT PLAN – 4^3 FACTORIAL EXPERIMENT CONFOUNDING NPK (3 df) TOTALLY IN REPLICATIONS I AND II.



GROSS PLOT SIZE 5 x 4 m

TREATMENTS

LEVELS OF NITROGEN

n_1 - 10 kg N/ha.
n_2 - 30 .. .. ..
n_3 - 50 .. .. ..
n_4 - 70 .. .. ..

LEVELS OF PHOSPHORUS

p_1 - 5 kg P_2O_5/ha.
p_2 - 15 .. .. ..
p_3 - 25 .. .. ..
p_4 - 35 .. .. ..

LEVELS OF POTASSIUM

k_1 - 10 kg K_2O/ha.
k_2 - 30 .. .. ..
k_3 - 50 .. .. ..
k_4 - 70 .. .. ..

2.2. Design of the Experiment

The experiment was laid out on a 4^3 confounded factorial in randomised blocks with two replications confounding NPK (3 df) totally. The lay out plan is appended in Fig. 2. The experimental details are furnished below.

Gross plot size	5 x 4 m
Spacing	20 x 20 cm
Net plot size	3.4 x 3.2 m
Number of blocks per replication	4
Number of plots per block	16
Number of replication	2
Total number of plots	128

For chemical analysis one row was selected on either side after leaving two border rows on the 4 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 collections.

2.3. Field Operation

2.3.1. Preparation of Main Field

The experimental plot was dug twice, weeds and stubbles removed, clods broken, levelled 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 application was done according to various treatments. Fertilizers used were urea, super phosphate and muriate of potash to N, P and K respectively. Three-fourth N, full P and K were applied as basal dose one day prior to sowing and balance quantity of N was applied as foliar spray at 3 per cent concentration on 25th to 30th day after sowing, keeping the discharge rate at 500 lit/ha.

2.3.3. Seeds and Sowing

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

2.3.4. After Cultivation

Thinning and intercultural operations were made in the second week after sowing. The second interculture operation and weeding were made on 25th day after sowing. Life saving irrigation was done on 12th and 22nd days after sowing, due to the scarcity of rain.

2.3.5. Plant Protection

Spraying of carbaryl 50 w.p. was done to control the attack of leaf and pod caterpillar during the flowering

period. During later stages of growth powdery mildew was noticed and spraying of wettable sulphur was carried out to control this disease.

2.3.6. Harvesting

The crop was harvested on 67th day after sowing. Harvesting was done by pulling out the plants, the root portions cut and the plants bundled. The bundles were kept for 3 to 4 days to hasten maturity. Then the bundles were spread, sun-dried and beaten with sticks to break open the capsules. Drying and threshing were continued for 3 more days.

3. OBSERVATION RECORDED

3.1. Growth Characters

Growth characters were recorded at 20 days intervals on the following:-

1) Height of the plant
2) Number of leaves per plant
3) Number of branches per plant
4) Leaf area index
5) Number of days required for 50% flowering.

3.2. Yield and Yield Components

1) Number of pods per plant at harvest
2) Weight of pods per plant
3) Weight of seeds per plant
4) Pod seed ratio
5) Weight of bhusa per plant
6) 1000 seed weight
7) Seed yield
8) Harvest index
9) Total dry matter production.

3.3. Quality Characteristics

1) Oil content of seed
2) Protein content of seed.

3.4. Plant Sample

Plant samples were analysed for the following nutrients at 20th, 40th, 60th day and at harvest.

3.4.1. Nitrogen Content of Plant

i) Percentage of N in plant sample
ii) Percentage of N in seed.

3.4.2. Phosphorus Content

i) Percentage of phosphorus in plant sample

ii) Percentage of phosphorus in seed.

3.4.3. Potassium content of Plant

i) Percentage of potash in plant sample

ii) Percentage of potash in seed

3.4.4. Uptake of nitrogen by Plant

i) Uptake of nitrogen by plant

ii) Uptake of nitrogen by seed

iii) Total uptake of nitrogen by the plant

3.4.5. Uptake of Phosphorus by Plant

i) Uptake of phosphorus by plant

ii) Uptake of phosphorus by seed

iii) Total uptake of phosphorus by the plant

3.4.6. Uptake of Potash by Plant

i) Uptake of potash by plant

ii) Uptake of potash by seed

iii) Total uptake of potash by plant.

4. Sampling Procedure

Observations on growth characters such as height of the plant, number of branches, number of pods per plant etc. were taken at 20th day, 40th day, 60th day and at harvest. Ten plants from each plot were selected for the purpose and tagged neatly. Ten rows were selected at random after eliminating the border rows and one plant from each row was selected at random as observation plant. For chemical analysis five plants were uprooted at a stretch from the third row after eliminating two border rows from the four metre long side of the plot. These plants were used for dry matter production and nutrient content studies. At harvest five out of ten observational plants were used for determining the dry matter and for chemical analysis.

5. DETAILS OF OBSERVATION PROCEDURE

5.1. Height of Plant

The plants from each plot were selected at random and tagged with treatment number and plant number. Height of the plant was taken from the ground level to the growing tip and was measured in cm. The average height of the plant was worked out and recorded. Observations were taken from the same plant at 20th, 40th, 60th day and at harvest.

5.2. Number of Leaves

Observations were made on 20th, 40th and 60th day and the leaves were counted and recorded. The number of leaves remained at harvest was also counted and the average number of leaves per plant was worked out and recorded at each stage.

5.3. Number of Branches

Number of primary branches seen on each observational plant was counted and the average number of branches per plant was worked out and recorded.

5.4. Leaf Area Index

The leaf area index was calculated using punch method on 20th, 40th, 60th day and at harvest.

5.5. Number of days required for 50% Flowering

The number of days taken for 50% flowering was observed and recorded for all observational plants and the average number of days taken for flowering was calculated and recorded.

5.6. Number of Pods per Plant

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

5.7. Weight of Pods per Plant

Pods separated from the observational plants were dried and average weight recorded.

5.8. Weight of seed per plant

Pods after drying were hulled and seeds separated and weight recorded.

5.9. Pod Seed Ratio

It was estimated based on the dry weight of pod and weight of seed. It is the ratio between the weight of seed and total weight of pod.

5.10. Weight of Bhusa

The dry weight of all plant parts except seed was taken for determining the weight of bhusa.

5.11. Harvest Index

Harvest index was calculated based on the formula

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

Y econ = Dry weight of seed and

Y biol = Total dry weight of plant (excluding root).

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

5.12. Thousand Seed Weight

Seeds obtained from the observational plants were dried. Two hundred seeds were counted, sun-dried and weight taken. Test weight was expressed for 1000 seed in gram.

5.13. Seed Yield

Crop harvested from the net plots was threshed, winnowed cleaned and sundried for three days. Weight of seed was taken and recorded. Yield was estimated in kg/ha. The yield of observational plants were also added to the net plot yield.

5.14. Total Dry matter Production

Five sample plants were uprooted on 20th, 40th and 60th day after sowing for determining the total dry weight of the plant. The observational plants were used for estimating the dry matter production at harvest. The dry matter production was estimated based on oven dry weight of the plant.

6. CHEMICAL ANALYSIS

Plant samples collected for recording dry weight at 20th, 40th and 60th day after sowing were used for chemical analysis. At harvest the observational plants were used for chemical analysis. During harvest the sample plants were separated into seeds and bhusa. They were analysed separately. The different components were oven-dried to constant weight and powdered for the estimation of total N, total P and total K 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 plant for 20th, 40th, 60th day and at harvest. At harvest the uptake by 'bhusa' and seeds were added to get the total uptake. The uptake values are presented in kg/ha.

6.3. Total Phosphorus Content

Phosphorus content was estimated colorimetrically by using triple acid (HNO_3 + H_2SO_4 + $HClO_4$) extraction method

(Jackson, 1967). The colour developed by using vanado-molybdate and phosphoric acid was read by using Spectronic 20.

6.4. Uptake of Phosphorus

This was estimated from the phosphorus content and the dry weight of the components. Uptake by bhusa and seed 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 sample using diacid mixture.

6.6. Total Uptake of Potash

This was calculated from the potash content and the dry weight of the components. Uptake of seed and bhusa was added to get the total plant uptake at harvest.

6.7. Oil Content

Oil content of oven dry seed was estimated by cold percolation method (Kartha and Sethi, 1957).

6.8. Protein Content

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

7. Soil Analysis

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

8. Statistical Analysis

Data on growth characters, yield and yield attributes and those on chemical analysis were analysed by employing the technique of analysis of variance in a 4^3 factorial experiment for N, P and K, confounding NPK (3 df) totally (Cochran and Cox, 1965).

The response surface describing the dose response relationship is given by the equation

$$y_u = b_0 + b_1x_{1u} + b_2x_{2u} + b_3x_{3u} + b_{11}x_{1u}^2 + b_{22}x_{2u}^2 + b_{33}x_{3u}^2 + b_{12}x_{1u}x_{2u} + b_{13}x_{1u}x_{3u} + b_{23}x_{2u}x_{3u}$$

(0, 1, 2, 3, 4, etc. as suffix)

where $u = 1, 2, 3, 4$

x_1, x_2, x_3 stands for N, P and K (Das and Giri, 1979).

RESULT 5

RESULTS

GROWTH CHARACTERS

1. Height of Plant

The mean height of plants at various stages of growth is presented in Table 1 and the analysis of variance in Appendix II.

The result revealed that application of nitrogen significantly influenced the height of plant at all stages of growth and the highest level of nitrogen (n_4) gave the maximum height. On 20th, 40th and 60th days after sowing n_4 level was on par with n_3 which in turn was on par with n_2. At harvest stage, n_4 level recorded the maximum height followed by n_3 which in turn was on par with n_2. The lowest height was observed with lowest level of nitrogen at all stages of growth.

Application of P and K was found to increase the plant height only during the later stages of growth. A dose of 15 kg P_2O_5 (p_2 level) and 30 kg K_2O /ha (k_2 level) were found to be sufficient at later stages of growth.

None of the interaction effects was found to be significant.

Table 1. Effect of Nitrogen, Phosphorus and Potassium on the height of plant at different stages of crop growth (cm)

1.1. 20 DAS.

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	7.71	7.84	8.41	8.78	8.29	8.61	7.41	8.44	8.18
N_2	8.73	8.60	9.41	9.69	9.13	8.88	9.03	9.39	9.10
N_3	9.88	9.83	9.16	9.63	9.72	9.50	9.69	9.58	9.62
N_4	9.50	11.18	9.85	10.75	9.56	9.50	10.79	11.44	10.32
Mean P/K	8.95	9.36	9.20	9.71	9.17	9.12	9.23	9.71	
K_1	8.94	8.57	9.75	9.44					
K_2	8.86	9.56	8.94	9.12	C.D. for marginal means			0.865	
K_3	8.87	9.87	8.19	9.97	C.D. for combination			1.730	
K_4	9.14	9.45	9.94	10.31					

1.2. 40 DAS.

N_1	44.03	47.94	45.50	46.37	45.06	48.69	47.75	42.34	45.96
N_2	51.19	56.94	51.06	49.81	49.19	56.81	55.19	47.81	52.25
N_3	51.72	54.56	51.31	51.09	47.84	54.69	54.53	51.62	52.17
N_4	52.81	53.44	53.44	45.62	49.25	51.94	53.19	50.94	51.33
Mean P/K	49.94	53.22	50.33	48.23	47.83	53.03	52.66	48.18	
K_1	47.09	47.94	48.25	48.06					
K_2	48.25	54.50	55.00	54.37	C.D. for marginal means			4.758	
K_3	50.94	55.44	54.31	49.97	C.D. for combination			9.516	
K_4	53.47	55.00	43.75	40.50					

1.3. 60 DAS.

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	80.31	81.81	93.75	84.12	81.75	83.06	87.06	88.12	85.00
N_2	91.81	100.62	100.54	98.75	91.44	101.79	101.50	97.00	97.93
N_3	96.19	100.50	101.75	100.75	93.12	98.69	106.37	101.00	99.79
N_4	101.56	101.00	101.31	97.00	99.31	105.62	94.00	101.94	100.22
Mean P/K	92.47	95.98	99.34	95.16	91.41	97.29	97.23	97.01	
K_1	86.00	93.19	94.06	92.37					
K_2	92.37	95.87	97.41	102.50	C.D. for marginal means			6.028	
K_3	98.50	98.37	104.50	87.56	C.D. for combination			12.056	
K_4	93.00	95.50	101.37	98.19					

1.4. Harvest

N_1	83.37	84.46	95.15	85.62	83.47	85.27	89.35	90.52	87.15
N_2	93.49	103.50	102.29	99.97	92.63	103.66	103.35	99.61	99.81
N_3	97.98	102.39	103.28	102.71	94.58	100.96	107.81	103.01	101.59
N_4	103.66	104.10	104.07	113.11	101.53	108.65	110.01	104.76	106.24
Mean P/K	94.63	98.61	101.19	100.35	93.05	99.63	102.63	99.47	
K_1	87.75	95.07	96.03	93.36					
K_2	94.89	99.09	99.91	104.66	C.D. for marginal means			4.134	
K_3	100.72	100.81	105.88	103.11	C.D. for combination			8.269	
K_4	95.16	99.48	102.98	100.27					

DAS : Days after sowing

2. Number of leaves per plant

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

The result revealed that nitrogen application at increasing level had a significant influence on the number of leaves per plant at all stages except at harvest and the highest level (n_4) registered the highest number of leaves at all stages of plant growth. But no perceptible difference between n_3 and n_4 was observed on 20 days after sowing. Similarly no difference in number of leaves was found between treatments n_4 and n_3 on 40 days after sowing. The different treatments recorded significant difference on 60 days after sowing, while it was not significant at harvest.

Application of phosphorus showed significant difference in the number of leaves at all stages of growth. The number of leaves increased with increased level of phosphorus on 20 days after sowing. But the treatments p_4 and p_3 were not significantly different at 20 days after sowing. At 40 days after sowing a significant increase in the number of leaves was observed when the level of P was increased from p_2 to p_3. Similar trend was observed at 60 days after sowing also.

Table 2. Effect of Nitrogen, Phosphorus and Potassium on number of leaves at different stages of crop growth

2.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	9.61	9.96	10.07	10.18	9.31	9.91	10.66	9.94	9.96
N_2	10.35	11.11	11.21	11.76	10.05	11.61	10.87	11.91	11.11
N_3	10.85	11.31	12.39	11.87	11.42	10.67	12.47	11.85	11.60
N_4	11.75	11.67	12.76	12.86	12.97	12.56	12.22	11.29	12.26
Mean P/K	10.64	11.01	11.61	11.67	10.94	11.19	11.56	11.24	
K_1	10.65	10.70	11.18	11.22					
K_2	10.47	10.88	11.52	11.87					
K_3	11.08	11.13	12.17	11.85					
K_4	10.35	11.34	11.56	11.72					

C.D. for marginal means 0.519

C.D. for combination 1.039

2.2 40 DAS

N_1	34.85	36.77	37.29	36.30	34.22	37.06	38.05	35.87	36.30
N_2	39.91	47.52	44.07	43.62	38.47	45.13	45.82	45.96	43.78
N_3	44.73	46.23	48.98	46.04	40.11	49.72	49.97	46.18	46.49
N_4	46.33	47.11	47.35	46.18	41.27	49.37	49.66	46.67	46.74
Mean P/K	41.46	44.41	44.42	43.03	38.52	45.32	45.88	43.60	
K_1	37.45	38.42	39.37	38.83					
K_2	42.59	47.31	45.53	45.85					
K_3	43.41	47.27	47.71	45.12					
K_4	42.38	44.62	45.07	42.33					

C.D. for marginal means 1.263

C.D. for combination 2.527

2.3. 60 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	63.02	69.62	71.22	72.31	62.53	67.98	73.97	71.69	69.04
N_2	76.61	87.59	84.55	85.13	69.38	85.56	89.10	89.84	83.47
N_3	82.78	86.82	91.13	87.95	76.55	89.05	93.12	89.97	87.17
N_4	89.79	90.39	92.66	89.74	78.86	93.61	95.00	95.10	90.64
Mean P/K	78.05	83.61	84.89	83.78	71.83	84.05	87.79	86.65	
K_1	71.04	70.55	71.88	73.86					
K_2	79.69	84.39	87.22	84.89					
K_3	80.49	91.79	90.57	88.33					
K_4	80.98	87.69	89.89	88.04					

C.D. for marginal means 1.944

C.D. for combination 3.887

2.4. Harvest

N_1	12.27	12.41	12.38	12.12	12.45	12.39	12.09	12.27	12.30
N_2	11.98	13.64	12.60	11.90	12.07	12.95	12.29	12.81	12.53
N_3	12.10	13.04	12.91	12.71	12.29	13.00	12.66	12.81	12.69
N_4	12.27	12.96	12.87	12.89	12.50	12.77	12.96	12.76	12.75
Mean P/K	12.16	13.01	12.69	12.40	12.33	12.78	12.50	12.66	
K_1	11.96	12.84	12.51	12.00					
K_2	11.71	13.59	12.82	12.99					
K_3	12.22	12.59	12.96	12.22					
K_4	12.74	13.04	12.47	12.41					

C.D. for marginal means 0.653

C.D. for combination 1.305

DAS : Days after sowing

But the treatments p_3, p_4 and p_2 did not differ significantly at 60 days after sowing. At harvest stage also, there was significant difference in the number of leaves, but the maximum number of leaves was observed at p_2 level.

The effect of applied potassium was found to be not significant at 20 days after sowing and at harvest. Applied K significantly influenced the number of leaves at 40 and 60 days after sowing. Potassium at k_3 level recorded the maximum number of leaves on these stages and the treatments k_3 and k_2 were on par at 40 days after sowing. Similarly there was not much difference between the treatments k_3 and k_4 on 60 days after sowing. On 40 and 60 days after sowing, k_3 level recorded the highest number of leaves.

Interaction effect of NP was significant at 60 days after sowing. On 20, 40 and 60 days after sowing interaction effect of NK was also found significant.

3. Number of branches per plant

The effect of NPK on the number of branches per plant at various stages of observation are presented in Table 3 and the analysis of variance in Appendix IV.

The result revealed that there was significant effect of applied nitrogen on the number of branches per plant at all stages of growth. But there was no significant difference in treatments n_2, n_3 and n_4 on 20th, 60th and at harvest stages. On 40th day n_2 level showed significant difference in number of branches produced. But the treatments n_3 and n_4 were on par on these stages.

The effect of applied phosphorus was found significant at all stages of growth. A dose of 15 kg P_2O_5/ha was found to be sufficient on 40 and 60 days after sowing and at harvest. On 20 days after sowing p_4 level and at later stages p_2 level produced maximum number of branches.

Potassium also influenced the number of branches at all stages of growth. In the initial stages there was a decrease in the number of branches when the level of K was raised from k_2 to k_3. This decreasing trend was observed beyond 40 days after sowing also when the level of K was increased from k_3 to k_4. At 20 and 60 days after sowing the treatments k_2 and k_4 were on par. But on 40 days after sowing there was significant difference between treatments. At harvest stage there was no significant difference between treatments k_3 and k_4 and also k_4 and k_2. From second stage

Table 3. **Effect of Nitrogen, Phosphorus and Potassium on the number of branches of plant at different stages of crop growth**

3.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1.04	1.11	1.12	1.13	1.05	1.09	1.15	1.11	1.09
N_2	1.14	1.20	1.19	1.33	1.11	1.31	1.18	1.25	1.21
N_3	1.22	1.18	1.40	1.29	1.06	1.43	1.40	1.20	1.27
N_4	1.37	1.14	1.35	1.35	1.16	1.46	1.31	1.27	1.30
Mean P/K	1.19	1.16	1.26	1.27	1.10	1.32	1.26	1.21	
K_1	1.17	0.99	1.12	1.11	C.D. for marginal means			0.091	
K_2	1.26	1.21	1.44	1.37					
K_3	1.10	1.28	1.27	1.38	C.D. for combination			0.183	
K_4	1.22	1.15	1.22	1.23					

3.2. 40 DAS

N_1	1.70	1.96	2.12	2.25	1.79	1.94	2.37	1.93	2.01
N_2	2.25	3.04	2.48	2.65	2.09	2.76	2.84	2.72	2.60
N_3	2.59	2.76	2.97	2.64	2.21	3.00	3.06	2.69	2.74
N_4	2.81	2.84	2.77	2.72	2.31	3.00	3.02	2.81	2.79
Mean P/K	2.34	2.65	2.58	2.57	2.10	2.68	2.83	2.54	
K_1	1.95	2.15	2.29	2.02	C.D. for marginal means			0.079	
K_2	2.50	2.79	2.67	2.74					
K_3	2.61	3.03	2.86	2.80	C.D. for combination			0.158	
K_4	2.29	2.63	2.53	2.71					

3.3. 60 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	2.31	2.50	2.76	2.70	2.22	2.52	2.96	2.57	2.57
N_2	2.79	3.44	2.92	2.87	2.45	3.16	3.18	3.23	3.00
N_3	2.92	3.09	3.13	3.12	2.58	3.28	3.27	3.14	3.07
N_4	3.16	3.06	3.11	3.05	2.55	3.19	3.31	3.31	3.09
Mean P/K	2.79	3.02	2.98	2.94	2.45	3.03	3.18	3.06	
K_1	2.37	2.46	2.45	2.52	C.D. for marginal means			0.113	
K_2	2.96	3.09	3.06	3.05					
K_3	2.97	3.41	3.22	3.12	C.D. for combination			0.227	
K_4	2.88	3.11	3.19	3.06					

3.4. Harvest

N_1	2.31	2.49	2.72	2.57	2.10	2.50	2.94	2.54	2.52
N_2	2.76	3.42	2.90	2.87	2.44	3.12	3.17	3.22	2.99
N_3	2.91	3.07	3.14	3.11	2.54	3.24	3.31	3.12	3.05
N_4	3.15	3.22	3.07	3.00	2.68	3.19	3.30	3.27	3.11
Mean P/K	2.78	3.05	2.96	2.88	2.44	3.01	3.18	3.04	
K_1	2.36	2.62	2.41	2.38	C.D. for marginal means			0.135	
K_2	2.92	3.09	3.02	3.02					
K_3	2.97	3.40	3.25	3.11	C.D. for combination			0.270	
K_4	2.88	3.09	3.15	3.05					

DAS : Days after sowing.

onwards the maximum number of branches was observed at k_3 level and in the initial stage k_2 produced maximum number of branches.

The interaction effect of NP, NK and PK were significant at 40 days after sowing. Similarly NP interactions were also significant at 60th day and at harvest stages of growth.

4. Leaf Area Index

The effect of NPK on leaf area index (LAI) at various stages of growth are presented in Table 4 and the analysis of variance in Appendix V.

Application of nitrogen significantly influenced LAI at all stages of growth and the highest LAI was observed at the highest level of nitrogen. The treatments n_4 and n_3 did not differ significantly on 20 days after sowing and at harvest stages of growth. Significant effect of nitrogen was observed at other stages of growth.

The effect of phosphorus on LAI was significant on 40 and 60 days after sowing. On 40th day a slight depressing effect of applied phosphorus was observed beyond p_2 level which has recorded the highest LAI. The same

Table 4. Effect of Nitrogen, Phosphorus and Potassium on Leaf Area Index at different stages of crop growth

4.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	0.45	0.44	0.45	0.48	0.44	0.48	0.44	0.46	0.45
N_2	0.49	0.48	0.49	0.52	0.47	0.49	0.49	0.53	0.49
N_3	0.52	0.54	0.53	0.52	0.50	0.54	0.52	0.55	0.53
N_4	0.56	0.55	0.56	0.54	0.52	0.56	0.56	0.57	0.55
Mean P/K	0.50	0.50	0.51	0.52	0.48	0.51	0.51	0.53	
K_1	0.48	0.47	0.48	0.49					
K_2	0.51	0.51	0.51	0.52	C.D. for marginal means			0.024	
K_3	0.49	0.50	0.50	0.52	C.D. for combination			0.049	
K_4	0.53	0.52	0.53	0.53					

4.2. 40 DAS

N_1	0.87	0.94	0.95	0.92	0.86	0.92	0.97	0.93	0.92
N_2	1.03	1.32	1.17	1.16	0.99	1.21	1.24	1.23	1.17
N_3	1.17	1.22	1.27	1.20	1.08	1.26	1.29	1.22	1.21
N_4	1.31	1.32	1.35	1.31	1.23	1.36	1.36	1.34	1.32
Mean P/K	1.09	1.20	1.18	1.15	1.04	1.19	1.22	1.18	
K_1	0.99	1.02	1.12	1.04					
K_2	1.09	1.26	1.19	1.21	C.D. for marginal means			0.020	
K_3	1.16	1.27	1.22	1.20	C.D. for combination			0.040	
K_4	1.13	1.24	1.20	1.15					

4.3. 60 DAS

P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
1.53	1.64	1.71	1.74	1.54	1.71	1.71	1.66	1.65
2.01	2.19	2.17	2.19	2.00	2.16	2.17	2.23	2.14
2.17	2.18	2.24	2.20	2.07	2.22	2.31	2.19	2.19
2.18	2.24	2.28	2.26	2.10	2.28	2.34	2.23	2.24
1.97	2.06	2.10	2.09	1.93	2.09	2.13	2.08	
1.91	1.91	1.92	1.98					
1.99	2.11	2.13	2.12	C.D. for marginal means			0.031	
2.04	2.13	2.19	2.16	C.D. for combination			0.062	
1.96	2.08	2.16	2.13					

4.4. Harvest

0.33	0.36	0.35	0.36	0.34	0.35	0.35	0.35	0.35
0.38	0.38	0.37	0.36	0.36	0.39	0.39	0.36	0.37
0.45	0.49	0.45	0.41	0.43	0.46	0.45	0.46	0.45
0.48	0.48	0.46	0.46	0.44	0.47	0.49	0.47	0.47
0.41	0.43	0.41	0.39	0.39	0.42	0.42	0.41	
0.37	0.40	0.42	0.38					
0.41	0.44	0.41	0.41	C.D. for marginal means			0.021	
0.44	0.43	0.40	0.39	C.D. for combination			0.043	
0.41	0.43	0.40	0.40					

DAS Days after sowing

trend was observed at harvest stage of growth. But on 60th day, the LAI was increased with increasing level of P up to p_3 level and thereafter a decreasing trend was seen.

Applied potassium had also significant effect on LAI, except at harvest stage of growth. On 20 days after sowing highest LAI was observed at k_4 level. On 40 and 60 days after sowing a slight increase in LAI at k_3 level and thereafter a decreasing trend was observed. There was no significant difference between k_2 and k_4 level on 40th and 60th days after sowing.

The interaction effect of NP, NK and PK were found to be significant on 40 and 60 days after sowing.

5. Number of days required for 50 per cent flowering

The effect of NPK on mean number of days required for 50 per cent flowering are presented in Table 5 and analysis of variance in Appendix V.

The effect of N and K in the number of days required for 50 per cent flowering was not significant. But at highest level of phosphorus there was significant reduction in the number of days taken for attaining 50 per cent flowering.

Table 5. Effect of Nitrogen, Phosphorus and Potassium on 50% flowering (days)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	36.81	37.06	36.75	35.87	36.75	37.25	36.12	36.37	36.62
n_2	36.62	36.75	36.75	37.37	37.25	37.25	36.62	36.37	36.87
n_3	36.62	36.81	38.00	36.37	36.75	37.12	37.37	36.56	36.95
n_4	36.25	37.50	37.37	37.56	37.25	36.56	37.25	37.62	37.17
Mean P/K	36.58	37.03	37.22	36.79	37.00	37.05	36.84	36.73	
k_1	37.12	36.50	37.87	36.50					
k_2	36.44	37.00	37.69	37.06	C.D. for marginal means			0.405	
k_3	36.12	36.75	37.12	37.37	C.D. for combination			0.811	
k_4	36.62	37.87	36.19	36.25					

The interaction effect of NP, PK and NK were also found significantly different.

YIELD AND YIELD ATTRIBUTES OF SESAMUM

1. Number of pods per plant at harvest

The data showing the mean number of pods at harvest are presented in Table 6 and the analysis of variance in Appendix VI.

Application of N and K significantly influenced the number of pods per plant. There was a decreasing trend in the number of pods beyond n_3 level. But the treatments n_3 and n_4 did not differ significantly.

Applied phosphorus did not show any significant influence on the number of pods per plant.

Potassium application recorded significant influence in the number of pods and maximum number of pods were obtained at k_3 level. There was a decreasing trend in the number of pods when the level of K was raised from k_3 to k_4. But the different treatments from k_2 to k_4 were on par.

The interaction effect of NP and PK were also found significant.

Table 6. Effect of Nitrogen, Phosphorus and Potassium on the number of pods per plant at harvest

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	17.42	22.26	22.32	22.16	18.85	20.54	21.72	23.06	21.04
n_2	22.97	30.84	24.66	22.44	23.14	29.98	24.26	26.52	25.23
n_3	28.25	28.52	28.45	26.92	23.52	27.32	33.27	28.02	28.04
n_4	30.49	25.49	26.69	26.76	22.64	29.43	27.91	29.45	27.36
Mean P/K	24.78	26.78	25.53	24.57	22.03	26.07	26.79	26.76	
k_1	21.65	21.25	24.80	20.45					
k_2	25.76	26.20	24.27	28.05	C.D. for marginal means				2.152
k_3	26.39	27.82	27.71	25.25	C.D. for combination				4.305
k_4	25.34	31.84	25.35	24.54					

2. Weight of pods per plant

The effect of NPK on the mean weight of pods per plant are presented in Table 7 and the analysis of variance in Appendix VI.

The main effect of N and P did not show any influence on the weight of pods per plant. But K had significant influence on the weight of pods per plant. The highest pod weight was produced at k_2 level beyond which a decreasing trend in pod weight was observed.

The interaction effect of NP was also found significant.

3. Weight of seed per plant

The mean weight of seed per plant are presented in Table 8 and the analysis of variance in Appendix VI.

Nitrogen application produced significant influence on the seed weight per plant. Increasing the level of nitrogen increased seed weight up to n_3 level, and thereafter a slight decline in the seed weight was observed. But there was no difference between the treatments n_3 and n_4.

The effect of phosphorus on seed weight per plant was not significant but an increasing trend was observed from the p_1 to p_2 levels.

Table 7. Effect of Nitrogen, Phosphorus and Potassium on weight of pods per plant (g)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	2.07	2.52	2.91	2.90	2.41	2.74	2.78	2.48	2.60
n_2	2.98	3.59	2.77	2.48	2.74	3.02	3.09	2.98	2.95
n_3	2.91	2.64	3.07	2.67	2.54	3.15	3.07	2.52	2.82
n_4	3.13	2.83	2.67	2.94	2.48	3.38	2.97	2.73	2.89
Mean P/K	2.78	2.89	2.86	2.75	2.54	3.07	2.98	2.68	
k_1	2.48	2.47	2.92	2.30					
k_2	3.01	3.01	2.91	3.36	C.D. for marginal means			0.270	
k_3	2.96	2.94	3.15	2.86	C.D. for combination			0.540	
k_4	2.65	3.14	2.45	2.47					

Table 8. Effect of Nitrogen, Phosphorus and Potassium on weight of seed per plant (g)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	0.84	1.09	1.11	1.13	0.92	1.00	1.10	1.15	1.04
n_2	1.16	1.56	1.23	1.11	1.20	1.33	1.23	1.30	1.27
n_3	1.42	1.43	1.42	1.34	1.18	1.36	1.66	1.40	1.40
n_4	1.53	1.31	1.32	1.35	1.15	1.39	1.43	1.54	1.38
Mean P/K	1.24	1.34	1.27	1.23	1.11	1.27	1.35	1.34	
k_1	1.09	1.06	1.27	1.03					
k_2	1.26	1.28	1.18	1.36	C.D. for marginal means				0.113
k_3	1.34	1.41	1.40	1.27	C.D. for combination				0.227
k_4	1.27	1.63	1.23	1.27					

Applied potassium had also significant effect in the weight of seed per plant and the highest seed weight was recorded at k_3 level of potassium.

The interaction effect of NP and PK were found significant.

4. Pod-seed ratio

The effect of NPK on pod-seed ratio are presented in Table 9 and the analysis of variance in Appendix VI.

All the main effects and their interactions had pronounced effect on pod-seed ratio. The highest pod-seed ratio was observed with lowest level of nitrogen. The pod-seed ratio decreased with increasing level of nitrogen up to n_3 level and then there was a slight increase which was not significantly different from n_3 level.

Phosphorus application had significant effect on the pod-seed ratio and highest pod-seed ratio was observed with the lowest level of phosphorus (p_1). The treatments p_2 and p_3 did not differ significantly.

Applied potassium also had significant influence on pod-seed ratio. The pod-seed ratio declined with increase in

Table 9. Effect of Nitrogen, Phosphorus and Potassium on pod-seed ratio

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	2.52	2.39	2.63	2.59	2.64	2.76	2.52	2.21	2.53
n_2	2.58	2.37	2.26	2.19	2.33	2.28	2.49	2.30	2.35
n_3	2.06	1.90	2.16	2.00	2.14	2.33	1.86	1.79	2.03
n_4	2.05	2.21	2.07	1.88	2.19	2.32	1.91	1.79	2.06
Mean P/K	2.30	2.22	2.28	2.16	2.32	2.42	2.19	2.02	
k_1	2.36	2.34	2.32	2.28					
k_2	2.44	2.42	2.51	2.33	C.D. for marginal means				0.089
k_3	2.29	2.21	2.27	2.02	C.D. for combination				0.179
k_4	2.11	1.91	2.04	2.02					

level of K. The treatments k_1 and k_2 (10 and 30 kg K_2O/ha) were not significantly different.

The interaction effect of NP and NK were also found to be significant.

5. Weight of Bhusa per plant

Effect of NPK on the weight of bhusa per plant are presented in Table 10 and the analysis of variance in Appendix VII.

Nitrogen and phosphorus recorded significant effect on bhusa yield per plant. Highest bhusa yield was obtained with highest level of nitrogen. The treatments n_2 and n_3 did not differ significantly.

Application of phosphorus also had significant effect on bhusa weight per plant. Highest bhusa yield was obtained with p_3 beyond which there was no effect. Phosphorus at p_2 level was found to be significant for getting optimum bhusa yield.

Potassium failed to show any significant effect on bhusa yield.

Interaction effect was found to be not significant.

Table 10. Weight of Bhusa per plant (g)

	P_1	P_2	P_3	P_4	k_1	k_2	k_3	k_4	Mean (N)
n_1	3.57	3.47	3.59	3.48	3.54	3.52	3.55	3.50	3.53
n_2	3.57	3.96	4.00	3.85	3.63	3.85	3.85	4.06	3.85
n_3	3.41	3.81	3.80	3.83	3.66	3.69	3.72	3.77	3.71
n_4	3.68	3.93	3.95	4.19	3.99	4.04	3.99	3.72	3.94
Mean P/K	3.56	3.79	3.84	3.84	3.71	3.77	3.77	3.76	
k_1	3.34	3.94	3.66	3.88					
k_2	3.55	3.80	3.89	3.86	C.D. for marginal means				0.213
k_3	3.72	3.73	3.88	3.79	C.D. for combination				0.042
k_4	3.62	3.70	3.92	3.81					

6. 1000 seed weight

The effect of NPK on the 1000 seed weight are presented in Table 11 and the analysis of variance in Appendix VII.

Application of nitrogen and phosphorus produced significant effect on 1000 seed weight but potassium failed to show any effect on this character.

Increasing the level of nitrogen beyond n_3 level recorded a depressing effect on 1000 seed weight. Different levels of nitrogen n_2 to n_4 did not differ significantly.

Application of phosphorus also produced significant effect on 1000 seed weight. Highest seed weight was observed with p_3 level and further increase recorded a declining trend. There was no significant difference between the treatments p_3 and p_2 while p_4 was significantly different from p_1 and p_3.

None of the interaction effect was significant.

7. Total seed yield

Data on total seed yield are presented in Table 12 and the analysis of variance in Appendix VII.

Table 11. Effect of Nitrogen, Phosphorus and Potassium on '1000' seed weight (g)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	2.74	2.66	2.92	2.73	2.77	2.76	2.69	2.84	2.77
n_2	3.06	3.12	3.09	2.74	2.99	3.01	3.00	3.01	3.00
n_3	3.04	3.22	3.15	2.94	3.11	3.17	3.04	3.04	3.09
n_4	3.15	2.99	2.99	2.77	3.09	3.02	2.95	2.83	2.97
Mean P/K	2.99	3.00	3.04	2.79	2.99	2.99	2.92	2.93	
k_1	3.03	3.05	3.06	2.82					
k_2	3.02	3.05	3.07	2.82	C.D. for marginal means				0.116
k_3	2.97	2.98	3.02	2.70	C.D. for combination				0.233
k_4	2.97	2.91	3.00	2.82					

Table 12. Effect of Nitrogen, Phosphorus and Potassium on Total Seed Yield (kg/ha)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	211.66	273.62	265.75	281.97	218.22	251.69	276.29	286.81	258.25
n_2	290.75	391.24	308.62	271.12	297.75	347.19	303.25	313.55	315.43
n_3	356.50	357.31	343.81	335.37	297.94	340.19	416.56	338.31	348.25
n_4	383.81	327.12	332.25	348.37	288.00	347.69	369.31	386.56	347.89
Mean P/K	310.68	337.33	312.61	309.21	275.48	321.69	341.35	331.31	
k_1	273.42	267.00	306.56	254.94					
k_2	316.44	321.00	308.87	340.44	C.D. for marginal means				27.543
k_3	335.56	353.62	338.81	337.41	C.D. for combination				55.087
k_4	317.31	407.68	296.19	304.06					

Application of nitrogen and phosphorus produced significant influence on total seed yield. Highest seed yield was obtained with n_3 level of nitrogen and further increase recorded a decreasing trend. However, the difference between n_3 and n_4 was not significant.

Seed yield was not influenced by the application of phosphorus.

Applied potassium was found to increase the seed yield and highest seed yield was obtained at k_3 level which was on par with k_2 and k_4.

Interaction effect of NP, NK and PK were also found significant and highest seed yield was obtained from $n_2p_2k_4$ combination.

8. Harvest Index

The effect of NPK on harvest index are presented in Table 13 and their analysis of variance in Appendix VII.

Application of nitrogen significantly influenced harvest index and it was highest at n_3 level followed by n_4 level. There was no significant difference in harvest index when the level of nitrogen was raised from n_3 to n_4.

Table 13. Effect of Nitrogen, Phosphorus and Potassium on Harvest Index

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	0.19	0.24	0.23	0.24	0.20	0.22	0.23	0.24	0.22
n_2	0.24	0.28	0.23	0.22	0.25	0.26	0.24	0.24	0.24
n_3	0.28	0.29	0.27	0.26	0.24	0.26	0.32	0.28	0.27
n_4	0.29	0.25	0.25	0.24	0.22	0.25	0.26	0.29	0.26
Mean P/K	0.25	0.26	0.24	0.24	0.23	0.25	0.26	0.26	
k_1	0.23	0.21	0.26	0.21					
k_2	0.26	0.25	0.23	0.26	C.D. for marginal means				0.028
k_3	0.26	0.28	0.26	0.26	C.D. for combination				0.049
k_4	0.26	0.31	0.23	0.24					

The main effect of phosphorus failed to produce any significant difference in harvest index. But potassium showed significant influence on harvest index and the highest value of harvest index was recorded at k_3 level and further increase in K had no effect. The treatment k_1 was significantly different from k_3 and k_4 while it was on par with k_2.

The interaction effect of PK was found significant.

9. Total dry matter production

The effect of NPK on dry matter production are presented in Table 14 and the analysis of variance in Appendix VIII.

Nitrogen and phosphorus had pronounced effect on dry matter production at all stages of growth.

Application of nitrogen increased the dry matter significantly and maximum dry matter was produced with highest level of nitrogen at all stages of growth. There was no significant difference in dry matter production between n_2 and n_4 levels on 60 and 80 days after sowing.

Increasing the level of phosphorus also increased dry matter production significantly at all stages of growth.

Table 14. Dry matter production at different stages of crop growth (kg/ha)

14.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	152.14	157.19	158.62	159.22	157.03	159.06	157.50	153.58	156.79
N_2	170.15	176.25	180.95	181.87	170.00	177.81	181.87	179.54	177.31
N_3	185.62	191.62	204.40	207.50	200.15	196.09	203.22	189.69	197.28
N_4	214.06	225.94	231.28	217.06	221.44	219.53	226.56	220.81	222.08
Mean P/K	180.49	187.75	193.81	191.41	187.15	188.12	192.28	185.91	
K_1	175.31	185.94	193.47	193.91					
K_2	182.50	184.84	196.41	188.75	C.D. for marginal means		7.681		
K_3	186.09	191.62	190.81	200.62	C.D. for combination		15.363		
K_4	178.08	188.59	194.57	182.37					

14.2. 40 DAS

N_1	374.52	371.56	383.32	388.13	371.03	377.72	382.06	386.70	379.38
N_2	409.22	464.55	468.40	474.00	441.97	466.85	451.37	455.97	454.04
N_3	429.60	485.34	498.36	500.40	477.92	481.89	477.59	471.70	477.27
N_4	501.01	511.06	524.78	521.50	502.31	520.02	528.49	512.52	514.58
Mean P/K	428.59	458.12	467.56	471.00	448.31	461.62	458.63	456.72	
K_1	422.86	440.40	457.22	472.75					
K_2	426.72	463.86	474.34	481.56	C.D. for marginal means		12.013		
K_3	431.11	456.16	468.30	478.94	C.D. for combination		24.026		
K_4	433.66	472.08	470.39	450.77					

14.3. 60 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1145.91	1167.58	1236.12	1195.72	1166.01	1183.92	1210.80	1184.61	1186.34
N_2	1222.74	1439.90	1346.64	1325.60	1245.16	1349.61	1360.58	1379.52	1333.72
N_3	1290.26	1331.71	1355.01	1322.30	1277.41	1298.24	1385.97	1337.65	1324.82
N_4	1347.88	1357.20	1352.57	1441.10	1319.72	1408.98	1417.30	1352.75	1374.69
Mean P/K	1251.70	1324.09	1322.59	1321.18	1252.07	1310.19	1343.66	1313.63	
K_1	1179.94	1279.03	1269.61						
K_2	1250.50	1323.51	1323.04		C.D. for marginal means		44.696		
K_3	1315.85	1338.61	1364.58		C.D. for combination		89.393		
K_4	1260.51	1355.26	1333.11						

14.4. Harvest

N_1	1104.37	1139.06	1175.94	1152.50	1115.93	1130.62	1162.50	1162.81	1142.97
N_2	1190.31	1380.31	1308.75	1240.94	1202.18	1295.62	1285.00	1337.50	1280.08
N_3	1239.69	1247.18	1305.62	1276.56	1259.06	1263.12	1284.69	1262.18	1267.26
N_4	1303.44	1309.37	1318.75	1394.37	1284.06	1358.12	1366.87	1316.87	1331.48
Mean P/K	1209.45	1268.98	1277.26	1266.09	1215.31	1261.87	1274.76	1269.84	
K_1	1130.00	1252.19	1233.75	1245.31					
K_2	1204.06	1270.31	1267.19	1305.94	C.D. for marginal means		52.949		
K_3	1281.56	1253.44	1319.69	1244.37	C.D. for combination		105.890		
K_4	1222.19	1300.00	1288.44	1268.75					

Maximum dry matter was obtained with p_3 level of phosphorus on 20 days after sowing and at harvest. On 40 and 60 days after sowing, p_4 and p_2 levels gave the maximum dry matter production. The different treatments from p_2 to p_4 did not show any difference on 60th days after sowing and at harvest, while p_3 and p_4 levels were on par in the initial stages (20th and 40th days after sowing). Lowest level (p_1) showed significant difference in all stages and gave the lowest dry matter production.

Applied potassium also recorded significant effect on dry matter production at all stages except on 20 days after sowing. Highest dry matter was obtained with k_3 level at all stages except on 40th days after sowing.

The interaction effect of NP was significant on 40 and 60 days after sowing.

QUALITY ATTRIBUTES

1. Oil content

The effect of NPK on oil content are presented in Table 15 and the analysis of variance in Appendix IX.

The major nutrients N, P and K produced significant influence on oil content of sesamum.

Table 15. Effect of Nitrogen, Phosphorus and Potassium on Oil Content (%)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	50.84	51.72	52.33	52.08	51.64	51.97	51.91	51.44	51.74
n_2	52.34	53.38	53.14	53.06	53.19	54.01	52.75	51.97	52.98
n_3	52.70	53.22	53.61	53.50	53.67	54.17	53.12	52.06	53.26
n_4	52.99	53.44	53.39	53.21	53.85	54.20	53.04	51.94	53.26
Mean P/K	52.22	52.94	53.12	52.96	53.09	53.59	52.71	51.85	
k_1	52.40	52.91	53.62	53.41					
k_2	52.84	53.64	53.80	54.07	C.D. for marginal means			0.650	
k_3	52.31	52.74	53.14	52.63	C.D. for combination			1.300	
k_4	51.30	52.46	51.91	51.74					

There was an increase in trend in the oil content by increasing the level of nitrogen up to n_3 level and further increase failed to give any effect in oil content. The treatment n_1 recorded significant difference with n_2, n_3 and n_4 levels of N.

In the case of phosphorus, an increase in phosphorus over p_3 level was found to decrease the oil content and here also the various levels of phosphorus from p_2 to p_4 did not show any difference. But the treatment p_1 recorded significant difference with p_2 to p_4 levels of phosphorus.

Potassium application at K_2 level recorded maximum oil content. However, higher levels of K recorded a decrease in oil content.

Interaction effects were not significant.

2. Protein content

The effect of NPK on protein content are presented in Table 16 and the analysis of variance in Appendix IX.

Nitrogen, phosphorus and potassium produced significant influence on the protein content of sesamum. Increased level of applied nitrogen increased oil content up to n_3 level and

Table 16. Effect of Nitrogen, Phosphorus and Potassium on Protein Content of sesamum seed (%)

	P_1	P_2	P_3	P_4	k_1	k_2	k_3	k_4	Mean (N)
n_1	20.50	21.39	22.24	23.04	21.71	21.84	21.92	21.69	21.79
n_2	21.58	22.30	22.80	22.99	21.65	22.28	22.72	23.02	22.42
n_3	21.76	22.82	22.94	22.60	22.15	22.24	22.69	23.05	22.53
n_4	22.11	22.61	22.31	22.59	21.41	22.44	22.95	22.82	22.41
Mean P/K	21.49	22.28	22.57	22.81	21.73	22.20	22.57	22.65	
k_1	20.81	21.58	22.29	22.24					
k_2	21.31	22.09	22.61	22.79	C.D. for marginal means			0.369	
k_3	21.71	22.64	22.79	23.15	C.D. for combination			0.738	
k_4	22.12	22.82	22.60	23.05					

further increase showed a slight decline in protein content. The treatment n_2 was on par with n_3 and which in turn was again on par with n_4 level, but significantly different from n_1.

ANALYSIS OF PLANT SAMPLE

Nitrogen content of plant at different stages of growth

The mean data on nitrogen content of plant at various stages of growth are presented in Table 17 and analysis of variance in Appendix X.

Application of nitrogen significantly influenced the nitrogen content of plant at all stages of growth and the highest N content was observed at the highest level of N (70 kg N/ha) at 20, 40 and 60 days after sowing. There was significant difference in N content of plant at 20 days after sowing. But on 40th day n_4 recorded significant difference from n_1 to n_3 while n_3 and n_2 were on par. On 60th day higher levels i.e. n_3 and n_4 failed to make any significant difference and n_3 was significantly different from the other two lower levels (n_2 and n_1). At harvest stage the different levels n_2, n_3 and n_4 showed no difference and the lowest level (n_1) was significantly different from the other three levels.

Table 17. Nitrogen content of plant at different stages of crop growth (%)

17.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	4.09	4.12	4.12	4.20	4.13	4.13	4.14	4.14	4.13
N_2	4.36	4.54	4.51	4.50	4.39	4.48	4.50	4.53	4.48
N_3	4.67	4.70	4.72	4.76	4.70	4.70	4.73	4.72	4.71
N_4	4.88	4.88	4.87	4.86	4.84	4.90	4.89	4.87	4.87
Mean P/K	4.50	4.56	4.55	4.58	4.52	4.55	4.56	4.57	
K_1	4.48	4.53	4.52	4.54	C.D. for marginal means			0.055	
K_2	4.50	4.56	4.54	4.62					
K_3	4.51	4.59	4.59	4.58	C.D. for combination			0.111	
K_4	4.53	4.56	4.58	4.59					

17.2. 40 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	3.14	3.12	3.15	3.16	3.13	3.13	3.15	3.15	3.14
N_2	3.33	3.36	3.37	3.41	3.33	3.38	3.39	3.38	3.37
N_3	3.40	3.45	3.50	3.52	3.45	3.46	3.48	3.49	3.47
N_4	3.53	3.60	3.61	3.62	3.57	3.58	3.62	3.59	3.59
Mean P/K	3.35	3.38	3.40	3.43	3.37	3.39	3.41	3.40	
K_1	3.34	3.37	3.36	3.41	C.D. for marginal means			0.108	
K_2	3.31	3.40	3.41	3.43					
K_3	3.36	3.39	3.43	3.46	C.D. for combination			0.216	
K_4	3.40	3.37	3.42	3.42					

17.3. 60 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
	2.43	2.43	2.44	2.43	2.44	2.44	2.43	2.42	2.44
	2.47	2.64	2.64	2.71	2.65	2.53	2.59	2.69	2.61
	2.74	3.00	2.91	2.97	2.92	2.78	2.95	2.97	2.90
	2.96	2.92	2.91	3.00	2.92	2.92	2.97	2.98	2.94
	2.65	2.75	2.73	2.78	2.74	2.67	2.74	2.77	
	2.67	2.74	2.74	2.81	C.D. for marginal means			0.102	
	2.65	2.63	2.61	2.79					
	2.69	2.76	2.76	2.73	C.D. for combination			0.204	
	2.59	2.87	2.81	2.79					

17.4. Harvest

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
	1.89	1.92	1.99	2.04	1.90	2.02	2.02	1.91	1.96
	2.09	2.22	2.21	2.19	2.15	2.17	2.22	2.17	2.18
	2.24	2.24	2.31	2.32	2.27	2.25	2.28	2.31	2.28
	2.20	2.25	2.34	2.33	2.21	2.26	2.32	2.33	2.28
	2.11	2.16	2.21	2.22	2.13	2.18	2.21	2.18	
	2.05	2.07	2.21	2.20	C.D. for marginal means			0.136	
	2.11	2.17	2.21	2.20					
	2.17	2.20	2.21	2.26	C.D. for combination			0.273	
	2.09	2.19	2.21	2.22					

DAS : Days after sowing

Except on 20 days after sowing, applied P had no significant effect on N content of plant. On 20th day the highest N content was recorded at maximum level of P (p_4) which was on par with p_3 and p_2 but significantly different from p_1.

Potassium application failed to show any significant influence on N content of plant. But increasing level of K increased their content.

The interaction effects were not significant.

Nitrogen content of seed

The result of N content of seed are presented in Table 18.1 and the analysis of variance in Appendix X.

The major nutrients N, P and K recorded significant influence on N content of seed. The highest value of N was recorded at n_3 level (50 kg N/ha) and further increase showed a slight declining trend. But the different treatments n_2, n_3 and n_4 levels (30, 50 and 70 kg N/ha) did not differ significantly.

Increasing the level of phosphorus increased the N content of seed and highest N content was observed at

Table 18. Nitrogen, Phosphorus and Potassium content of seed (%)

18.1. Nitrogen content

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
n_1	3.32	3.04	3.55	3.68	3.09	3.54	3.50	3.47	3.40
n_2	3.45	3.55	3.65	3.68	3.45	3.56	3.63	3.67	3.58
n_3	3.47	3.65	3.66	3.61	3.54	3.55	3.62	3.68	3.59
n_4	3.53	3.59	3.55	3.65	3.45	3.57	3.64	3.65	3.58
Mean P/K	3.45	3.46	3.60	3.65	3.38	3.55	3.60	3.62	
k_1	3.32	3.07	3.56	3.59	C.D. for marginal means			0.141	
k_2	3.45	3.53	3.59	3.64					
k_3	3.47	3.62	3.62	3.70	C.D. for combination			0.282	
k_4	3.54	3.61	3.64	3.69					

18.2. Phosphorus content

n_1	0.46	0.47	0.49	0.50	0.47	0.48	0.48	0.49	0.48
n_2	0.48	0.49	0.50	0.53	0.51	0.50	0.50	0.50	0.50
n_3	0.49	0.50	0.52	0.55	0.51	0.51	0.51	0.52	0.51
n_4	0.51	0.50	0.51	0.53	0.50	0.51	0.51	0.52	0.51
Mean P/K	0.48	0.49	0.50	0.53	0.49	0.50	0.50	0.51	
k_1	0.48	0.49	0.50	0.52	C.D. for marginal means			0.015	
k_2	0.48	0.49	0.51	0.52					
k_3	0.48	0.48	0.50	0.53	C.D. for combination			0.023	
k_4	0.48	0.49	0.52	0.54					

18.3. Potassium content

n_1	0.46	0.45	0.46	0.47	0.43	0.45	0.47	0.49	0.46
n_2	0.48	0.49	0.51	0.54	0.47	0.50	0.53	0.53	0.51
n_3	0.52	0.53	0.52	0.50	0.51	0.51	0.53	0.52	0.52
n_4	0.53	0.53	0.52	0.53	0.50	0.52	0.54	0.55	0.53
Mean P/K	0.50	0.50	0.50	0.51	0.47	0.49	0.51	0.52	
k_1	0.47	0.47	0.47	0.49	C.D. for marginal means			0.012	
k_2	0.50	0.49	0.49	0.50					
k_3	0.51	0.52	0.52	0.52	C.D. for combination			0.023	
k_4	0.52	0.52	0.52	0.52					

maximum level (p_4 level) of P. There was no significant difference between the treatments p_4 and p_3 and similarly the treatment p_2 was on par with p_1.

Applied K also exerted significant effect on the N content of seed and here also the highest N content was observed at maximum level of potassium (k_4 level). There was no difference in treatments from k_2 to k_4.

The interaction effects were not significant.

Phosphorus content of plant at different stages of growth

The effect of NPK on P content of plant at different stages of growth are presented in Table 19 and the analysis of variance in Appendix XI.

Nitrogen application significantly influenced the P content from second stage onwards. On 40 days after sowing, different levels of N from n_1 to n_3 did not differ significantly and the N content decreased with increased level of nitrogen beyond n_2 level (30 kg N/ha). There was no significant difference between treatments n_3 and n_4 levels on 40 days after sowing. On 60 days after sowing n_3 and n_4 levels were on par and which differed significantly from other two levels (n_1 and n_2). At harvest stage also,

Table 19. Phosphorus content of plant at different stages of crop growth (%)

19.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1.02	1.05	1.07	1.08	1.06	1.08	1.05	1.03	1.06
N_2	0.99	1.05	1.05	1.08	1.05	1.07	1.03	1.02	1.04
N_3	0.99	1.02	1.09	1.09	1.05	1.06	1.05	1.04	1.05
N_4	1.00	1.06	1.09	1.07	1.07	1.08	1.06	1.02	1.06
Mean P/K	1.00	1.04	1.07	1.08	1.06	1.07	1.05	1.03	
K_1	1.00	1.04	1.08	1.11	C.D. for marginal means			0.024	
K_2	1.02	1.06	1.09	1.11					
K_3	1.00	1.05	1.07	1.07	C.D. for combination			0.048	
K_4	0.98	1.02	1.07	1.04					

19.2. 40 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1.05	1.06	1.05	1.09	1.08	1.08	1.05	1.04	1.06
N_2	1.08	1.11	1.07	1.06	1.06	1.11	1.08	1.06	1.08
N_3	1.02	1.06	1.08	1.03	1.06	1.04	1.05	1.03	1.05
N_4	0.97	1.04	1.03	1.03	1.03	1.02	1.01	1.00	1.02
Mean P/K	1.03	1.07	1.06	1.05	1.06	1.06	1.05	1.03	
K_1	1.04	1.09	1.07	1.04	C.D. for marginal means			0.033	
K_2	1.04	1.09	1.07	1.06					
K_3	1.03	1.06	1.06	1.05	C.D. for combination			0.067	
K_4	1.01	1.03	1.02	1.05					

19.3. 60 DAS

P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
0.83	0.83	0.84	0.85	0.84	0.84	0.84	0.83	0.84
0.79	0.84	0.89	0.86	0.82	0.84	0.88	0.83	0.84
0.83	0.87	0.88	0.90	0.87	0.88	0.87	0.86	0.87
0.83	0.88	0.89	0.92	0.87	0.89	0.89	0.89	0.88
0.82	0.86	0.88	0.88	0.85	0.86	0.87	0.85	
0.82	0.85	0.88	0.88	C.D. for marginal means			0.026	
0.81	0.84	0.89	0.90					
0.85	0.87	0.86	0.89	C.D. for combination			0.053	
0.81	0.86	0.88	0.86					

19.4. Harvest

0.83	0.83	0.83	0.83	0.82	0.82	0.83	0.84	0.83
0.78	0.80	0.85	0.87	0.82	0.82	0.81	0.84	0.83
0.80	0.82	0.86	0.88	0.83	0.82	0.86	0.85	0.84
0.81	0.86	0.88	0.87	0.85	0.86	0.86	0.85	0.86
0.81	0.83	0.85	0.86	0.83	0.83	0.84	0.85	
0.79	0.82	0.85	0.86	C.D. for marginal means			0.022	
0.81	0.84	0.83	0.86					
0.81	0.82	0.85	0.87	C.D. for combination			0.045	
0.82	0.83	0.89	0.85					

DAS : Days after sowing

there was no difference in treatments n_3 and n_4 while n_1 and n_2 recorded the lowest P content.

Phosphorus also recorded positive influence on P content of plant and increased level of P showed an increasing trend except on 40 days after sowing. On 20 days after sowing there was no difference between p_4 and p_3, while during later stages the levels from p_2 to p_4 were on par.

Except on 20 days after sowing, K application did not influence the P content of plant.

The interaction effects were not significant.

Phosphorus content of Seed

The mean data on P content of seed are presented in Table 18.2 and the analysis of variance in Appendix XI.

Nitrogen and Phosphorus recorded significant influences on P content of seed while K failed to show any significant effect.

The highest P content was observed at n_3 level and further increase in N did not show any effect. The different levels of nitrogen from n_2 to n_4 did not affect the P content of seed.

Applied P at higher levels increased the P content and highest P content was obtained at highest level. But there was no significant difference in treatments from p_1 to p_3 and p_4 showed significant difference with other treatments.

The interaction effects were not significant.

Potassium content of plant at different stages of growth

Data on the effect of NPK on potassium content of plant at different stages of growth are presented in Table 20 and the analysis of variance in Appendix XII.

Applied nitrogen produced significant influence on K content of plant at all stages of growth. At initial and final stages highest level of nitrogen recorded highest K content. But during 40 and 60 days after sowing the highest K content was observed at k_2 level (30 kg K_2O/ha). There was no difference between the treatments n_3 and n_4 on 60 days after sowing and at harvest.

Phosphorus also produced significant effect on the K content of plant at 20th and 40th days after sowing and at harvest. It is seen that highest K content was recorded at p_3 level on 20 and 40 days after sowing and further

Table 20. Potassium content of plant at different stages of crop growth (%)

20.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	0.86	0.83	0.92	0.80	0.83	0.85	0.88	0.87	0.85
N_2	0.89	0.89	0.92	0.83	0.86	0.90	0.87	0.89	0.88
N_3	0.97	0.93	0.99	0.87	0.89	0.94	0.95	0.96	0.94
N_4	0.96	1.03	1.05	0.97	0.97	1.01	1.00	1.02	1.00
Mean P/K	0.92	0.92	0.97	0.87	0.89	0.93	0.93	0.94	
K_1	0.85	0.89	0.95	0.86	C.D. for marginal means			0.029	
K_2	0.93	0.90	0.99	0.88					
K_3	0.94	0.94	0.97	0.86	C.D. for combination			0.059	
K_4	0.96	0.94	0.98	0.87					

20.2. 40 DAS

N_1	0.95	0.97	1.05	0.95	0.95	0.97	0.99	1.00	0.98
N_2	1.09	1.17	1.16	1.00	1.08	1.09	1.12	1.13	1.11
N_3	1.13	1.09	1.09	0.94	1.05	1.07	1.08	1.06	1.07
N_4	0.84	0.86	0.94	0.89	0.84	0.88	0.92	0.89	0.88
Mean P/K	1.00	1.03	1.06	0.95	0.98	1.00	1.03	1.03	
K_1	0.94	1.00	1.05	0.93	C.D. for marginal means			0.036	
K_2	1.00	1.01	1.05	0.95					
K_3	1.02	1.06	1.08	0.94	C.D. for combination			0.071	
K_4	1.05	1.03	1.05	0.97					

20.3. 60 DAS

P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
1.02	1.05	1.07	1.00	0.96	1.02	1.09	1.06	1.03
1.07	1.20	1.07	1.13	1.07	1.08	1.17	1.15	1.12
1.12	1.05	1.08	1.04	1.03	1.09	1.08	1.09	1.07
1.03	1.08	1.09	1.08	1.04	1.09	1.09	1.07	1.07
1.06	1.09	1.08	1.07	1.03	1.07	1.11	1.09	
1.02	1.06	1.04	0.99	C.D. for marginal means			0.029	
1.07	1.09	1.08	1.04					
1.08	1.12	1.13	1.12	C.D. for combination			0.058	
1.06	1.12	1.08	1.11					

20.4. Harvest

0.75	0.77	0.78	0.74	0.72	0.74	0.79	0.79	0.76
0.79	0.92	0.87	0.87	0.84	0.83	0.87	0.92	0.87
0.91	0.93	0.96	0.97	0.90	0.95	0.97	0.95	0.94
0.99	1.01	0.98	0.98	0.97	1.01	0.99	1.00	0.99
0.86	0.91	0.89	0.89	0.86	0.88	0.91	0.92	
0.84	0.85	0.89	0.86	C.D. for marginal means			0.023	
0.87	0.89	0.88	0.87					
0.87	0.93	0.90	0.92	C.D. for combination			0.047	
0.88	0.96	0.91	0.92					

DAS : Days after sowing

increase showed a declining trend. At 60th day after sowing the effect of P was not significant. But at harvest K content was maximum at p_2 level and here also an increase in applied phosphorus recorded a decreased effect on K content of plant. There was no difference between the treatments p_1 and p_2 on 20 days after sowing, p_3 and p_2 on 40 days after sowing and p_2 to p_4 at harvest stages of growth.

Application of potassium also produced significant effect on the K content of plant at all stages of growth. The K content was maximum at k_3 level on 40 and 60 days after sowing beyond which there was a decreasing trend. But K content was maximum with k_4 level on 20th and harvest stages of growth. The different treatments k_2, k_3 and k_4 were on par on 20 and 40 days after sowing. Similarly the different levels of K at k_3 and k_4 could not exert any difference on 60th day after sowing and harvest.

The interaction effect of NP was significant on 40 and 60 days after sowing and also at harvest.

Potassium content of seed

The mean data on K content of seed are presented in Table 18.3 and analysis of variance in Appendix XII.

It is seen that applied nitrogen significantly influenced the K content of seed. The highest K content was observed at highest level of nitrogen. But there was no significant difference in treatments from n_2 to n_4 levels.

Phosphorus did not have any effect on K content of seed. But potassium produced significant influence on K content of seed and highest K content was observed at highest K level. The treatments k_4 and k_3 were on par and k_3 was also on par with k_2. But k_4 was found to be superior to k_1 and k_2. There was also no difference between the treatments k_1 and k_2 in increasing the K content of seed.

The interaction effects of NP was also found significant.

Uptake of Nitrogen by plant at different stages of growth

The effect of NPK on the uptake of nitrogen by plant at different stages of growth are furnished in Table 21 and the analysis of variance in Appendix XIII.

The major nutrients N and P exerted significant influence on the uptake of nitrogen by plant at all stages of growth. Maximum N uptake was observed at highest level

Table 21. Uptake of Nitrogen at different stages of crop growth (kg/ha)

21.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	6.37	6.47	6.51	6.69	6.49	6.53	6.51	6.50	6.51
N_2	7.45	8.00	8.14	8.17	7.47	7.97	8.19	8.14	7.94
N_3	8.74	9.00	9.64	9.88	9.40	9.22	9.61	9.02	9.31
N_4	9.11	11.03	11.26	10.57	9.47	10.66	11.09	10.77	10.49
Mean P/K	7.92	8.62	8.89	8.83	8.21	8.59	8.85	8.61	
K_1	6.67	8.49	8.80	8.87	C.D. for marginal means			0.485	
K_2	8.18	8.49	8.96	8.76					
K_3	8.49	8.86	8.81	9.25	C.D. for combination			0.970	
K_4	8.34	8.67	8.98	8.44					

21.2. 40 DAS

N_1	11.38	11.58	12.06	12.34	11.69	11.83	12.05	11.78	11.84
N_2	13.64	14.43	15.69	15.92	14.49	15.13	15.09	14.97	14.92
N_3	14.51	16.71	17.22	16.34	16.39	16.65	16.55	15.19	16.19
N_4	17.66	18.37	18.98	18.88	17.94	18.63	18.92	18.40	18.47
Mean P/K	14.29	15.27	15.99	15.87	15.13	15.56	15.65	15.09	
K_1	14.07	14.96	15.46	16.02	C.D. for marginal means			0.747	
K_2	14.19	15.22	16.25	16.58					
K_3	14.53	15.28	16.16	16.64	C.D. for combination			1.495	
K_4	14.40	15.62	16.08	14.25					

21.3. 60 DAS

P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
26.36	27.25	27.75	27.64	26.67	27.12	27.67	27.54	27.25
28.70	35.88	35.49	33.15	31.43	33.85	33.39	34.55	33.31
34.88	37.74	37.37	36.63	34.95	35.06	39.03	37.58	36.66
37.06	37.59	37.48	41.00	36.32	38.95	39.95	37.91	38.28
31.75	34.62	34.53	34.61	32.34	33.74	35.01	34.40	
29.37	33.06	32.82	34.13	C.D. for marginal means			1.274	
31.62	34.60	34.05	34.71					
33.76	35.09	35.70	35.50	C.D. for combination			2.549	
32.25	35.71	35.53	34.09					

21.4. Harvest

16.86	14.15	17.92	17.77	16.91	15.41	17.68	16.71	16.68
19.07	21.97	22.08	21.44	19.70	21.05	21.84	21.97	21.14
19.76	21.03	21.94	22.24	21.27	20.73	21.18	21.79	21.24
20.24	22.04	23.06	24.36	22.03	22.71	23.21	21.75	22.42
18.98	19.80	21.25	21.46	19.97	19.97	20.97	20.55	
17.77	20.33	20.26	21.53	C.D. for marginal means			1.665	
18.70	18.24	21.53	21.43					
20.43	20.38	21.43	21.67	C.D. for combination			3.331	
19.02	20.24	21.79	21.18					

DAS: Days after sowing

of nitrogen. Except at harvest, N showed significant effect at each level of nitrogen application. At harvest stage there was no difference in treatments from n_2 to n_3 levels of N.

On 20th and 40th days after sowing, phosphorus at p_3 level recorded the maximum nitrogen uptake. But on 60th day and at harvest maximum uptake was obtained at p_2 and p_4 levels respectively. There was no significant difference between treatments p_2, p_3 and p_4 at all stages of growth. But p_1 showed significant difference with other treatments.

Application of potassium could exert significant influence only at 60 days after sowing. Maximum uptake was recorded at k_3 level at all stages of growth.

The interaction effect of NP was significant at 60 days after sowing.

Uptake of Nitrogen by Seed

The mean data on nitrogen uptake by seed are presented in Table 22.1 and analysis of variance in Appendix XIII.

Nitrogen application significantly influenced the N uptake by seed and highest uptake of N was observed at

Table 22. Uptake of Nitrogen, Phosphorus and Potassium by seed (kg/ha)

22.1. Uptake of Nitrogen

	P_1	P_2	P_3	P_4	k_1	k_2	k_3	k_4	Mean (N)
n_1	7.05	9.29	9.90	10.41	8.06	8.97	9.71	9.91	9.16
n_2	10.03	13.93	11.18	10.45	10.27	11.89	11.43	11.99	11.40
n_3	12.38	13.06	13.06	12.11	10.55	12.04	15.09	12.93	12.65
n_4	13.58	11.85	11.66	12.80	9.98	12.45	13.54	13.92	12.47
Mean P/K	10.76	12.03	11.45	11.44	9.72	11.34	12.44	12.19	

k_1	9.10	9.15	11.37	9.24
k_2	10.96	11.32	10.71	12.36
k_3	11.73	12.82	12.75	12.48
k_4	11.24	14.85	10.98	11.69

C.D. for marginal means 1.032

C.D. for combination 2.064

22.2. Uptake of Phosphorus

n_1	0.97	1.31	1.37	1.42	1.09	1.23	1.33	1.43	1.27
n_2	1.39	1.91	1.56	1.49	1.50	1.66	1.56	1.63	1.59
n_3	1.72	1.78	1.83	1.83	1.51	1.74	2.11	1.82	1.79
n_4	1.95	1.65	1.74	1.84	1.49	1.78	1.88	2.02	1.79
Mean P/K	1.50	1.66	1.63	1.64	1.40	1.60	1.72	1.72	

k_1	1.31	1.32	1.65	1.32
k_2	1.55	1.59	1.49	1.77
k_3	1.62	1.70	1.76	1.80
k_4	1.55	2.03	1.60	1.70

C.D. for marginal means 0.155

C.D. for combination 0.310

22.3. Uptake of Potassium

n_1	0.99	1.23	1.28	1.32	0.99	1.14	1.29	1.41	1.21
n_2	1.41	1.95	1.55	1.51	1.39	1.67	1.65	1.70	1.60
n_3	1.86	1.90	1.85	1.65	1.49	1.75	2.20	1.82	1.81
n_4	2.04	1.73	1.72	1.86	1.44	1.81	1.98	2.11	1.84
Mean P/K	1.57	1.70	1.60	1.59	1.33	1.59	1.78	1.76	

k_1	1.32	1.24	1.50	1.25
k_2	1.58	1.60	1.47	1.71
k_3	1.72	1.84	1.81	1.76
k_4	1.66	2.13	1.62	1.63

C.D. for marginal means 0.145

C.D. for combination 0.291

n_3 level and further increase revealed a slight declining effect. But the difference between n_3 and n_4 was not significant.

Applied phosphorus did not produce significant effect on the uptake of N by seed. The highest uptake was recorded at p_2 level and increasing the level of P beyond p_2 level showed a declining trend. But the various treatments p_2 to p_4 did not differ significantly.

Potassium also produced significant effect on the uptake of nitrogen by seed. The highest uptake was recorded at k_3 level and further increase revealed a declining trend. The treatments k_3 and k_4 did not show any difference whereas k_4 was on par with k_2.

The interaction effects of NP and PK were also significant on the N uptake by seed.

Total uptake of Nitrogen by Plant

The effect of NPK on the total uptake of N by plant are presented in Table 25.1 and the analysis of variance in Appendix XVI.

The major nutrients N, P and K significantly influenced the total uptake of nitrogen by plant. Maximum uptake of N

was observed at highest level of N. The treatment n_4 was on par with n_3 which in turn was on par with n_2. But n_4 showed significant difference with n_2. Lowest uptake was observed at lowest level of nitrogen (n_1).

The lowest level of P (p_1) was significantly different from other levels whereas higher levels of P (from p_2 to p_4) were on par. Here also the highest level of P (p_4) recorded maximum uptake of nitrogen.

Eventhough applied K produced significant effect, the highest uptake was observed at k_3 level. There was a decreasing trend when the level of K was increased beyond k_3. The different levels of K from k_2 to k_4 did not differ significantly.

The interaction effects were not significant.

Uptake of Phosphorus by plant at different stages of growth

The effect of NPK on the uptake of phosphorus by plant at different stages of growth are presented in Table 23 and the analysis of variance in Appendix XIV.

Applied nitrogen produced significant effect in increasing P uptake at all stages of growth. On 20th day

Table 23. Uptake of Phosphorus at different stages of crop growth (kg/ha)

23.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1.55	1.63	1.70	1.72	1.66	1.70	1.66	1.59	1.65
N_2	1.69	1.86	1.89	1.95	1.79	1.88	1.90	1.82	1.85
N_3	1.86	1.95	2.22	2.28	2.10	2.09	2.14	1.98	2.08
N_4	2.16	2.47	2.53	2.33	2.45	2.37	2.40	2.27	2.37
Mean P/K	1.82	1.98	2.08	2.07	2.00	2.01	2.02	1.91	
K_1	1.75	2.01	2.09	2.15	C.D. for marginal means			0.095	
K_2	1.86	1.95	2.13	2.10					
K_3	1.89	2.02	2.04	2.15	C.D. for combination			0.190	
K_4	1.77	1.92	2.08	1.88					

23.2. 40 DAS

N_1	3.82	3.92	4.02	4.23	4.00	4.08	4.01	3.88	3.99
N_2	4.40	5.16	5.01	5.14	4.69	5.17	4.90	4.96	4.93
N_3	4.39	5.27	5.32	5.13	5.05	5.04	5.04	4.99	5.03
N_4	4.92	5.32	5.38	5.38	5.27	5.31	5.31	5.11	5.25
Mean P/K	4.38	4.91	4.93	4.97	4.75	4.89	4.82	4.74	
K_1	4.41	4.78	4.89	4.92	C.D. for marginal means			0.194	
K_2	4.40	5.04	5.07	5.07					
K_3	4.44	4.48	4.95	5.04	C.D. for combination			0.388	
K_4	4.29	5.00	4.79	4.86					

23.3. 60 DAS

P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
9.51	9.71	10.37	10.15	9.82	9.83	10.22	9.86	9.93
9.64	12.18	11.98	11.64	10.45	11.52	11.93	11.54	11.36
10.71	11.51	11.86	12.18	11.16	11.17	12.52	11.41	11.57
11.11	12.07	12.19	13.18	11.49	12.65	12.84	11.57	12.14
10.24	11.37	11.60	11.79	10.73	11.29	11.88	11.09	
9.48	10.98	11.11	11.36	C.D. for marginal means			0.487	
10.17	11.43	11.50	12.06					
10.12	11.76	12.16	12.39	C.D. for combination			0.97	
10.12	11.30	11.63	11.34					

23.4. Harvest

7.45	7.19	7.46	7.27	7.30	7.28	7.41	7.36	7.34
7.09	8.01	8.46	8.35	7.48	7.95	7.94	8.54	7.98
7.07	7.84	8.15	8.42	7.87	7.56	8.06	7.98	7.87
7.46	8.45	8.75	9.11	8.52	8.71	8.57	7.98	8.44
7.27	7.87	8.20	8.28	7.79	7.87	7.99	7.97	
6.86	8.13	7.83	8.36	C.D. for marginal means			0.496	
7.14	8.00	8.05	8.31					
7.69	7.67	8.22	8.41	C.D. for combination			0.992	
7.39	7.69	8.71	8.09					

DAS : Days after sowing

each level of N revealed significant difference, whereas during later stages n_4 was found to be significantly different from other levels and there was no difference between treatments n_2 and n_3 on 40th day, 60th day and at harvest stages.

Phosphorus also exerted significant influence on P uptake by the plant. Here also increased levels of P increased P uptake and p_1 level recorded the lowest uptake at all stages of growth. On 20 days after sowing p_3 and p_4 levels were on par and significantly different from p_2. But p_2 and p_1 levels were not significantly different. During later stages of growth an increase in phosphorus increased P uptake and maximum uptake was recorded at p_4 level at all stages of growth. The different treatments p_2, p_3 and p_4 did not differ significantly at 40th day and 60th day and at harvest stages.

Except on 60 days after sowing, the effect of applied K was not significant. The highest uptake was noticed at k_3 level and further increase recorded a declining trend. k_3 level was significantly different from other three levels of K, while k_4 and k_2 were on par. The lowest uptake of K was observed at k_1 level.

The interaction effects were not significant.

Uptake of Phosphorus by Seed

The mean data on the uptake of phosphorus are presented in Table 22.2 and the analysis of variance in Appendix XIV.

While the application of N and K significantly influenced the uptake of phosphorus by seed, P failed to show any effect on the uptake of phosphorus. Highest uptake of phosphorus was observed at n_3 level and no increase in P uptake was seen when the level of nitrogen was raised to n_4. The treatments n_1 and n_2 revealed significant difference from n_3 and n_4 levels.

Regarding potassium, highest uptake was observed at k_3 level which was on par with k_4 and k_2 levels.

The interaction effects of NP and PK were also significant.

Total uptake of Phosphorus by plant

The influence of NPK on total phosphorus uptake by plant are presented in Table 25.2 and the analysis of variance in Appendix XVI.

Table 25. Total uptake of Nitrogen, Phosphorus and Potassium (kg/ha)

25.1. Total uptake of Nitrogen

	p_1	p_2	p_3	p_4	k_1	k_2	k_3	k_4	Mean (N)
n_1	23.91	25.82	27.83	28.18	24.97	26.75	27.39	26.63	26.43
n_2	29.09	35.89	33.27	31.88	29.96	32.95	33.27	33.97	32.54
n_3	32.14	34.08	35.00	34.40	31.82	32.77	36.27	34.76	33.90
n_4	33.82	33.89	34.73	33.17	32.01	35.16	36.76	35.68	34.90
Mean P/K	29.74	32.42	32.71	32.91	29.79	31.91	33.42	32.76	
k_1	26.87	29.49	31.64	30.76					
k_2	29.67	31.93	32.24	33.79					
k_3	32.16	33.19	34.18	34.16					
k_4	30.26	35.09	32.77	32.92					

C.D. for marginal means 1.855

C.D. for combination 3.709

25.2. Total uptake of Phosphorus

n_1	8.42	8.50	8.82	8.69	8.39	8.51	8.74	8.79	8.60
n_2	8.48	9.92	10.01	9.85	8.98	9.61	9.50	10.17	9.57
n_3	8.79	9.62	9.98	10.25	9.38	9.29	10.17	9.80	9.66
n_4	9.42	10.09	10.49	10.87	10.05	10.48	10.34	10.00	10.22
Mean P/K	8.78	9.54	9.83	9.91	9.20	9.47	9.69	9.69	
k_1	8.17	9.45	9.48	9.71					
k_2	8.69	9.59	9.54	10.07					
k_3	9.32	9.37	9.97	10.08					
k_4	8.94	9.72	10.31	9.78					

C.D. for marginal means 0.473

C.D. for combination 0.946

25.3. Total uptake of Potassium

n_1	7.61	7.91	8.36	7.65	7.22	7.74	8.24	8.33	7.88
n_2	8.49	11.07	10.19	9.85	9.06	9.59	9.95	10.99	9.90
n_3	10.02	10.66	10.85	10.91	9.91	10.54	11.29	10.68	10.61
n_4	11.17	11.64	12.16	12.22	11.81	11.95	11.97	11.45	11.79
Mean P/K	9.32	10.32	10.39	10.16	9.50	9.96	10.37	10.37	
k_1	8.54	9.60	10.33	9.54					
k_2	9.32	10.19	10.19	10.13					
k_3	9.80	10.51	10.57	10.59					
k_4	9.62	10.99	10.48	10.37					

C.D. for marginal means 0.563

C.D. for combination 1.127

N and P recorded significant effect on total uptake of phosphorus while K did not exhibit any effect.

The treatments n_1 and n_2 were significantly different whereas, n_2 and n_3 were on par. The highest uptake of P was recorded by n_4 which was significantly different from other three levels of nitrogen.

Like nitrogen, highest level of P recorded highest uptake and there was no significant difference between treatments from p_2 to p_4.

Potassium application and various interaction effects were not significant.

Uptake of Potassium at different stages of growth

The mean data on the uptake of potassium by plant at different stages of growth are presented in Table 24 and the analysis of variance in Appendix XV.

Application of N and P produced significant result on the K uptake at all stages of growth, whereas K had shown significant effect only on 40 and 60 days after sowing. At initial and final stages of growth highest level of nitrogen recorded maximum uptake of potassium. But during 40 and 60 days after sowing, the maximum uptake was with n_3 and n_2

Table 24. Uptake of Potassium at different stages of crop growth (kg/ha)

24.1. 20 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	1.31	1.27	1.45	1.27	1.26	1.34	1.37	1.33	1.32
N_2	1.50	1.54	1.67	1.50	1.46	1.60	1.58	1.58	1.55
N_3	1.80	1.77	1.91	1.80	1.79	1.84	1.93	1.72	1.82
N_4	2.07	2.32	2.42	2.09	2.15	2.23	2.27	2.26	2.22
Mean P/K	1.67	1.72	1.86	1.67	1.67	1.75	1.79	1.72	
K_1	1.49	1.64	1.85	1.67					
K_2	1.70	1.68	1.96	1.67	C.D. for marginal means			0.100	
K_3	1.76	1.80	1.86	1.72	C.D. for combination			0.200	
K_4	1.72	1.76	1.79	1.60					

24.2. 40 DAS

N_1	3.47	3.60	4.00	3.62	3.51	3.66	3.82	3.71	3.67
N_2	4.46	5.42	5.40	4.83	4.77	5.08	5.02	5.24	5.03
N_3	4.85	5.32	5.40	4.71	5.02	5.15	5.12	5.00	5.07
N_4	4.22	4.42	4.94	4.63	4.20	4.59	4.81	4.61	4.55
Mean P/K	4.25	4.69	4.94	4.44	4.38	4.62	4.69	4.64	
K_1	3.96	4.38	4.78	4.38					
K_2	4.25	4.68	4.96	4.59	C.D. for marginal mean			0.218	
K_3	4.41	4.83	5.06	4.46	C.D. for combination			0.436	
K_4	4.38	4.87	4.94	4.36					

24.3. 60 DAS

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
	11.65	12.28	13.09	11.96	11.19	11.95	13.26	12.58	12.25
	13.06	17.34	14.41	15.12	13.52	14.58	15.94	15.89	14.98
	14.43	13.91	14.67	13.38	13.05	13.81	15.05	14.47	14.09
	13.87	14.62	14.88	15.60	13.70	15.37	15.42	14.47	14.74
	13.25	14.54	14.26	14.02	12.87	13.93	14.92	14.35	
	12.07	13.62	13.16	12.62					
	13.42	14.39	14.10	13.81	C.D. for marginal means			0.539	
	14.15	14.94	15.40	15.17	C.D. for combination			1.078	
	13.36	15.21	14.39	14.46					

24.4. Harvest

6.61	6.68	6.95	6.32	6.25	6.48	6.95	6.88	6.64
7.20	9.12	8.64	8.34	7.67	7.92	8.42	9.29	8.33
8.11	8.76	9.13	9.24	8.42	8.78	9.08	8.97	8.81
9.13	9.92	10.44	10.26	10.37	10.14	9.90	9.34	9.94
7.76	8.62	8.79	8.54	8.18	8.33	8.59	8.62	
7.24	8.36	8.82	8.29					
7.73	8.59	8.59	8.42	C.D. for marginal means			0.594	
8.18	8.68	8.76	8.73	C.D. for combination			1.188	
7.91	8.86	8.97	8.73					

DAS : Days after sowing

levels of nitrogen respectively. There was significant difference between all levels of nitrogen at 20 days after sowing. But n_3 and n_2 levels of nitrogen were on par at 40 and 60 days after sowing. On 60th day after sowing, the highest uptake was observed at n_2 level, which was on par with n_4 level. At this stage n_1 and n_3 levels were significantly different from n_2 and n_4 levels of N.

The highest uptake of phosphorus was observed at p_3 level on 20th day, 40th day and at harvest while it was at p_2 level on 60 days after sowing. There was no difference in treatments between p_4 and p_1 on 20 and 40 days after sowing whereas p_3 and p_2 differed significantly on these stages of growth. Similarly p_2, p_3 and p_4 did not differ significantly on 60 days after sowing and harvest stage of growth.

Applied K exerted significant influence on 40 and 60 days after sowing and maximum uptake of K was observed at k_3 level on 20, 40 and 60 days after sowing while it was at k_4 level at harvest. There was no significant difference in K uptake when the level of K was increased from k_2 to k_4 on these stages of growth. At the initial and final stages, the effect of K was not significant.

The interaction effect of NP was found significant on 60 days after sowing.

Uptake of Potassium by Seed

The mean data on uptake of K are presented in Table 22.3 and the analysis of variance in Appendix XV.

Nitrogen and potassium produced significant effect on potassium uptake by seed while P had no effect. The highest uptake of potassium was recorded by highest level (n_4) which was on par with n_3. There was significant difference between n_2 and n_1 levels of nitrogen in K uptake by seed.

In the case of potassium the highest uptake of seed was observed at k_3 level which was on par with k_4. k_1 and k_2 levels also recorded significant difference in the uptake of K by seed. The treatment n_3 also showed significant difference from n_1 and n_2.

The interaction effects of NP and PK were also significant.

Total uptake of Potassium by plant

The effect of NPK on total uptake of potassium by plant are presented in Table 25.3 and analysis of variance in Appendix XVI.

There was significant effect of N, P and K on total uptake of K by plant.

Nitrogen significantly influenced the total uptake of K by plant and maximum uptake was observed at highest level of nitrogen. The different levels showed significant influence on total uptake of K.

Total uptake of K was also influenced by applied phosphorus and highest uptake was observed at p_3 level. There was no significant difference between the treatments p_2, p_3 and p_4, but the lowest level of P recorded significant difference.

Total uptake of potassium was significantly influenced by applied potassium and maximum uptake was recorded at k_3 level and beyond which there was no effect. There was no significant difference between treatments k_2, k_3 and k_4 levels, but k_1 differed significantly with k_3 and k_4. Further, the treatment k_1 was also found to be on par with k_2.

None of interactions was found to be significant.

SOIL ANALYSIS

Total Nitrogen content of Soil after Experiment

The effect of NPK on total nitrogen content of soil after harvest are furnished in Table 26.1 and the analysis of variance in Appendix XVII.

It is seen that nitrogen significantly influenced the total K content of soil and highest level of nitrogen (n_4) recorded highest nitrogen content in the soil followed by n_3. There was no significant difference between n_4 and n_3 and n_3 level was also on par with n_2 and n_1.

P and K failed to produce any significant effect on nitrogen content of soil.

The interaction effects were also not significant.

Available Phosphorus content of Soil after Experiment

The data on available P content of soil after experiment are presented in Table 26.2 and the analysis of variance in Appendix XVII.

Soil P was influenced by applied P and K whereas N had no effect. Increasing P increased the available P content

Table 26. Soil fertility status after the experiment

26.1. Total Nitrogen content (%)

	P_1	P_2	P_3	P_4	K_1	K_2	K_3	K_4	Mean (N)
N_1	0.082	0.075	0.073	0.075	0.080	0.080	0.073	0.073	0.076
N_2	0.073	0.070	0.082	0.078	0.078	0.078	0.075	0.073	0.076
N_3	0.087	0.080	0.078	0.080	0.085	0.080	0.070	0.089	0.081
N_4	0.096	0.096	0.094	0.085	0.089	0.089	0.092	0.101	0.093
Mean P/K	0.085	0.080	0.082	0.079	0.083	0.082	0.077	0.084	
K_1	0.08	0.08	0.08	0.08					
K_2	0.09	0.08	0.08	0.07	C.D. for marginal means			0.0121	
K_3	0.08	0.08	0.07	0.07	C.D. for combination			0.024	
K_4	0.09	0.08	0.08	0.08					

26.2. Available P_2O_5 (kg/ha)

N_1	42.25	42.36	42.45	43.72	42.91	43.27	43.05	41.57	42.69
N_2	42.86	43.02	42.52	43.75	42.94	43.28	43.24	42.68	43.04
N_3	42.92	42.95	43.13	43.38	43.00	43.32	43.01	43.05	43.09
N_4	43.10	42.97	43.16	43.39	43.20	43.29	43.06	43.06	43.16
Mean P/K	42.78	42.82	42.82	43.56	43.01	43.29	43.09	42.59	
K_1	42.73	43.05	43.14	43.13					
K_2	43.06	43.06	43.03	44.01	C.D. for marginal means			0.391	
K_3	42.99	42.69	43.00	43.67	C.D. for combination			0.782	
K_4	42.34	42.51	42.09	43.44					

26.3. Available Potassium (kg/ha)

N_1	43.26	41.96	42.09	42.92	42.52	41.98	42.91	42.81	42.55
N_2	43.20	42.37	42.75	43.92	43.07	42.49	43.42	43.26	43.06
N_3	43.59	43.01	43.24	43.61	43.65	43.11	43.85	42.84	43.36
N_4	43.55	43.80	43.79	44.05	43.69	43.65	44.41	43.44	43.79
Mean P/K	43.40	42.79	42.96	43.63	43.23	42.81	43.65	43.08	
K_1	43.76	43.74	42.62	42.81					
K_2	42.06	42.24	42.96	43.97	C.D. for marginal means			1.019	
K_3	43.94	42.71	43.79	44.16	C.D. for combination			2.039	
K_4	43.84	42.46	42.49	43.56					

of soil and the treatment p_4 was significantly different from p_3. But p_3 and p_2 were on par. Potassium also exhibited significant effect on available P content of soil.

The interaction effects were also not significant.

Available Potassium content of Soil after Experiment

The effect of NPK on available K content of soil are presented in Table 26.3 and the analysis of variance in Appendix XVII.

The major nutrients failed to produce any significant effect on available K content of soil.

Economics of Fertilizer application

The economics of fertilizer application in sesamum has been worked out and the details are presented in Table 27.

The data revealed that the combined application of 30 kg N, 15 kg P_2O_5 and 70 kg K_2O per hectare ($n_2p_2k_4$) gave the highest yield and net profit of Rs. 2505.70 per hectare. The net return per Rupee investment was also found to be high at $n_2p_2k_2$ level. Thus it can be seen that $n_2p_2k_4$

combination of nitrogen, phosphorus and potassium gave the maximum profit followed by $n_2p_1k_3$. The least profit was obtained with the combination of $n_3p_4k_1$.

Optimum and Economic dose of Nitrogen, Phosphorus and Potassium

The response surface describing the dose-response relationship is given by the equation:

$$Y_u = -20.53 + 114.56x_{1u} + 71.15x_{2u} + 73.44x_{3u} - 15.21x_{1u}^2 - 8.25x_{2u}^2 - 11.67x_{3u}^2 - 9.13x_{1u}x_{2u} + 5.45_{1u}x_{3u} - 3.37x_{2u}x_{3u}$$ with the coefficient of determination (R^2) equal to 0.97 where

$$x_{1u} = 10 + (u - 1)\ 20$$
$$x_{2u} = 5 + (u - 1)\ 10$$
$$x_{3u} = 10 + (u - 1)\ 20$$
$$u = 1, 2, 3, 4.$$

The value of R^2 shows that the above surface fit the data well. The mathematical and economic optimum doses for a given price of N = Rs. 5.10, P = Rs. 5.90 and K = Rs. 2.25 and sesamum yield Rs. 10/- per kg are estimated and presented in the following table.

Optimum dose combination of N, P and K

Factor	Mathematical optimum	Economic optimum
N	72	72
P	8	7
K	68	68

Table 27. Economics of sesamum production under various treatment combinations

Sl. No.	Treatments	Cost of cultivation (Excluding treatment) (Rs./ha)	Additional cost of treatment (Rs./ha)	Total cost of production (Rs./ha)	Yield of sesamum seed (kg/ha)	Gross income (Rs./ha)	Net income profit/ loss (Rs./ha)	Net return per Rupee investment
1	2	3	4	5	6	7	8	9
1	$n_1p_1k_1$	2000.00	102.50	2102.50	142.90	1429.00	-673.50	0.67
2	$n_1p_1k_2$	2000.00	146.00	2146.00	192.50	1925.00	-221.00	0.89
3	$n_1p_1k_3$	2000.00	189.50	2189.50	213.75	2137.50	-52.00	0.97
4	$n_1p_1k_4$	2000.00	232.50	2232.50	297.50	2975.00	+724.50	1.33
5	$n_1p_2k_1$	2000.00	162.00	2162.00	261.00	2610.00	+448.00	1.20
6	$n_1p_2k_2$	2000.00	205.50	2205.50	214.75	2147.50	-58.00	0.97
7	$n_1p_2k_3$	2000.00	248.50	2248.50	273.50	2735.00	+486.50	1.22
8	$n_1p_2k_4$	2000.00	292.00	2292.00	345.25	3452.50	+1160.50	1.50
9	$n_1p_3k_1$	2000.00	221.50	2221.50	233.00	2330.00	+108.50	1.05
10	$n_1p_3k_2$	2000.00	264.50	2264.50	260.25	2602.50	+338.00	1.15
11	$n_1p_3k_3$	2000.00	308.00	2308.00	305.25	3052.50	+744.50	1.32
12	$n_1p_3k_4$	2000.00	351.50	2351.50	264.50	2645.00	+293.50	1.12
13	$n_1p_4k_1$	2000.00	280.50	2280.50	236.00	2360.00	+79.50	1.03
14	$n_1p_4k_2$	2000.00	324.00	2324.00	339.25	3392.50	+1068.50	1.46
15	$n_1p_4k_3$	2000.00	367.50	2367.50	312.65	3126.50	+759.00	1.32
16	$n_1p_4k_4$	2000.00	410.50	2410.50	240.00	2400.00	-10.50	0.99

Table 27. (Contd.)

1	2	3	4	5	6	7	8	9
17	$n_2p_1k_1$	2000.00	204.50	2204.50	280.00	2800.00	+595.50	1.27
18	$n_2p_1k_2$	2000.00	248.00	2248.00	319.50	3195.00	+947.00	1.42
19	$n_2p_1k_3$	2000.00	291.50	2291.50	300.00	3000.00	+708.50	1.31
20	$n_2p_1k_4$	2000.00	234.50	2234.50	263.50	2635.00	+400.50	1.18
21	$n_2p_2k_1$	2000.00	264.00	2264.00	298.25	2982.50	+718.50	1.32
22	$n_2p_2k_2$	2000.00	307.50	2307.50	423.50	4235.00	+1927.50	1.84
23	$n_2p_2k_3$	2000.00	350.50	2350.50	353.25	3532.50	+1182.00	1.50
24	$n_2p_2k_4$	2000.00	394.00	2394.00	489.97	4899.70	+2505.70	2.05
25	$n_2p_3k_1$	2000.00	323.50	2323.50	366.25	3662.50	+1339.00	1.58
26	$n_2p_3k_2$	2000.00	366.50	2366.50	323.25	3232.50	+866.00	1.37
27	$n_2p_3k_3$	2000.00	410.50	2410.50	263.25	2632.50	+222.00	1.09
28	$n_2p_3k_4$	2000.00	453.50	2453.50	281.75	2817.50	+364.00	1.15
29	$n_2p_4k_1$	2000.00	383.00	2383.00	246.50	2465.00	+82.00	1.03
30	$n_2p_4k_2$	2000.00	426.50	2426.50	322.50	3225.00	+798.50	1.33
31	$n_2p_4k_3$	2000.00	469.50	2469.50	296.50	2965.00	+495.50	1.20
32	$n_2p_4k_4$	2000.00	563.00	2563.00	219.00	2190.00	-373.00	0.85
33	$n_3p_1k_1$	2000.00	307.00	2307.00	317.75	3177.50	+870.50	1.38
34	$n_3p_1k_2$	2000.00	350.50	2350.50	344.75	3447.50	+1097.00	1.47
35	$n_3p_1k_3$	2000.00	393.50	2393.50	433.25	4332.50	+1939.00	1.81
36	$n_3p_1k_4$	2000.00	437.00	2437.00	330.25	3302.50	+865.50	1.36

Table 27. (Contd.)

1	2	3	4	5	6	7	8	9
37	$n_3p_2k_1$	2000.00	366.50	2366.50	256.75	2567.50	+201.00	1.08
38	$n_3p_2k_2$	2000.00	409.50	2409.50	319.25	3192.50	+783.00	1.32
39	$n_3p_2k_3$	2000.00	453.00	2453.00	438.00	4380.00	+1927.00	1.79
40	$n_3p_2k_4$	2000.00	496.50	2496.50	445.25	4152.50	+1656.00	1.66
41	$n_3p_3k_1$	2000.00	425.50	2425.50	368.50	3685.00	+1259.00	1.52
42	$n_3p_3k_2$	2000.00	469.00	2469.00	316.75	3167.50	+698.50	1.28
43	$n_3p_3k_3$	2000.00	512.50	2512.50	428.00	4280.00	+1767.50	1.70
44	$n_3p_3k_4$	2000.00	555.50	2555.50	262.00	2620.00	+64.50	1.02
45	$n_3p_4k_1$	2000.00	485.00	2485.00	248.75	2487.50	+2.50	1.00
46	$n_3p_4k_2$	2000.00	528.50	2528.50	380.00	3800.00	+1271.50	1.50
47	$n_3p_4k_3$	2000.00	571.50	2571.50	367.00	3670.00	+1098.50	1.43
48	$n_3p_4k_4$	2000.00	615.00	2615.00	345.75	3457.50	+842.50	1.32
49	$n_4p_1k_1$	2000.00	409.00	2409.00	353.00	3530.00	+1121.00	1.46
50	$n_4p_1k_2$	2000.00	453.50	2453.50	409.00	4090.00	+1636.50	1.66
51	$n_4p_1k_3$	2000.00	495.00	2495.00	395.25	3952.50	+1457.50	1.58
52	$n_4p_1k_4$	2000.00	439.00	2439.00	378.00	3780.00	+1341.00	1.55

Table 27. (Contd.)

1	2	3	4	5	6	7	8	9
53	$n_4P_2k_1$	2000.00	468.50	2468.50	252.00	2520.00	+51.50	1.02
54	$n_4P_2k_2$	2000.00	511.50	2511.50	326.50	3265.00	+753.50	1.30
55	$n_4P_2k_3$	2000.00	545.00	2545.00	349.75	3497.50	+952.50	1.37
56	$n_4P_2k_4$	2000.00	598.50	2598.50	380.25	3802.50	+1204.00	1.46
57	$n_4P_3k_1$	2000.00	528.00	2528.00	258.50	2585.00	+57.00	1.02
58	$n_4P_3k_2$	2000.00	571.00	2571.00	335.25	3352.50	+781.50	1.30
59	$n_4P_3k_3$	2000.00	615.00	2615.00	358.75	3587.50	+972.50	1.37
60	$n_4P_3k_4$	2000.00	658.00	2658.00	376.50	3765.00	+1107.00	1.42
61	$n_4P_4k_1$	2000.00	588.00	2588.00	288.50	2885.00	+297.00	1.11
62	$n_4P_4k_2$	2000.00	630.50	2630.50	320.00	3200.00	+569.50	1.22
63	$n_4P_4k_3$	2000.00	674.00	2674.00	373.50	3735.00	+1061.00	1.40
64	$n_4P_4k_4$	2000.00	717.00	2717.00	411.50	4115.00	+1398.00	1.51

Cost of 1 kg N Rs. 5.10
Cost of 1 kg P_2O_5 Rs. 5.90
Cost of 1 kg K_2O Rs. 2.15
Price of 1 kg Sesamum seed Rs. 10.00

DISCUSSION

DISCUSSION

1. Growth Characters

1.1. Height of the Plant

The result on Table 1 revealed that incremental doses of nitrogen increased the height of the plant at all stages of growth. Since nitrogen is a major constituent of protoplasm which is regarded as the physical basis of life, higher doses of nitrogen resulted in the synthesis of more protoplasm and as such nitrogen favours vegetative growth. This is in conformity with the findings of Rahman et al. (1978), Sirry et al. (1979).

Phosphorus and potassium also exerted positive influence in increasing the height of plants at later stages of growth. Since P and K are the major nutrients required for growth of plants it is natural that increasing the levels of these nutrients increased the height of plants. This is in agreement with the finding of Rahman et al. (1978), Sirry et al. (1979).

1.2. Number of leaves per plant

Significant influence of nitrogen was observed on the number of leaves per plant at 20th, 40th and 60th days after

sowing while the effect of phosphorus was significant at all stages of growth. But potassium did influence only on 40th and 60th days after sowing. As N, P and K are the major nutrients which enhance vegetative growth of plants, these might have influenced the increase in number of leaves required for the synthesis of food. The present study is in agreement with the finding of Gopalakrishnan et al. (1974), Jalaludeenkutty (1985).

Phosphorus application might have increased better root development and more nutrient uptake for better growth. Moursi and Abdel-Gawad (1966) observed that P application increased dry matter of leaves, stems and fruits.

Potassium has significant effect on number of leaves on 40th and 60th days after sowing. Maximum number of leaves was observed at k_3 level (50 kg/ha) and at later stages K had no effect on number of leaves. This might be due to the fact that at later stages there was less production of leaves.

1.3. Number of Branches per Plant

The result revealed that nitrogen significantly influenced the number of branches per plant. As explained,

the positive effect of N on vegetative growth might have increased the number of branches. The present findings are in confirmity with the results of Subramonian et al. (1979). Girija Devi (1985) also obtained positive effect of N on the number of branches in an experiment on sesamum.

Significant influence on the number of branches per plant was observed by the application of phosphorus. But the requirement of P was not high as in the case of N. The highest number of branches was observed at p_2 level on 40th day onwards. This may be due to the fact that P has only little role in modifying vegetative character.

The significant influence of K on the number of branches per plant observed in the present study may be due to the low level of K in the soil and similar result was obtained by Balamurugan and Venkatesan (1983) in K deficient soil of Bavanisagar.

1.4. Leaf Area Index

The result (Table 4) revealed that N significantly influenced leaf area index at all stages of growth. This may be due to the complimentary effect of N on vegetative character like height of the plant (Table 1), number of

leaf per plant (Table 2) and number of branches (Table 3). The result of the present study is in agreement with the finding of Moursi et al. (1966), Girija Devi (1985) and Jalaludeenkutty (1985).

The effect of P was significant at 40 and 60 days after sowing. As it is well known, in the initial stage P is better utilised for establishment and development of roots than for leaf production. Hence leaf area index was not influenced by P in the early stage. Phosphorus could not exert significant influence at harvest stage also because of reduction in the number of leaves at harvest. Results obtained by Girija Devi (1985) supports the findings in this study.

Potassium showed significant effect on leaf area index except at harvest stage. Potassium is one among the major nutrients required for growth and this nutrient plays a vital role in translocation of raw food from base to top

1.5. Number of days required for 50% flowering

It is observed that N and K had no significant influence in the number of days required for attaining 50% flowering. However, phosphorus at highest level reduced

the number of days taken for attaining 50% flowering. This is due to the favourable effect of P in growth characters which in turn had resulted in the reduction of days required for attaining 50% flowering.

2. Yield and Yield Attributes of Sesamum

2.1. Number of Pods per plant

It is seen that N and K significantly influenced the number of pods per plant. The beneficial effect of nitrogen on growth character has manifested in the increased number of pods. The present result is in agreement with the findings of Mourai et al. (1966), Rahman et al. (1978), Singh et al. (1978) and Girija Devi (1985).

Phosphorus did not exert any significant influence on the number of pods per plant in the present study. But an increase in potassium showed significant influence on this character. This may be due to the low K content of the soil. Balamurugan and Venkatesan (1983) observed positive influence of K in K deficient soils of Bavanisagar. Rao (1979) observed that number of capsule per plant increased with higher level of K in groundnut.

2.2. Weight of Pods per plant

The mean data presented in Table 7 revealed that different levels of nitrogen increased the weight of capsule from 2.6 g to 2.89 g per plant, although the increase was not significant. As in the case of number of pods per plant, P could not exert any significant effect on the weight of pod per plant. But K exerted significant effect on this character. It can be seen that weight of pod had a positive increase up to 50 kg (2.98 g) with K and the result is in agreement with the findings of Girija Devi (1985).

2.3. Weight of Seed per plant

The mean data on Table 8 indicate that N application produced significant effect on the seed weight per plant. Increased level of nitrogen might have facilitated the efficient accumulation of photosynthates in seed during the later stages of vegetative growth. The data on number of pod per plant (Table 6) also revealed the fact that higher levels of nitrogen could increase the number of pod per plant. More number of pods and more seed per pod contributed the increased weight of seed per plant.

Phosphorus could not produce any effect on seed weight as in the case of number of pods per plant (Table 6). But K had a significant effect on the weight of seed per plant. K helped the translocation of photosynthate from source to sink and hence the significant effect. The result is in agreement with the findings of Aipe (1981).

2.4. Pod-Seed Ratio

The main effect of N, P and K had pronounced influence on the pod-seed ratio. It is seen that the lowest level of N had highest pod-seed ratio. Nitrogen at higher levels, it might probably be sufficient for the proper filling of seed, while at lower levels, it might have been sufficient only for the formation of pod, which resulted in high pod-seed ratio at lower level of N.

Phosphorus also had the same trend in respect of pod-seed ratio as in the case of N. Rahman et al. (1978) observed increased number of heads with increased level of P in sunflower.

Applied K produced significant effect on pod-seed ratio and increased level of K application resulted in low pod-seed ratio. As K is also a major nutrient influencing growth

and other yield attributes, a low level of K might have produced a high pod-seed ratio.

2.5. Weight of Bhusa per Plant

The result (Table 10) revealed that N and P had significant effect on Bhusa yield per plant. Since the above nutrients had positive influence on vegetative characters like, height of plant (Table 1), number of leaves (Table 2), number of branches (Table 3) and Leaf Area Index (Table 4), it is quite natural that these nutrients have increased the Bhusa yield also. Many workers have reported the significant influence of nitrogen in the vegetative growth of sesamum (Moursi et al., 1966; Gopalakrishnan, 1971; Rahman et al., 1978 and Girija Devi, 1985).

Phosphorus also produced significant influence on bhusa yield per plant. Increase in the rate of phosphorus increased most of the vegetative characters as explained in the case of N above and hence the significant effect. The present result is in conformity with the findings of Rahman et al. (1978), Pal (1979), Vir and Verma (1979) and Girija Devi (1985).

Potassium had no effect on Bhusa yield in the present study.

2.6. 1000 Seed weight

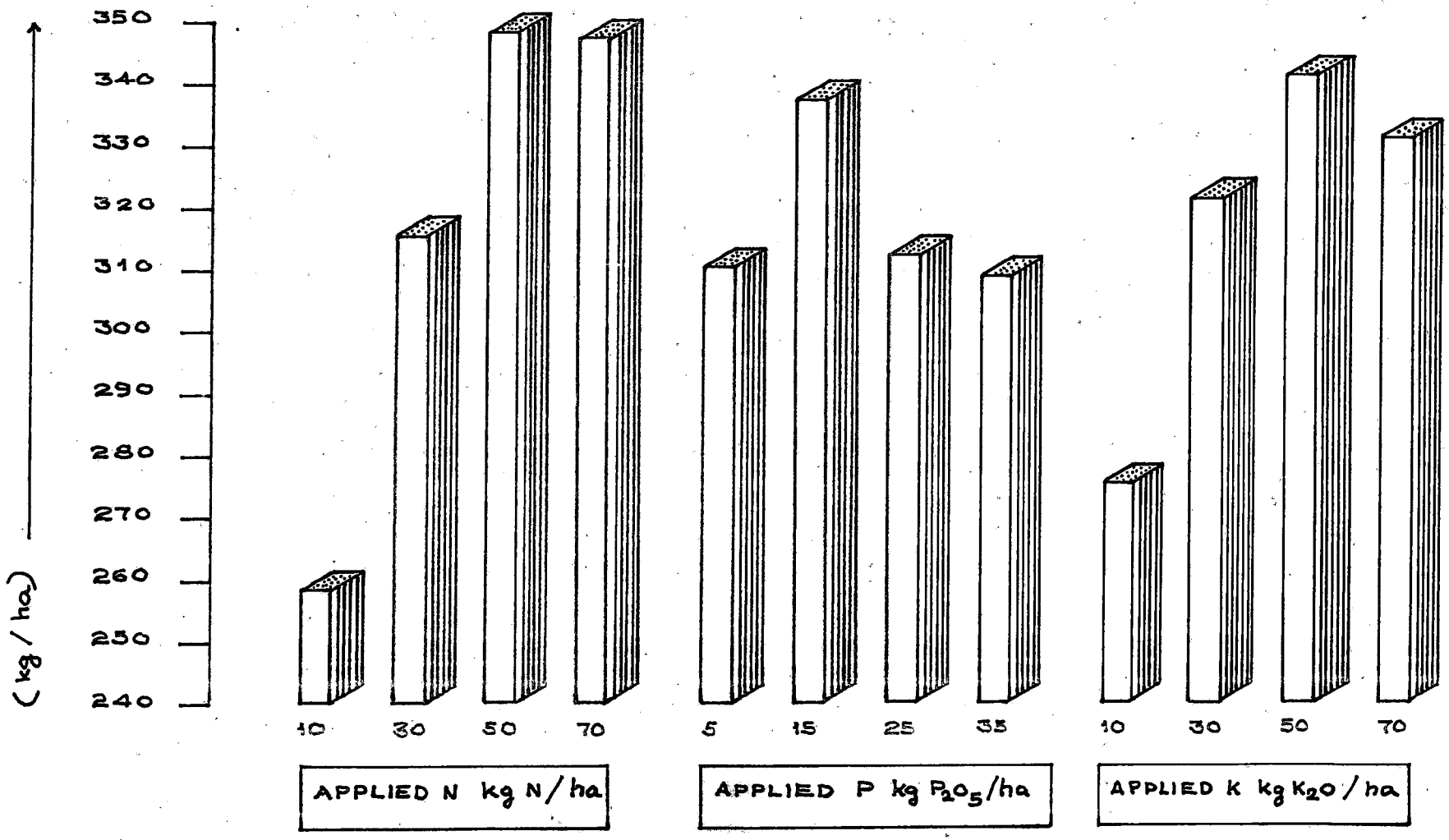
The data presented in Table 11 revealed that N and P had a pronounced effect on 1000 seed weight. The highest thousand seed weight of 3.09 g was obtained at 50 kg N/ha. It can be seen that highest uptake of N was observed at 50 kg N/ha (Table 22.1) and the higher uptake of N naturally increased the thousand seed weight. The present study was in conformity with the finding of Andhale and Kalbhor (1978), Ghosh and Sen (1980) and Girija Devi (1985) and Jalaludeenkutty (1985).

Phosphorus was also found to produce significant effect on thousand seed weight. Positive influence of P on 1000 seed weight of sesamum was reported by Girija Devi (1985) and Jalaludeenkutty (1985). However, K did not exert any significant effect on 1000 seed weight. Satyanarayana (1978) found that 1000 seed weight was not influenced by K application.

2.7. Total Seed yield

The result (Table 12) revealed that nitrogen and potassium produced pronounced influence on the total seed

FIG. 3. EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON SEED YIELD OF SESAMUM (kg / ha)



yield, while P did not show any positive effect. Among the different levels of N the highest seed yield of 348.25 kg/ha was produced at 50 kg N/ha. The combined effect of N on yield attributes like number of pod per plant (Table 7), weight of seed per plant (Table 8), pod-seed ratio (Table 9) and 1000 seed weight (Table 11) was responsible in increasing the grain yield in the present study. The favourable effect of N in increasing seed yield of sesamum has been reported by many workers (Rai and Srivastheva, 1968; Gaur and Trehan, 1973; Singh and Koushal, 1975; Gowda, 1974; Reddy, 1977; Aleshebenko, 1978; Mehrotra et al., 1978; Satyanarayana, 1978; Sennaiyan and Arunachalam, 1978; Girija Devi, 1985 and Jalaludeenkutty, 1985).

Although phosphorus could not increase the seed yield significantly, K could contribute much in increasing the seed yield. The highest seed yield obtained with K was 341.35 kg/ha at 50 kg K_2O/ha. Menon and Unnithan (1965) got highly significant and consistent grain yield of sesamum in three seasons with applied K in sandy tracts of Onattukara. Similar results were also reported by Michell et al. (1976), Gowda et al. (1977), Satyanarayana (1978), Rao (1979), Aipe (1981) and Jalaludeenkutty (1985).

The maximum seed yield of 489.97 kg/ha was obtained from the treatment combination of $n_2p_2k_4$ (30 kg N, 15 kg P_2O_5 and 70 kg K_2O /ha) followed by $n_3p_2k_3$ (50 kg N, 15 kg P_2O_5 and 50 kg K_2O /ha - 438 kg/ha.

2.8. Harvest Index

From the present study it is seen that nitrogen application increased the harvest index. The highest harvest index was obtained at 50 kg N/ha. Applied nitrogen significantly increased most of the yield attributing characters like number of pod per plant (Table 7), weight of seed per plant (Table 8) and 1000 seed weight (Table 11). The role of nitrogen was selective in the sense that the vegetative characters were improved only to the extent to contribute substantially to the productive attributes so as to get a high harvest index.

Phosphorus did not produce any significant effect on harvest index. But K showed significant effect on harvest index. Jalaludeenkutty (1985) observed positive effect of K on harvest index under sandy loam tracts of Onattukara in Kerala on sesamum crop.

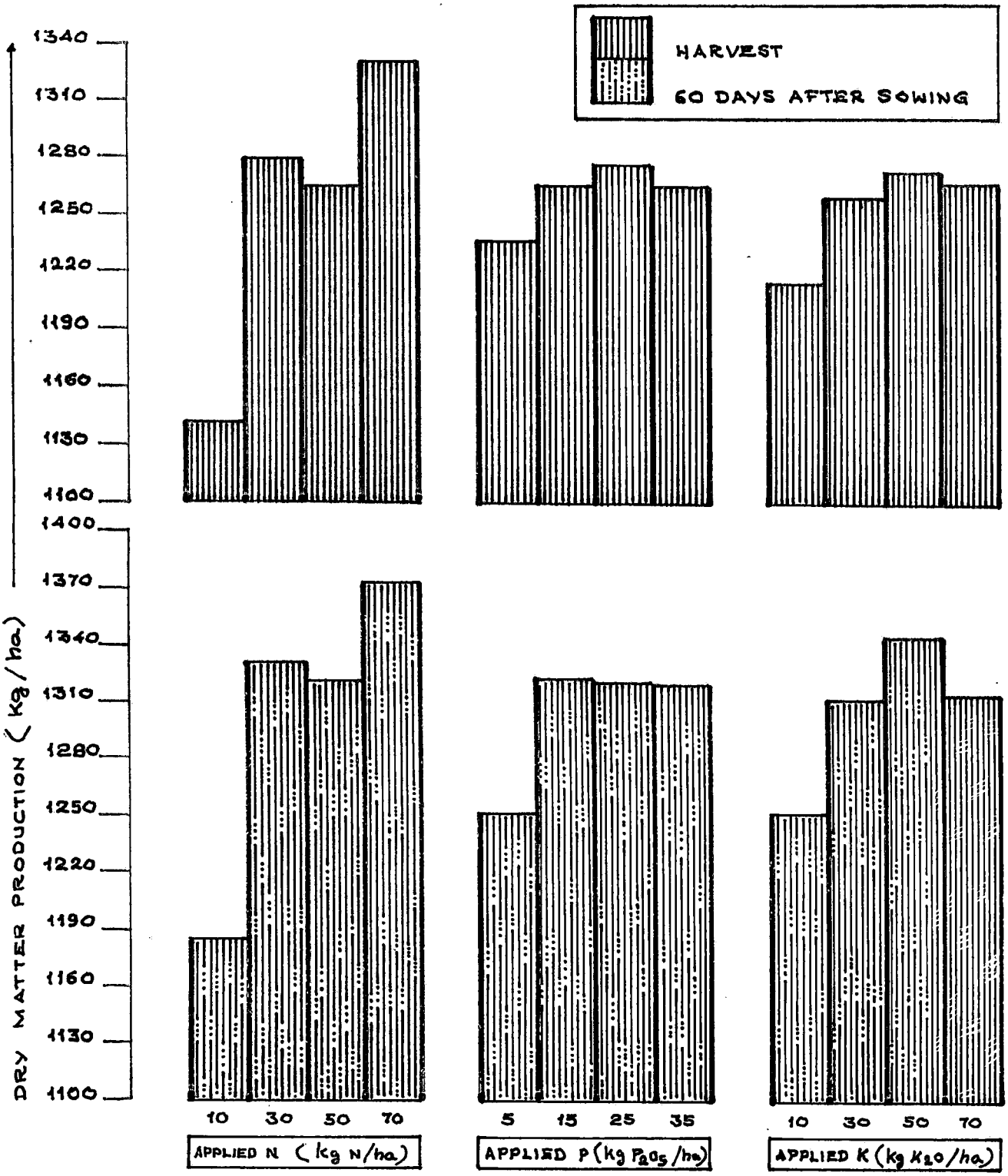
2.9. Total Dry matter production

From the result (Table 14, Fig. 4) it can be seen that N and P significantly influenced the total dry matter production at all stages of growth. Nitrogen significantly influenced all the vegetative characters like height of plant (Table 1), number of leaves per plant (Table 2), number of branches (Table 3) and leaf area index (Table 4). Therefore it is quite natural that the total dry matter production also had increased. The favourable influence of nitrogen on dry matter yield of different oil crop had been reported by workers like Moursi et al. (1960), Pal (1979), Vir and Verma (1979), Jalaludeenkutty (1985).

The effect of phosphorus on total dry matter production was also found to be significant at all stages of growth. As in the case of N, P also exerted positive influence on vegetative characters and thereby increased the total dry matter production. The result of the present study is in agreement with the findings of Pal (1979) and Jalaludeenkutty (1985).

The effect of K on dry matter production was found to be significant only at later stages of growth. Significant

FIG. 4. EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON TOTAL DRY MATTER PRODUCTION OF SESAMUM.



influence of K on dry matter yield was obtained by Maine et al. (1965), Rao (1979), Aipe (1981) and Jalaludeenkutty (1985).

3. QUALITY ATTRIBUTES

3.1. Oil Content

The result (Table 15) revealed that the three major nutrients N, P and K exerted significant influence in oil content. The oil content increased significantly up to 50 kg N/ha (n_3 level) and further increase of N had no effect on this. The present study is in agreement with the finding of Singh et al. (1960), Rameswamy et al. (1974), Satyanarayana (1978) and Mane (1983). Similar findings were reported by Girija Devi (1985) and Jalaludeenkutty (1985) in sesamum.

The effect of P on oil content was similar to that of N. Favourable effect of P on oil seed was reported by Bhuiya & Choudhary (1974), Ravenko (1977) and Friederich (1983). The effect of K on oil content of sesamum was also significant. The high oil content of 53.59% was obtained at 30 kg K_2O/ha. The significant effect of K on oil content of oil yielding crop like sunflower was reported by Stoyenova et al. (1975). Satyanarayana (1978), Aipe (1981) and Balamurugan

and Venkatesan (1983) also obtained increased oil content by the application of K in sesamum.

3.2. Protein Content

It is seen that the protein content of sesamum was significantly influenced by different levels of N, P and K. There was a gradual increase in protein content, when the level of N was raised from 10 to 50 kg N/ha. But at highest level there was decrease in protein content. Since proteins are made up of amino acids which are rich in N, increase in N level will increase protein content also. The result is quite in confirmity with the findings of Bhuiya and Choudhary (1974), Michell et al. (1976), Aulakh et al. (1980), Shelke and Kurpe (1981) and Girija Devi (1985).

Phosphorus also increased the protein content of seed and highest value of protein was observed (22.81%) at highest level of phosphorus. Phorsphorus being a major constituent of protein, higher uptake of phosphorus might be responsible for the significant increase in protein content of seed. Significant increase in protein content of sesamum was reported by Bhuiya and Chowdhary (1974) in groundnut, Girija Devi (1985) and Jalaludeenkutty (1985) in sesamum.

Positive effect of K on protein content was also observed. The highest protein content was noted at the highest level of K (22.65%) applied. The result is in agreement with the findings of Bhuiya and Chowdhary (1974) who have reported that the protein content of groundnut seed was increased when applied potassium was increased from zero to 44.8 kg/ha. Michell et al. also reported similar result and he concluded that application of K increased the individual protein and amino acid in the seed material of sesamum due to increase in protein concentration. Jalaludeenkutty (1985) also observed similar result in sesamum.

4. ANALYSIS OF PLANT SAMPLE

4.1. Nitrogen Content of plant at different stages of plant growth

Nitrogen content of plant was significantly influenced by graded levels of nitrogen at all stages of growth. The data presented in Table 12 revealed that the maximum N content was at 20 days after sowing which decreased gradually to harvest. It may be due to the fact that N might have been translocated to the growing points and at maturity due to

senescence the content might be low. The increase in dry matter production at later stages of growth resulted the quick mobilisation of N to other growing tissues. Reddy and Narayanan (1983) found that accumulation of N in plant parts of sesamum and nutrients concentration in all vegetative plant parts increased until six weeks after sowing followed by gradual decrease towards maturity. Remobilisation of N occurs from leaf, stem and roots to the pod during reproductive phase. Significant influence of N on N content of plant was reported by Girija Devi (1985) and Jalaludeenkutty (1985) in sesamum plant.

Except on 20 days after sowing, P failed to show any significant effect. But K did not show significant effect on the N content of plant at any of the stages of growth.

4.2. Nitrogen Content of Seed

The result (Table 18.1) revealed that N, P and K significantly influenced the N content of seed. The highest N content observed was 3.59% with 50 kg N/ha. Similar trend has been reported by several workers in other oil yielding crops. Vir and Verma (1979) found that increasing the rate of N from zero to 30 and 60 kg/ha increased the seed nitrogen content in mustard. Girija Devi (1985) also obtained significant effect of N on N content of seed.

Phosphorus and potassium also showed positive effect on N content of seed. Vir and Verma (1979) while studying the effect of phosphorus on N content reported that the nitrogen content of seed increased with higher levels of phosphorus. Girija Devi (1985) also obtained significant effect of phosphorus and potassium on N content of seed of sesamum.

Potassium also produced significant effect on N content of seed. Translocation of K from other parts of plant to seed at maturity may be the reason for higher N content due to K. Rao (1979) reported that the uptake of N and P was found to be increased with applied K at zero to 40 and 80 kg K_2O/ha in TMV-2 groundnut.

4.3. Phosphorus Content of Plant at different stages of growth

Nitrogen application significantly influenced the P content of plant from 40th day onwards. Bishnol and Kanwar Singh (1979) studied the effect of N levels on the nitrogen, phosphorus and potash uptake of raya and found that applied nitrogen increased the nitrogen and phosphorus content and their uptake.

Phosphorus also exerted significant effect on P content of plant sample. Increasing phosphorus level showed an increasing trend at all stages of growth except on 40 days after sowing. This is in agreement with the findings of Vir and Verma (1979) and Joao and Reddy (1981). Except on 20 days after sowing applied K did not produce significant effect on the P content of plant.

4.4. Phosphorus Content of Seed

The result (Table 18.2) revealed that phosphorus content of seed is significantly influenced by N and P. The present finding is in conformity with the observations of Vir and Verma (1979) and Joao and Reddy (1981).

Potassium did not make any significant influence on this character.

4.5. Potassium content of Plant at different stages of growth

The result (Table 20) revealed that different levels of N has significant effect on potassium content of plant at all stages of growth. The effect of N or K content was high at 40 and 60 days after sowing and thereafter a declining trend was observed. This is in line with the findings of Habeebulla *et al.* (1977) and Reddy and Narayanan (1983).

Phosphorus also produced significant effect on K content of plant. The highest K content was observed at 40 and 60 days after sowing and at maturity and K content showed a declining trend. The effect of K also was significant at all stages of growth and the content of K also showed a declining trend towards harvest stage. The result is in agreement with the findings of Reddy and Narayanan (1983), Aipe (1981), and Jalaludeenkutty (1985).

4.6. Potassium Content of Seed

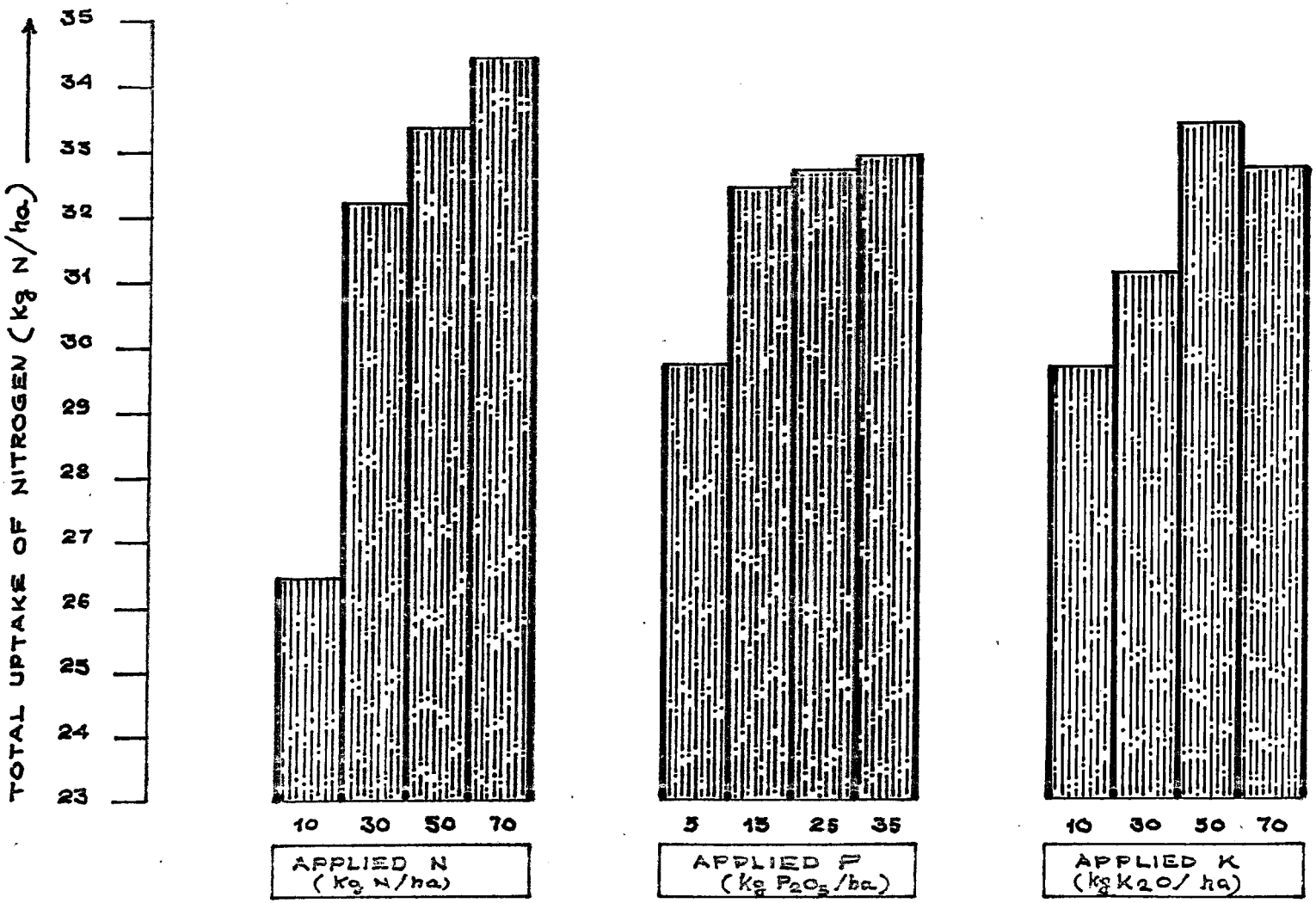
It is seen from the result (Table 18.3) that N and K could significantly influence the potassium content of seed while P had no effect on this. When the plant is supplied with higher level of potassium, as it is well established, plant would absorb higher amount of potassium which in turn would reflect on the percentage content of the nutrient in seed. Girija Devi (1985) recorded significant effect of N and K on seed content of Thilothama variety of sesamum under Vellayani conditions.

5. Uptake of Nutrients

5.1. Uptake of Nitrogen by plant at different stages of growth

The result (Table 21) revealed that the main effect of N, P and K has positively influenced the uptake of N at all

FIG.5. EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF NITROGEN



stages of growth, while K has shown significant influence on 60 days after sowing. There was a progressive increase in the uptake of N at different stages and the average nitrogen uptake was maximum at 60 days after sowing. It can be seen that the N uptake decreased when the plant approached harvest stage. This may probably be due to the decrease in dry weight of plant by loss of leaves after 60 days after sowing. The result of the present study is in agreement with the findings of workers like Vir and Verma (1979), Girija Devi (1985) and Jalaludeenkutty (1985).

The effect of P on N uptake was significant and as in the case of N the highest uptake was observed at 60 days after sowing. The positive effect of phosphorus on N uptake was reported by Vir and Verma (1979) on rainfed mustard. They found that application of P_2O_5 at the rate of 30 kg/ha increased seed phosphorus content and uptake of nitrogen and potassium. Girija Devi (1985) also reported that P application significantly increased the N uptake in sesamum. The effect of K had significant effect only at 60 days after sowing.

5.2. Uptake of Nitrogen by Seed

It is seen (Table 22.1) that N and K had significant effect in the uptake of N by seed. Increased dose of P also

had an increased uptake of P by seed. The significant effect of N on the uptake of N by seed was reported by workers like Vir and Verma (1979), Bishnoi and Kanwar Singh (1979) and Girija Devi (1985).

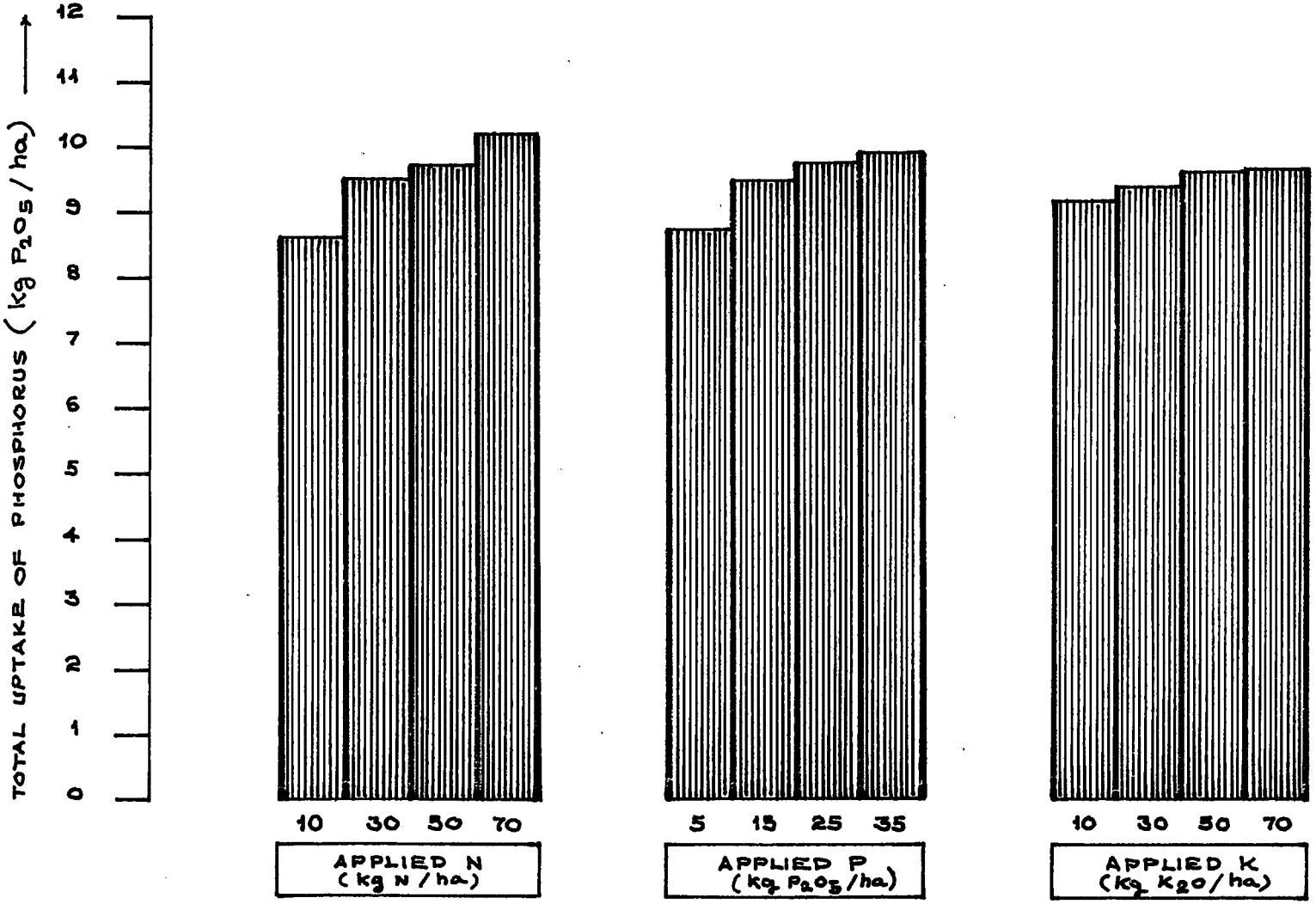
5.3. Total uptake of Nitrogen by plant

It is seen that there was significant increase in the total uptake of nitrogen with increasing levels of nitrogen and total uptake was higher with higher level of N. The total uptake of nitrogen was also significantly influenced by different levels of P and K. It can be seen that nitrogen content of plant at different stages of growth and seed nitrogen content were significantly influenced by nitrogen application and this increasing trend in the uptake of nitrogen by plant and seed at different stages of growth has been reflected in the total uptake of N also. Increasing levels of P and K also had significant influence on the total uptake of nitrogen by plant.

5.4. Uptake of Phosphorus at different stages of growth

The data presented in Table 23 revealed that N and P significantly influenced the phosphorus uptake of plant at different stages of growth while K could exert significant

FIG. 6. EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF PHOSPHORUS



effect only at 60 days after sowing. As in the case of N highest uptake was observed at 60 days after sowing which decreased at harvest stage. Girija Devi (1985) observed significant effect of N and P on phosphorus content and P uptake in sesamum. The effect of K was also found significant at 60 days after sowing. The increase in dry weight at 60th day might have facilitated higher uptake of nutrients including K and potassium along with phosphorus produced significant effect in uptake of P at 60 days after sowing.

5.5. Uptake of Phosphorus by Seed

It is seen that P content of seed was significantly influenced by N and K. There was an increasing trend with uptake of P by increased dose of phosphorus. Graded dose of potassium also had a beneficial effect on uptake of K by seed. This was in conformity with the findings of Aipe (1981).

5.6. Total uptake of Phosphorus

It is seen that different levels of nitrogen and phosphorus significantly influenced the total P uptake by the plant. When the phosphorus content and uptake of phosphorus were significantly influenced by nitrogen and phosphorus it is natural that the total uptake would also be significant.

In the case of K there was no significant effect. Girija Devi (1985) recorded similar result under Vellayani conditions in sesamum crop.

5.7. Uptake of Potassium at different stages of growth

The result (Table 24) revealed that nitrogen and phosphorus significantly influenced the uptake of K at all stages of growth. The uptake of potassium was also highest at 60 days after sowing, which declined towards harvest. The effects of N and P were same as explained in the case of uptake of N and phosphorus. The result of the present study is in agreement with the findings of Bishnoi and Kanwar Singh (1979) and Jalaludeenkutty (1985).

The effect of K was significant only at 40 and 60 days after sowing. Reddy and Narayanan (1983) studied the concentration of potassium in plant parts of sesamum and found that nutrient concentrations in all vegetative plant parts increased up to 6 weeks after sowing after which there was a gradual decline. Similar results were also obtained by Girija Devi (1985) and Jalaludeen kutty (1985) in sesamum crop.

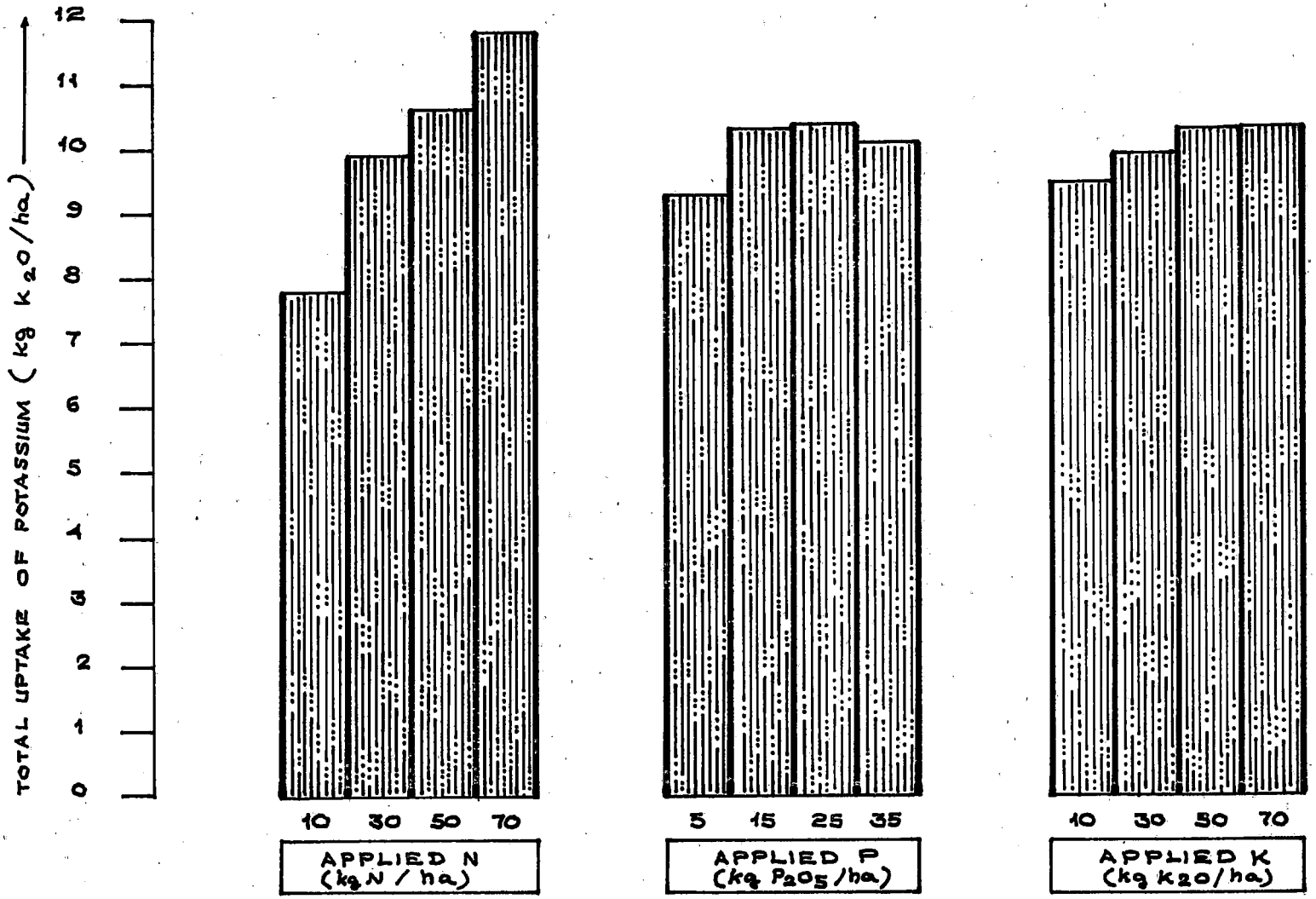
5.8. Uptake of Potassium by Seed

In the case of uptake of potassium by seed it can be seen (Table 22.3) that N and K significantly influenced the potassium uptake. Higher uptake of potassium was observed at highest level of nitrogen and this may be due to the favourable effect of N on K. The effect of phosphorus was not significant on the uptake of potassium. But applied K exerted positive effect on the uptake of K by seed. Positive effect of K on the uptake of potassium has been reported by Aipe (1981) and Girija Devi (1985) in sesamum.

5.9. Total Uptake of Potassium by Plant

Total uptake of potassium was significantly influenced by N, P and K. By increasing the level of nitrogen the total uptake of potassium was increased and maximum uptake was observed at n_4 level. It can be seen that uptake of potassium by plant at all stages were significantly influenced by N and hence N could exert significant influence on the total uptake of K also. Phosphorus and potassium also had similar effect on the total uptake of potassium. The maximum uptake of K was observed at p_3 (25 kg P_2O_5/ha) and k_3 (50kg K_2O/ha) levels of P and K respectively.

FIG. 7. EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE TOTAL UPTAKE OF POTASSIUM



6. SOIL ANALYSIS AFTER THE EXPERIMENT

6.1. Total Nitrogen Content

The data on soil analysis after the experiment showed that there was a positive increase in soil nitrogen with increased level of N application. But P and K could not exert any significant influence on N content of soil nitrogen.

6.2. Available Phosphorus content of Soil

In the case of available phosphorus P and K could make significant effect while N could not exert any significant influence on this character. There was a positive increase of P_2O_5 content with increasing levels of P and K.

6.3. Available Potassium content of Soil

The data revealed that all the three nutrients failed to produce any significant effect on available potassium content of soil. But graded levels of N showed a progressive trend in increasing the K content of soil.

Economics of Sesamum Production

The data presented in Table 27 revealed that the best combination of $n_2p_2k_4$ gave the highest net profit. The

higher potassium requirement of the sesamum in the present study may be due to the low potassium content of the soil.

The R^2 value (0.97) showed that the fitted quadratic response surface explains the dose-response relationship very well (Das and Giri, 1979). The economic optimum dose combination was estimated as 72 kg N + 7 kg P_2O_5 + 68 kg K_2O per hectare.

SUMMARY

SUMMARY

A field investigation was carried out under garden land condition at the Instructional Farm, College of Agriculture, Vellayani, to study the effect of nitrogen, phosphorus and potassium on growth, yield, quality, content and uptake of mineral nutrients (N, P and K) and also to work out the economics of sesamum production with the pre-release culture 42-1 (now released as Soorya or ACV-2) during semirabi season 1984. The experiment was laid out as a 4^3 confounded factorial experiment in randomised blocks with two replications confounding NPK (3 df) totally. The experiment consisted of 64 treatments with all possible combinations of four levels of nitrogen (10, 30, 50 and 70 kg N/ha), four levels of phosphorus (5, 15, 25 and 35 kg P_2O_5/ha) and four levels of potassium (10, 30, 50 and 70 kg K_2O/ha).

Observations on various growth characters were recorded on 20, 40, 60 days after sowing and at harvest. The analysis of data recorded on various growth characters and also those of chemical composition of plants and seeds revealed the following results, which are summarised below.

1. Nitrogen application significantly influenced the height of plant at all stages of growth but phosphorus and

potassium could influence this character only during later stages of growth.

2. Except at harvest stage, nitrogen application had significant influence on the number of leaves per plant, while applied phosphorus could exert significant influence at all stages of growth. The effect of potassium on this character was significant only on 40 and 60 days after sowing.

3. Nitrogen, phosphorus and potassium had significant effect on the number of branches per plant at all stages of growth. A dose of 15 kg P_2O_5/ha was found to be sufficient on 40 days after sowing and at harvesting stage.

4. Nitrogen application significantly influenced Leaf Area Index at all stages of growth and highest leaf area index was observed at the highest level. Phosphorus also exerted significant influence on this character on 40 and 60 days after sowing. Positive and significant influence of potassium was observed at all stages except at harvesting stage.

5. Nitrogen and potassium had no significant effect on the number of days taken for attaining 50% flowering but at highest level of phosphorus there was significant

reduction in the number of days taken for attaining 50% flowering.

6. Number of pods per plant was significantly influenced by applied nitrogen and potassium and maximum pods were recorded at 50 kg N and 50 kg K_2O/ha.

7. The weight of pods per plant was found to be influenced by potassium application with the maximum pod weight at 30 kg K_2O/ha.

8. Application of nitrogen and potassium significantly influenced the weight of seeds per plant. The highest pod weight was observed at the level of 50 kg N and 50 kg K_2O per hectare.

9. Nitrogen, phosphorus and potassium had pronounced effect on the pod-seed ratio and the highest level of nutrient reduced the pod-seed ratio.

10. The bhusa weight per plant was significantly influenced by the application of nitrogen and phosphorus. Maximum bhusa weight was recorded at 70 kg N and 25 kg P_2O_5 per hectare.

11. Nitrogen and phosphorus produced significant influence on thousand seed weight and highest thousand seed weight was obtained at 50 kg N and 25 kg P_2O_5 per hectare.

12. Nitrogen and potassium produced pronounced influence on total seed yield and highest seed yield was obtained at the level of 50 kg each of N and K_2O per hectare. The maximum seed yield was obtained with the combination $n_2p_2k_4$ levels of nitrogen, phosphorus and potassium (30 kg N, 15 kg P_2O_5 and 70 kg K_2O/ha).

13. Nitrogen and potassium had significant effect on harvest index and highest harvest index was obtained at 50 kg N and 50 kg K_2O/ha.

14. Nitrogen and phosphorus exerted significant influence on total dry matter production at all stages of growth, while the effect of potassium was significant only at later stages of growth.

15. The major nutrients nitrogen, phosphorus and potassium produced significant influence on oil content of sesamum seed. Highest oil content was obtained at n_3 level (50 kg N/ha) of nitrogen, p_3 level (25 kg P_2O_5/ha) of phosphorus and k_2 level (30 kg K_2O/ha) of potassium.

16. Nitrogen, phosphorus and potassium also exerted significant effect on protein content of sesamum. Maximum protein content in sesamum seed was recorded at n_3 level (50 kg N/ha)

of nitrogen, p_4 level (35 kg P_2O_5/ha) of phosphorus and k_4 level (70 kg K_2O/ha) of potassium.

17. Nitrogen content of plant was significantly influenced by graded doses of nitrogen and highest nitrogen content was observed at highest level (70 kg N/ha) of nitrogen. Phosphorus could significantly influence the nitrogen content only at 20 days after sowing and the effect of potassium was not significant.

18. Nitrogen, phosphorus and potassium could produce positive and significant effect on the nitrogen content of sesamum seed.

19. Nitrogen application produced significant effect on phosphorus content of plant at all stages except on 20 days after sowing. The effect of phosphorus was also significant and barring at 20 days after sowing the effect of potassium was not significant at all stages of growth of the crop.

20. Phosphorus content of seed was significantly influenced by nitrogen and phosphorus.

21. Potassium content of the plant was significantly influenced by nitrogen and potassium at all stages of growth.

At initial and final stages, highest level of nitrogen recorded highest potassium content. The effect of phosphorus was significant at all stages except on 60 days after sowing. Significant effect of potassium was also observed with maximum potassium content at 50 kg K_2O/ha on 40 and 60 days after sowing.

22. Nitrogen and potassium had significant effect on potassium content of seed with maximum potassium content at 70 kg N and 70 kg K_2O per hectare.

23. The uptake of nitrogen was significantly influenced by nitrogen and phosphorus at all stages of growth, while the effect of K was significant only on 60 days after sowing.

24. The uptake of nitrogen by seed was significantly influenced by nitrogen and potassium and the highest uptake of nitrogen by seed was observed at 50 kg each of N and K_2O per hectare.

25. Nitrogen, phosphorus and potassium exerted significant influence on the total uptake of nitrogen. The uptake was maximum at highest level of N (70 kg N/ha) and phosphorus (35 kg P_2O_5/ha) and at k_3 level (50 kg K_2O/ha) of potassium.

26. Nitrogen and phosphorus significantly influenced the uptake of phosphorus at all stages of growth and the effect of potassium was significant only on 60 days after sowing.

27. Application of nitrogen and potassium significantly influenced the uptake of phosphorus by seed and the highest uptake was observed at 50 kg each of N and K_2O per hectare.

28. Total uptake of phosphorus was significantly influenced by nitrogen and phosphorus and the highest uptake was observed at highest levels of nitrogen (70 kg N/ha) and phosphorus (35 kg P_2O_5/ha).

29. Application of nitrogen and phosphorus produced significant result on the potassium uptake by plant at all stages of growth, whereas the influence of potassium was significant on 40 and 60 days after sowing.

30. Potassium uptake by seed was significantly influenced by nitrogen and highest potassium uptake was recorded at 70 kg N and 50 kg K_2O per hectare.

31. Total uptake of potassium was significantly influenced by nitrogen, phosphorus and potassium and the uptake was highest at 70 kg N, 25 kg P_2O_5 and 50 kg K_2O per hectare.

32. The study revealed that yield performance of sesamum culture 42-1 (Soorya or ACV-2) under garden land condition was highest with $n_2p_2k_4$ combination of NPK (30 kg N, 15 kg P_2O_5 and 70 kg K_2O/ha) and the highest profit was also obtained with the combination of $n_2p_2k_4$. The economic optimum level was estimated as 72 kg N, 7 kg P_2O_5 and 68 kg K_2O/ha. Therefore it can be concluded that a combination of 30 kg N, 15 kg P_2O_5 and 70 kg K_2O/ha is the most advantageous fertilizer dose for sesamum culture 42-1 (Soorya or ACV-2) under garden land condition of Vellayani.

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(* Original not seen)

APPENDICES

APPENDIX I

Weather data during the crop year, 1984 and for the last five years, 1979-85.

No.	Standard weeks	Rainfall (mm) (weekly total)		Relative humidity (%) (weekly average)		Temperature (°C) (weekly average)			
						Maximum		Minimum	
		Crop year	Last 5 years	Crop year	Last 5 years	Crop year	Last 5 years	Crop year	Last 5 years
40	Oct 1-7, 1984	172.3	22.4	87.6	86.1	28.4	30.2	22.1	22.4
41	Oct 8-14	9.6	57.7	78.9	85.4	29.5	30.5	23.2	22.2
42	Oct 15-21	0.0	6.6	72.4	86.1	30.2	30.9	23.7	22.3
43	Oct 22-28	19.9	50.9	76.6	89.4	30.3	30.4	22.5	22.3
44	Oct 29-Nov 4	0.0	42.3	74.2	89.2	30.3	30.2	23.7	22.5
45	Nov 5-11	42.5	45.6	75.9	85.2	30.6	29.9	23.9	22.1
46	Nov 12-18	26.2	80.6	80.0	86.0	30.2	30.4	21.5	22.3
47	Nov 19-25	58.3	15.1	81.7	86.3	30.1	30.5	23.5	22.6
48	Nov 26-Dec 2	4.6	30.1	85.0	83.1	30.4	30.5	23.8	22.2
49	Dec 3-9	5.4	12.8	85.0	81.1	30.5	30.8	23.5	22.2
50	Dec 10-16	0.0	10.5	80.0	81.1	30.8	30.8	21.5	21.9
51	Dec 17-23	0.0	10.1	75.0	85.7	30.2	30.8	20.2	22.2
52	Dec 24-31	0.0	15.3	77.6	84.9	30.9	31.2	20.2	21.5
1	Jan 1-7, 1985	5.2	1.9	78.0	75.4	30.5	30.9	21.6	21.2

APPENDIX II

Analysis of variance for Height of the plant - stagewise

Source	df	Mean Square			
		20 DAS	40 DAS	60 DAS	Harvest.
Blocks	7	9.100**	496.352**	383.214	164.339*
N	3	25.875**	289.343**	1671.167**	2131.125**
P	3	3.222	137.447	256.5	272.791**
K	3	2.350	251.208*	267.21	520.583**
NP	9	2.238	34.107	86.777	112.152
PK	9	2.562	136.611	163.305	32.305
NK	9	2.543	24.944	143.013	45.902
NPK	24	2.275	51.451	143.092	38.439
Error	60	2.994	90.556	145.352	68.391

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Analysis of Variance for Number of Leaves per plant - Stagewise

Source	df	Mean Square			
		20 DAS	40 DAS	60 DAS	Harvest
Blocks	7	3.202**	13.825	43.205*	0.2218
N	3	30.25**	760.151**	2881.625**	1.2949
P	3	7.810**	63.432**	302.958**	4.3372*
K	3	2.071	359.270**	1722.417**	1.2356
NP	9	0.735	16.973	42.590	1.0416
PK	9	0.490	7.272	40.736	1.2105
NK	9	4.852**	17.803**	44.423**	0.4594
NPK	24	0.839	6.416	6.949	0.2073
Error	60	1.080	6.385	15.110	1.7036

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX IV

Analysis of variance for Number of branches per plant - Stagewise

Source	df	Mean Square			
		20 DAS	40 DAS	60 DAS	Harvest
Blocks	7	0.066	0.0839**	0.278**	0.285**
N	3	0.255**	4.1363**	1.947**	2.331**
P	3	0.103*	0.5924**	0.305**	0.422**
K	3	0.278**	3.1156**	3.429**	3.408**
NP	9	0.044	0.3331**	0.268**	0.228**
PK	9	0.049	0.0727**	0.0507	0.0434
NK	9	0.047	0.1463**	0.113	0.0888
NPK	24	0.018	0.0589	0.0732	0.0837
Error	60	0.033	0.0249	0.0514	0.0732

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX V

Analysis of variance for Leaf Area Index - stagewise and 50% flowering

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	50% flowering days
Blocks	7	0.000425	0.00497**	0.00991*	0.00165	0.897
N	3	0.057**	0.9287**	2.368**	0.1123**	1.630
P	3	0.00110	0.0662**	0.1106**	0.00458	2.284*
K	3	0.0118**	0.1932**	0.2585**	0.00420	0.656
NP	9	0.00173	0.0217**	0.0132**	0.00252	2.600**
PK	9	0.000458	0.0108**	0.00958*	0.00219	3.439**
NK	9	0.00117	0.0099**	0.0108*	0.000913	1.828**
NPK	24	0.00062	0.0059**	0.00740	0.000993	1.131
Error	60	0.0024	0.0016	0.00384	0.001917	0.657

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX VI

Analysis of variance for Yield attributing factors - per plant basis

Source	df	Mean Square			
		No.of pods at harvest	Weight of pod	Weight of seed	Pod-seed ratio
Blocks	7	17.409	0.3009	0.0642	0.0534
N	3	317.877**	0.7712	0.8654**	1.8701**
P	3	31.786	0.1519	0.0846	0.1235*
K	3	166.028**	1.9816**	0.4005**	0.9623**
NP	9	58.659**	1.1817**	0.1613**	0.1468**
PK	9	40.401*	0.5478	0.1213**	0.0332
NK	9	32.901	0.1831	0.0806	0.1819**
NPK	24	18.586	0.1878	0.0504	0.0511
Error	60	18.534	0.2916	0.0516	0.0322

* Significant at 5% level

** Significant at 1% level

APPENDIX VII

Analysis of variance for yield attributing factors

Source	df	Mean Square			
		Weight of bhusa per plant	1000 seed weight per plant	Total seed yield (kg/ha)	Harvest index
Blocks	7	0.3537	0.0949	2904.857	0.00108
N	3	1.011**	0.5920**	57425.33**	0.01466**
P	3	0.5689**	0.3886**	5676.667	0.00266
K	3	0.0371	0.0475	27126.34**	0.00839*
NP	9	0.1451	0.0906	10280.11**	0.00409
PK	9	0.1329	0.0095	7191.00*	0.00451
NK	9	0.1288	0.0381	6213.222*	0.00365
NPK	24	0.1159	0.0206	3562.963	0.0020
Error	60	0.1810	0.0543	3034.55	0.00209

* Significant at 5% level

** Significant at 1% level

APPENDIX VIII

Analysis of variance for Total Dry Matter Production - stagewise

Source	df	Mean Square			
		20 DAS	40 DAS	60 DAS	Harvest
Blocks	7	132.785	2233.143	27040.0**	35136.0**
N	3	24914.5**	104100.7**	214970.7**	204516.0**
P	3	1080.5**	11890.0**	40272.0**	30810.67*
K	3	244.833	1045.333	46890.67**	23813.34*
NP	9	199.388	1719.333**	18986.67*	17514.67
PK	9	177.722	862.444	2936.88	9491.55
NK	9	119.944	336.222	6849.77	6398.22
NPK	24	106.685	516.814	9976.296	7960.88
Error	60	236.041	577.266	7991.2	11214.67

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX IX

Analysis of variance for Quality attributes

Source	df	Mean Square	
		Oil content	Protein content
Blocks	7	0.9598	0.5206
N	3	16.770**	3.5820**
P	3	5.218*	10.515*
K	3	17.187**	5.657**
NP	9	0.486	1.647**
PK	9	0.718	0.355
NK	9	1.239	0.862
NPK	24	0.552	0.294
Error	60	1.690	0.545

* Significant at 5% level

** Significant at 1% level

APPENDIX X

Analysis of variance for Nitrogen Content of plant - stagewise and Seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	N content of seed
Blocks	7	1.035	0.166	0.1343**	0.0433	0.0502
N	3	3.326**	1.159**	1.905**	0.7111**	0.2744*
P	3	0.0349*	0.0349	0.0977	0.0931	0.3492**
K	3	0.019	0.0105	0.0538	0.0336	0.3633*
NP	9	0.0133	0.00446	0.0369	0.00809	0.1493
PK	9	0.0022	0.00509	0.0363	0.00705	0.0913
NK	9	0.0058	0.0013	0.0175	0.0146	0.0513
NPK	24	0.0018	0.0027	0.0391	0.00509	0.0664
Error	60	0.0122	0.0469	0.0418	0.0746	0.0796

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XI

Analysis of variance for Phosphorus Content of Plant - stagewise and seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	P content of seed
Blocks	7	0.000599	0.00207	0.00263	0.00235	0.000847
N	3	0.00167	0.02201**	0.01554**	0.00613**	0.00675**
P	3	0.0424**	0.00824	0.02463**	0.0205**	0.01249**
K	3	0.0114**	0.00677	0.00202	0.00179	0.000943
NP	9	0.00246	0.00461	0.00262	0.00296	0.000429
PK	9	0.00154	0.00141	0.00246	0.00212	0.000350
NK	9	0.000457	0.00130	0.00136	0.00106	0.000220
NPK	24	0.000617	0.000722	0.00134	0.00115	0.000180
Error	60	0.00229	0.00448	0.00277	0.00203	0.000532

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XII

Analysis of variance for Potassium content of plant - stagewise and Seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	P content of seed
Blocks	7	0.00159	0.00146	0.00187	0.00447	0.000186
N	3	0.1367**	0.3102**	0.03892**	0.3397**	0.02667**
P	3	0.0567**	0.0724**	0.00850	0.01232**	0.000654
K	3	0.01432*	0.0152*	0.04174**	0.0221**	0.01385**
NP	9	0.00412	0.0206**	0.01579**	0.00616*	0.00187**
PK	9	0.00393	0.00353	0.00396	0.00241	0.000221**
NK	9	0.00123	0.00152	0.00491	0.00351	0.000801
NPK	24	0.00208	0.00302	0.00219	0.00146	0.000327
Error	60	0.00350	0.00509	0.00337	0.00229	0.000537

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XIII

Analysis of variance for uptake of Nitrogen - stagewise and seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	N uptake of seed
Blocks	7	0.8277	1.2399	11.7589	19.095	4.886
N	3	94.9781**	244.908**	761.255**	205.118**	82.319**
P	3	6.3974**	19.1399**	64.156**	45.019*	8.703
K	3	2.2822	2.7063	41.880**	7.617	48.559**
NP	9	1.4611	1.9194	21.875**	9.881	13.889**
PK	9	1.5440	3.0839	4.404	4.916	11.028*
NK	9	1.0517	1.0601	8.406	4.394	5.380
NPK	24	1.2362	0.778	7.766	5.355	3.555
Error	60	0.9414	2.2361	6.496	11.097	4.260

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XIV

Analysis of variance for uptake of Phosphorus - stagewise and seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	P uptake of seed
Blocks	7	0.0186	0.2379	1.8551	1.7204	8.0187
N	3	3.1715**	9.7843**	28.0852**	6.5779**	1.963*
P	3	0.4848**	2.4886**	15.3724**	6.8142**	0.1612
K	3	0.0814	0.1712	7.2929**	0.2657	0.7417
NP	9	0.0685	0.2208	1.9073	1.0352	0.2453*
PK	9	0.0372	0.0584	0.4190	0.8088	0.2056*
NK	9	0.01563	0.0877	1.171	0.8272	0.1169
NPK	24	0.01603	0.0479	0.7396	0.6744	0.0634
Error	60	0.03632	0.1502	0.9506	0.9837	0.09625

DAS : Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XV

Analysis of variance for Potassium uptake by plant at different stages and by seed

Source	df	Mean Square				
		20 DAS	40 DAS	60 DAS	Harvest	K uptake of seed
Blocks	7	0.0307	0.2693	3.271	1.834	0.0945
N	3	4.7685**	13.4859**	49.087**	59.963**	2.7307**
P	3	0.2702**	2.846**	9.777**	6.6425**	0.1122
K	3	0.0843	0.6326**	24.004**	1.4342	1.4048**
NP	9	0.0364	0.344	8.539**	1.322	0.2657**
PK	9	0.04453	0.1016	0.7061	0.2582	0.1998*
NK	9	0.0172	0.1188	1.4149	1.9148	0.1285
NPK	24	0.0186	0.1068	0.1765	0.9628	0.0734
Error	60	0.04006	0.1898	1.1627	1.411	0.0848

DAS . Days after sowing

* Significant at 5% level

** Significant at 1% level

APPENDIX XVI

Analysis of variance for total uptake of Nitrogen, Phosphorus and Potassium

Source	df	Mean Square		
		Total uptake of N	Total uptake of P	Total uptake of K
Blocks	7	18.862	1.926	2.040
N	3	461.877**	14.319**	86.168**
P	3	70.406**	8.503**	7.810**
K	3	84.635**	1.695	5.432**
NP	9	19.041	0.749	1.874
PK	9	8.548	0.627	0.547
NK	9	4.703	0.730	1.671
NPK	24	5.136	0.579	0.817
Error	60	13.761	0.894	1.269

* Significant at 5% level

** Significant at 1% level

APPENDIX XVII

Analysis of variance for Nitrogen, Phosphorus and Potassium in soil after experiment

Source	df	Mean Square		
		Total N	Available P_2O_5	Available K_2O
Blocks	7	0.000235	0.433	4.352
N	3	0.00201*	1.3541	8.677
P	3	0.000166	4.583**	4.791
K	3	0.000255	2.755**	3.947
NP	9	0.000191	0.670	0.993
PK	9	0.0000648	0.579	3.852
NK	9	0.000231	0.946	0.652
NPK	24	0.000179	0.355	0.587
Error	60	0.000588	0.611	4.160

* Significant at 5% level

** Significant at 1% level

NUTRITIONAL REQUIREMENT OF PRE-RELEASE SESAMUM CULTURE 42-1 IN GARDEN LAND

By

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ABSTRACT OF A THESIS
Submitted in partial fulfilment of the
requirement for the degree
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1987

ABSTRACT

A 4^3 factorial experiment confounding NPK (3 df) totally in replication I and II was conducted under garden land condition at the Instructional Farm, College of Agriculture, Vellayani, during semirabi season 1984, to study the effect of graded doses of nitrogen (10, 30, 50 and 70 kg/ha), phosphorus (5, 15, 25 and 35 kg P_2O_5/ha) and potassium (10, [ ], 30, 50 and 70 kg K_2O/ha) on the growth, yield, quality, content and uptake of mineral nutrients and also to work out the economics of production with the pre-release sesamum culture 42-1 (now released as Soorya or ACV-2).

The study revealed that application of nitrogen significantly influenced growth, yield and yield attributing characters. Phosphorus and potassium produced significant influence on number of leaves and leaf area index on 40 and 60 days after sowing. Significant effect of phosphorus was also observed on number of branches, pod-seed ratio, bhusa yield, thousand seed weight and total dry matter production. Applied potassium significantly influenced the yield and yield attributing characters like number of pods, weight of pod per plant, weight of seed per plant, pod-seed ratio, seed yield and harvest index.

Nitrogen, phosphorus and potassium produced significant influence on oil and protein content of sesamum seed. Maximum oil yield was obtained at the level of 50 kg N, 25 kg P_2O_5 and 30 kg K_2O per hectare. Protein content was also highest at the level of 50 kg N, 35 kg P_2O_5 and 70 kg K_2O per hectare.

Applied nitrogen significantly influenced the nitrogen, phosphorus and potassium content of plant, seed and its uptake. Phosphorus could influence nitrogen content only on 20 days after sowing, but it influenced phosphorus content and total uptake of N, P and K. Potassium also produced significant influence on potassium content and total uptake of N, P and K.

The seed yield as well as profit were highest with 30 kg N, 15 kg P_2O_5 and 70 kg K_2O/ha. So the most advantageous fertilizer dose for sesamum culture 42-1 is a combination of 30 kg N, 15 kg P_2O_5 and 70 kg K_2O / ha ($n_2p_2k_4$) under garden land conditions of Vellayani.