NUTRIENT REQUIREMENT OF MANGO — GINGER (*Curcuma amada* Roxb.)

By

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Thesis

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DECLARATION

I hereby declare that this thesis entitled **"Nutrient requirement of mango-ginger (*Curcuma amada* Roxb.)"** 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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CERTIFICATE

Certified that this thesis, entitled "**Nutrient requirement of mango-ginger (*Curcuma amada* Roxb.)**" is a record of research work done independently by **Smt. MRIDULA. K.R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

A.O.A.C.	-	Association of Official Agricultural Chemists
BR	-	Bulking Rate
CGR	-	Crop Growth Rate
DAP	-	Days After Planting
DMP	-	Dry Matter Production
HI	-	Harvest Index
LAI	-	Leaf Area Index
NAR	-	Net Assimilation Rate
NVEE	-	Non-Volatile Ether Extract
UI	-	Utilization Index

INTRODUCTION

INTRODUCTION

The dependence of mankind on plant resources is inevitable. In spite of the rich flora that offers great promise, man depends only on a very small fraction of the plant wealth. Of the global wealth of 80,000 edible plants, only about 150 fall in the major useful category and of these about 20 species provide 90 per cent of the world's food. Considering the potential usefulness of such under-utilised and under-exploited plant species and the need for producing more food, fodder, medicine and other basic necessities for rapidly increasing population, Nair (1984), Randhawa (1988) and Paroda (1988) emphasized the importance of popularising the under-utilised and under-exploited plant species.

Mango-ginger (*Curcuma amada* Roxb.) is an under-exploited, but important spice crop, belonging to the family Zingiberaceae. It is a perennial herb grown as an annual for its rhizomes. In addition to Kerala, it is cultivated in Bengal, Assam, Konkan Coast, Andhra Pradesh, Orissa and Tamil Nadu. The rhizomes possess gracious flavour, profile scent of fresh mango mingled with mild turmeric and ginger notes and sweet, bitter and cooling sensation of the tongue (Verghese, 1990).

Mango-ginger (*Curcuma amada* Roxb.) and turmeric (*Curcuma longa* L.) belong to the same genus *Curcuma* and the morphological features and growth pattern of these crops have many similarities. However, the crop duration for mango-ginger is shorter, maturing within six months. The leaves are broader than turmeric and dark green in colour. The rhizomes of mango-ginger have many resemblance to those of true ginger and also have mango-like flavour but they have no pungency like ginger.

The rhizomes of mango-ginger are used for preparing chutneys, pickles, salads, meat products and other culinary preparations. According to Sankaram (1942) the pickle prepared using mango-ginger, lime juice, chillies and salt is a special favourite for Andhra people. The rhizomes have excellent medicinal properties, alexiteric, antipyretic, laxative, useful as stomachic, carminative, in the treatment of biliousness, itching, skin diseases, bronchitis asthma, hiccough and inflamation due to injuries. In the crushed pulp form it is applied over contusions, sprains, and bruises for rapid healing (Verghese, 1990). Mango-ginger rhizomes contain 1.1 per cent essential oil (Anon., 1950). The essential oil has anti-fungal properties (Barthakur and Bordoloi, 1992).

Mango-ginger is grown in a limited extent in the homesteads of Kerala. It is one of the crop components grown along with other annual and perennial crops. The coconut chutney with the mango-ginger is a preferred item to get the mango flavour. The pickle prepared from mango-ginger has good demand now a days. There is scope for exploiting and popularising this crop. Package of practices recommendations for the scientific cultivation of mango-ginger has to be standardised.

Thus, the present study on "Nutrient requirement of mango-ginger (*Curcuma amada* Roxb.)" was taken up with the following objectives.

1. To find out the effects of nitrogen, phosphorus and potassium on the growth, yield and quality of mango-ginger.

2. To find out the optimum dose of nitrogen, phosphorus and potassium for high yield and

3. To work out the economics of cultivation under varying nutrient levels.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Mango-ginger is cultivated in a limited extent in homesteads of Kerala. Research work on this under-exploited but important spice crop is very scanty. According to Sankaram (1942) the crop responded fairly well to manuring. But information regarding fertilizer requirement of mango-ginger is meagre. However the significance of fertilizer application in relation to growth, yield and quality of related spice crops, namely turmeric and ginger has been brought out by many works.

The research works on fertilizer requirement of turmeric and ginger along with other related crops are reviewed.

NITROGEN

Nitrogen is considered as the kingpin in crop nutrition and one of the main function of nitrogen is to promote vegetative growth. It is an integral component of chlorophyll, enzymes and amino acids and is essential for carbohydrate utilization within plants. Nitrogen stimulate root growth and development as well as uptake of other nutrients (Brady, 1996).

Effect on growth

Nitrogen application significantly increased plant height and number of tillers per plant in turmeric (Nair, 1964). Application of 120 kg N ha^{-1} increased the plant height, number of leaves, tillers and leaf area in turmeric (Balashanmugam and Chezhiyan, 1986). Application of nitrogen produced significant effect on plant height, vegetative characters and girth of plants except number of leaves in turmeric. Maximum number of tillers per plant was recorded when 200 kg N ha^{-1} was applied in turmeric (Pandey, 1993).

Dasaradhi *et al.* (1971) observed the importance of nitrogen at the active growth and tillering stage of ginger during which nitrogen consumption was high and the leaves contained 3 per cent nitrogen. Nitrogen at the rate of 70 kg ha^{-1} increased significantly the number of tillers in ginger (Muralidharan *et al.*, 1974). There was a progressive increase in plant height and number of tillers per plant with an increase in the nitrogen applied upto 90 kg ha^{-1} in ginger (Aclan and Quisumbing, 1976).

Application of 56-112 kg N ha^{-1} decreased dry matter content in ginger (Aiyadurai, 1966).

Leaf area index was increased by nitrogen application in sweet potato (*Ipomoea batatas* L.). Nitrogen application also increased CGR and total plant dry weight (Bourke, 1985).

Effect on yield

Nitrogen has a significant effect on the yield and yield supporting characters in turmeric (Nair, 1964). Aiyadurai (1966) found that application of 100 kg ha^{-1} of ammonium sulphate doubled the yield over that of unmanured crop. Application of 100 kg N ha^{-1} was found sufficient for maximum yield in Wynad (Muralidharan and Balakrishnan, 1972). In Andhra Pradesh, Rao *et al.* (1975) and Rao and Reddy (1977) reported response to very high doses of 189 and 375 kg N ha^{-1}. According to Ahmedshah and Muthuswamy (1981) application of 140 kg N ha^{-1} along with 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} recorded 56.9 per cent higher yield than the plants which received no nitrogen. Studies in Punjab (Randhawa *et al.*, 1984) did not reveal any significant response to N application. Increase in N levels upto 120 kg ha^{-1} signifiantly increased the fresh rhizome yield in turmeric (Umate *et al.*, 1984; Balashanmugam and Chezhiyan, 1986). Application of 40 kg N ha^{-1} gave signifiantly higher yield (Govind *et al.*, 1990). Pandey (1993) reported maximum yield of fresh rhizome in turmeric by the application of 160 kg N ha^{-1}.

In ginger, Samad (1953) recorded increase in yield with 100 kg N ha^{-1}. Increases in yield of ginger by N application were reported by Aiyadurai (1966). Higher doses of N decreased the yield (Muralidharan, 1973). Application 70 of kg N ha^{-1} increased significantly the yield of ginger (Muralidharan *et al.*, 1974). The yield of ginger doubled when the N level was increased from 30 to 90 kg ha^{-1} (Aclan and Quiscumbing, 1976). Sadanandan and Sasidharan (1979) found that the effect of N on yield of ginger was significant and the highest yield was recorded at

50 kg N ha^{-1}, and when the levels were further increased yield reduction was observed.

According to Lee *et al.* (1981) in ginger, fertilizer nitrogen significantly increased the number of third order shoots and fourth order rhizome branches and the total yields of shoots and rhizomes and a N dose of 200-300 kg ha^{-1} gave maximum yield. Nitrogen use efficiency decreased with increasing rate of N application in ginger (Lee *et al.*, 1981).

Patil (1987) observed that N application along with biofertilizers also enhanced yield in ginger. Application of N was reported to be ineffective in ginger (Anon., 1994).

Wormer (1934) reported that abundant supply of nitrogen will favour top growth and impair the process of tuberisation by diverting more energy to vegetative growth, while relatively low doses of N can reduce vigorous top growth and hasten process of tuberisation. Wilson (1964) reported similar results in cassava (*Manihot esculenta*).

Effect on quality

In turmeric N at 80 kg ha^{-1} gave highest curcumin content and increasing N fertilizer above this dose decreased the curcumin content of rhizome (Singh *et al.*, 1992). Vijayakumar *et al.* (1992) also found that nitrogenous fertilizer increased curcumin content of rhizome.

Saraswat (1972) found adverse effect of N on oil content of ginger. But the fibre and starch contents of ginger were not affected by N (Aclan and Quisumbing, 1976). Nair and Das (1982) found that planofix alone as well as the combinations of 2 per cent urea and 400 ppm planofix led to greater accumulation of oleoresin, though urea alone failed to produce any significant result. But crude fibre content was not influenced by N application in ginger.

Rao *et al.* (1983) opined that N has considerable influence on essential oil content in coriander (*Coriandrum sativum*). According to Rahman *et al.* (1990) essential oil content of coriander seeds was found to be increasing with the increase in N application from 0 to 60 kg ha^{-1}.

Increasing the levels of nitrogen reduced the starch content in colocasia (*Colocasia esculenta*) (Anon., 1980). Premraj (1980) also observed that in colocasia, at lower level of N starch content was highest and vice versa. Ashokan and Nair (1984) observed that starch content of colocasia cormels increased significantly with increasing levels of nitrogen. Patel and Mehta (1987) found that applied N increased the nitrogen, phosphorus, potassium and starch content in corms of elephant foot yam (*Amorphophallus companulatus*).

Ramanujam (1986) observed that the chlorophyll content of the leaf was significantly increased by higher levels of N in cassava.

Effect on nutrient uptake

Nitrogenous fertilizer application improved the vigour of turmeric plants and resulted in increased uptake and accumulation of other nutrients in rhizomes (Lynrah, 1991). Application of 80 kg N ha^{-1} had better effect on nitrogen, phosphorus and potassium accumulation in the turmeric rhizome (Singh *et al.*, 1992).

According to Lee and Asher (1981) in ginger increased leaf nitrogen concentration was observed with 336 kg N ha^{-1}. The total N in ginger shoots and rhizomes increased with increasing N application in ginger (Lee *et al.*, 1981).

In general, nitrogen encourages vegetative growth and controls to some extent the effective utilization of phosphorus and potassium.

PHOSPHORUS

A good supply of phosphorus has been associated with increased root growth of crops. Plant roots proliferate extensively in the areas of phosphate treated soil (Tisdale *et al.*, 1995). Phosphorus is essential for plant growth and metabolism and it plays a critical role in the life cycle of plants (Brady, 1996).

Effect on growth

Purewal and Dargon (1957) found that application of phosphorus had no effect on height of plants, leaf area and number of leaves in colocasia. Influence of phosphorus on improving plant height was documented in cassava by Ngongi (1976). Increase in LAI and UI due to phosphorus was reported by Nair (1986) in cassava.

Effect on yield

Response to applied phosphorus in turmeric has been reported upto 175 kg ha^{-1} with the combination of other nutrients (Rao and Reddy, 1977). Gupta *et al.* (1990) obtained highest yield, fresh weight of rhizome and curing percentage with 90 kg P_2O_5 ha^{-1} in turmeric.

Phosphatic fertilization with 56-112 kg P_2O_5 ha^{-1} not only registered 14-20 per cent higher yield, but also improved the dry matter content of rhizomes in ginger (Aiyadurai, 1966). Phosphorus at 20 and 40 kg ha^{-1} increased the yield by 21.5 and 11.5 per cent respectively (Saraswat, 1972). The response of P in ginger was not clear in some cases (Anon., 1953; Muralidharan *et al.*, 1974; Aclan and Quisumbing, 1976).

Effect on quality

Aclan and Quisumbing (1976) observed that P has no effect on yield and fibre content of ginger rhizomes.

Effect on nutrient uptake

Application of P increased the P content but decreased the K content of taro leaves (Pena, 1967).

Thus phosphorus influences the vigour of plants and encourages the formation of new cells, promotes root growth and hastens leaf development.

POTASSIUM

Potassium is essential for photosynthesis, protein synthesis, for starch formation and translocation of sugars and tuber development (Brady, 1996).

Effect on growth

Application of highest level of K (240 kg ha^{-1}) recorded the highest plant height, tiller number, number of leaves and number of mother, primary and secondary rhizomes in turmeric (Rathinavel, 1983).

A higher dose of potassium reduced height of ginger plants (Muralidharan *et al*., 1974).

Potassium increased plant height and leaf area but it had no effect on the number of leaves of colocasia (Purewal and Dargon, 1957). They also reported an increase in plant height and leaf area due to application of potassium. Karikari (1974) stated that potassium fertilizer had a corresponding effect on leaf area in cocoyam (*Dioscorea* spp). Premraj (1980) found that plant height, stem girth, leaf number and leaf area were increased with increasing levels of potassium in colacasia. Ashokan and Nair (1984) stated that the height of plants and number of leaves produced per plant in taro were not significantly influenced by higher levels of potassium. They further observed that the number of suckers per plant was maximum and significnatly superior with 80 kg of potassium compared to 40 and 120 kg K_2O ha^{-1}. Bourke (1985) observed that K application was found to increase total plant dry weight in sweet potato.

Effect on yield

Application of K significnatly increased yield with 180 kg K_2O ha^{-1} and the highest level of K (240 kg ha^{-1}) recorded highest yield in turmeric (Rathinavel, 1983). Muthuvel *et al*. (1989) did not observe any significant effect due to varying levels of K on CO-1 turmeric and suggested that 60 kg K_2O ha^{-1} was adequate. Thamburaj (1991) observed that application of K at 90 kg ha^{-1} in four splits recorded higher yield of rhizomes in turmeric.

Anon. (1953) and Saraswat (1972) revealed that there was no response for potassium, in ginger. Higher dose of potassium reduced yield in ginger (Muralidharan *et al.*, 1974).

Effect on quality

Mohanbabu and Muthuswamy (1984) and Ahmedshah *et al.* (1988) observed that graded doses of potassium significantly improved the curcumin content of rhizomes in turmeric. A high percentage of curcumin (3.21) was found with application of 90 kg K_2O ha^{-1} in the mother rhizome while at 60 kg K_2O ha^{-1}, both primary and secondary rhizomes had higher levels of curcumin (3.13 and 2.82% respectively).

Potassium increased the starch content of colocasia tubers (Premraj, 1980). Mohandas and Sethumadhavan (1980) reported that higher levels of potassium upto 150 kg ha^{-1} had a positive influence on starch content of taro tubers compared to 90 kg ha^{-1}. Ashokan and Nair (1984) observed that dry matter percentage and starch content were not positively influenced by potassium levels, in colocasia.

Muthuswamy (1983) reported that increasing levels of potassium had no influence on crude protein and crude fibre content but there was an increase in dry matter accumulation in elephant foot yam. Nair and Aiyer (1985) recorded that with increase in the levels of potassium upto 100 kg ha^{-1} there was negative response of fibre content in cassava.

Effect on nutrient uptake

Singh *et al.* (1992) observed that application of potassium significantly increased N, P and K content in turmeric rhizome and the increase was more pronounced with increasing doses of potassium.

Application of K increased K content but decreased Ca and Mg contents in taro leaves (Pena, 1967). Application of potassium recorded increase of N, P and K content in turnip (*Brassica rapa* L.) (Rajput and Singh, 1981).

In general, potassium exerts a balancing effect on the effect of both nitrogen and phosphorus, consequently it is especially important in multinutrient fertilizer use (Brady, 1996).

EFFECT OF COMBINED APPLICATION OF N, P AND K

Effect on growth

Increased tillering and plant height resulted in turmeric with application of 312.5 : 112.5 : 200 kg NPK ha^{-1} (Rao and Reddy, 1977). In turmeric an increasing trend in the number of tillers as well as leaf production with increasing fertilization upto 40:40:80 kg NPK ha^{-1} in the shade was observed (Anon.,1983). However NPK 30:30:60 kg ha^{-1} recorded the maximum height in the shade and NPK 20:20:40 kg ha^{-1} in the open. Application of 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} increased plant height and branch numbers in ginger (Randhawa and Nandpuri 1969).

Application of 112.5:75:75 kg N, P_2O_5 and K_2O ha^{-1} produced maximum plant height, number of tillers and leaves, NAR and total chlorophyll, chlorophyll a and b, in ginger. CGR and DMP was also found to be significantly higher with this level. LAI found to be increasing with increased fertilizer levels (Ancy, 1992).

According to Pillai (1967) in colocasia, plant height and number of suckers were not significantly influenced by application of nitrogen, phosphorus and potassium. The largest leaf area was recorded under the combination of 80 kg nitrogen and 65 kg potassium ha^{-1}.

Saiev (1978) found that leaf area $plant^{-1}$ increased with increase in the rate of applied NP and NPK in potato. Hafizuddin and Haque (1979) observed that length of vine was not affected by N and K treatments in sweet potato.

Nambiar *et al.* (1976) reported no significant effect on the weight of vine in sweet potato due to increased fertilizer application. Geetha (1983) opined that N at the rate of 60 kg ha^{-1} and K at the rate of 120 kg ha^{-1} were sufficient to produce the highest dry matter yield in coleus (*Coleus parviflorus* Benth.). The dry matter production increased significantly due to the application of different levels of N, P and K in potato (Rajanna *et al.*, 1987). Total dry weight at harvest stage did not vary significantly due to fertilizer levels in crops like lesser yam, tannia (*Xanthosoma sagittifolium*), and elephant foot yam but in greater yam (*Dioscorea alata*) dry matter production was found to be the highest at the highest fertilizer dose of 80:60:80 kg NPK ha^{-1} (Pushpakumari, 1989).

In tannia, fertilizer treatments did not show any significant influence on the LAI at any stage of growth whereas in greater yam, LAI was found to be significantly influenced by different fertilizer levels at 190 DAP and maximum LAI was observed for the highest fertilizer dose of 80:60:80 kg NPK ha^{-1}. NAR in crops like lesser yam, greater yam, elephant foot yam and tannia and CGR in tannia did not vary significantly due to fertilizer levels. But in greater yam highest fertilizer dose (80:60:80 kg NPK ha^{-1}) gave significantly lower CGR (Pushpakumari, 1989).

Effect on yield

Muralidharan and Balakrishnan (1972) observed that 100:100:200 kg NPK ha^{-1} gave significantly higher yield in turmeric. Rao (1973) recorded highest yield through split application of fertilizers containing 312.5 kg N, 112.5 kg P_2O_5 and 200 kg K_2O ha^{-1}. Rao and Reddy (1977) observed that the yield of fresh rhizomes increased significantly with increased doses of N, P and K and highest level of fertilization (375, 225 and 237.5 kg NPK ha^{-1}) gave highest yield of fresh rhizomes in turmeric. Shankaraiah and Reddy (1988) reported that a high dose of 250:80:200 kg $N:P_2O_5:K_2O$ ha^{-1} gave the highest yield of fresh rhizome in turmeric. Muthuvel *et al.* (1989) reported that 90 kg N and 60 kg K_2O ha^{-1} had a better effect on the yield of turmeric.

Singh and Lynrah (1991) suggested that application of 80 kg N and 80 kg K_2O ha^{-1} form an optimum dose of fertilization in turmeric. Highest yield of turmeric was obtained with N at 40 kg ha^{-1} and P_2O_5 at 20 kg ha^{-1} (Sheogovino *et al.*, 1990). Singh *et al.* (1992) found that application of 80 kg N, 80 kg P_2O_5 and 80 kg K_2O ha^{-1} increased the productivity of turmeric.

According to Sadanandan and Hamza (1996) there was a significant increase in rhizome yield due to application of NPK in the four turmeric varieties namely "Suvarna," "Suguna," "Sudarshana" and "Alleppey" turmeric. Application of 90:75:180 kg ha^{-1} NPK with micronutrients were superior and on par with the same level of fertilizer without micronutrients. They also recommended 68:56 and 136 kg NPK ha^{-1} for "Suguna," 51:42:101 kg NPK ha^{-1} for "Sudarshana" and 58:48:and 116 kg NPK ha^{-1} for "Alleppey" as the optimum dose.

In ginger, bulking rate was found to be maximum with highest level of fertilizer application (Ancy, 1992). She also reported lowest values of UI and HI with higher levels of fertilizer application.

Lokanath and Dash (1964) observed significant increase in yield with the application of 60 kg N, 40 kg P_2O_5 and 60 kg K_2O ha^{-1} whereas Thomas (1965) obtained no significant response with 4 levels of N (0, 50, 100 and 150 kg ha^{-1}) and 3 levels of P_2O_5 (0, 45 and 90 kg ha^{-1}) in ginger. Kannan and Nair (1965) recommended 36 kg N, 36 kg P_2O_5 and 72 kg K_2O ha^{-1} for optimum yield of ginger. Application of N and P each at 57 and 114 kg ha^{-1} increased the total yield by 18-32 per cent and 13-19 per cent respectively in ginger (Aiyadurai, 1966). Nair (1969) and Paulose (1970) recommended 60:60:150 kg NPK ha^{-1} for economic yield of ginger. Randhawa and Nandpuri (1969) found that the combination of 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1} as the best for ginger. Application of N above 50 kg ha^{-1} reduced the yield of ginger significantly, P and K had no significant effect on the yield at the levels studied (Muralidharan, 1973). The yield of ginger doubled with the application of 30 kg N ha^{-1}. Yield also increased slightly with that of potassium but not with phosphorus (Aclan and Quisumbing, 1976).

Saha (1989) obtained highest yield of fresh ginger rhizomes with N_{90} P_{60} K_{90} kg ha^{-1}. Maximum yield of ginger was obtained with N_{125} P_{70} K_{150} kg ha^{-1} (Mohanty *et al.*, 1992).

Highest green ginger yield was obtained with highest fertilizer dose of 112.5:75:75 kg NPK ha^{-1}. Under open conditions, 93.75:62.5:62.5 kg NPK ha^{-1} was found to give highest dry ginger yield and at 25 per cent shade level 112.5:75:75 kg NPK ha^{-1} produced higher dry ginger yield. (Ancy, 1992). She also found an increasing trend in top yield of ginger with increasing fertilizer doses.

Loue (1979) pointed out that N and K fertilizers increased the size of tubers in potato. Fertilizer levels were reported to influence the length and girth of tubers in lesser yam (Sasidharan, 1985). Pushpakumari (1989) observed no significant difference in the length of tuber in lesser yam with varying fertilizer levels whereas in greater yam, the plants receiving the highest fertilizer dose 80:60:80 kg NPK ha^{-1} recorded maximum tuber length when grown as intercrops in coconut garden.

Sasidharan (1985) observed no significant influence of fertilizer levels on the bulking rate of tuber in lesser yam. According to Pushpakumari (1989) bulking rate was not significantly influenced by fertilizer levels for crops like lesser yam, tannia and elephant foot yam.

Satyanarayana and Arora (1985) observed that in potato 150 kg N and 120 kg K_2O ha^{-1} resulted in larger tubers, higher bulking rate and higher tuber yield. In potato, Roy and Tripathi

(1986) found that yield was increasing with increasing NPK rates and were highest with 225 kg each of N, P_2O_5 and K_2O ha^{-1}

Greater yam recorded highest yield at highest fertilizer dose of 80:60:60 kg NPK ha^{-1} when grown as intercrop in coconut garden, whereas in lesser yam maximum yield was at medium fertilizer level and in elephant foot yam at lowest level (Pushpakumari, 1989).

Greater yam and elephant foot yam recorded significantly lower top yields at lowest fertilizer levels of 40:30:40 and 40:30:50 kg NPK ha^{-1} respectively (Pushpakumari, 1989).

Mahabaleshwar *et al*. (1990) reported that in tapioca highest yield was obtained with N_{120} P_{60} K_{180} kg ha^{-1} beyond which vegetative growth was promoted. It was also observed that the dry matter of the tubers were low at higher rate of fertilizers and suggested that this may be due to more retention of moisture in the soil and tubers due to higher nutrient contents in soil.

Effect on quality

The curing percentage of turmeric was found to be influenced by fertilizer application (Rao, 1965). Higher levels of N, P and K recorded a lower percentage of curing and curcumin content (Rao and Reddy, 1978).

Saifuddin (1981) observed that oleoresin content of turmeric remained unaffected by the application of graded doses of NPK. Singh *et al.* (1992) found that application of 80 kg N, 80 kg P_2O_5 and 80 kg K_2O ha^{-1} gave increasing productivity of turmeric with enhanced accumulation of N, P and K contents as well as curcumin content in rhizomes. NPK @ 30, 25, 60 kg ha^{-1} plus micronutrients gave the highest curcumin recovery in turmeric (Sadanandan and Hamza, 1996).

Aclan and Quisumbing (1976) reported that none of the three elements N, P and K influenced fibre content of ginger rhizomes. Ancy (1992) observed that fertilizers have not affected the volatile oil, NVEE and fibre content of ginger rhizomes. The quality of ginger rhizomes was not adversely affected by increased levels of fertilizer application (Ancy and Jayachandran, 1993).

Carvenho *et al.* (1983) observed no significant effect of fertilizers on crude protein and fibre content of sweet potato. Geetha (1983) observed that the application of nitrogen and phosphorus each at 90 kg ha^{-1} enhanced protein content and starch content in coleus. In lesser yam crude fibre content was not influenced by different levels of fertilizers (Sasidharan, 1985).

Effect on nutrient uptake

The NPK concentration in plant tops and tubers of potato increased with increase in NPK and irrigation rates (Roy and Tripathi, 1986). Sharma and Grewal (1991) reported that N, P and K uptake by potato crop increased progressively with increase in their rate of application and the nutrient uptake was found closely linked with productivity.

The uptake of N, P and K were found to be maximum with the highest level of applied fertilizers in ginger (Ancy, 1992).

MATERIALS AND METHODS

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A field experiment was conducted to study the effects of nitrogen, phosphorus, potassium and their interactions on growth, yield, quality and nutrient uptake of mango-ginger, at the Instructional Farm, College of Agriculture, Vellayani, during the year 1995. The details of the materials used and methods followed are presented.

Experimental site

The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, situated at 8°5' North latitude and 77°1' East longitude, and at an altitude of 29 m above mean sea level.

Soil

The soil of the experimental area was lateritic red loam belonging to the Vellayani series. The physical and chemical characteristics of experimental field are given in Table 1.

Table 1 Soil characteristics of the experimental field

A. Mechanical composition

Coarse sand	:	16%
Fine sand	:	47%
Silt	:	12%
Clay	:	23%

B. Chemical properties

Available nitrogen (kg ha^{-1})	:	158.8
Available P_2O_5 (kg ha^{-1})	:	16.4
Available K_2O (kg ha^{-1})	:	128.6
pH	:	5.2

Cropping history of the field

The experimental field was under mulberry cultivation for the last two years.

Season

The experiment was carried out in June to December 1995.

MATERIALS

Planting materials

Healthy and disease free rhizome bits each weighing 15 g were used for the experiment.

Manures and fertilizers

A uniform dose of 40 tonnes of cattle manure per hectare was applied in the experimental area at the time of planting. The fertilizers used for the experiment were urea (46% N), Super phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O).

METHODS

Design and Layout

The experiment was laid out as 3^3 + 1 factorial design in randomised blocks with 3 replications. The layout of the experiment is given in Figure 1. The details of the layout are given below.

No. of treatments	-	28
No. of blocks	-	3
No. of plots in a block	-	28
Total no. of plots	-	84
Plot size	-	1.2 x 3 m
Spacing	-	30 x 30 cm
Replications	-	3

Treatments

The treatments consisted of 3 levels each of N, P_2O_5 and K_2O and their combinations with absolute control as detailed below.

N

Fig 1. LAYOUT PLAN - $3^3 + 1$ FACTORIAL RANDOMISED BLOCK DESIGN

3m × 1.2 m (plot size); 40 cm (spacing)

$N_3P_1K_2$	$N_1P_3K_3$	$N_3P_1K_3$	$N_2P_1K_2$	$N_2P_3K_3$	$N_2P_2K_3$	$N_3P_3K_2$	$N_3P_1K_3$	$N_1P_3K_2$	$N_2P_2K_1$	$N_1P_2K_1$	$N_1P_1K_2$
$N_1P_3K_2$	$N_3P_3K_2$	$N_1P_2K_3$	$N_1P_3K_1$	$N_2P_3K_1$	$N_3P_2K_2$	$N_2P_2K_1$	$N_3P_3K_1$	$N_3P_3K_2$	$N_1P_1K_3$	$N_1P_2K_2$	$N_3P_3K_3$
$N_2P_3K_3$	$N_1P_2K_2$	$N_2P_1K_3$	$N_1P_1K_1$	$N_3P_1K_2$	$N_3P_3K_3$	$N_2P_2K_2$	$N_2P_3K_2$	$N_2P_1K_1$	$N_0P_0K_0$	$N_1P_1K_1$	$N_3P_1K_3$
$N_3P_2K_3$	$N_3P_1K_1$	$N_2P_2K_1$	$N_2P_1K_1$	$N_3P_1K_1$	$N_0P_0K_0$	$N_1P_3K_3$	$N_3P_2K_3$	$N_1P_3K_1$	$N_3P_2K_1$	$N_1P_3K_3$	$N_2P_3K_2$
$N_3P_2K_2$	$N_2P_3K_2$	$N_2P_2K_3$	$N_3P_3K_1$	$N_1P_2K_3$	$N_1P_1K_2$	$N_1P_1K_3$	$N_3P_2K_1$	$N_3P_3K_1$	$N_2P_1K_2$	$N_2P_2K_2$	$N_1P_1K_2$
$N_2P_2K_2$	$N_2P_3K_1$	$N_1P_1K_2$	$N_1P_2K_1$	$N_2P_1K_2$	$N_1P_2K_1$	$N_1P_3K_2$	$N_1P_1K_1$	$N_2P_3K_1$	$N_1P_2K_3$.	$N_3P_2K_3$	$N_3P_1K_1$
$N_1P_1K_3$	$N_3P_2K_1$	$N_3P_3K_3$	$N_0P_0K_0$	$N_1P_3K_1$	$N_1P_2K_2$	$N_2P_1K_1$	$N_2P_1K_3$	$N_2P_3K_3$	$N_3P_2K_2$	$N_2P_1K_3$	$N_2P_2K_3$
Replication I				Replication II				Replication III			

(i) Levels of nitrogen

N_1 - 15 kg N ha^{-1}

N_2 - 30 kg N ha^{-1}

N_3 - 45 kg N ha^{-1}

(ii) Levels of phosphorus

P_1 - 15 kg P_2O_5 ha^{-1}

P_2 - 30 kg P_2O_5 ha^{-1}

P_3 - 45 kg P_2O_5 ha^{-1}

(iii) Levels of potassium

K_1 - 30 kg K_2O ha^{-1}

K_2 - 60 kg K_2O ha^{-1}

K_3 - 90 kg K_2O ha^{-1}

(iv) Absolute control

N_0 P_0 K_0 - No fertilizer

The different treatment combinations were as follows.

N_1 P_1 K_1	N_2 P_1 K_1	N_3 P_1 K_1
N_1 P_1 K_2	N_2 P_1 K_2	N_3 P_1 K_2
N_1 P_1 K_3	N_2 P_1 K_3	N_3 P_1 K_3
N_1 P_2 K_1	N_2 P_2 K_1	N_3 P_2 K_1
N_1 P_2 K_2	N_2 P_2 K_2	N_3 P_2 K_2
N_1 P_2 K_3	N_2 P_2 K_3	N_3 P_2 K_3
N_1 P_3 K_1	N_2 P_3 K_1	N_3 P_3 K_1
N_1 P_3 K_2	N_2 P_3 K_2	N_3 P_3 K_2
N_1 P_3 K_3	N_2 P_3 K_3	N_3 P_3 K_3

Plate 1 & 2

Field views of the experimental plot

Plate 1

Plate 2

Land preparation and planting

The mainfield was dug twice and beds of size 1.2 x 3 m were laid out with a spacing of 40 cm between beds. Individual beds were again dug and levelled. Small pits were taken at a spacing of 30 x 30 cm in these beds and farm yard manure at the rate of 40 t ha^{-1} was applied as basal dose. Seed rhizomes were planted in the pits at a depth of 4-5 cm. The pits were then covered with soil.

Application of fertilizer

Full dose of P and half dose of K as basal dose, 2/3 N at 30 DAP and 1/3 N plus remaining K at 60 DAP, applied as per treatments except the control.

Mulching

Mulching was done immediately after planting with green leaves at the rate of 15 t ha^{-1} and repeated after 50 days with same quantity of green leaves.

After cultivation

Hand weeding was done at 30, 60 and 120 days after planting and earthing up was done after 60 days.

Plant protection

Incidence of shoot borers (*Dichocrocis punctiferalis*) was noticed and it was kept under check by periodic spraying of quinalphos.

Observations

Five plants were selected at random as observational plants for recording observations and the mean was worked out. Observations on plant height, number of tillers and leaves per plant were taken on 60, 105 and 150 DAP. Observations on dry matter production were taken on 90, 120 and 150 DAP. Yield was recorded at 180 DAP.

A. Growth parameters

Sprouting

The number of plants germinated was counted at 45 DAP and expressed as percentage.

Plant height

The height of the plant was measured from the base of the plant to the tip of the youngest fully opened leaf and expressed in cm.

Number of tillers per plant

The number of aerial shoots arising around a single plant was counted and expressed as the number of tillers per plant.

Number of leaves per plant

The number of fully opened leaves was taken.

Leaf area index (LAI)

Leaf area index was calculated at 90, 120 and 150 DAP. Five sample plants were randomly selected for each treatment, and the number of leaves was counted on each plant. Maximum length (from the base of the leaf excluding the petiole, to the tip) and maximum width of leaves from all the sample plants were recorded separately and leaf area was computed based on the length breadth method.

The relationship between leaf area (Y) and the product of length and breadth (X) was found to be Y = 9.026 + 0.6245 X.

This relationship was utilized for estimating the leaf area. And the leaf area index (LAI) was computed using the following equation.

$$\text{Leaf area index (LAI)} = \frac{\text{Sum of leaf area of N sample plants } (cm^2)}{\text{Area of land covered by N plants } (cm^2)}$$

Dry matter production (DMP)

Pseudostem, leaves and rhizomes of the uprooted plants were separated and dried to constant weight at 70-80°C in a hot air oven. The sum of the dry weight of the components gave the dry matter yield and expressed as g $plant^{-1}$.

Net Assimilation Rate (NAR)

The procedure given by Watson (1958) as modified by Buttery (1970) was followed. The following formula was used to derive NAR and expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{\frac{(t_2 - t_1)\,(A_1 + A_2)}{2}} \quad \text{where}$$

W_2 - total dry weight of plant g m^{-2} at time t_2.

W_1 - total dry weight of plant g m^{-2} at time t_1.

$(t_2 - t_1)$ - time interval in days

A_2 - Leaf area index at time t_2.

A_1 - Leaf area index at time t_1.

Crop growth rate (CGR)

CGR was calculated using the formula of Watson (1958).

CGR = NAR x LAI expressed as g m^{-2} day^{-1}

B. Yield parameters

Rhizome spread

The length of rhizome was measured and the mean value expressed in cm.

Bulking rate (BR)

The rate of bulking in rhizome was worked out on the basis of increase in dry weight of rhizome and expressed in g $plant^{-1}$ day^{-1}.

$$\text{Bulking rate} = \frac{W_2 - W_1}{t_2 - t_1} \quad \text{where}$$

W_2 - Dry weight of rhizome at time t_2.

W_1 - Dry weight of rhizome at time t_1.

Top yield

The yield of top in individual treatments was recorded from the net area and expressed in kg ha^{-1} on dry weight basis.

Rhizome yield

The yield of fresh rhizomes from each treatment was recorded from the net area and expressed in kg ha^{-1}.

Drying percentage and recovery of dry rhizome

Immediately after harvest, rhizome samples were taken from each treatment. The skin of rhizome was scraped off and cleaned thoroughly. They were chopped into small pieces for easy drying and were dried in sun for two days. After this the rhizomes were dried to constant weight in a hot air oven at 70-80°C. Drying percentage was calculated and the weight of dry mango-ginger was expressed in kg ha^{-1}.

Utilization index (UI)

Utilization Index is the ratio of the rhizome weight to the top weight. This is calculated from the dry weight of rhizomes and dry weight of top parts.

Harvest index (HI)

Harvest index was calculated as follows.

$$HI = \frac{Yecon}{Ybiol}$$ where

Yecon and Ybiol were dry weight of rhizome and total dry weight of plant respectively.

C. Chemical analysis

Chlorophyll a and b

Chlorophyll a and chlorophyll b content of leaves were estimated at 150 DAP by the spectrophotometric method as described by Starnes and Hadley (1965) and expressed in mg g^{-1} fresh weight.

Volatile oil

The content of volatile oil was estimated by Clevenger distillation method (A.O.A.C., 1975) and expressed as percentage (V/W) on dry weight basis.

Non Volatile Ether Extract (NVEE)

Non-volatile ether extract was estimated by Soxhlet distillation method (A.O.A.C., 1975) and expressed as percentage on dry weight basis.

Fibre content

The crude fibre was estimated by the A.O.A.C. (1975) method and expressed as percentage on dry weight basis.

Starch

Starch content was analysed using copper reduction method (A.O.A.C., 1975) and expressed as percentage on dry weight basis.

Soil Analysis

The soil was analysed for available nitrogen, phosphorus and potassium before and after the experiment. Before the experiment, composite soil samples from different replication and after the experiment treatment wise soil samples were collected for analysis.

Available nitrogen

Available nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

Available phosphorus

Available phosphorus was estimated by chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1958).

Available potassium

Available potassium was determined by ammonium acetate method (Jackson, 1967).

Uptake of nutrients

The nitrogen content of haulm and rhizome was determined by modified micro-kjeldhal method (Jackson, 1973), phosphorus content by the vanadomolybdophosphoric yellow colour method (Jackson, 1973) and potassium content by extraction with neutral normal ammonium acetate extract and then reading in an EEL flame photometer.

The total uptake of nitrogen, phosphorus and potassium was computed from their contents in the plant parts and dry weight. The values were expressed in kg ha^{-1}.

D. Economics of cultivation

Net return

Net return was worked out and expressed in rupees per hectare. Labour charges of locality, cost of inputs and the extra treatment cost were taken together as the expenditure. Price of mango-ginger rhizome at current local market rate was taken as the total receipts and net return was calculated by substracting total (variable) cost of cultivation from the gross return for differnt treatments.

Benefit cost ratio (Return per rupee invested)

This was calculated by using the relationship

$$\text{Return per rupee invested} = \frac{\text{Gross return}}{\text{Total (variable) cost of cultivation}}$$

Return per rupee invested on fertilizers

This was calculated by using the relationship.

$$\text{Return per rupee invested on fertilizers} = \frac{\text{Net return}}{\text{Cost of fertilizers}}$$

E. Statistical analysis

The data relating to each character were analysed using the analysis of variance technique as applied to 3^3+1 factorial experiment in RBD described by Snedecor and Cochran, 1967.

Response function models of different types were fitted to predict the optimum response. It was found that the response pattern could satisfactorily be represented by the quadratic response function of the form

$$Y = b_0 + b_1N + b_2P + b_3K + b_4NP + b_5 NK + b_6 N^2 + b_7P^2 + b_8 K^2$$

where Y is the predicted yield, and N, P and K are the nutrient doses.

The economic dose was estimated by equating the partial derivatives to the respective input/output price ratios.

Correlation analysis of plant characters with yield was also done.

RESULTS

RESULTS

An experiment was laid out in Factorial Randomised Block Design with twenty eight treatments and three replications to find out the optimum dose of nitrogen, phosphorus and potassium for mango-ginger. The results of the study after statistical analysis are presented below.

Sprouting

The data on sprouting as a result of varying levels of N, P, K and their interactions are presented in Table 2 and 3.

The application of phosphorus alone and the combinations NxP, NxK and PxK were found to have significant influence on sprouting percentage of mango-ginger. P_3 (45 kg ha^{-1}) produced higher sprouting (79.52%) and this was on par with P_2 (78.85%). The control registered significantly lower sprouting (51.76%) compared to fertilizer applied plots.

Among NxP combinations, N_3P_2 produced maximum sprouting (84.24%). N_3K_3 gave maximum sprouting (85.81%) among NxK combinations. In case of PxK interaction P_3K_1 (85.30%) showed maximum value for sprouting.

Plant height

The data on plant height presented in Table 2 and 3 revealed that N, P, K and their interactions significantly influenced this character. At 60 and 150 days after planting (DAP) the application of nitrogen influenced plant height with N_1 (15 kg ha^{-1}) and N_2 (30 kg ha^{-1}) giving maximum values (42.77 cm and 101.25 cm respectively). Phosphorus application exerted significant influence only at 150 DAP, when P_2 (30 kg ha^{-1}) registered significantly higher plant height (100.21 cm) compared to P_3 and P_1. Application of 90 kg K_2O ha^{-1} (K_3) produced maximmum plant height throughout growth. Control registered significantly lower plant height compared to treatment at all stages.

NxP interaction was significant at 60 DAP, and at this stage N_1P_1 produced maximum plant height (43.29 cm) and N_3P_1 lower height (38.08 cm). Among NxK interaction N_2K_1 produced maximum plant height at all stages. N_2K_2 produced lower plant height at initial stages and N_1K_1 at later stage. Among PxK interaction P_2K_3 recorded maximum plant height throughout the growth period. P_2K_2 produced lower plant height at initial stages and P_1K_2 during later stage.

Number of tillers per plant

Application of N, P and K was found significantly influencing the number of tiller per plant, throughout the plant growth period (Table 2 and 3). Highest dose of nitrogen (45 kg ha^{-1}) recorded maximum number of tillers at all stages. Effect of N_3 was comparable with N_2 at 60 and 150 DAP, while it was significantly different from the lower doses at 105 DAP.

Table 2 Effect of nitrogen, phosphorus and potassium on sprouting, plant height and number of tillers per plant

Levels of nutrients	Sprouting (%)	Plant height (cm) 60 DAP	105 DAP	150 DAP	Number of tillers per plant 60 DAP	105 DAP	150 DAP
Nitrogen (N kg ha^{-1})							
15 (N_1)	78.44 (62.33)	42.77	73.33	94.67	1.54	4.30	5.37
30 (N_2)	74.45 (59.34)	41.09	73.25	101.21	1.68	4.15	6.26
45 (N_3)	78.86 (62.60)	40.15	71.65	98.78	1.74	4.50	6.49
F test	NS	S	NS	S	S	S	S
Phosphorus (P_2O_5 kg ha^{-1})							
15 (P_1)	72.84 (58.59)	40.61	72.07	96.49	1.77	4.21	5.84
30 (P_2)	78.85 (62.62)	41.69	73.39	100.21	1.53	4.46	6.29
45 (P_3)	79.52 (63.09)	41.71	72.77	97.97	1.66	4.29	5.99
F test	S	NS	NS	S	S	S	S
Potassium (K_2O kg ha^{-1})							
30 (K_1)	77.61 (61.76)	41.86	73.64	96.15	1.67	4.34	5.85
60 (K_2)	76.67 (61.12)	39.82	70.19	97.68	1.59	4.21	5.88
90 (K_3)	77.10 (61.41)	42.34	74.40	100.83	1.70	4.41	6.40
F test	NS	S	S	S	S	S	S
SE	1.012	0.437	0.621	0.525	0.028	0.051	0.099
CD(0.05)	2.87	1.24	1.76	1.49	0.08	0.14	0.28
Control ($N_0P_0K_0$)	51.76 (46.01)	32.40	62.31	92.20	1.13	3.86	5.05
Treatment VS Control	S	S	S	S	S	S	S

( ) Transformed values in bracket

Table 3 Interaction effect of NxP, NxK and PxK on sprouting, plant height and number of tillers per plant

Treatment	Sprouting (%)		Plant height (cm)			Number of tillers per plant		
			60 DAP	105 DAP	150 DAP	60 DAP	105 DAP	150 DAP
N_1P_1	74.04	(59.37)	43.29	72.39	93.24	1.80	4.46	5.52
N_1P_2	80.66	(63.91)	42.87	73.87	97.55	1.42	4.51	5.33
N_1P_3	80.37	(63.70)	42.16	73.75	93.21	1.39	3.93	5.27
N_2P_1	69.84	(56.69)	40.47	73.16	99.09	1.71	3.82	5.37
N_2P_2	70.86	(57.33)	41.92	75.23	103.93	1.69	4.44	6.82
N_2P_3	80.76	(63.98)	40.89	71.36	100.61	1.64	4.19	6.60
N_3P_1	74.73	(59.82)	38.08	70.67	97.13	1.79	4.34	6.63
N_3P_2	84.24	(66.61)	40.29	71.08	99.16	1.49	4.41	6.73
N_3P_3	77.35	(61.58)	42.08	73.21	100.08	1.98	4.74	6.12
F test	S		S	NS	NS	S	S	S
N_1K_1	81.78	(64.73)	42.04	71.73	88.71	1.61	4.40	5.08
N_1K_2	76.24	(60.83)	42.20	73.29	99.61	1.49	4.26	5.06
N_1K_3	77.11	(61.42)	44.07	74.98	95.68	1.51	4.24	5.99
N_2K_1	80.76	(63.98)	44.09	79.48	104.56	1.78	4.60	6.29
N_2K_2	73.57	(59.06)	37.69	65.39	94.69	1.53	3.72	6.04
N_2K_3	67.05	(54.97)	41.48	74.88	104.38	1.73	4.13	6.46
N_3K_1	69.65	(56.57)	39.43	69.92	95.19	1.61	4.01	6.19
N_3K_2	80.05	(63.47)	39.56	71.88	98.74	1.77	4.64	6.54
N_3K_3	85.81	(67.87)	41.47	73.36	102.44	1.86	4.84	6.76
F test	S		S	S	S	S	S	NS
P_1K_1	72.62	(58.45)	40.26	72.87	96.50	1.77	4.26	5.56
P_1K_2	71.16	(57.52)	40.74	70.98	93.83	1.79	4.18	5.89
P_1K_3	74.73	(59.82)	40.83	72.37	99.13	1.74	4.19	6.08
P_2K_1	74.04	(59.37)	42.87	75.70	97.13	1.61	4.56	6.22
P_2K_2	83.93	(66.37)	38.20	68.13	98.51	1.33	4.18	5.99
P_2K_3	78.12	(62.11)	44.01	76.34	104.98	1.60	4.63	6.68
P_3K_1	85.30	(67.46)	42.44	72.36	94.82	1.57	4.20	5.78
P_3K_2	74.19	(59.47)	40.51	71.45	100.69	1.67	4.27	5.77
P_3K_3	78.44	(62.33)	42.18	74.50	98.38	1.76	4.40	6.44
F test	S		S	S	S	S	S	NS
SE	1.75		0.76	1.08	0.91	0.05	0.88	0.17
CD(0.05)	4.97		2.15	3.05	2.58	0.13	0.25	0.48

( ) Transformed values in bracket

Application of 15 kg P_2O_5 ha^{-1} (P_1) recorded significantly higher number of tillers at 60 DAP (1.77), but P_2 produced significantly higher number of tillers at 105 and 150 DAP (4.46 and 6.29 respectively).

Highest dose of potassium (K_3) resulted in maximum number of tillers at all stages of growth. At early stages of growth the effect of K_3 and K_1 were on par, but at 150 DAP significantly higher number of tillers were produced by K_3 (6.4) compared to K_2 ie. 60 kg ha^{-1} (5.88) and K_1 ie. 30 kg ha^{-1} (5.85) which were on par.

NxP interaction was significant at all stages of growth. N_3P_3 recorded higher value at early stages and N_2P_2 at 150 DAP. N_1P_3 gave lower number of tillers at 60 and 150 DAP and N_2P_1 at 105 DAP. NxK interaction was significant at 60 and 105 DAP with N_3K_3 giving maximum value. PxK interaction was significant at 60 and 105 DAP, with P_1K_2 and P_2K_3 producing maximum values respectively.

Number of leaves

The data on number of leaves as a result of varying levels of nutrients are presented in Table 4 and 5. Application of 45 kg N ha^{-1} (N_3) resulted in higher number of leaves at 105 and 150 DAP (17.17 and 32.49 respectively) and the effect was comparable with N_2 (16.95) at 105 DAP.

Phosphorus application produced significant influence at later stages. Application of 45 kg P_2O_5 ha^{-1} produced maximum leaf number (17.24) at 105 DAP and 30 kg P_2O_5 ha^{-1} at 150 DAP (31.75).

Potassium application significantly influenced the leaf number at all stages. Application of 30 kg K_2O ha^{-1} produced significantly higher number of leaves at initial stages. At 150 DAP an increasing trend with increase in K levels was observed and 90 kg K_2O ha^{-1} produced highest leaf number (31.56) which was on par with K_2 (31.36).

All the interaction effects were significant at every stage of plant growth (Table 5). In case of NxP interaction N_1P_1 produced higher leaf number (6.8) at 60 DAP and N_3P_3 produced maximum leaf number at 105 DAP (19.13). At 150 DAP, N_3P_2 recorded highest leaf number (33.64).

Among NxK interactions N_2K_1 gave higher leaf number at early stages and later N_3K_2 gave higher leaf number. N_2K_2 produced lower number of leaves at early stages while later N_1K_1 produced lower number of leaves.

The effect of P_2K_1 was higher among PxK combinations at early stages and P_1K_3 produced higher leaf number during later stage.

Control registered lower number of leaves throughout plant growth.

Table 4 Effect of nitrogen, phosphorus and potassium on number of leaves and leaf area index

Levels of nutrients	Number of leaves			Leaf area index		
	60 DAP	105 DAP	150 DAP	90 DAP	120 DAP	150 DAP
Nitrogen (N kg ha^{-1})						
15 (N_1)	6.23	16.31	28.96	1.87	3.31	4.59
30 (N_2)	6.18	16.95	31.09	2.05	4.07	5.18
45 (N_3)	6.07	17.17	32.49	2.13	4.45	5.11
F test	NS	S	S	S	S	S
Phosphorus (P_2O_5 kg ha^{-1})						
15 (P_1)	6.15	16.70	30.48	1.79	3.76	5.02
30 (P_2)	6.11	16.48	31.75	2.09	4.01	5.13
45 (P_3)	6.22	17.24	30.32	2.16	4.06	4.74
F test	NS	S	S	S	S	S
Potassium (K_2O kg ha^{-1})						
30 (K_1)	6.34	17.46	29.63	2.61	3.78	4.71
60 (K_2)	5.97	16.33	31.36	1.74	3.91	4.94
90 (K_3)	6.16	16.63	31.56	1.69	4.14	5.24
F Test	S	S	S	S	S	S
SE	0.056	0.183	0.462	0.021	0.039	0.081
CD(0.05)	0.16	0.52	1.31	0.06	0.11	0.23
Control ($N_0P_0K_0$)	4.67	14.93	26.65	1.09	2.62	4.25
Treatment VS Control	S	S	S	S	S	S

Table 5 Interaction effect of NxP, NxK and PxK on number of leaves and leaf area index

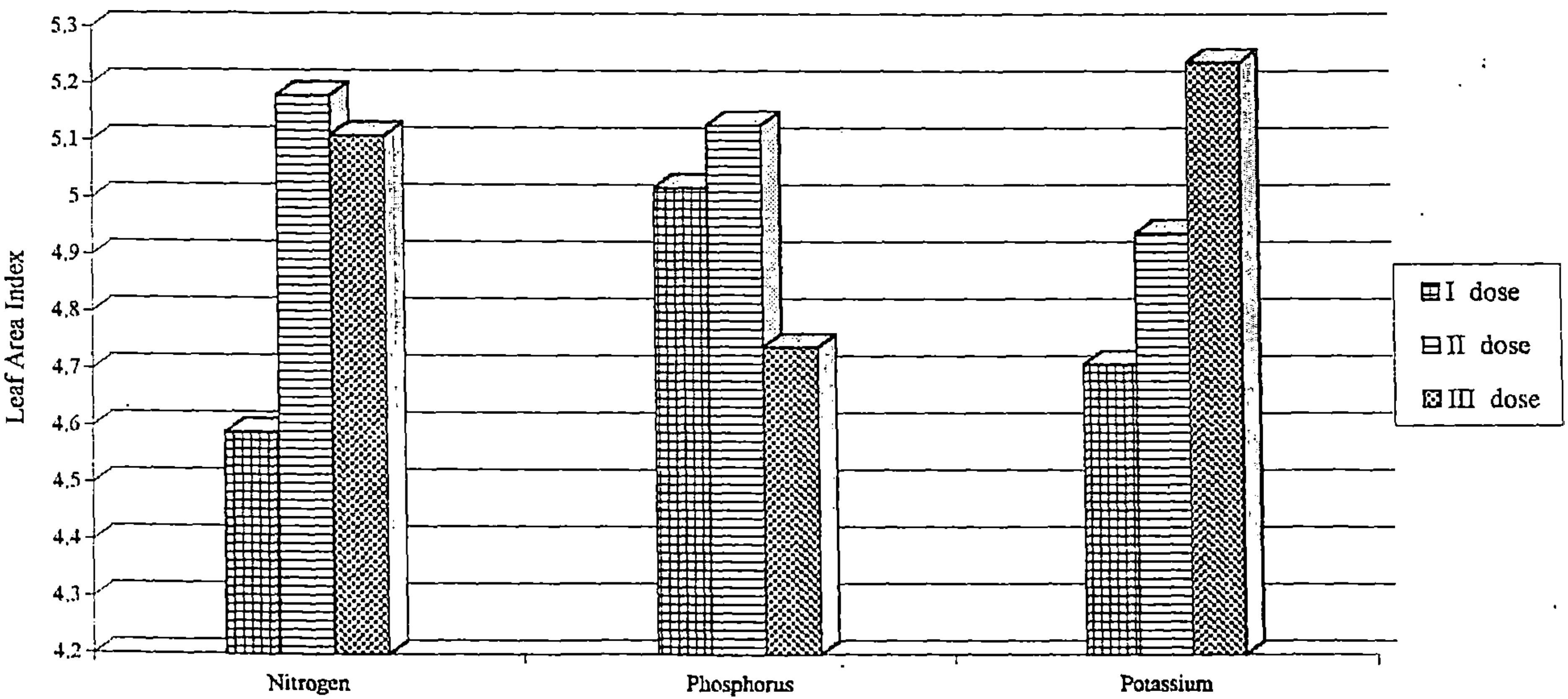
Treatment	Number of leaves			Leaf area index		
	60 DAP	105 DAP	150 DAP	90 DAP	120 DAP	150 DAP
N_1P_1	6.80	17.27	30.13	1.44	3.24	4.54
N_1P_2	6.10	16.13	29.57	2.51	3.56	4.76
N_1P_3	5.80	15.53	27.19	1.66	3.12	4.50
N_2P_1	5.90	16.20	29.29	1.75	3.82	5.20
N_2P_2	6.40	17.58	32.04	1.69	4.17	5.59
N_2P_3	6.20	17.08	31.95	2.72	4.22	4.74
N_3P_1	5.80	16.63	32.04	2.19	4.23	5.30
N_3P_2	5.80	15.73	33.64	2.09	4.29	5.04
N_3P_3	6.70	19.13	31.82	2.11	4.84	4.99
F test	S	S	S	S	S	S
N_1K_1	6.49	16.99	27.33	3.12	3.58	4.17
N_1K_2	5.98	15.81	29.41	1.53	3.12	4.74
N_1K_3	6.21	16.13	30.13	0.96	3.22	4.89
N_2K_1	6.78	18.80	28.79	2.38	3.15	5.22
N_2K_2	5.73	15.72	31.64	1.68	4.55	4.55
N_2K_3	6.03	16.34	32.84	2.09	4.51	5.76
N_3K_1	5.77	16.60	32.77	2.34	4.60	4.75
N_3K_2	6.20	17.47	33.04	2.02	4.05	5.51
N_3K_3	6.24	17.42	31.69	2.04	4.70	5.08
F test	S	S	S	S	S	S
P_1K_1	6.22	16.79	28.43	1.93	3.74	4.68
P_1K_2	6.32	16.24	29.67	1.68	3.51	5.33
P_1K_3	5.91	17.07	33.36	1.77	4.03	5.04
P_2K_1	6.48	17.81	31.32	3.32	3.24	4.98
P_2K_2	5.64	15.96	31.47	1.57	4.25	4.81
P_2K_3	6.20	15.69	32.47	1.40	4.54	5.60
P_3K_1	6.33	17.80	29.15	2.60	4.35	4.48
P_3K_2	5.94	16.80	32.96	1.97	4.97	4.67
P_3K_3	6.38	17.13	28.84	1.92	3.87	5.08
F test	S	S	S	S	S	S
SE	0.095	0.321	0.804	0.035	0.067	0.138
CD(0.05)	0.27	0.91	2.28	0.10	0.19	0.39

Leaf Area Index (LAI)

The effect of N, P and K alone and their interactions significantly influenced LAI in mango-ginger at all growth stages (Table 4 and 5). During early stages ie. 90 and 120 DAP N_3 recorded significantly higher LAI (2.13 and 4.45 respectively) compared to lower levels N_2 (2.05 and 4.07 respectively) and N_1 (1.87 and 3.31 respectively). But at later stage ie. 150 DAP N_2 recorded higher value (5.18) and this was significantly superior to N_3 (5.11) and N_1 (4.59). Among the different P levels tried, the highest level P_3 significantly increased the LAI at 90 and 120 DAP (2.16 and 4.06 respectively) compared to lower P levels. At later stage ie. 150 DAP P_2 level recorded highest LAI (5.13) which was on par with P_1, but significantly superior to P_3 (4.74). During early stage ie 90 DAP the lowest K level, K_1 recorded highest LAI (2.61) while in later stages ie. 120 and 150 DAP K_3 recorded highest LAI in mango-ginger (4.14 and 5.24 respectively).

Interaction effects of N and P had significant influence on the LAI in mango-ginger. At early stages N_2P_3 and N_3P_3 recorded highest LAI (2.72 and 4.84 respectively), but in later stage ie. 150 DAP N_2P_2 recorded highest LAI (5.59). Among NxK interactions N_1K_1, N_3K_3 and N_2K_3 recorded highest LAI at 90, 120 and 150 DAP respectively. Regarding PxK interactions P_2K_1 at 90 DAP and P_2K_3 at 120 and 150 DAP registered maximum LAI.

Fig 2 Effect of nitrogen, phosphorus and potassium on leaf area index (LAI) of mango-ginger plants at 150 DAP



The control produced significantly lower LAI at all stages.

Dry matter production (DMP)

The data on dry matter production with varying levels of N, P, K and their interactions are presented in Table 6 and 7.

The highest level of nitrogen (45 kg ha^{-1}) produced significantly higher DMP than other levels at 90 and 120 DAP (19.79 and 54 g $plant^{-1}$ respectively). At 150 DAP N_2 (30 kg ha^{-1}) produced maximum DMP (78.43 g $plant^{-1}$) which was significantly higher to N_1 (54.54 g $plant^{-1}$) and N_3 (72.32 g $plant^{-1}$). Phosphorus produced significant effect on DMP at later stage of growth only, when P_3 gave significantly higher value (80.28 g $plant^{-1}$) compared to lower levels. At 90 and 120 DAP K_1 was found to produce greater DMP compared to higher doses. The DMP was not affected by K at later stage.

All the two factor interactions significantly influenced DMP. Among NxP combinations N_3P_2 produced higher dry matter production (22.56 g $plant^{-1}$) at 90 DAP. N_3P_3 and N_1P_1 respectively produced higher and lower values at 120 DAP. N_2P_3 produced higher DMP at 150 DAP (87.5 g $plant^{-1}$). Considering NxK combinations N_3K_1 was found to be superior at 90 and 120 DAP (22.83 and 58.39 g $plant^{-1}$ respecitvley). N_1K_2 recorded maximum dry matter production at 150 DAP (81.11 g $plant^{-1}$).

P_3K_1 exhibited higher DMP at 90 and 150 DAP (22.83 and 86.39 g plant^{-1} respectively), while P_1K_3 recorded higher and DMP at 120 DAP.

Net Assimilation Rate (NAR)

The different levels of N, P, K and their combinations were found to have significant influence on NAR (Table 6 and 7).

At the first phase of growth (90-120 DAP) N_2 gave maximum NAR (0.355 g m^{-2} day^{-1}) and this was comparable with N_1 (0.331 g m^{-2} day^{-1}). At 120-150 DAP N_1 gave higher NAR (0.259 g m^{-2} day^{-1}) and this effect was comparable with N_2 (0.257 g m^{-2} day^{-1}). Phosphorus at 15 kg ha^{-1} recorded significantly higher NAR (0.367 g m^{-2} day^{-1}) at early phase, but 45 kg ha^{-1} ranked first during later phase. Highest level of potassium resulted in higher NAR (0.336 g m^{-2} day^{-1}) at 90 - 120 DAP and it was on par with K_2 (0.325 g m^{-2} day^{-1}).

The combination N_2P_1 ranked first (0.481 g m^{-2} day^{-1}) among NxP combinations at 90-120 DAP growth phase. N_3P_3 gave minimum NAR (0.158 g m^{-2} day^{-1}) at this phase. At 120-150 DAP N_2P_3 registered higher NAR (0.355 g m^{-2} day^{-1}) and N_3P_1 lower NAR (0.074 g m^{-2} day^{-1}). Regarding NxK interaction, N_2K_3 produced higher NAR (0.427 g m^{-2} day^{-1}) at initial phase. The combination N_2K_2 recorded maximum NAR (0.302 g m^{-2} day^{-1}) and N_3K_1 lower NAR (0.110 g m^{-2} day^{-1}) at later phase. In case of PxK interaction

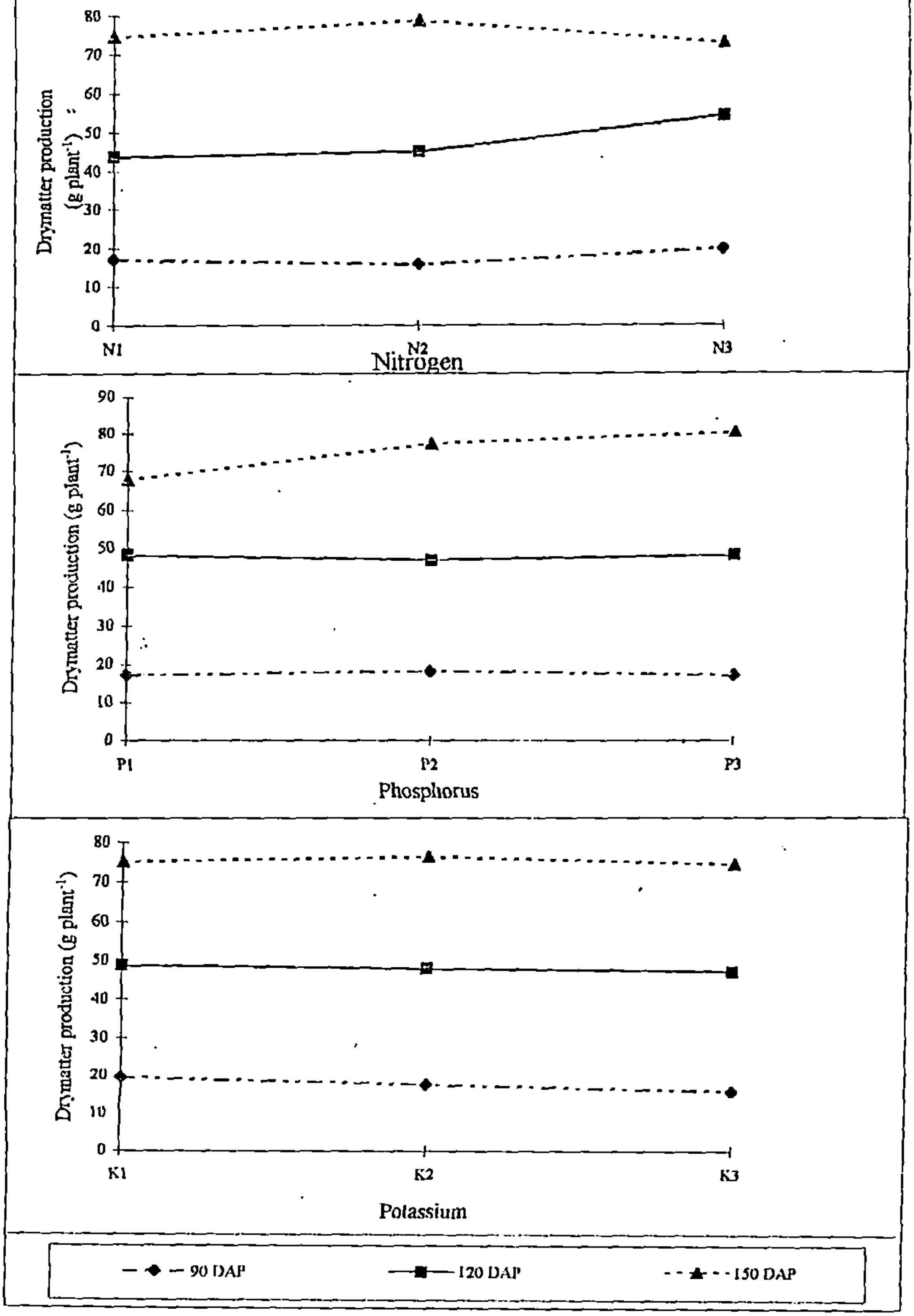
Table 6 Effect of nitrogen, phosphorus and potassium on dry matter production, net assimilation rate and crop growth rate

Levels of nutrients	Dry matter production ($g\ plant^{-1}$)			Net assimilation rate ($g\ m^{-2}\ day^{-1}$)		Crop growth rate ($g\ m^{-2}\ day^{-1}$)	
	90 DAP	120 DAP	150 DAP	90-120 DAP	120-150 DAP	90-120 DAP	120-150 DAP
Nitrogen (N $kg\ ha^{-1}$)							
15 (N_1)	17.06	43.78	74.54	0.331	0.259	0.900	1.014
30 (N_2)	15.78	45.15	78.43	0.355	0.257	0.974	1.107
45 (N_3)	19.79	54.00	72.32	0.267	0.124	0.841	0.622
F test	S	S	S	S	S	S	S
Phosphorus (P_2O_5 $kg\ ha^{-1}$)							
15 (P_1)	17.22	48.06	67.69	0.367	0.156	1.026	0.642
30 (P_2)	18.24	46.81	77.32	0.312	0.234	0.879	1.014
45 (P_3)	17.17	48.06	80.28	0.275	0.252	0.809	1.086
F test	NS	NS	S	S	S	S	S
Potassium (K_2O $kg\ ha^{-1}$)							
30 (K_1)	19.56	48.67	75.11	0.292	0.213	0.885	0.871
60 (K_2)	17.44	47.57	76.19	0.325	0.229	0.873	0.959
90 (K_3)	15.63	46.69	73.98	0.336	0.197	0.958	0.912
F Test	S	S	NS	S	NS	S	NS
SE	0.413	0.67	0.864	0.010	0.011	0.024	0.033
CD(0.05)	1.17	1.92	2.45	0.029	0.030	0.068	0.093
Control ($N_0P_0K_0$)	13.50	32.17	58.33	0.363	0.219	0.660	0.750
Treatment VS Control	S	S	S	NS	NS	S	NS

Table 7 Interaction effect of NxP, NxK and PxK on dry matter production, net assimilation rate and crop growth rate

Treatments	Dry matter production (g $plant^{-1}$)			Net assimilation rate (g m^{-2} day^{-1})		Crop growth rate (g m^{-2} day^{-1})	
	90 DAP	120 DAP	150 DAP	90-120 DAP	120-150 DAP	90-120 DAP	120-150 DAP
N_1P_1	21.33	37.22	64.72	0.198	0.227	0.529	0.901
N_1P_2	17.17	49.67	80.83	0.404	0.255	1.140	1.037
N_1P_3	12.67	44.44	78.06	0.390	0.297	1.030	1.101
N_2P_1	15.00	53.06	74.44	0.481	0.166	1.266	0.693
N_2P_2	15.00	41.11	73.33	0.309	0.249	0.858	1.067
N_2P_3	17.33	41.28	87.50	0.275	0.355	0.799	1.559
N_3P_1	15.33	53.89	63.89	0.421	0.074	1.284	0.332
N_3P_2	22.56	49.67	77.78	0.223	0.194	0.638	0.937
N_3P_3	21.50	58.44	75.28	0.158	0.104	0.600	0.598
F test	S	S	S	S	S	S	S
N_1K_1	16.83	42.61	71.94	0.313	0.266	0.852	0.945
N_1K_2	19.17	47.89	81.11	0.332	0.265	0.942	1.108
N_1K_3	15.17	40.83	70.56	0.346	0.248	0.907	0.987
N_2K_1	19.00	45.00	80.61	0.257	0.284	0.873	1.187
N_2K_2	15.50	41.67	75.78	0.382	0.302	0.870	1.155
N_2K_3	12.83	48.78	78.89	0.427	0.204	1.180	0.978
N_3K_1	22.83	58.39	72.78	0.307	0.110	0.929	0.479
N_3K_2	17.67	53.17	71.68	0.261	0.122	0.805	0.617
N_3K_3	18.89	50.44	72.50	0.235	0.139	0.788	0.772
F test	S	S	S	S	S	S	S
P_1K_1	17.50	42.33	64.17	0.307	0.177	0.827	0.711
P_1K_2	19.17	47.37	72.22	0.342	0.203	0.938	0.826
P_1K_3	15.17	54.44	66.67	0.451	0.087	1.313	0.389
P_2K_1	19.00	53.94	74.78	0.325	0.162	1.075	0.695
P_2K_2	15.50	47.72	85.50	0.357	0.301	0.842	1.260
P_2K_3	12.83	38.78	71.67	0.255	0.234	0.721	1.086
P_3K_1	22.83	49.72	86.39	0.245	0.300	0.752	1.205
P_3K_2	17.67	46.61	70.83	0.277	0.184	0.838	0.792
P_3K_3	18.89	46.83	83.61	0.302	0.271	0.840	1.261
F test	S	S	S	S	S	S	S
SE	0.716	1.174	1.495	0.177	0.019	0.042	0.057
CD(0.05)	2.03	3.33	4.24	0.501	0.053	0.118	0.161

Fig 3 Effect of nitrogen, phosphorus and potassium on dry matter production of mango-ginger (g $plant^{-1}$) at 90, 120 and 150 DAP



P_1K_3 registered higher NAR (0.451 g m^{-2} day^{-1}) at 90-120 DAP. At later phase higher NAR was given by P_2K_2 combination (0.301 g m^{-2} day^{-1}).

In both phases there was no significant difference between the treatment and control.

Crop Growth Rate

The crop growth rate under varying levels of nutrients are depicted in Tables 6 and 7.

N_2 produced superior CGR at both phases of growth (90-120 DAP and 120-150 DAP) of mango-ginger plants (0.974 and 1.107 g m^{-2} day^{-1} respectively. At initial phase, application of 15 kg P_2O_5 ha^{-1} produced higher CGR (1.026 g m^{-2} day^{-1}) compared to P_2 (0.879 g m^{-2} day^{-1}) and P_3 (0.809 g m^{-2} day^{-1}) which were on par. At second growth phase, an increasing trend in CGR was observed with increase in P dose and P_3 produced maximum CGR (1.086 g m^{-2} day^{-1}) which was comparable with P_2 (1.014 g m^{-2} day^{-1}). Potassium application produced significant result at 90-120 DAP when K_3 (0.958 g m^{-2} day^{-1}) produced significantly higher CGR. However the values were not significant at 120 - 150 DAP.

With respect to NxP interaction N_3P_1 and N_1P_1 recorded higher and lower CGR respectively at 90-120 DAP. In the second phase (120-150 DAP) N_2P_3 resulted in higher CGR. In the case of NxK interaction N_2K_3 and N_2K_1 recorded higher CGR at first and second phase respectively. Considering PxK interaction maximum CGR was registered with P_1K_3 at 90-120 DAP, while P_3K_3 gave higher CGR at later phase.

The control registered significantly lower CGR (0.660 g m^{-2} day^{-1}) at first phase, but at later phase there was no significant difference between control and treatments.

Bulking Rate (BR)

The data on bulking rate as influenced by N, P, K and their interactions are depicted on Table 8 and 9.

The effect of nitrogen was significant and an increasing trend with higher doses was observed at first phase (90 - 120 DAP). Significantly higher BR was obtained with 45 kg N ha^{-1} (0.657 g $plant^{-1}$ day^{-1}) at this phase and at 120-150 DAP the effect of N was not significant. N_2 gave significantly higher BR at 150 - 180 DAP (1.692 g $plant^{-1}$ day^{-1}). At 90-120 DAP, P_2 gave higher BR (0.649 g $plant^{-1}$ day^{-1}) and this was comparable with P_3 (0.643 g $plant^{-1}$ day^{-1}). At 120 - 150 DAP, P_3 showed superior BR (0.267 g $plant^{-1}$ day^{-1}). Application of 30 kg P_2O_5 ha^{-1} resulted in higher BR at 150 - 180 (1.595 g $plant^{-1}$ day^{-1}) and the effect was comparable with 15 kg P_2O_5 ha^{-1} (1.564 g $plant^{-1}$ day^{-1}). The effect of potassium on BR was not significant at initial phases, but 60 kg K_2O ha^{-1} produced significantly higher bulking rate at 150 - 180 DAP (1.736 g $plant^{-1}$ day^{-1}).

There was significant variation between treatment and control.

Among NxP interactions, N_3P_3 produced higher BR at initial phase while N_2P_3 produced higher bulking rate at second and third phases of growth. Among NxK interactions N_3K_1, N_1K_2 and N_2K_2 showed higher values at first, second and third phases respectively. Regarding PxK interaction, P_2K_1 showed higher BR at initial phase while P_3K_1 and P_2K_2 produced higher values at second and third phases respectively.

Rhizome spread

The effect of phosphorus and all the interaction effects significantly influenced rhizome spread (Table 8 and 9). P_2 recorded higher rhizome spread (29.08 cm) and the effect was comparable with P_1 (28.93 cm). Among two factor interactions N_2P_2, N_2K_1 and P_2K_1 recorded superior values for rhizome spread (31.17, 30.36, 32.56 cm respectively). The control and treatments did not show any significant variation.

Top yield

The data on top yield of mango-ginger plant at harvest are presented in Table 8 and 9. N_2 recorded significantly higher top yield (3812 kg ha^{-1}) compared to N_1 (3568 kg ha^{-1}) and N_3 (3206 kg ha^{-1}). With increase in P levels, top yield went on increasing and P_3 registered maximum value (3778 kg ha^{-1}), the

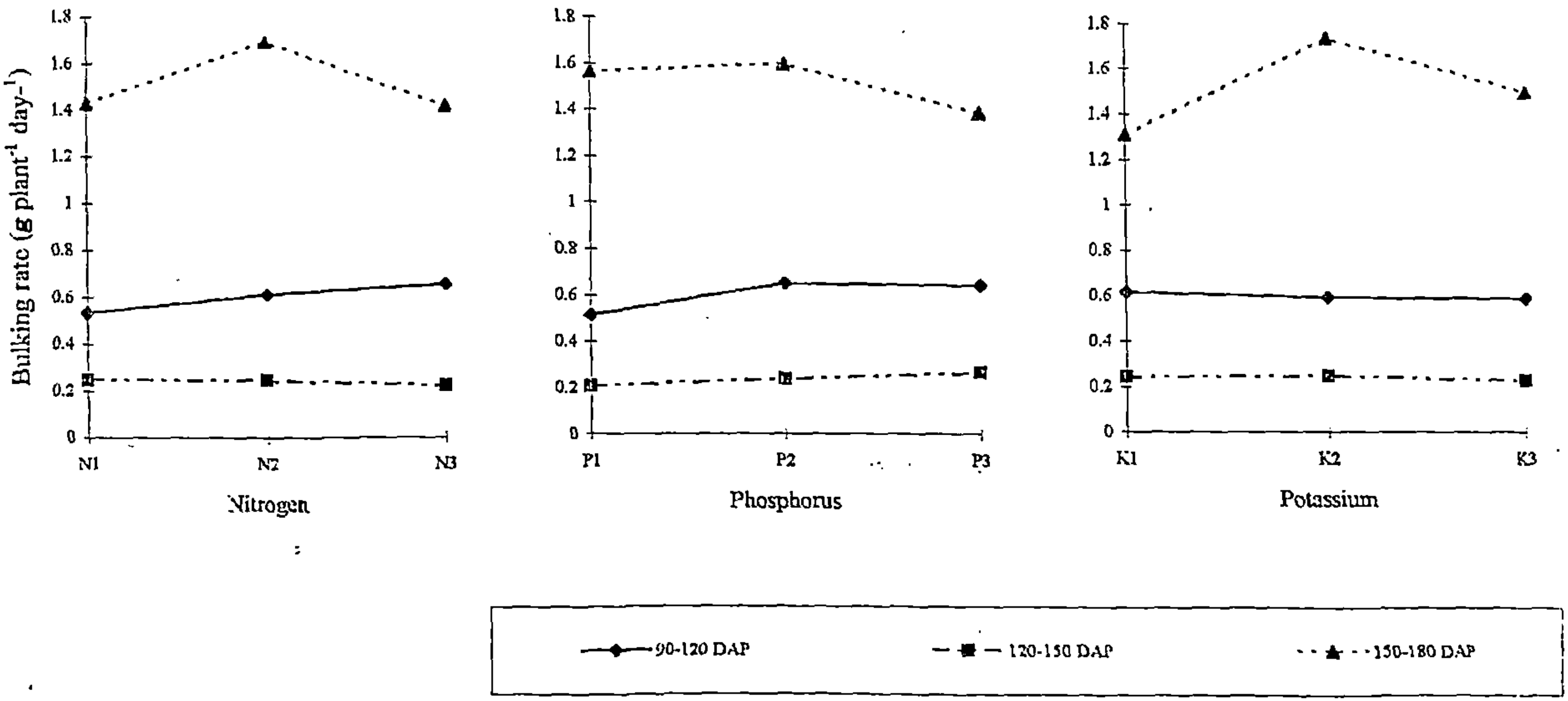
Table 8 Effect of nitrogen, phosphorus and potassium on bulking rate, rhizome spread and top yield

Levels of nutrients	Bulking rate ($g\ plant^{-1}\ day^{-1}$)			Rhizome spread (cm)	Top yield ($kg\ ha^{-1}$)
	90-120 DAP	120-150 DAP	150-180 DAP		
Nitrogen ($N\ kg\ ha^{-1}$)					
15 (N_1)	0.534	0.248	1.431	28.76	3567.57
30 (N_2)	0.614	0.245	1.692	28.82	3812.67
45 (N_3)	0.657	0.223	1.419	28.23	3206.73
F test	S	NS	S	NS	S
Phosphorus ($P_2O_5\ kg\ ha^{-1}$)					
15 (P_1)	0.514	0.209	1.564	28.93	3152.26
30 (P_2)	0.649	0.239	1.595	29.08	3656.08
45 (P_3)	0.643	0.267	1.383	27.81	3778.63
F test	S	S	S	S	S
Potassium ($K_2O\ kg\ ha^{-1}$)					
30 (K_1)	0.619	0.242	1.309	28.95	3479.06
60 (K_2)	0.596	0.248	1.736	28.82	3506.29
90 (K_3)	0.591	0.226	1.498	28.05	3601.61
F Test	NS	NS	S	NS	NS
SE	0.013	0.014	0.026	0.296	48.394
CD(0.05)	0.037	0.039	0.074	0.84	137.22
Control ($N_0P_0K_0$)	0.333	0.137	0.701	30.00	2757.38
Treatment VS Control	S	S	S	NS	S

Table 9 Interaction effect of NxP, NxK and PxK on bulking rate, rhizome spread and top yield

Levels of nutrients	Bulking rate ($g\ plant^{-1}\ day^{-1}$)			Rhizome spread (cm)	Top yield ($kg\ ha^{-1}$)
	90-120 DAP	120-150 DAP	150-180 DAP		
N_1P_1	0.35	0.19	1.48	28.11	3145.45
N_1P_2	0.80	0.27	1.44	28.34	3737.78
N_1P_3	0.45	0.29	1.38	29.82	3819.48
N_2P_1	0.63	0.16	1.69	30.18	3553.95
N_2P_2	0.61	0.20	1.67	31.17	3513.09
N_2P_3	0.61	0.37	1.72	25.12	4370.95
N_3P_1	0.57	0.28	1.52	28.49	2757.38
N_3P_2	0.53	0.25	1.68	27.72	3717.35
N_3P_3	0.87	0.14	1.05	28.49	3145.45
F test	S	S	S	S	S
N_1K_1	0.55	0.21	1.30	28.56	3492.68
N_1K_2	0.49	0.33	1.55	29.16	3839.90
N_1K_3	0.56	0.20	1.43	28.57	3370.13
N_2K_1	0.52	0.32	1.41	30.36	3942.03
N_2K_2	0.65	0.17	2.04	27.31	3492.67
N_2K_3	0.67	0.24	1.62	28.80	4003.29
N_3K_1	0.78	0.19	1.21	27.93	3002.48
N_3K_2	0.65	0.24	1.61	29.89	3186.30
N_3K_3	0.55	0.24	1.44	26.78	3431.40
F test	S	S	S	S	S
P_1K_1	0.42	0.14	1.47	28.99	3043.33
P_1K_2	0.54	0.19	1.67	29.16	3288.42
P_1K_3	0.58	0.29	1.56	28.63	3125.03
P_2K_1	0.76	0.26	1.36	32.56	3451.82
P_2K_2	0.71	0.27	1.85	27.89	4105.42
P_2K_3	0.48	0.18	1.57	26.79	3410.98
P_3K_1	0.68	0.32	1.09	25.30	3942.03
P_3K_2	0.54	0.28	1.69	29.41	3125.03
P_3K_3	0.71	0.21	1.36	28.72	4268.83
F test	S	S	S	S	S
SE	0.02	0.03	0.05	0.52	83.82
CD(0.05)	0.06	0.07	0.13	1.46	237.67

Fig 5 Effect of nitrogen, phosphorus and potassium on bulking rate (g $plant^{-1}$ day^{-1}) of rhizome at the different phases of growth



effect being comparable with P_2 (3656 kg ha^{-1}). Though variation was not significant, the top yield went on increasing with increasing K dose and K_3 recorded maximum value (3601 kg ha^{-1}). The control registered significantly lower top yield (2757 kg ha^{-1}) compared to treatments.

N_2P_3 and N_3P_1 ranked first and last in top yield among NxP values, while N_2K_3 and N_3K_1 came first and last among NxK combinations. In the case of PxK, P_3K_3 registered maximum value and P_1K_1 the minimum value.

Fresh rhizome yield (kg ha^{-1})

The application of nitrogen, phosphorus and potassium were found to have profound influence on rhizome yield of mango-ginger plants. The combination NxP and NxK significantly influenced the yield (Table 10 and 11).

Among nitrogen levels N_2 ie. 30 kg ha^{-1} was found to produce significantly higher rhizome yield (28950 kg ha^{-1}) than N_3 ie. 45 kg N ha^{-1} (27468 kg ha^{-1}) and N_1 ie. 15 kg N ha^{-1} (25927 kg ha^{-1}).

Phosphorus levels also had significant influence on the rhizome yield of mango-ginger. P_2 level ie. 30 kg P_2O_5 ha^{-1} recorded highest rhizome yield (28598 kg ha^{-1}) and this P level was significantly superior to P_1 (27190 kg ha^{-1}) and P_3 (26557 kg ha^{-1}).

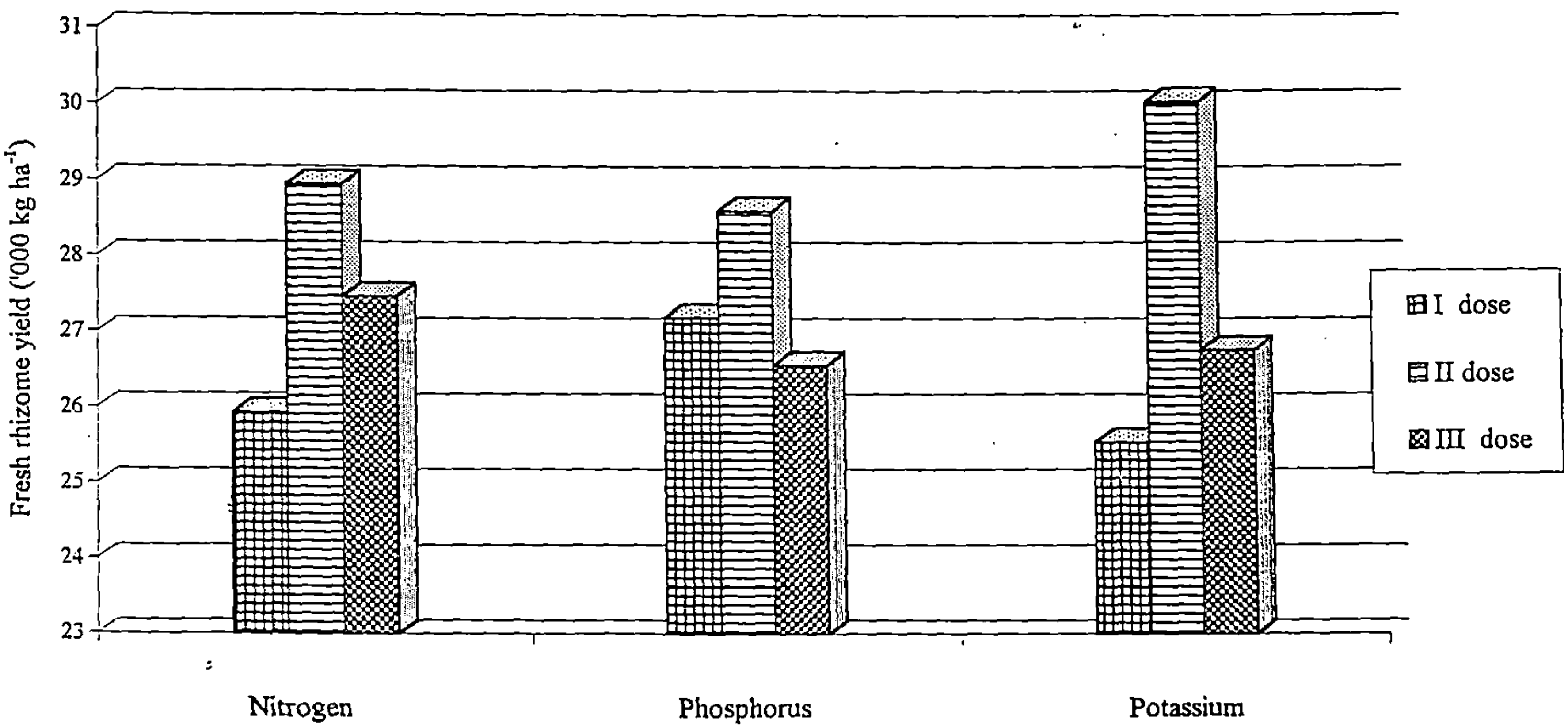
Table 10 Effect of nitrogen, phosphorus and potassium on fresh rhizome yield, drying percentage and recovery of dry rhizome

Levels of nutrients	Fresh rhizome yield ($kg\ ha^{-1}$)	Drying percentage (%)	Recovery of dry rhizome ($kg\ ha^{-1}$)
Nitrogen ($N\ kg\ ha^{-1}$)			
15 (N_1)	25927.10	19.51	5051.67
30 (N_2)	28950.74	19.62	5684.04
45 (N_3)	27468.23	19.08	5244.67
F test	S	S	S
Phosphorus ($P_2O_5\ kg\ ha^{-1}$)			
15 (P_1)	27190.79	19.48	5297.85
30 (P_2)	28598.41	19.42	5551.61
45 (P_3)	26556.87	19.31	5130.91
F test	S	S	S
Potassium ($K_2O\ kg\ ha^{-1}$)			
30 (K_1)	25551.68	19.44	4961.45
60 (K_2)	30037.64	19.47	5853.47
90 (K_3)	26756.75	19.29	5165.46
F Test	S	S	S
SE	246.980	0.060	76.904
CD(0.05)	700.31	0.17	218.06
Control ($N_0P_0K_0$)	15303.43	20.13	3079.57
Treatment VS Control	S	S	S

Table 11 Interaction effect of NxP, NxK and PxK on fresh rhizome yield, drying percentage and recovery of dry rhizome

Treatment	Fresh rhizome yield (kg ha^{-1})	Drying percentage (%)	Recovery of dry rhizome (kg ha^{-1})
N_1P_1	25092.11	19.49	4882.87
N_1P_2	28242.67	19.32	5456.03
N_1P_3	24446.51	19.72	4816.10
N_2P_1	29023.93	19.61	5706.06
N_2P_2	27818.86	19.70	5482.03
N_2P_3	30009.42	19.53	5864.02
N_3P_1	27456.32	19.33	5304.63
N_3P_2	29733.70	19.23	5716.77
N_3P_3	25214.68	18.67	4712.62
F test	S	S	S
N_1K_1	24213.84	19.69	4759.49
N_1K_2	27939.18	19.37	5410.78
N_1K_3	25628.27	19.47	4984.74
N_2K_1	26052.07	19.62	5105.01
N_2K_2	32766.83	19.88	6509.91
N_2K_3	28033.31	19.37	5437.19
N_3K_1	26389.11	19.01	5019.85
N_3K_2	29406.91	19.17	5639.72
N_3K_3	26608.67	19.05	5074.46
F test	S	S	S
P_1K_1	25209.56	19.54	4915.57
P_1K_2	29156.70	19.54	5702.38
P_1K_3	27206.10	19.36	5275.60
P_2K_1	26389.10	19.48	5131.60
P_2K_2	31771.10	19.48	6188.95
P_2K_3	27635.03	19.31	5334.28
P_3K_1	25056.38	19.31	4837.17
P_3K_2	29185.11	19.39	5669.07
P_3K_3	25429.12	19.22	4886.49
F test	NS	NS	S
SE	427.78	0.11	76.904
CD(0.05)	1212.97	0.30	218.06

Fig 4 Effect of nitrogen, phosphorus and potassium on fresh rhizome yield (kg ha^{-1}) of mango-ginger plants



Rhizome yield of mango-ginger was highest at K_2 level ie. 60 kg K_2O ha^{-1} (30038 kg ha^{-1}) and this level of potassium was significantly superior to other K levels, K_3 (26757 kg ha^{-1}) and K_1 (25552 kg ha^{-1}).

All the treatments produced significantly higher rhizome yield compared to control (15303 kg ha^{-1}).

Regarding NxP interaction N_2P_3 (30 kg N and 45 kg P_2O_5 ha^{-1}) produced higher rhizome yield (30009 kg ha^{-1}) but this was on par with N_3P_2 (29733 kg ha^{-1}) and N_2P_1 (29023 kg ha^{-1}). The combination N_1P_3 registered lower yield (24447 kg ha^{-1}) among NxP combinations. Among NxK interactions the combination N_2K_2 (30 kg N and 60 kg K_2O ha^{-1}) produced significantly higher rhizome yield (32766 kg ha^{-1}) followed by N_3K_2 (29407 kg ha^{-1}). N_1K_1 produced significantly, lower rhizome yield (24213 kg ha^{-1}) among NxK combinations.

Among the treatments, NPK combination of 30:30:60 kg ha^{-1} produced highest rhizome yield of 33915 kg ha^{-1} (Table 12). The effect of $N_2P_2K_2$ (30:30:60 kg NPK ha^{-1}) was found to be comparable with that of $N_2P_3K_2$ ie. 30:45:60 kg NPK ha^{-1}(33731 kg ha^{-1}) and $N_3P_2K_2$ ie. 45:30:60 (32031 kg ha^{-1}).

The control recorded significantly lower rhizome yield (15303 kg ha^{-1}) compared to treated plots.

Table 12 Effect of NPK treatment combination on fresh rhizome yield of mango-ginger

Levels of nutrients	Fresh rhizome yield (kg ha^{-1})
$N_1P_1K_1$	21415.61
$N_1P_1K_2$	27573.75
$N_1P_1K_3$	26286.98
$N_1P_2K_1$	27926.09
$N_1P_2K_2$	29366.04
$N_1P_2K_3$	27435.88
$N_1P_3K_1$	23299.82
$N_1P_3K_2$	28877.74
$N_1P_3K_3$	23161.95
$N_2P_1K_1$	27742.28
$N_2P_1K_2$	30652.88
$N_2P_1K_3$	28676.70
$N_2P_2K_1$	23345.77
$N_2P_2K_2$	33915.75
$N_2P_2K_3$	26195.06
$N_2P_3K_1$	27068.23
$N_2P_3K_2$	33731.89
$N_2P_3K_3$	29228.16
$N_3P_1K_1$	26470.80
$N_3P_1K_2$	29243.52
$N_3P_1K_3$	26654.63
$N_3P_2K_1$	27895.45
$N_3P_2K_2$	32031.51
$N_3P_2K_3$	29274.13
$N_3P_3K_1$	24801.09
$N_3P_3K_2$	26945.69
$N_3P_3K_3$	23897.25
Control ($N_0P_0K_0$)	15303.43
F test	S
SE	742.79
CD(0.05)	2100.93

Drying percentage

The percentage recovery of dry rhizome was influenced by varying levels of nitrogen and the combinations NxP and NxK (Table 10 and 11). Application of 30 kg N ha^{-1} produced higher percentage recovery (19.62%) and it was on par with N_1 (19.51%) but significantly higher to N_3 (19.08%). N_1P_3 give higher value among NxP combinations. Among NxK combinations N_2K_2 (19.88%) produced higher percentage of drying. The control produced higher drying percentage (20.13%) than other treatment.

Recovery of dry rhizome (kg ha^{-1})

Recovery of dry mango-ginger rhizome followed the same trend as in case of fresh rhizome yield and it was influenced by N, P, K andtheircombinations (Table 10 and 11). Application of 30 kg N ha^{-1} showed its superiority by producing significantly higher recovery (5684 kg ha^{-1}) followed by N_3 (5244 kg ha^{-1}) and N_1 (5051 kg ha^{-1}. Application of 30 kg P_2O_5 ha^{-1} produced significantly higher dry rhizome (5551 kg ha^{-1}) followed by P_1 and P_3. Application of 60 kg K_2O ha^{-1} produced higher value (5853 kg ha^{-1}) followed by K_3 (5165 kg ha^{-1}) and K_1 (4961 kg ha^{-1}).

N_2P_3, N_2K_2 and P_2K_2 respectively produced higher dry rhyzome yield in the case of NxP, NxK and PxK combinations. Control registered significantly lower recovery of dry rhizome (3079 kg ha^{-1}) compared to treated plots.

Utilization Index

The main effects and the interaction effects of N, P and K were found to be significantly influencing the utilization index of mango-ginger (Table 13 and 14).

As the N levels increased from N_1 to N_3 the UI showed an increasing trend and N_3 gave significantly higher UI (1.64). In the case of P, P_1 produced highest UI (1.68) and a decreasing trend with increasing P levels was observed. Application of 60 kg K_2O ha^{-1} produced significantly higher UI (1.67). Control registered significantly lower UI (1.11) compared to treated plots.

Among NxP interactions N_3P_1 and N_1P_3 recorded significantly higher (1.93) and lower (1.29) UI respectively. Regarding NxK interaction, N_3K_2 and N_2K_2 resulted in higher UI (1.88) and N_2K_1 lower UI (1.34). In the case of PxK, P_3K_2 (1.88) and P_3K_3 (1.17) produced higher and lower UI respectively.

Harvest Index

The main effect of N, P, K and their interaction were found to have significant effect on HI (Table 13 and 14). With increase in levels of N there was a significant increase in HI and maximum HI was found with 45 kg N ha^{-1}. P_1 produced higher HI (0.627) and a significant decreasing trend with higher P levels was noted. Application of 60 kg K_2O ha^{-1} resulted in

Table 13 Effect of nitrogen, phosphorus and potassium on utilization index, harvest index, volatile oil, non-volatile ether extract, fibre and starch content

Levels of nutrients	Utilization index	Harvest index	Volatile oil v/w (%)	NVEE (%)	Fibre (%)	Starch (%)
Nitrogen (N kg ha^{-1})						
15 (N_1)	1.42	0.587	0.527	7.11	7.19	34.65
30 (N_2)	1.49	0.599	0.597	6.93	8.56	34.93
45 (N_3)	1.64	0.625	0.560	8.62	11.33	34.89
F test	S	S	S	S	S	NS
Phosphorus (P_2O_5 kg ha^{-1})						
15 (P_1)	1.68	0.627	0.499	7.74	8.11	34.90
30 (P_2)	1.52	0.603	0.589	7.50	8.48	34.68
45 (P_3)	1.36	0.580	0.596	7.42	10.50	34.89
F test	S	S	S	S	S	NS
Potassium (K_2O kg ha^{-1})						
30 (K_1)	1.43	0.591	0.621	8.29	9.25	35.09
60 (K_2)	1.67	0.628	0.544	7.57	9.33	34.85
90 (K_3)	1.43	0.592	0.519	6.70	8.50	34.54
F Test	S	S	S	S	S	NS
SE	0.025	0.004	0.005	0.060	0.049	0.38
CD(0.05)	0.07	0.01	0.014	0.17	0.13	-
Control ($N_0P_0K_0$)	1.11	0.528	0.553	7.50	3.5	30.79
Treatment VS Control	S	S	NS	NS	S	S

Table 14 Interaction effect of NxP, NxK and PxK on utilization index, harvest index, volatile oil, non-volatile ether extract, fibre and starch content

Treat-ment	Utiliza-tion index	Harvest index	Volatile oil v/w (%)	NVEE (%)	Fibre (%)	Starch (%)
N_1P_1	1.57	0.609	0.489	8.17	7.17	35.90
N_1P_2	1.48	0.594	0.567	6.73	5.75	33.67
N_1P_3	1.29	0.559	0.524	6.43	8.67	34.37
N_2P_1	1.61	0.616	0.534	5.26	6.00	34.05
N_2P_2	1.55	0.606	0.653	8.03	9.01	35.40
N_2P_3	1.43	0.575	0.603	7.49	10.67	34.93
N_3P_1	1.93	0.658	0.473	9.79	11.17	34.76
N_3P_2	1.58	0.609	0.548	7.73	10.67	34.96
N_3P_3	1.65	0.607	0.659	8.32	12.17	34.96
F-test	S	S	S	S	S	NS
N_1K_1	1.39	0.578	0.731	7.09	7.42	35.93
N_1K_2	1.42	0.585	0.358	6.41	7.67	34.32
N_1K_3	1.52	0.599	0.791	7.83	6.50	33.70
N_2K_1	1.34	0.569	0.684	6.46	8.17	34.85
N_2K_2	1.88	0.651	0.592	8.39	9.67	35.80
N_2K_3	1.38	0.578	0.514	5.93	7.84	34.17
N_3K_1	1.70	0.628	0.447	11.32	12.17	34.50
N_3K_2	1.88	0.646	0.683	7.90	10.67	34.43
N_3K_3	1.56	0.599	0.550	6.62	11.17	35.75
F-test	S	S	S	S	S	NS
P_1K_1	1.62	0.617	0.580	9.93	6.67	35.94
P_1K_2	1.78	0.636	0.493	6.43	8.33	34.43
P_1K_3	1.72	0.630	0.423	6.84	8.33	31.87
P_2K_1	1.49	0.598	0.649	7.93	10.25	34.24
P_2K_2	1.52	0.601	0.599	8.56	7.50	32.41
P_2K_3	1.59	0.611	0.520	6.10	7.68	37.39
P_3K_1	1.32	0.559	0.633	7.00	9.83	35.09
P_3K_2	1.88	0.646	0.541	7.71	12.17	35.22
P_3K_3	1.17	0.535	0.612	7.53	9.50	34.37
F-test	S	S	S	S	S	S
SE	0.044	0.007	0.008	0.104	0.082	0.65
CD(0.05)	0.124	0.019	0.024	0.296	0.232	1.85

significantly higher HI (0.638). Among NxP interactions N_3P_1 (0.658) and N_1P_3 (0.559) produced higher and lower HI respectively. N_2K_2 (0.651) and N_2K_1 (0.569) gave higher and lower HI respectively. In case of PxK, P_3K_2 gave higher HI (0.646) and P_3K_3 lower HI (0.535).

Volatile oil (%)

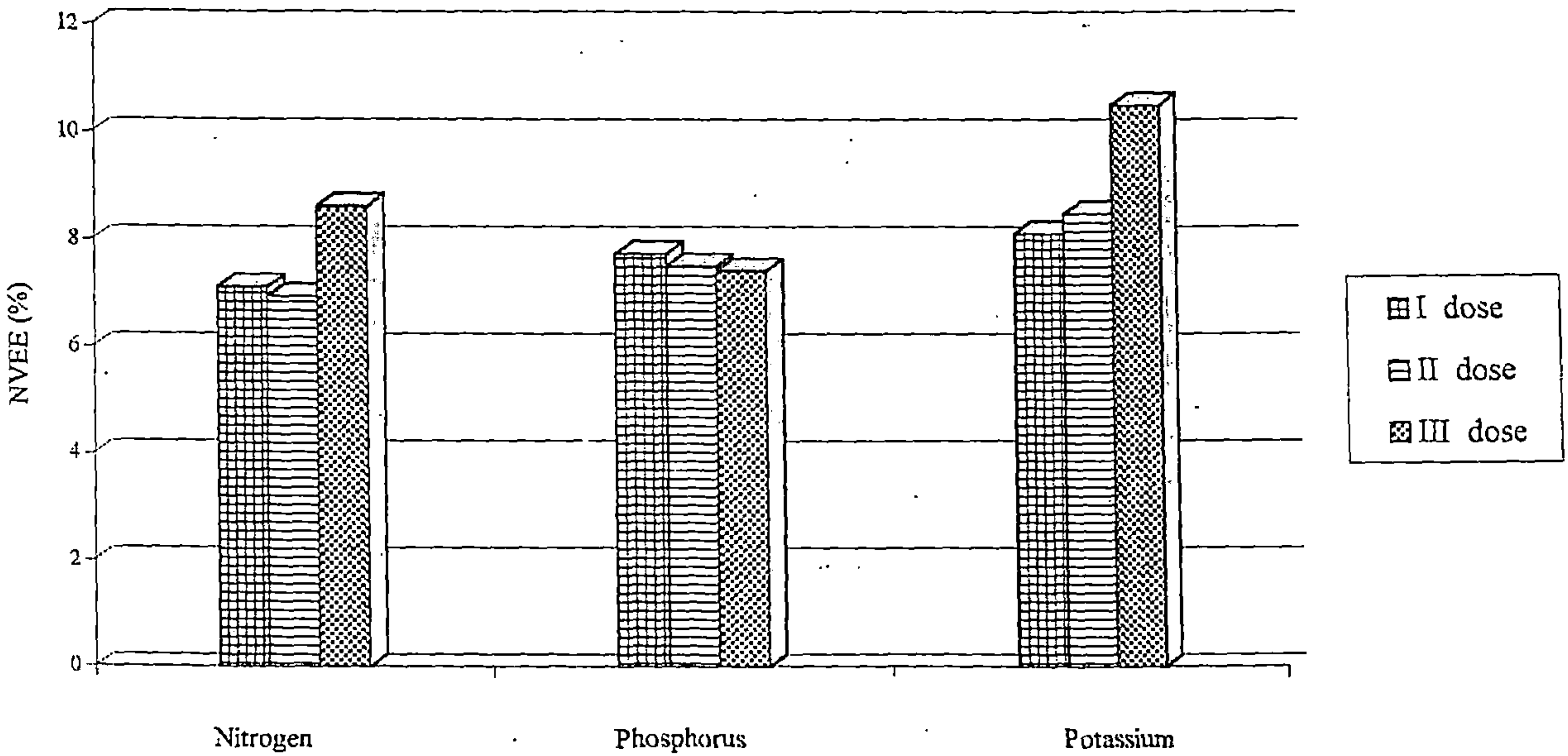
N, P and K produced significant variation in volatile oil content of mango-ginger rhizome (Table 13 and 14). Application of 30 kg N ha^{-1} produced significantly higher volatile oil content (0.597%) followed by 45 kg N ha^{-1} (0.560 %). Volatile oil content went on increasing with increase in P levels. P_3 produced higher volatile oil (0.596%) and this was on par with P_2 (0.589%). In the case of K, 30 kg ha^{-1} produced significantly higher oil content (0.621%). However there was no significant difference between treatment and control (0.55%). N_3P_3, N_1K_3 and P_2K_1 produced higher volatile oil among NxP, NxK and PxK interaction respectively.

Non Volatile Ether Extract (NVEE)

The data on the effect of varying levels of N, P and K on NVEE are presented in Table 13 and 14.

There was significant variation among N, P, K levels and NVEE content. A progressive increase in NVEE with N levels was observed and 45 kg ha^{-1} showed higher NVEE (8.62%). A

Fig 7 Effect of nitrogen, phosphorus and potassium on non-volatile ether extract (%) of mango-ginger on dry weight basis



progressive reduction in NVEE with increase in P doses was noted and 15 kg P_2O_5 ha^{-1} recorded higher NVEE of 7.74 per cent. In the case of potassium K_1 produced significantly higher NVEE of 8.29 per cent. The control and treatments did not show any significant difference in the NVEE content. Among NxP, NxK and PxK interactions N_3P_1 (9.79%) N_3K_1 (11.32%) and P_1K_1 (9.93%) recorded higher NVEE.

Fibre content (%)

The data on effect of N, P, K and their combination on fibre content are presented in Table 13 and 14.

Significant difference in fibre content was noticed among the various levels of nitrogen and fibre content went on increasing with the increase in dose of N. Highest dose of N (45 kg ha^{-1}) registered significantly higher value of fibre (11.33%) Highest dose of P, (45 kg ha^{-1}) produced significantly higher fibre content in mango-ginger rhizome (10.5%). In the case of K, K_2 produced maximum fibre content (9.33%) and this was on par with K_1 (9.25%). The control registered significantly lower fibre content (3.5%) than treated plants.

Among NxP combinations N_3P_3 resulted maximum value (12.17%) for fibre. Regarding NxK interaction N_3K_1 produced higher (12.17%) fibre content. For PxK, P_3K_2 (12.17%) recorded higher content of fibre.

Starch content (%)

The data on effect of N, P, K and their combinations on starch content are presented in Table 13 and 14.

The different levels of nitrogen, phosphorus and potassium were not found to be influencing the starch content of mango-ginger rhizomes. Though there was no significant difference among the treatments in starch content, the control and treatments differed significantly. A significantly lower starch content was shown by the control (30.79%).

Taking into account the various combinations namely NxP, NxK and PxK, the effect of PxK only was statistically significant. P_2K_3 produced higher starch content (37.39%).

Chlorophyll a and b (mg g^{-1})

The effect of nutrients on chlorophyll content of leaves are furnished in Table 15 and 16.

Chlorophyll a and b behaved similarly to the different levels of N, P and K. The highest dose of N produced higher chlorophyll a (0.711 mg g^{-1}), chlorophyll b (0.407 mg g^{-1}) and total chlorophyll (1.13 mg g^{-1}), the effect being comparable with N_2. The application of highest dose of P ie. 45 kg ha^{-1} resulted in superior chlorophyll a (0.742 mg g^{-1}) chlorophyll b (0.403 mg g^{-1}) and total chlorophyll (1.15 mg g^{-1}). K_1 recorded higher value for chlorophyll a (0.743 mg g^{-1}), chlorophyll b (0.412 mg g^{-1}) and total chlorophyll (1.16 mg g^{-1}). The control recorded significantly lower chlorophyll a (0.561 mg g^{-1}), chlorophyll b (0.280 mg g^{-1}) and total chlorophyll (0.841 mg g^{-1}) than the treatments.

Among NxP interactions N_2P_3 (0.855 mg g^{-1}) produced higher chlorophyll a and total chlorophyll but N_3P_3 gave higher chlorophyll b. N_3K_1 produced higher chlorophyll a while N_2K_3 produced maximum value for chlorophyll b and total chlorophyll. P_3K_1 recorded higher value for chlorophyll a, b and total chlorophyll among PxK combinations.

Uptake of nutrients

The uptake of nutrients by mango-ginger plants were found to be influenced by the varying levels of applied nutrients (Tables 15 and 16).

Uptake of nitrogen

Higher uptake of nitrogen (234.58 kg ha^{-1}) was noticed when N at 30 kg ha^{-1} was applied and the effect being significantly higher to other N levels. Significantly higher N

Table 15 Effect of nitrogen, phosphorus and potassium on chlorophyll a, chlorophyll b, total chlorophyll and uptake of nutrients

Levels of nutrients	Chlorophyll a (mg g^{-1})	Chlorophyll b (mg g^{-1})	Total Chlorophyll (mg g^{-1})	Uptake of nutrients ($kg\ ha^{-1}$)		
				N	P	K
Nitrogen (N kg ha^{-1})						
15 (N_1)	0.622	0.334	0.99	210.30	61.79	169.69
30 (N_2)	0.702	0.378	1.10	234.58	56.29	197.16
45 (N_3)	0.711	0.407	1.13	199.77	56.32	169.68
F test	S	S	S	S	S	S
Phosphorus (P_2O_5 kg ha^{-1})						
15 (P_1)	0.647	0.360	1.08	195.39	54.67	181.53
30 (P_2)	0.646	0.356	1.00	219.55	60.75	171.47
45 (P_3)	0.742	0.403	1.15	229.72	58.98	183.53
F test	S	S	S	S	S	S
Potassium (K_2O kg ha^{-1})						
30 (K_1)	0.743	0.412	1.16	210.90	56.33	162.59
60 (K_2)	0.611	0.319	0.95	224.25	58.99	179.73
90 (K_3)	0.681	0.387	1.13	209.51	59.09	194.20
F Test	S	S	S	S	NS	S
SE	0.014	0.012	0.032	3.171	0.896	0.423
CD(0.05)	0.040	0.033	0.09	8.99	2.54	6.70
Control ($N_0P_0K_0$)	0.561	0.280	0.841	132.97	35.92	118.77
Treatment VS Control	S	S	S	S	S	S

Table 16 Interaction effect of NxP, NxK and PxK on chlorophyll a, chlorophyll b, total chlorophyll and uptake of nutrients

Levels of nutrients	Chlorophyll a ($mg\ g^{-1}$)	Chlorophyll b ($mg\ g^{-1}$)	Total Chlorophyll ($mg\ g^{-1}$)	Uptake of nutrients ($kg\ ha^{-1}$)		
				N	P	K
N_1P_1	0.655	0.343	1.100	193.80	58.74	150.56
N_1P_2	0.573	0.311	0.884	195.12	64.17	151.19
N_1P_3	0.638	0.348	0.986	241.99	62.48	207.30
N_2P_1	0.642	0.440	1.113	229.86	55.09	214.02
N_2P_2	0.609	0.318	0.927	249.00	58.39	184.61
N_2P_3	0.855	0.417	1.272	224.87	55.39	192.83
N_3P_1	0.645	0.338	1.028	162.49	50.18	180.01
N_3P_2	0.757	0.439	1.196	214.52	59.71	178.59
N_3P_3	0.733	0.444	1.177	222.31	59.08	150.56
F-test	S	S	S	S	NS	S
N_1K_1	0.644	0.319	0.963	198.95	61.33	167.51
N_1K_2	0.621	0.364	0.986	232.06	63.91	163.51
N_1K_3	0.601	0.318	1.021	199.91	60.14	178.04
N_2K_1	0.712	0.412	1.125	271.02	54.18	165.83
N_2K_2	0.568	0.218	0.786	217.92	56.16	207.99
N_2K_3	0.826	0.565	1.401	214.79	58.53	217.89
N_3K_1	0.873	0.506	1.378	162.74	53.48	154.95
N_3K_2	0.644	0.377	1.067	222.76	56.90	167.68
N_3K_3	0.617	0.339	0.957	213.83	58.58	186.92
F-test	S	S	S	S	NS	S
P_1K_1	0.785	0.394	1.129	199.57	56.12	152.05
P_1K_2	0.645	0.350	1.042	207.17	55.92	189.73
P_1K_3	0.561	0.335	1.069	179.42	51.97	202.81
P_2K_1	0.683	0.347	1.03	186.15	49.92	161.57
P_2K_2	0.534	0.286	0.819	249.49	70.81	173.21
P_2K_3	0.721	0.436	1.157	222.51	61.53	179.62
P_3K_1	0.811	0.496	1.301	246.96	62.95	174.16
P_3K_2	0.654	0.322	0.976	215.59	50.24	176.24
P_3K_3	0.762	0.390	1.152	226.59	63.76	200.18
F-test	S	S	S	S	S	S
SE	0.024	0.020	0.055	5.495	1.548	4.095
CD(0.05)	0.069	0.057	0.157	15.58	4.39	11.61

uptake was noticed with increase in P dose from 15 to 45 kg ha^{-1} and 229.72 kg ha^{-1} of N uptake was recorded by P_3. In the case of potassium, K_2 read a significantly higher N uptake (224.25 kg ha^{-1}). The control recorded significantly lower N uptake (132.97 kg ha^{-1}).

Comparing NxP combinations N_2P_2 showed a higher uptake (249 kg ha^{-1}) and N_3P_1 a lower uptake (162.49 kg ha^{-1}). Among NxK interactions N_2K_1 (271.02 kg ha^{-1}) and N_3K_1 (162.74 kg ha^{-1}) ranked first and last respectively while P_2K_2 (249.99 kg ha^{-1}) and P_1K_3 (179.42 kg ha^{-1}) reported higher and lower values among PxK interaction.

Uptake of phosphorus

Uptake of phosphorus by mango-ginger plants was influenced by varying levels of N, P and the PxK combination. N at 15 kg ha^{-1} ranked first in uptake of phosphorus (61.79 kg ha^{-1}) and the effect was significantly higher to N_3 and N_2 which were on par. P_2 produced higher uptake and the effect was comparable with P_3. The control registered significantly lower value (35.92 kg ha^{-1}). In the case of PxK interaction P_2K_2 registered the highest value (70.81 kg ha^{-1}) and P_2K_1 (49.92 kg ha^{-1}) the lowest value.

Uptake of potassium

In the case of potassium uptake, application of N_2 resulted in significantly higher uptake (197.16 kg ha^{-1}).

Phosphorus at P_3 level resulted in maximum K uptake (183.53 kg ha^{-1}). K uptake progressively increased with higher K doses. Highest dose of potassium K_3, caused significantly higher K uptake (194.2 kg ha^{-1}). The control recorded significantly lower K uptake (118.77 kg ha^{-1}) compared to the treated plots. N_2P_1 (214.02 kg ha^{-1}) produced maximum and N_3P_3 and N_1P_1 a minimum K uptake. Among NxK combinations N_2K_3 resulted in higher K uptake and N_3K_1 a lower uptake. Among PxK interaction P_1K_3 showed maximum K uptake (202.81 kg ha^{-1}) while P_1K_1 a minimum uptake (152.05 kg ha^{-1}).

Soil analysis

The data on soil analysis after the experiment are presented in Table 17 and 18.

Soil analysis revealed that there was significant difference among the varying levels of N, P and K on the available N, P and K content of soil. With increase in N application a progressive increase in soil N was found. The plots treated with N_3 showed highest available nitrogen after the experiment (200.69 kg ha^{-1}) followed by N_2 and N_1. The effect of P was significant with P_2 giving significantly higher value (188.86 kg ha^{-1}) followed by P_3 and P_1. Application of 30 kg K_2O ha^{-1} resulted in significantly higher available N in soil (190.25 kg ha^{-1}) followed by K_2 and K_1 which were on par. Comparing NxP

Table 17 Effect of nitrogen, phosphorus and potassium on available nitrogen, phosphorus and potassium content in soil

Levels of nutrients	Available soil nitrogen ($kg\ ha^{-1}$)	Available soil phosphorus ($kg\ ha^{-1}$)	Available soil potassium ($kg\ ha^{-1}$)
Nitrogen (N $kg\ ha^{-1}$)			
15 (N_1)	163.74	21.90	136.20
30 (N_2)	179.44	22.45	131.82
45 (N_3)	200.69	20.08	156.39
F test	S	S	S
Phosphorus (P_2O_5 $kg\ ha^{-1}$)			
15 (P_1)	173.52	20.24	141.87
30 (P_2)	188.86	20.16	147.07
45 (P_3)	181.50	24.23	135.47
F test	S	S	S
Potassium (K_2O $kg\ ha^{-1}$)			
30 (K_1)	190.25	23.31	125.82
60 (K_2)	176.98	21.57	138.40
90 (K_3)	176.65	19.75	160.19
F Test	S	S	S
SE	1.45	0.43	0.49
CD(0.05)	4.12	1.21	1.40
Control ($N_0P_0K_0$)	144.25	10.45	107.50
Treatment VS Control	S	S	S

Table 18 Interaction effect of NxP, NxK and PxK on available nitrogen, phosphorus and potassium content in soil

Treatment	Available soil nitrogen (kg ha^{-1})	Available soil phosphorus (kg ha^{-1})	Available soil potassium (kg ha^{-1})
N_1P_1	172.48	16.43	137.53
N_1P_2	168.33	20.41	143.33
N_1P_3	160.42	28.87	127.74
N_2P_1	200.69	24.64	134.74
N_2P_2	157.85	20.91	134.32
N_2P_3	179.79	22.40	126.39
N_3P_1	147.39	19.66	153.56
N_3P_2	240.39	19.16	163.56
N_3P_3	214.29	21.4	152.29
F-test	S	S	S
N_1K_1	164.12	22.15	125.73
N_1K_2	179.21	20.90	120.68
N_1K_3	147.39	22.65	162.20
N_2K_1	187.10	26.63	111.71
N_2K_2	157.84	23.89	134.37
N_2K_3	193.39	17.42	149.38
N_3K_1	219.52	21.16	140.02
N_3K_2	193.39	19.91	160.16
N_3K_3	189.19	19.16	169.00
F-test	S	S	S
P_1K_1	180.83	21.65	114.53
P_1K_2	181.89	21.65	127.37
P_1K_3	157.85	17.42	183.71
P_2K_1	198.62	18.42	136.69
P_2K_2	185.62	21.16	152.30
P_2K_3	182.90	20.91	152.20
P_3K_1	191.29	29.87	126.24
P_3K_2	163.99	21.90	135.24
P_3K_3	189.21	20.91	144.64
F-test	S	S	S
SE	2.52	0.74	0.86
CD(0.05)	7.14	2.10	2.43

combinations N_3P_2 resulted in highest soil nitrogen (240.39 kg ha^{-1}) and N_3P_1 the lowest value (147.39 kg ha^{-1}). N_3K_1 (219.52 kg ha^{-1}) and N_1K_3 (147.39) recorded higher and lower values respectively among NxK combinations. P_2K_1 (198.62 kg ha^{-1}) and P_1K_3 (157.85 kg ha^{-1}) recorded maximum and minimum values among PxK combinations.

In the case of available soil phosphorus among N levels, N_2 recorded higher value (22.45 kg ha^{-1}) followed by N_1. Application of 45 kg P_2O_5 ha^{-1} produced significantly higher phosphorus content than lower doses. P content decreased significantly with each increase in K dose and lowest soil P was noted in K_3 (19.75 kg ha^{-1}). The control produced lower soil P content (10.45 kg ha^{-1}) compared to treatments.

Among the combinations, the highest and lowest values for available P were shown respectively by N_1P_3 and N_1P_1 in case of NxP, N_2K_1 and N_2K_3 in the case of NxK and P_3K_1 and P_1K_3 in case of PxK interaction.

Available soil K content was influenced by various levels of N, P, K and their combinations. Among N levels N_3 application resulted in highest soil K (156.39 kg ha^{-1}). Regarding P levels P_2 produced significantly higher soil K compared to P_1 and P_3. With the increase in K doses the soil K level progressively increased and a significantly higher amount was produced by K_3 (160.19 kg ha^{-1}). Control plot registered the lowest value (107.5 kg ha^{-1}).

With regard to NxP the combination N_3P_2 (163.56 kg ha^{-1}) revealed its superiority over others and N_2P_3 produced lowest value (126.39 kg ha^{-1}). N_3K_3 recorded highest soil K (169 kg ha^{-1}) and N_2K_1 (111.71 kg ha^{-1}) the lowest among NxK levels. With respect to PxK, P_1K_3 produced maximum (183.71 kg ha^{-1}) while P_1K_1 minimum value (114.53 kg ha^{-1}) for available K content in soil.

Economics

Net returns

The data on net returns are presented in Tables 19, 20 and 21. Upto the second dose of N, P and K there was a significant increase in net returns. And when the dose was raised from N_2 to N_3, P_2 to P_3 and K_2 to K_3 the net returns diminished. The combination N_2P_3 and N_2K_2 produced higher net returns among NxP and NxK combinations.

Among treatment combinations $N_2P_2K_2$ recorded maximum net returns (Rs. 103132 ha^{-1}), closely followed by $N_2P_3K_2$ (Rs. 101725 ha^{-1}) and $N_3P_2K_2$ (Rs. 91716.66 ha^{-1}) and these three treatments were on par. The control registered the least with a loss of Rs. 7179 ha^{-1} .

Benefit Cost Ratio

The data on BCR are presented in Tables 19, 20 and 21. N_2 registered significantly higher BCR (1.73) among N levels,

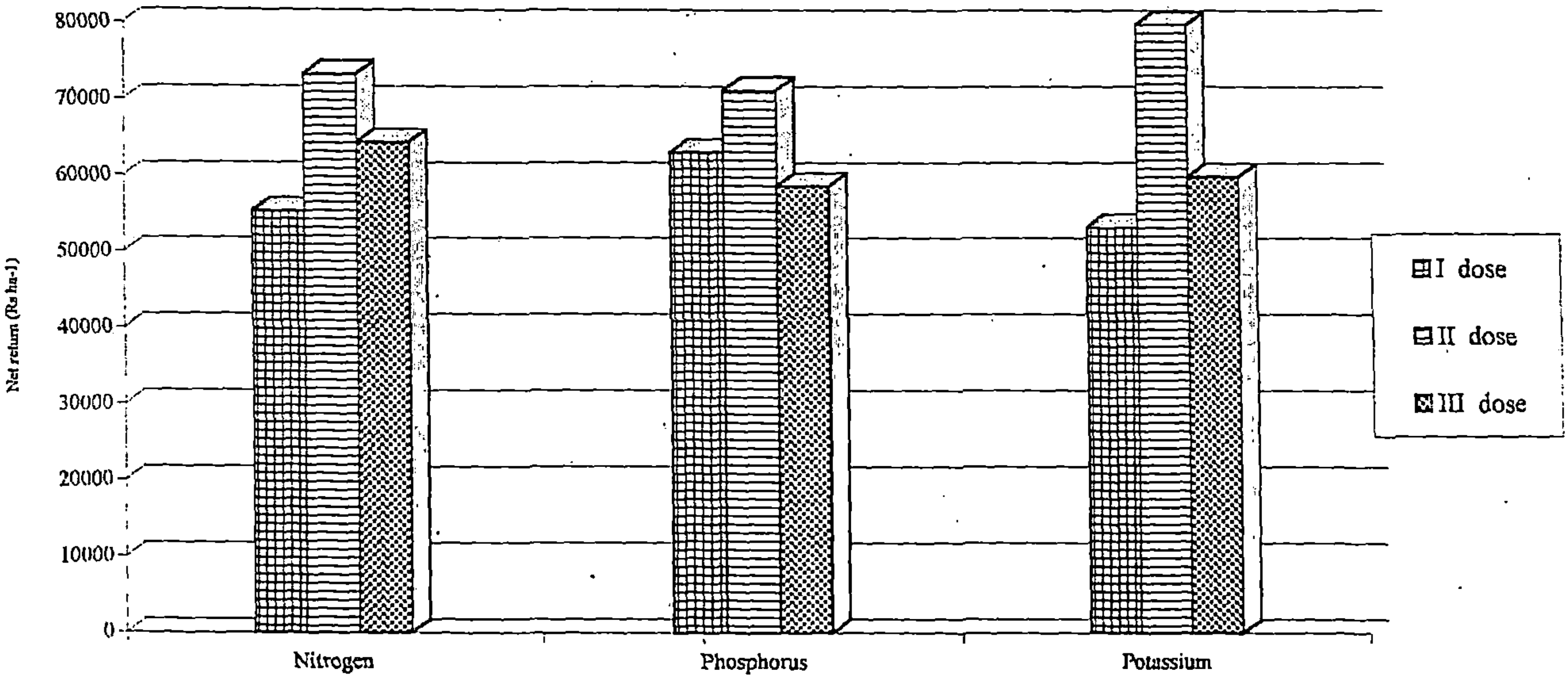
Table 19 Effect of nitrogen, phosphorus and potassium on net returns, benefit cost ratio and return per rupee invested on fertilizers

Levels of nutrients	Net return (Rs. ha^{-1})	Benefit cost ratio	Return per rupee invested on fertilizers (Rs.)
Nitrogen (N kg ha^{-1})			
15 (N_1)	55311.58	1.55	46.79
30 (N_2)	73342.72	1.73	56.51
45 (N_3)	64336.98	1.64	46.59
F test	S	S	S
Phosphorus (P_2O_5 kg ha^{-1})			
15 (P_1)	63087.68	1.63	60.89
30 (P_2)	71228.75	1.71	53.30
45 (P_3)	58674.87	1.58	35.71
F test	S	S	S
Potassium (K_2O kg ha^{-1})			
30 (K_1)	53213.87	1.53	51.05
60 (K_2)	79864.13	1.79	60.68
90 (K_3)	59913.30	1.59	38.19
F Test	S	S	S
SE	1482.011	0.015	1.167
CD(0.05)	4202.24	0.042	3.31
Control ($N_0P_0K_0$)	7179.39	0.93	-
Treatment VS Control	S	S	S

Table 20 Interaction effect of NxP, NxK and PxK on net return, benefit cost ratio and return per rupee invested on fertilizers

Treatment	Net return (Rs ha^{-1})	Benefit cost ratio	Return per rupee invested on fertilizers (Rs.)
N_1P_1	50606.34	1.51	53.09
N_1P_2	69205.02	1.69	57.19
N_1P_3	46123.38	1.46	30.20
N_2P_1	74086.55	1.74	72.59
N_2P_2	66551.46	1.60	48.99
N_2P_3	79390.21	1.79	48.99
N_3P_1	64570.14	1.64	57.09
N_3P_2	77929.78	1.78	53.73
N_3P_3	50511.01	1.50	28.98
F-test	S	S	S
N_1K_1	45297.54	1.45	47.19
N_1K_2	67384.07	1.67	56.31
N_1K_3	53253.13	1.53	36.89
N_2K_1	56216.32	1.56	54.98
N_2K_2	96239.24	1.96	72.04
N_2K_3	67572.65	1.67	42.50
N_3K_1	58127.77	1.58	50.97
N_3K_2	75969.05	1.76	53.68
N_3K_3	58914.13	1.59	35.16
F-test	S	S	S
P_1K_1	51465.79	1.52	63.96
P_1K_2	74883.16	1.75	71.00
P_1K_3	62914.08	1.63	47.74
P_2K_1	58238.41	1.58	53.57
P_2K_2	90264.91	1.89	66.25
P_2K_3	65182.96	1.65	40.09
P_3K_1	49937.42	1.49	35.61
P_3K_2	74444.30	1.74	44.78
P_3K_3	51642.88	1.51	26.74
F-test	NS	NS	NS
SE	2573.30	0.03	2.02
CD(0.05)	7278.49	0.07	5.72

Fig 8 Effect of nitrogen, phosphorus and potassium on net return of mango-ginger (Rs ha^{-1})



P_2 (1.71) among P levels and K_2 (1.79) among K levels. The combinations N_2P_3 and N_2K_2 produced maximum BCR among the respective combinations.

Among treatment combinations $N_2P_2K_2$ registered higher BCR (2.03). But the effect of $N_2P_2K_2$ was found to be comparable with $N_2P_3K_2$ (2.01) and $N_3P_2K_2$ (1.91). The control recorded the lowest BCR (0.93) among all the treatments.

Return per rupee invested on fertilizers

The data on return per rupee invested on fertilizers are furnished in Tables 19, 20 and 21.

Significantly higher return per rupee invested on fertilizers was given with N_2 (Rs.56.51) while N_1 and N_3 produced similar effect. A significant decreasing trend was observed with each increase in P dose and P_1 showed maximum value (Rs. 60.89). In case of K, K_2 produced significantly higher value (Rs. 60.68) than K_1 (Rs. 51.05) and K_3 (Rs. 38.19). N_2P_1 and N_2K_2 produced higher value among them NxP and NxK combinations.

Among NPK level $N_2P_1K_1$ registered maximum return per rupee invested on fertilizers (Rs. 84.22) and it was on par with $N_2P_1K_2$ (Rs. 79.33) and $N_2P_2K_2$ (Rs. 75.74). The lowest value was recorded by $N_3P_3K_3$ (Rs. 20.73).

Table 21 Economics of cultivation of mango-ginger

NPK treatment combination	Cost of cultivation excluding treatment (Rs. ha^{-1})	Additional cost of treatment (Rs. ha^{-1})	Total cost of cultivation (A) (Rs. ha^{-1})	Yield (kg ha^{-1})	Gross returns (B) (Rs. ha^{-1})	Net returns (B - A) (Rs. ha^{-1})	Benefit Cost Ratio	Return per rupee invested on fertilizers Rs. Ps.
$N_1P_1K_1$	99000	680.05	99680.85	21415.61	128493.70	28812.83	1.29	42.36
$N_1P_1K_2$	99000	946.35	99946.35	27573.75	165442.50	65496.17	1.66	69.20
$N_1P_1K_3$	99000	1211.85	100211.85	26286.98	157721.90	57510.02	1.57	47.46
$N_1P_2K_1$	99000	985.50	99985.50	27296.08	167556.50	67571.00	1.68	68.60
$N_1P_2K_2$	99000	1251.00	100251.00	29366.04	176196.30	75945.26	1.76	60.71
$N_1P_2K_3$	99000	1516.50	100516.50	27435.88	164615.30	64098.80	1.64	43.27
$N_1P_3K_1$	99000	1290.15	100290.15	23299.82	139798.90	39508.77	1.39	30.62
$N_1P_3K_2$	99000	1555.65	100555.65	26877.44	161266.50	60710.80	1.60	39.03
$N_1P_3K_3$	99000	1821.15	100821.15	23161.95	138971.70	38150.58	1.38	20.95
$N_2P_1K_1$	99000	791.55	99791.55	27742.26	166453.60	66662.00	1.67	84.22
$N_2P_1K_2$	99000	1057.05	100057.05	30652.83	183917.00	83859.94	1.84	79.33
$N_2P_1K_3$	99000	1322.55	100322.55	28676.70	172060.20	71737.69	1.72	54.24
$N_2P_2K_1$	99000	1096.20	100096.20	23345.77	140074.61	39978.43	1.39	36.47
$N_2P_2K_2$	99000	1361.70	100361.70	33915.75	203494.50	103132.80	2.03	75.74
$N_2P_2K_3$	99000	1627.20	100627.20	26195.06	157170.40	56543.15	1.56	34.75
$N_2P_3K_1$	99000	1400.85	100400.85	27068.23	162409.40	62008.53	1.62	44.26
$N_2P_3K_2$	99000	1666.35	100666.35	33731.89	202391.30	101725.00	2.01	61.05
$N_2P_3K_3$	99000	1931.85	100931.85	29228.16	175368.90	74437.09	1.74	38.53
$N_3P_1K_1$	99000	902.25	99902.25	26470.80	158824.80	58922.55	1.59	65.30
$N_3P_1K_2$	99000	1167.75	100167.75	29243.52	175461.10	75293.35	1.75	64.48
$N_3P_1K_3$	99000	1433.25	100433.25	26654.63	159927.80	59494.52	1.59	41.51
$N_3P_2K_1$	99000	1206.90	100206.90	27895.45	167372.70	67165.78	1.67	55.65
$N_3P_2K_2$	99000	1472.40	100472.40	32031.51	192189.10	91716.66	1.91	62.29
$N_3P_2K_3$	99000	1731.90	100737.90	29274.13	175644.80	74906.91	1.74	43.25
$N_3P_3K_1$	99000	1511.55	100511.55	24801.09	148806.50	48294.96	1.48	31.95
$N_3P_3K_2$	99000	1777.05	100777.05	26945.69	161674.20	60897.12	1.60	34.27
$N_3P_3K_3$	99000	2042.55	101042.55	23897.25	143383.50	42340.96	1.42	20.73
Control	99000	-	99000.00	15303.43	91820.60	-7179.39	0.93	-

Cost of inputs

Seed mango-ginger - Rs. 8 kg^{-1} FYM - Rs. 350 t^{-1}

Nitrogen - Rs.7.38 kg^{-1} Phosphorus - Rs. 20.31 kg^{-1} Potassium - Rs. 8.85 kg^{-1}

Plant protection chemicals - Rs.3000 ha^{-1}. Labour charge - Rs. 84 per head

Price of fresh mango-ginger - Rs. 6 kg^{-1}

Optimum doses of nutrients

The quadratic response equation of the model developed from the yield data is as follows

$$Y = -3660.598 + 11179.41\,N + 7380.453\,P + 16734.23\,K - 399.13\,NP - 298.8333\,NK - 2253.222\,N^2 - 1724.778\,P^2 - 3883.5\,K^2$$

The physical optimum doses of nitrogen, phosphorus, and potassium were found to be 32.66, 28.31 and 62.12 kg ha^{-1} respectively. The expected yield at this physical optimum was worked out to be 32796.22 kg ha^{-1}.

The economic doses of nitrogen, phosphorus and potassium were estimated at the prevailing market rates of Rs.6 per kg of fresh mango-ginger rhizomes, Rs. 7.38 per kg of nitrogen, Rs.20.31 per kg of phosphorus and Rs.8.85 per kg of potassium. The economic doses of nitrogen, phosphorus and potassium can be fixed as 32.73 : 28.32 and 62.12 kg ha^{-1} respectively. The expected total yield at the economic doses of the nutrients was worked out to be 32979 kg ha^{-1} fetching a net return of Rs.95710 ha^{-1}.

Correlation studies

The data on correlation coefficients of yield with various plant characters are shown in Table 22.

Table 22 Correlation coefficients of yield with various plant characters

Sl. No.	Characters studied	Correlation coefficient
1.	Plant height	0.054
2.	Number of leaves	0.249*
3.	Number of tillers	0.092
4.	Leaf area index	0.225*
5.	Chlorophyll content	0.446**
6.	Dry matter production	0.313**
7.	Net assimilation rate	0.059
8.	Crop growth rate	0.129
9.	Bulking rate	0.999*
10.	Rhizome spread	-0.268*
11.	Top yield	0.204
12.	Utilization index	0.468**
13.	Harvest index	0.478**
14.	Uptake of nitrogen	0.217*
15.	Uptake of phosphorus	0.200
16.	Uptake of potassium	0.277*

Table value of r_{82} 0.215 at 5% level
0.280 at 1% level

* significant at 5% level
** significant at 1% level

Correlation study of yield with various plant characters showed that a positive and significant correlation exists between number of leaves, leaf area index, chlorophyll content, dry matter production and bulking rate with yield. Uptake of N and K had a positive and significant correlation with yield.

DISCUSSION

DISCUSSION

Fertilizer schedule constitutes an important component of improved package of practices of crop plants. Importance of NPK fertilization is projected by various workers in relation to quality and productivity of spices. It is well known that crop yield is the result of interaction among factors like heredity, environment and plant nutrition.

The manurial and fertilizer requirement of a crop vary according to the agro-ecological situations prevailing in a particular locality. The amount of nutrients taken up by a crop varies considerably with the soil type, climatic conditions, quantity of nutrients present in the soil, variety of the crop and yield. Balanced fertilizer application for optimum economic response involves application of adequate quantities of appropriate fertilizers, which together with the plant foods already present in the soil, will provide the growing crop with a steady supply of nutrients.

Mango-ginger responds fairly well to manuring. In the present investigation an attempt had been made to study the effect of nitrogen, phosphorus and potassium on the growth, yield and quality of mango-ginger.

Based on the yield trends the optimum dose of nutrients required for maximum yield had been worked out. The results of the observations on growth, yield and quality parameters are discussed hereunder.

Sprouting

Adequate supply of nutrients is necessary for metabolic activity which in turn influences the growth and yield of crops. Results depicted in Table 2 revealed that nitrogen and potassium levels had no significant influence on the sprouting of mango-ginger, but all the nitrogen and potassium levels registered significantly higher percentage of sprouting than the control. This result was in line with the report of Balashanmugam and Chezhiyan (1986) in turmeric. It was noted that phosphorus application significantly influenced the percentage of sprouting. Application of highest dose of 45 kg P_2O_5 ha^{-1} recorded maximum sprouting. Phosphorus being a constituent of cell nucleus and essential for cell division and for the development of meristem tissue, might have favourably influenced the sprouting of rhizomes. The role played by phosphorus in increasing the root growth of crops is an established fact.

Among the two factor interactions significantly influencing sprouting, combined application of 45 kg N + 30 kg P_2O_5 ha^{-1}, 45 kg N + 90 kg K_2O ha^{-1} and 45 kg P_2O_5 + 30 kg K_2O ha^{-1}

among PxK resulted in higher sprouting. This may be due to complementary effect of nutrients (Tisdale *et al.*, 1995).

Plant height

Nitrogen application significantly influenced plant height at 60 and 150 DAP. At the initial stage a lower dose of 15 kg N ha^{-1} produced significantly higher value but later 30 kg N ha^{-1} produced maximum plant height. This increase in plant height may be due to increased cell division and cell elongation brought about by nitrogen application. Nitrogen being the most potential nutrient element for the vegetative growth and development of plants, its supply and availability would have helped the plant to produce more height. The effect of nitrogen application in increasing plant height was reported by various workers in ginger (Aclan and Quisumbing, 1976) and turmeric (Nair, 1964, Balashanmugam and Chezhiyan, 1986 and Pandey, 1993).

The application of phosphorus showed significant difference only at 150 DAP, when 30 kg P_2O_5 ha^{-1} produced significantly higher plant height. Phosphorus application might have resulted in better root formation during initial stages of growth and later this in turn resulted in increased plant height. Beneficial effect of phosphorus application in increasing plant height was reported by Panda (1972) in green gram, Murali (1989) in *Sesbania rostrata* and Thakuria and Luikham (1991) in fodder cowpea.

Application of highest dose of K (90 kg ha^{-1}) produced maximum plant height throughout the growth stage of the crop. This may be due to the complementary effect of potassium with other nutrients on the growth of plants, better utilization of carbohydrates, promotion of enzyme action and water transport. Beneficial effect of K application in increasing plant height was reported by Purewal and Dargon (1957) in sweet potato, Premraj (1980) in colocasia and Rathinavel (1983) in turmeric.

NxP interaction was significant at 60 DAP and 15 kg N with 15 kg P_2O_5 ha^{-1} produced higher plant height. NxK interaction significantly influenced plant height with 30 kg N + 30 kg K_2O ha^{-1} producing taller plants. Among PxK interaction 30 kg P_2O_5 + 90 kg K_2O ha^{-1} recorded maximum plant height during all stages of growth. The results revealed that NPK fertilization is necessary for increasing plant height in mango-ginger, since plants received NPK exhibited in significantly higher plant height compared to the control.

Number of tillers per plant

Application of 45 kg N ha^{-1} (N_3) was found to produce maximum tiller number at all stages of growth. This can be attributed to the higher absorption of nitrogen leading to production of proteins, carbohydrates and other macromolecules of biological significance (Childers, 1966). Dasaradhi *et al.* (1971) stressed the importance of nitrogen for the active growth and tillering of ginger. Similar results were observed by Nair (1964), Balashanmugam and Chezhiyan (1986) and Pandey (1993) in turmeric and Muralidharan *et al*. (1974) and Aclan and Quisambing (1976) in ginger.

At 105 and 150 DAP, 30 kg P_2O_5 ha^{-1} recorded significantly higher tiller number. Since phosphorus is a constituent of cell nucleus, it is closely associated with cell division and meristematic activity (Ferman, 1965). Its application at higher levels might have resulted in higher rates of availability of this nutrient leading to an increase in the number of tillers per plant. Similar results were reported by Gill *et al*. (1974) and Joseph (1982) in chillies.

In the case of potassium, maximum number of tillers was found with highest dose throughout the growth period. Potassium plays an important role in the conversion of aminoacids to proteins and soluble sugars to starch and other polysacharides (Ferman, 1965). This might have led to higher vegetative growth at higher levels of K application. Similar results were obtained in turmeric (Rathinavel, 1983) and in taro (Ashokan and Nair, 1984).

Application of 45 kg each of N and P resulted in higher number of tillers at early stages, while it was 30 kg of both N and P at 150 DAP, which may be a manifestation of main effects. The NxK and PxK interactions were significant at 60 and 105 DAP.

45 kg N + 90 kg K_2O ha^{-1} gave higher number of tillers, 15 kg P_2O_5 + 60 kg K_2O ha^{-1} and 30 kg N + 90 kg K_2O ha^{-1} recorded maximum values for PxK, at 60 and 105 DAP.

The control registered significantly lower number of tillers compared to treatments. This means that the supply of nutrients in adequate quantity was essential for good tiller production.

Number of leaves

Application of nitrogen caused significant difference in leaf number at 105 and 150 DAP with 45 kg ha^{-1} registering maximum value. Better plant growth and tillering as a result of nitrogen application led to the formation of more number of leaves. This may be explained on the basis of the simple fact that, N being an active constituent of protoplasm, enzyme and chlorophyll, plays the role of a catalytic agent in various physiological processes, accelerate cell division and speed up photoassimilation which in turn boost the plant growth and improve the plant building structures. If a plant is supplied with high concentrations of nitrogen, there is a tendancy to increase leaf cell number and cell size with an over all increase in leaf production (Noggle and Fritz, 1992). Bourke (1985) in sweet potato and Balashanmugam and Chezhiyan (1986) in turmeric reported similar effects.

Phosphorus application at the highest dose resulted in maximum number of leaves at 105 DAP and 30 kg at 150 DAP. Phosphorus being a constituent of nucleic acids, phospholipids and coenzymes, is essential for the plant processes like photosynthesis, carbohydrate and nitrogen metabolism. Thus, its application at higher levels might have favourably influenced leaf production.

Maximum leaf number was obtained with 30 kg K_2O ha^{-1} at initial stages while 90 kg produced maximum leaf number at 150 DAP and the effect being comparable with 60 kg K_2O ha^{-1}. Potassium influences photosynthesis, chlorophyll development and water content of leaves. The complementary action of potassium with other nutrients might have led to increased leaf production. Significant increase in leaf number with application of K was found by Rathinavel (1983) in turmeric.

Application of 15 kg N + 15 kg P_2O_5 ha^{-1} at 60 DAP, 45 kg N + 45 kg P_2O_5 ha^{-1} at 105 DAP and 45 kg N + 30 kg P_2O_5 ha^{-1} at 150 DAP were found to produce maximum leaf number, among NxP interactions. Application of 30 kg each of N and K produced higher leaf number at early stages, while the combination 45 kg N + 60 kg K_2O ha^{-1} produced higher leaf number at later stage. Among PxK combinations 30 kg P_2O_5 + 60 kg K_2O ha^{-1} produced higher value at early stages and later it was replaced by the combination 15 kg P_2O_5 + 90 kg K_2O ha^{-1}.

The control registered significantly lower number of leaves compared to treatments. In general, there was an increase in leaf number with application of N, P and K. The correlation study revealed that there exists a positive and significant correlation with number of leaves and yield. The study pointed out the need of chemical fertilizers in enhancing yield.

Leaf Area Index (LAI)

From the data on LAI (Table 4) it is clear that N application significantly increased LAI at all the stages of growth. Higher the nitrogen application, higher was the number of tillers and number of leaves. This shows that nitrogen application helped to increase the leaf area significantly. Thus more leaf area was made available to the crop for the various physiological activities including photosynthesis. Russel (1973) stated that for many crops the amount of leaf area available for photsynthesis is roughly proportional to the amount of nitrogen applied. Significant increase in LAI due to N application, was reported in coleus (Geetha, 1983), cassava (Ngongi, 1976 and Nair, 1986), sweet potato (Bourke, 1985) and turmeric (Balashanmugam and Chezhiyan, 1986).

During initial stages of plant growth highest dose of P resulted in higher LAI, but at 150 DAP, 30 kg P_2O_5 ha^{-1} produced higher LAI. Phosphorus being a constituent of cell nucleus, its increased availability at higher rates of application might have resulted in higher cell division and meristematic activity leading to higher LAI. Higher number of tillers and leaves at higher doses of P might have also contributed to higher LAI. Phosphorus application increased LAI in cassava (Anon.,1977 and Nair, 1986).

The highest dose of K (90 kg K_2O ha^{-1}) produced significantly higher LAI at later stages of growth. Potassium is important in the photosynthetic process and it increases leaf area and carbondioxide assimilation (Russell, 1973). This may be the reason for higher LAI at higher levels of its application. Beneficial effect of K application on leaf area was reported by Purewal and Dargon (1957) in colocasia, Karikari (1974) in cocoyam, Premraj (1980) in colocasia, Geetha (1983) in coleus and Ngongi (1976) and Nair (1986) in cassava.

Among NxP combinations 30 kg N + 45 kg P_2O_5 ha^{-1} and 45 kg N + 45 kg P_2O_5 ha^{-1} recorded maximum LAI at 90 and 120 DAP respectively while 30 kg N + 30 kg P_2O_5 ha^{-1} recorded maximum LAI at 150 DAP. In the case of NxK interaction the combination 15 kg N + 30 kg K_2O ha^{-1} at 90 DAP, 45 kg N + 90 kg K_2O ha^{-1} at 120 DAP and 30 kg N + 60 kg K_2O ha^{-1} at 150 DAP produced maximum result. The combination 30 kg P_2O_5 + 30 kg K_2O ha^{-1} at 90 DAP and 30 kg P_2O_5 + 90 kg K_2O ha^{-1} at 120 and 150 DAP respectively produced maximum LAI. This may be due to additive effects of nutrients in producing good LAI.

In general, there was significant increase in LAI in treated plots compared to control. The correlation study (Table 22) revealed positive and significant correlation of LAI with yield and hence the importance of application of chemical fertilizers.

Dry matter production (DMP)

At 90 and 120 DAP application of highest dose of N (45 kg ha^{-1}) produced higher DMP, but later 30 kg N ha^{-1} gave maximum DMP. Nitrogen encourages the vegetative development of plants and controls to some extent, the efficient utilization of phosphorus and potassium. According to Russel (1973) as the nitrogen supply increases the extra protein produced allows the plant leaves to grow larger and hence to have more surface area available for photosynthesis, which result in better nitrogen use efficiency of plant and enhanced growth. This might have led to increased assimilation, high productivity and increased DMP. The increased DMP with higher doses of N may be due to increased plant height, leaf number, leaf area index and tillering at higher doses. Comparable results were observed in chillies (Joseph, 1982, Singh *et al*., 1986 and Machanda and Singh, 1987) and in sweet potato (Bourke, 1985).

The effect of phosphorus on DMP was not significant at 90 and 120 DAP. But at 150 DAP, the highest dose of P (45 kg ha^{-1}) produced maximum DMP. This may be due to the cumulative effect of phosphorus on plant height, leaf number and tillering at this stage.

Application of 30 kg K_2O ha^{-1} resulted in higher DMP at initial stages. Potassium complemented the action of nitrogen in promoting vegetative growth at early stages. Since the bulking rate was not significantly different due to K application at initial phases it reflected in DMP also.

Among NxP interactions 45 kg N + 30 kg P_2O_5 ha^{-1}, 45 kg N + 45 kg P_2O_5 ha^{-1} and 30 kg N + 45 kg P_2O_5 ha^{-1} produced maximum DMP at 90, 120 and 150 DAP respectively. In the case of NxK interaction, the combination 45 kg N + 30 kg K_2O ha^{-1} was superior at 90 and 120 DAP and 15 kg N + 60 kg K_2O ha^{-1} at 150 DAP. Regarding PxK combination, 45 kg P_2O_5 + 30 kg K_2O ha^{-1} resulted in superior DMP at 90 and 150 DAP while, 15 kg P_2O_5 + 90 kg K_2O ha^{-1}, recorded higher DMP at 120 DAP.

A significantly lower DMP was shown by the control compared to all other treatments. This showed that the nutrients had a greater influence on both top growth and rhizome yield. Adequate supply of nutrients through application of chemical fertilizers might have activated many metabolic processes leading to production of complex substances which in turn influenced the growth and yield of mango-ginger. From the correlation study a positive and significant correlation of DMP with yield was observed. This emphasized the need of application of fertilizers to boost up production.

Net Assimilation Rate (NAR)

Net assimilation rate is a physiological index which is closely connected with photosynthetic efficiency of plant. It is a measure of the amount of photosynthetic product going into plant material. At 90-120 DAP the application of 30 kg N ha^{-1} gave maximum NAR while at 120-150 DAP 15 kg N ha^{-1} recorded higher NAR. In case of phosphorus, 15 kg P_2O_5 ha^{-1} produced significantly higher NAR at first phase (90 -120 DAP) while 45 kg P_2O_5 ha^{-1} recorded higher NAR at second growth phase (120-150 DAP). In the case of potassium 90 kg K_2O ha^{-1} produced higher NAR at initial phase and later no significant variation was noticed. There was no significant difference between treatment and control. Pushpakumari (1989) reported similar result showing no significant variation in NAR due to fertilizer levels in crops like lesser yam, greater yam, elephant foot yam and tannia.

At first phase 30 kg N + 15 kg P_2O_5 ha^{-1} registered higher NAR while 30 kg N + 45 kg P_2O_5 ha^{-1} registered higher NAR at second growth phase. In the case of NxK combination, 30 kg N + 90 kg K_2O ha^{-1} produced higher NAR at 90-120 DAP and 30 kg N + 60 kg K_2O ha^{-1} at later phase. The combination 15 kg P_2O_5 + 90 kg K_2O ha^{-1} and 30 kg P_2O_5 + 60 kg K_2O ha^{-1} registered higher NAR at first and second growth phases respectively.

Here, though significant variation was noticed among the nutrient levels, the control and treatments did not differ significantly. This may be due to averaging effect of the 27 treatments replicated thrice.

Crop Growth Rate (CGR)

Application of 30 kg N ha^{-1} ranked first among N levels in case of CGR at both phases. Increase in CGR with nitrogen was observed by Bourke (1985) in sweet potato. Though CGR was found to be highest with 15 kg P_2O_5 ha^{-1} at 90-120 DAP later 45 kg P_2O_5 ha^{-1} produced maximum CGR. This may be due to the higher DMP with 45 kg P_2O_5 ha^{-1} at 150 DAP. Application of 90 kg K_2O ha^{-1} resulted in higher CGR at initial phase and later no significant results were observed. This may be due to the insignificance of potassium application on DMP and bulking rate at this stage.

At the first growth phase significant difference between treatment and control were observed, but later there was no significant difference between the two. No significant variation in CGR due to fertilizer treatments was observed by Pushpakumari (1989) in tannia, but in greater yam the effect was significant with the lowest CGR recorded by highest fertilizer dose.

The combination of 45 kg N ha^{-1} with 15 kg P_2O_5 ha^{-1} produced maximum CGR at first phase and at second phase the combination 30 kg N with 45 kg P_2O_5 ha^{-1} ranked first in CGR. Among NxK interactions, 30 kg N + 90 kg K_2O ha^{-1} and 30 kg N + 30 kg K_2O ha^{-1} recorded maximum CGR at initial and final phase of observations respectively. Considering PxK interaction 15 kg P_2O_5 with 90 kg K_2O ha^{-1} and 45 kg P_2O_5 + 90 kg K_2O ha^{-1} produced higher CGR at first and second phases of observations respectively.

Bulking Rate (BR)

45 kg N ha^{-1} registered higher BR at first phase and an increase of 97.29 per cent in BR compared to control was noted. 30 kg N ha^{-1} produced higher bulking rate at 150 - 180 DAP. BR might have been influenced by the higher LAI (Table 4) and increased N uptake (Table 15). Similar observations were made by Russel (1973) where he stated that root crops benefitted from nitrogen manuring through the increased leaf area brought about by nitrogen. Geetha (1983) reported concurrent results in coleus.

Effect of phosphorus on BR was significant throughout the growth stage. Application of 30 kg P_2O_5 ha^{-1} produced maximum BR at first phase (90-120 DAP) and 150 -180 DAP while 45 kg P_2O_5 ha^{-1} produced significantly higher BR at 120-150 DAP. This increased BR can be attributed to increased nutrient availability at higher doses of fertilizers.

The effect of potassium on bulking rate was not significant at early stages but 150 - 180 DAP 60 kg K_2O ha^{-1} gave higher bulking rate. Potassium is involved in the translocation of photosynthate to economic parts and potassium at 60 kg ha^{-1} may be sufficient to produce a good bulking rate. Significantly higher rates of bulking with higher K levels were reported in potato (Shukla and Singh, 1975) and coleus (Geetha, 1983). Pushpakumari (1989) noticed no significant influence of fertilizer levels on bulking rate of tannia.

The combination of 45 kg N ha^{-1} with 45 kg P_2O_5 ha^{-1} registered higher BR at 90-120 DAP while 30 kg N + 45 kg P_2O_5 ha^{-1} produced maximum BR later. Regarding NxK combinations, 45 kg N + 30 kg K_2O ha^{-1} and 15 kg N + 60 kg K_2O ha^{-1} and 30 kg N + 60 kg K_2O ha^{-1} produced higher values at first, second and third phases of observation respectively. In the case of PxK 30 kg P_2O_5 + 30 kg K_2O ha^{-1} combination gave higher BR compared to other levels at initial phase. 45 kg P_2O_5 + 30 kg K_2O ha^{-1} and 30 kg P_2O_5 + 60 kg K_2O ha^{-1} showed higher BR at 120-150 DAP and 150 - 180 DAP respectively.

Control registered significantly lower bulking rate at all phases. An overall increase in bulking rate occured at higher levels of nutrients. The correlation study showed a positive and significant correlation of bulking rate with yield (Table 22). Thus chemical fertilizers contributed to yield through their effect on translocation of photosynthates to economic parts. An increased BR with fertilizer levels were observed in ginger (Ancy, 1992).

Rhizome spread

Rhizome spread was influenced by phosphorus application and 30 kg P_2O_5 ha^{-1} resulted in higher spread. The application of N and K did not influence spread of rhizome, the control and treatment plots behaved similarly. This was in agreement with the findings of Sasidharan (1985) and Pushpakumari (1989) who observed no significant influence of fertilizer levels on tuber length of lesser yam.

30 kg N + 30 kg P_2O_5 ha^{-1} recorded higher BR in the case of NxP, 30 kg N + 30 kg K_2O ha^{-1} registered maximum BR in case of NxK and 30 kg P_2O_5 ha^{-1} with 30 kg K_2O ha^{-1} among PxK combinations.

Top yield

The data on Table 8 reveal significant influence of graded doses of N and P on top yield of mango-ginger. With 30 kg N ha^{-1} significantly higher top yield was observed and there was an increase of 38.27 per cent over control. This may be due to enhanced plant height, leaf number, tiller number and DMP resulted from N application at higher levels. Moreover the adequate supply of N is related to carbohydrate utilisation and protein synthesis thereby enhancing vegetative growth of crop. Krishnappa and Shivasankara (1981) obtained increased top yield with higher N application in potato.

Highest level of phosphorus resulted in higher top yield and all levels of P produced significantly higher top yield compared to control. The cumulative effect of phosphorus on plant height, leaf number and LAI may be the reason for this. Application of K did not significantly influence the top yield. In this connection it may be remembered that potassium levels could not influence DMP, NAR and CGR at later phase of plant growth (Table 6), thus resulting in insignificant influence on top yield. Pushpakumari (1989) reported that top yield was not significantly influenced by fertilizer levels in lesser yam.

The combination, 30 kg N + 45 kg P_2O_5 ha^{-1} produced higher top yield in case of NxP, while 30 kg N + 90 kg K_2O ha^{-1} produced higher top yield among NxK interactions. Among PxK interactions 45 kg P_2o_5 + 90 kg K_2O ha^{-1} reported higher top yield. This may be due to additive effects of nutrients.

Control registered significantly lower top yield. A general trend of increase in top yield was observed with higher levels of N, P and K. This was in line with the findings of Samad (1953) in ginger, Pushpakumari (1989) in greater yam and elephant foot yam and Ancy (1992) in ginger.

Fresh rhizome yield

The graded doses of N, P, K and the interactions NxP and NxK significantly influenced the rhizome yield of mango-ginger.

Perusal of the data on fresh rhizome yield (Table 10) revealed that application of nitrogen upto 30 kg ha^{-1} significantly increased the rhizome yield of mango-ginger. Such significant and positive increase in rhizome yield with increasing levels of nitrogen was reported by many scientists in turmeric (Aiyadurai, 1966; Umate *et al.*, 1986; Balashanmugham and Chezhiyan, 1986; Govind *et al.* 1990 and Singh *et al.*, 1992).

It was found that nitrogen application significantly increased the rhizome yield of mango-ginger compared to control. An increase by 69.42, 89.18 and 79.49 per cent was recorded with 15 kg N, 30 kg N and 45 kg N respectively over control. It was noted that an yield reduction by 11.69 per cent was observed beyond 30 kg N ha^{-1}. A reduction in nitrogen uptake (Table 15) by 17.43 per cent was noticed when nitrogen level was increased from 30 kg to 45 kg. Such an yield reduction in ginger at higher nitrogen level was reported by Johnson (1978). From this it can be inferred that for mango-ginger 30 kg N ha^{-1} is best for higher rhizome yield and further increase in nitrogen level beyond 30 kg ha^{-1} is not economical.

An increase in rhizome yield was observed with increasing P level upto 30 kg P_2O_5 ha^{-1}, beyond which a reduction was observed. Significantly higher rhizome yield over control was noticed at all P levels. Application of 15 and 30 kg P_2O_5 ha^{-1} resulted in an increase by 77.68 and 86.88 per cent in yield respectively over control. Application of phosphorus resulted in significant increase in the uptake of N, P and K. Plant height, number of tillers, number of leaves, DMP and bulking rate were significantly enhanced by higher levels of phosphatic fertilization. This may be the reason for higher yield at this P levels. This was in confirmity with the findings of Rao and Reddy (1977) and Gupta *et al*. (1990) in turmeric and Aiyadurai (1966) and Saraswat (1972) in ginger.

Application of K upto 60 kg ha^{-1} increased rhizome yield significantly. An increase by 66.96 per cent in yield over control was observed with 30 kg K_2O ha^{-1}. The yield was again increased by 17.6 per cent on raising K level from 30 to 60 kg ha^{-1}. This may be attributed to the favourable influence of K on translocation of carbohydrates to the economic parts which is an established fact. In turmeric, Muthuvel *et al*. (1989) reported that 60 kg K_2O ha^{-1} was adequate to get good yield. Balashanmugam and Subramanian (1991) and Thamburaj (1991) also reported significant influence of K on the rhizome yield of turmeric.

Regarding NxP interaction, the combination of 30 kg N with 45 kg P_2O_5 ha^{-1} produced maximum yield, while 30 kg N ha^{-1}

with 60 kg K_2O ha^{-1} registered maximum value among NxK levels. The combination 30 kg P_2O_5 + 60 kg K_2O ha^{-1} was found to produce higher yield among PxK combinations. These may be the manifestation of the main effects.

Among treatment combinations, 30:30:60 kg NPK ha^{-1} produced maximum fresh rhizome yield (33,915 kg ha^{-1}) which was on par with 30:45:60 kg NPK ha^{-1} and 45:30:60 kg NPK ha^{-1}. This can be attributed to the favourable N/K ratio of 1:2 leading to better translocation of photosynthates to the economic part namely rhizome. This was in line with the results of Anon. (1993) and Sadanandan and Hamza (1996) in turmeric.

Considering the economics of cultivation the NPK combination of 30:30:60 kg ha^{-1} produced the highest net returns and benefit cost ratio and this was on par with 30:45:60 kg NPK ha^{-1} and 45:30:60 kg NPK ha^{-1}. This may be due to the higher rhizome yield of these combinations. Regarding the return per rupee invested on fertilizers the combination 30:15:30 kg NPK ha^{-1} registered maximum value followed by 30:15:60 and 30:30:60 kg NPK ha^{-1}.

Thus, it was observed that for raising an economic crop of mango-ginger, a fertilizer dose of 30:30:60 kg NPK ha^{-1} can be recommended.

Drying percentage

Nitrogen levels significantly influenced the percentage of dry rhizome recovery. Application of 30 kg N ha^{-1} produced higher recovery percentage. But,in ginger dry recovery was not significantly influenced by fertilizer levels (Ancy, 1992). Here also P and K did not exert any influence on drying percentage. The control produced higher percentage of drying compared to treatments. This may be due to higher amount of moisture absorbed by the plants treated with chemical fertilizers.

Recovery of dry rhizome

The recovery of dry rhizome followed the same trend as in fresh rhizome yield. Application of 30 kg N ha^{-1} produced significantly higher dry recovery. Application of 30 kg P_2O_5 ha^{-1} resulted in higher recovery percentage. With 60 kg K_2O ha^{-1} maximum dry yield was observed. Higher yield of fresh rhizome obtained at these levels may be the reason for these results. In ginger Ancy (1992) reported higher dry rhizome yield at higher fertilizer levels.

Utilization index and harvest index

It can be deciphered from the Table 13 that the utilization index and harvest index vary significantly with different levels of N, P and K. Highest dose of nitrogen produced maximum UI and HI. The lower top yield shown by this level may be the reason for this.

Top yield and rhizome yield were found to be higher with medium dose of nitrogen, because of considerably increased dry matter production under this level as evidenced by the data in Table 6. But further decrease in N level led to decreased rhizome yield leading to lower UI and HI. A decreasing trend in UI and HI was noted with increase in P levels. The dry matter production, top yield (Table 8) and NAR went on increasing with higher P doses. But the rhizome yield was maximum at medium dose of P. This means that a major proportion of assimilate was utilized for top growth at highest dose of P ie, proportionate assimilate partioning to rhizome was higher at 30 kg P_2O_5 ha^{-1}. In the case of potassium, medium dose resulted in higher values, possibly because of higher rhizome yield at this level. Among interactions the combination of higher dose of N with lower P in the case of NxP, medium dose of N and K and higher dose of N with medium dose of K among NxK and higher dose of P with medium dose of K among PxK resulted in higher UI and HI.

The control registered significantly lower value for UI and HI, indicating that the application of fertilizer significantly influenced assimilate partitioning in mango-ginger.

Quality of the produce

An examination of the composition of mango-ginger rhizome revealed that, it contain essential oil 0.93 percentage, total ether extractives 6.55 percentage, crude fibre 10.63 percentage and starch 45.64 percentage, on dry weight basis. On fresh weight basis, rhizome contain essential oil 0.1 percentage, starch 6.9 percentage and crude fibre 1.49 percentage (Shankaracharya, 1982). According to Dutt and Tayal (1941), the yield of essential oil was 1.1 percentage.

Volatile oil (%)

Examination of Table 13 revealed that with 30 kg N ha^{-1} the rhizome produced higher volatile oil. Medium dose of nitrogen may be congenial for production of good volatile oil in mango-ginger. Highest dose of phosphorus accounted maximum volatile oil content. Similar results were observed by Rao *et al.* (1983) and Rahman *et al.* (1990) in coriander. Higher dose of potassium reduced volatile oil content. Mohanbabu and Muthuswamy (1984) and Ahmedshah *et al.* (1988) revealed little effect of potassium application (60-90 kg ha^{-1}) on essential oil content of turmeric. Though the effect of N, P and K was significant, there was no significant difference between control and treatments. This was in close agreement with the findings of Ratna *et al.* (1993) in turmeric where they did not observe any significant difference in essential oil content between plants treated with N and P and control (no fertilizers).

45 kg ha^{-1} of both N and P produced higher volatile oil content. The combination of 15 kg N + 90 kg K_2O ha^{-1} resulted in a higher volatile oil content. The combination of medium dose of P with lower dose of K produced higher volatile oil content.

Non Volatile Ether Extract (NVEE)

From Table 12 it is clear that the higher dose of N (45 kg ha^{-1}) produced significantly higher NVEE. The results of this experiment were in confirmity with the findings of Nair and Das (1982) in ginger. A decreasing trend in NVEE with increasing P doses was observed. In the case of potassium, the lower dose produced significantly higher NVEE. Though the effect of N, P and K on NVEE content was significant, there was no significant difference in NVEE content between control and treatment.

In turmeric, oleoresin content remained unaffected by application of graded doses of NPK (Saifuddin, 1981). Ratna *et al.* (1991) observed no significant difference in NVEE content between plants treated with N, and P and control (no fertilizers).

Pawar and Patil (1987) observed an increase in oleoresin content due to nutrition in ginger. But Ancy and Jayachandran (1993) revealed that the NVEE of ginger rhizome was not adversely affected by increased levels of fertilizers.

Higher level of N with lower dose of P produced higher NVEE. In the case of NxK combination also the highest N level with lower K registered maximum NVEE. Combining P and K, the lower dose combination of 15 kg P_2O_5 and 30 kg K_2O ha^{-1} registered higher NVEE. These may be due to the additive effect of nutrients.

Fibre content

Considering the percentage of fibre present in rhizomes of mango-ginger, significant variation was observed with the various nutrients. An increasing trend in fibre content was observed with higher levels of N. But Nair and Das (1980) reported that there was no significant variation in fibre content with N application in ginger. Phosphorus application at highest level registered significantly higher fibre content. But with higher dose of 90 kg K_2O ha^{-1}, a lower fibre content was noted.

Aclan and Quisuimbing (1976) and Ancy and Jayachandran (1993) recorded no significant variation in fibre content of ginger with N, P and K. But Nair and Aiyer (1985) noted that with increase in K level upto 100 kg ha^{-1} fibre content in cassava decreased. Pagutharivu (1990) also documented similar results in colocasia.

With 45 kg N + 45 kg P_2O_5 ha^{-1} maximum fibre content was registered, which was evident from the main effects of N and P. The combination 45 kg N + 30 kg K_2O ha^{-1} expressed higher fibre content. The PxK interaction was also significant with 45 kg P_2O_5 + 60 kg K_2O ha^{-1} producing maximum value.

The fibre content in control plants was significantly lower and it can be considered as a desirable character. Control plots received 40 t ha^{-1} of FYM alone and the result was in favour of organic farming.

Starch content

Examining Table 13, it can be inferred that the effect of nitrogen, phosphorus and potassium had no significant influence on starch content of mango-ginger rhizome. This effect of nitrogen on starch content was possibly because nitrogen promoted the growth of additional tissues at the cost of photosynthates thus leaving little balance of carbohydrates for accumulation in the form of starch. This was in line with the results of Rajanna *et al*. (1987) in potato. Though potassium is involved in starch formation and translocation of sugars (Brady, 1996), in the present experiment the different levels of K could not produce any significant variation in starch content. This was in accordance with the findings of Pagutharivu (1990) in colocasia.

Control registered a significantly lower starch content than the treatments. Enhanced starch accumulation with application of fertilizers was reported in coleus (Geetha, 1983).

In contrast to this, increasing rates of NPK tended to decrease the starch content of potato tubers (Mazur and Dworakwoski, 1979).

Among the different combinations of N, P and K the effect of PxK was significant and the combination of 30kg P_2O_5 ha^{-1} with 90 kg K_2O ha^{-1} produced maximum starch content. The interaction effect of NxP and NxK was not found to be statistically significant.

In general, the quality of mango-ginger rhizome was influenced by varying levels of nutrients. The control and treatment did not show any significant variation in volatile oil and NVEE content. But the fibre and starch contents were significantly lower in the control plots.

Chlorophyll a and b

N, P and K application significantly influenced chlorophyll content of leaves. With higher levels of N an increase in the chlorophyll a, b and total chlorophyll was observed. Nitrogen is an integral part of chlorophyll molecule, thus its supply at higher amounts would have favoured the production of chlorophyll which in turn increased the photosynthetic efficiency of plant and thus yield. Ramanujam (1985) obtained similar result in cassava. In the case of P, higher levels increased leaf chlorophyll content.

Potassium at 30 kg ha^{-1} resulted in higher chlorophyll content. This may be sufficient for the production of a good amount of chlorophyll.

Among NxP interactions the combination 30 kg N + 45 kg P_2O_5 ha^{-1} registered maximum chlorophyll a and total chlorophyll, while 45 kg N + 45 kg P_2O_5 ha^{-1} showed higher chlorophyll b. Application of 45 kg N and 30 kg K_2O ha^{-1} registered higher chlorophyll a, but 30 kg N + 90 kg K_2O ha^{-1} showed higher chlorophyll b and total chlorophyll. In the case of PxK interaction 45 kg P_2O_5 + 30 kg K_2O ha^{-1} produced higher values for all these characters.

The control registered significantly lower amount of all the above parameters. The correlation study also showed positive and significant correlation of chlorophyll content with yield, emphasizing the importance of fertilizer application to boost up production. Application of fertilizers increased the chlorophyll content in ginger (Ancy, 1992).

Uptake studies

The results presented in Table 15 revealed that there was an increase in the uptake of N, P and K by mango-ginger with application of graded doses of major nutrients to soil.

Uptake of nitrogen

The application of N upto 30 kg ha^{-1} increased the uptake of N (234.58 kg ha^{-1}), which resulted in a corresponding increase in both rhizome yield and top yield. But N uptake decreased, when level was increased from 30 kg to 45 kg. Rhizome yield and top yield were also reduced beyond 30 kg N ha^{-1}. This shows that the plant was able to consume more N and produce good yield when it was supplied with moderate levels of N and thus application of 30 kg N ha^{-1} was sufficient. Such a positive response in the uptake of N with its application was reported in turmeric by many workers earlier (Lee *et al*., 1981 and Lynrah, 1991).

A progressive increase in N uptake with higher P levels was observed here. This was in confirmity with the results of Rajput and Singh (1981) in turnip (*Brassica rapa* L.). At 45 kg P_2O_5 ha^{-1} the increased uptake of N was utilised for top growth resulting in less yield compared to 30 kg P_2O_5 ha^{-1}.

Application of potassium upto 60 kg ha^{-1} resulted in maximum N uptake. The role of potassium in increasing nitrogen uptake is an established fact (Tisdale, 1995). This was reflected in higher UI and good yield. A positive response in uptake of N with K application was observed earlier by Singh *et al*. (1992) in turmeric.

Among interactions, application of 45 kg N + 30 kg P_2O_5 ha^{-1}, 30 kg N + 30 kg K_2O ha^{-1} and 30 kg P_2O_5 + 30 kg K_2O ha^{-1} ranked first in N uptake, which may be the manifestation of main effects.

Uptake of phosphorus

N and P application influenced P uptake of mango-ginger. With application of 15 kg N ha^{-1} 72.02 per cent increase in uptake over control was noticed. Patel and Mehta (1987) found that applied nitrogen increased P uptake in elephant foot yam. Lynrah (1991) and Singh *et al.* (1992) obtained enhanced P uptake with N application in turmeric.

Application of P upto 30 kg ha^{-1} enhanced the P uptake and beyond this a reduction in uptake was noticed. The yield followed similar trends, showing maximum value at 30 kg P_2O_5 ha^{-1}. This confirmed that mango-ginger needs a phosphorus level of 30 kg ha^{-1} for good yield. Compared to control application of 15, 30 and 45 kg P_2O_5 ha^{-1} resulted in an increase in uptake by 52.19 per cent, 69.15 per cent and 64.19 per cent respectively. This may be due to increased availability of P subsequent to its application. Application of P increased the P content of taro leaves (Pena, 1967). Application of K was not significant in P uptake. P uptake was influenced by PxK combination and combined application of 30 kg P_2O_5 + 60 kg K_2O ha^{-1} registered maximum value.

Uptake of potassium

Increased K uptake with increased N application was observed upto 30 kg N ha^{-1}. At 30 kg N ha^{-1}, 66 per cent increase in K uptake was observed, compared with no nitrogen. This was in agreement with the results obtained by Patel and Mehta (1987) in elephant foot yam. Application of 45 kg P_2O_5 ha^{-1} resulted in maximum K uptake.

With higher K dose, a progressive increase in K uptake was observed and application of 90 kg K_2O ha^{-1} resulted in maximum uptake. The increase in the uptake of K with increased rates of application is quite natural. Highest uptake of K was recorded under 90 kg K_2O ha^{-1} in turmeric by Balashanmugam and Subramanian (1991). Singh *et al*. (1992) reported that application of K registered higher uptake of N, P and K in rhizomes of turmeric.

Among NxP, NxK and PxK interactions application of 30 kg N + 15 kg P_2O_5 ha^{-1}, 30 kg N + 90 kg K_2O ha^{-1} and 15 kg P_2O_5 + 90 kg K_2O ha^{-1} respectively produced maximum K uptake.

Soil analysis

Available N, P and K content of soil after the experiment was influenced by graded levels of various nutrients. In general, all the treatments registered higher available nutrient status compared to control. Control registered lower nutrient status after the experiment, but there was an increase in available nutrient status of soil in all the treated plots.

Available soil N progressively increased with higher doses of its application. Phosphorus levels enhanced N status of soil and with 30 kg P_2O_5 ha^{-1} maximum N was left in the soil. The K application at 30 kg ha^{-1} produced higher residual soil nitrogen.

Gradual increase in available P content was observed upto 30 kg N ha^{-1}. Among P levels 45 kg P_2O_5 ha^{-1} produced maximum soil P status, after the experiment. A decreasing trend in available P content was observed with graded doses of K.

The K status of the soil differed with graded doses of N, P and K. Highest N dose registered maximum K uptake. Application of 30 kg P_2O_5 ha^{-1} reported higher K status, after experiment, among P levels. Significant increase in K status was observed with increasing rate of K application.

All the two factor interactions influenced N, P and K status of soil, after the experiment. With regard to available N status, 45 kg N with 30 kg P_2O_5 ha^{-1} produced higher soil N. Combined application of 45 kg N + 30 kg K_2O ha^{-1}, 30 kg P_2O_5 + 30 kg K_2O ha^{-1} resulted in maximum N status. Regarding available P status 15 kg N + 45 kg P_2O_5 ha^{-1} produced maximum soil P. Application of 30 kg N + 30 kg K_2O ha^{-1}, 45 kg P_2O_5 + 30 kg K_2O ha^{-1} showed higher residual P after the experiment. Regarding available K after experiment, combined application of higher dose of N with 30 kg P_2O_5 ha^{-1} resulted in higher value. Highest dose combination of N, with K and 15 kg P_2O_5 + 90 kg K_2O ha^{-1} resulted in higher K status. This may be due to complementary effect of nutrients.

In general, as the fertilizer rate increased the residual value also increased. This was in line with the findings of Tisdale *et al*. (1995).

Economics

Application of N, P and K significantly influenced the net returns, benefit cost ratio and return per rupee invested on fertilizers from mango-ginger.

The application of N at 30 kg ha^{-1} accounted for significantly higher net returns (Rs. 73342 ha^{-1}), benefit cost ratio (1.73) and return per rupee invested on fertilizers (Rs. 56.51). Application of 30 kg P_2O_5 ha^{-1} produced significantly higher net returns (Rs. 71228 ha^{-1}) and benefit cost ratio (1.71). Application of 15 kg P_2O_5 ha^{-1} recorded maximum value for return per rupee invested on fertilizers (Rs. 6.0.89). Potassium @ 60 kg ha^{-1} exhibited the highest net returns (Rs. 79864 ha^{-1}), benefit cost ratio (1.79) and return per rupee invested on fertilizers (Rs. 60.68).

Among NPK treatments combinations 30:30:60 kg NPK ha^{-1} produced maximum net returns (Rs.1,03,132 ha^{-1}) and benefit cost ratio (2.03). This was found to be on par with that of 30:45:60 kg NPK ha^{-1} and 45:30:60 kg NPK ha^{-1}.

The data on fresh rhizome yield also followed similar trend. Thus it can be concluded that nitrogen, phosphorus and potassium @ 30:30:60 kg ha^{-1} was the best combination regarding both yield and economics.

Optimum doses of nutrients

From the present study it has been revealed that nitrogen, phosphorus and potassium @ 32.66:28.31:62.12 kg respectively were required for maximum yield (32796 $kgha^{-1}$) and a dose of 32.73:28.32:62.82 kg ha^{-1} for economic optimum yield (32979 kg ha^{-1}) fetching a net return of Rs. 95710 ha^{-1}.

At present, there is no nutrient recommendation for mango-ginger. The economic dose of nitrogen, phosphorus and potassium for mango-ginger obtained in the present study are similar to the nutrient recommendation for the related crop, turmeric by Anon.(1993). Thus, NPK dose of 33:28:63 kg ha^{-1} can be recommended for obtaining maximum productivity from such a crop, which can yield as high as 33 t ha^{-1}, which more than compensates the cost of additional fertilizers.

Future line of work

In the present experiment, a nutrient recommendation of 30:30:60 kg NPK ha^{-1} was arrived at for the lateritic red loam soil type of southern tracts of Kerala (Vellayani). Nutrient dose for mango-ginger for other soil types should also be worked out. The possibility of reducing the quantity of FYM from 40 t ha^{-1} has to be find out. The nutrient requirement for growing mango-ginger under partial shade of coconut garden and homesteads should also be standardised.

SUMMARY

A field experiment was conducted at the College of Agriculture, Vellayani, to study the effects of nitrogen, phosphorus and potassium on growth, yield and quality of mango-ginger. The treatments comprised of combinations of three levels each of nitrogen (15, 30 and 45 kg N ha^{-1}), phosphorus (15, 30 and 45 kg P_2O_5 ha^{-1}) and potassium (30, 60 and 90 kg K_2O ha^{-1}) and an absolute control ($N_0P_0K_0$). The experiment was laid out in 3^3 + 1 Factorial Randomised Block Design. Nitrogen, phosphorus and potassium were supplied in the form of urea, single superphosphate and muriate of potash respectively. The results of the investigation are summarised below.

Higher sprouting was observed with all the N, P and K treatments compared to control. Application of highest dose of P resulted in maximum sprouting. Plant height was maximum at 30 kg ha^{-1} in the case of N and P and 90 kg ha^{-1} in the case of K.

Number of tillers was maximum with highest level of nitrogen (45 kg ha^{-1}) throughout plant growth. Though 15 kg P_2O_5 ha^{-1} produced higher tiller number at early stages and 30 kg produced maximum effect at later stages. Highest dose of K (90 kg K_2O ha^{-1}) produced maximum tiller number throughout growth.

Higher dose of nitrogen, phosphorus and potassium resulted in maximum number of leaves during later stages. Higher levels of of N, P and K produced maximum LAI.

Highest dose of 45 kg N ha^{-1} produced maximum DMP at early stages while 30 kg N ha^{-1} resulted in higher DMP, later Highest dose of phosphorus showed higher DMP. The lower dose of K produced maximum DMP at earlystages after which the effect was not significant.

NAR responded to nitrogen upto 30 kg ha^{-1} at initial phase and upto 15 kg ha^{-1} later. In the case of phosphorus, response upto 15 kg ha^{-1} was produced at first phase while 45 kg ha^{-1} gave maximum NAR later. NAR responded to K application at first phase when higher NAR was found with 90 kg ha^{-1}.

Nitrogen application significantly increased CGR upto 30 kg ha^{-1}. At first, response to P was maximum at 15 kg ha^{-1} but later, 45 kg ha^{-1} gave higher value. The response to potassium upto 90 kg ha^{-1} was shown at first phase, but later the effect was not significant.

The bulking rate was maximum with medium dose of nitrogen, phosphorus and potassium.

The effect of application of nitrogen and potassium was not significant in rhizome spread. But phosphorus upto 30 kg ha^{-1} enhanced rhizome spread.

Top yield responded upto 30 kg N ha^{-1}. Phosphorus application at 45 kg ha^{-1} produced higher top yield. Potassium had no significant influence on this character.

The medium dose of nutrients namely 30 kg N, 30 kg P_2O_5 and 60 kg K_2O ha^{-1} produced significantly higher rhizome yield among N, P and K. Among the treatment combinations maximum yield was reported by combined application of 30:30:60 kg NPK ha^{-1}.

The drying percentage was increased by nitrogen application upto 30 kg ha^{-1} while P and K had no effect. The recovery of dry rhizome was maximum at 30 kg N ha^{-1}. In the case of phosphorus 30 kg P_2O_5 ha^{-1} registered higher value, while response upto 60 kg K_2O ha^{-1} was shown.

An increasing trend in UI and HI with N application was found. Phosphorus at lower dose produced higher UI and HI. UI and HI responded upto 60 kg K_2O ha^{-1}.

Application of 30 kg N ha^{-1} produced higher percentage of volatile oil. A significant increase in volatile oil content with increase in P application was found. Potassium application decreased volatile oil content.

Higher dose of nitrogen resulted in significantly higher NVEE. But lower doses of P and K produced higher NVEE.

Increased fibre content was recorded at higher levels of N and P. But with higher dose of potassium, a lower fibre content was observed.

The different levels of N, P and K failed to produce any significant variation on starch content of mango-ginger rhizomes.

Higher levels of both N and P increased chlorophyll content of leaves but with higher doses of potassium a decreasing trend was produced.

A corresponding increase in uptake of nutrients with their application was observed. The soil nutrient status after the experiment was significantly higher in the treated plots compared to initial level.

Application of nitrogen, phosphorus and potassium significantly increased the net returns and benefit cost ratio and return per rupee invested on fertilizers. Application of 30 kg N ha^{-1} produced maximum value in these respects. Application of 30 kg P_2O_5 ha^{-1} recorded higher net returns and benefit cost ratio. The highest return per rupee invested on fertilizers was noted by 15 kg P_2O_5 ha^{-1}. In the case of potassium 60 kg K_2O ha^{-1} gave higher value for all these parameters. The treatment combination 30:30:60 kg NPK ha^{-1} resulted in higher net returns and benefit cost ratio, but the treatment combinations 30:15:30 kg NPK ha^{-1} registered maximum return per rupee invested on fertilizers.

From the present study, it was observed that a fertilizer dose of 33:28:63 kg NPK ha^{-1} was found to be optimum for production of maximum and economic yield in mango-ginger.

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NUTRIENT REQUIREMENT
OF
MANGO — GINGER
(*Curcuma amada* Roxb.)

By

MRIDULA. K. R.

Abstract of the Thesis

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ABSTRACT

A field experiment was conducted at the College of Agriculture, Vellayani, during the period June-December 1995, to study the effects of different doses of nitrogen, phosphorus and potassium on the growth, yield and quality of mango-ginger. The treatments consisted of factorial combinations of 3 levels each of nitrogen (15, 30 and 45 kg N ha^{-1}), phosphorus (15, 30 and 45 kg P_2O_5 ha^{-1}) and potassium (30, 60 and 90 kg K_2O ha^{-1}) with absolute control. The experiment was laid out as 3^3+1 Factorial Randomised Block Design with three replications.

Nitrogen (30 kg ha^{-1}) recorded maximum values for most of the characters namely plant height, leaf area index, dry matter production, crop growth rate, bulking rate, top yield, fresh rhizome yield, recovery of dry rhizome, volatile oil. Application of highest dose namely, 45 kg N ha^{-1} resulted in highest number of tillers, number of leaves, utilization index, harvest index, non-volatile ether extract, fibre content and chlorophyll content.

Phosphorus (30 kg ha^{-1}) registered higher values for plant height, number of leaves, leaf area index, bulking rate, rhizome spread, fresh rhizome yield and recovery of dry rhizome. Application of 45 kg P_2O_5 ha^{-1} produced maximum sprouting, number

of tillers, number of leaves, dry matter production, net assimilation rate, top yield, volatile oil, fibre content and chlorophyll fractions.

Application of 60 kg K_2O ha^{-1} registered maximum leaf area index, bulking rate, fresh rhizome yield, recovery of dry rhizome, utilization index, harvest index and fibre content. Potassium at 90 kg K_2O ha^{-1} recorded highest plant height, number of tillers, number of leaves and top yield. Lower dose of 30 kg K_2O ha^{-1} produced higher volatile oil, non-volatile ether extract and chlorophyll contents.

Significant increase in nutrient uptake was observed with their application at higher levels. Soil nutrient status after the experiment was maximum at higher rates of application of the respective nutrients.

Among treatment combinations 30:30:60 kg NPK ha^{-1} recorded maximum fresh rhizome yield. This combination also recorded the highest net returns and benefit cost ratio. Thus 30:30:60 kg NPK ha^{-1} can be recommended as the fertilizer dose for mango-ginger. The physical and economic optimum dose was worked out to be 33:28:62 kg N, P_2O_5 and K_2O ha^{-1}.