NUTRITION OF TISSUE - CULTURED PLANTS OF *Dendrobium* SONIA - 17

By

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THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN HORTICULTURE

FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1999

DEDICATED

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DECLARATION

I hereby declare that this thesis entitled **"Nutrition of tissue-cultured plants of *Dendrobium* Sonia - 17"** 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 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 **"Nutrition of tissue-cultured plants of *Dendrobium* Sonia - 17"** is a record of research work done independently by Miss. R. Uma Maheswari 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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ACKNOWLEDGEMENT

I place on record my deep sense of gratitude to Dr. Sabina George, T., Assistant Professor, Dept. of Horticulture, College of Agriculture, Vellayani and Chairman, Advisory Committee for her valuable guidance, constant help, constructive criticisms and encouragement throughout the course of this study.

I express my heartful gratitude to Dr. S. Ramachandran Nair, Professor and Head, Dept. of Horticulture, Dr. K. Rajmohan, Associate Professor, Dept. of Horticulture and Dr. Rajendran, Associate Professor, Dept. of Soil Science and Agricultural Chemistry, members of the advisory committee for their valuable help in planning and executing of this study, valuable suggestions and scientific support given during the entire period of this study.

Sincere thanks are also due to Dr. Vijayaraghavakumar, Associate Professor, Dept. of Agricultural Statistics for his help in the analysis and interpretation of the data and Mr. C. E. Ajithkumar, Junior Programmer, Computer Centre, College of Agriculture, Vellayani for analysing the experimental data.

Heartful thanks to Dr. C. Gokulapalan, Associate Professor of Plant Pathology for his valuable suggestions rendered in the course of this study.

My sincere thanks are also due to other teaching and non-teaching staff members of the Dept. of Horticulture, College of Agriculture, Vellayani for their support at the various stages of this study.

I sincerely thank Kerala Agricultural University for granting me KAU Junior Research Fellowship.

I am thankful to ARDRA, Vellayani for their efforts in neatly type setting the manuscript.

I owe a lot to Raji and Kanna for their support and encouragement in the completion of this work.

I wish to place on record my sincere gratitude and heartful thanks to Rekha, Renji, Sathi, Bhadra and all other friends for their constant encouragement and help throughout the study.

Above all I gratefully bow before the Almighty God for the blessings showered upon me all throughout.

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INTRODUCTION

1. INTRODUCTION

During the past few decades, floriculture has attained commercial status as a viable agri business in India. This has been made possible by the extreme focus given to floriculture by the government of India as one of the most potential areas for export promotion and the significantly high growth rate of 10.0 per cent sustained by the industry during the period. The export earnings from floriculture has increased from Rs. 14.45 crores in 1991-92 to Rs. 60.10 crores in 1995-96. In this, the share of cut flowers has increased from 2.76 per cent to 17.00 per cent (Raghava and Dadlani, 1997).

The cut flower crops which have been selected for intensive cultivation and deligated into specific floriculture zones include rose, gladiolus, carnation, gerbera, orchid, anthurium, jasmine and tuberose. Among them orchids and anthuriums have been identified for intensive cultivation in Kerala and were given special emphasis in developmental programmes during the eighth plan period itself. The climatic conditions of Kerala are conducive to cultivation of orchids without the use of expensive environmental control devices. However to compete in international markets our produce should satisfy their quality and cultural specifications. Export oriented production requires the streamlining of cultural practices to a greater degree than is conventionally done.

Thus commercialization of cultivation necessitates the mass production on a scale sufficient to meet the steady demand from internal and export markets. This in turn requires mass production of tissue-cultured planting material of varieties with cut flower attributes. The average period for which a specific variety maintains its demand in international markets is 5 to 7 years. So Package of Practices specific to varieties in demand are to be evolved periodically.

Dendrobium Sonia-17 is one of the most popular orchids grown and marketed in Kerala. Mass production by tissue-culture was standardised in this cultivar at the Kerala Agricultural University. To be supplied as quality planting material of this cultivar, the tissue-cultured plants are to be grown to a size which can be handled and managed easily by growers. So also, the earlier production of large sized shoots is necessary for the earlier production of marketable flowers.

In this context the present study was undertaken with the objectives, to assess the growth of tissue-cultured plants of *Dendrobium* Sonia-17 in response to nutrient treatments, during the first year of the *ex-vitro* phase and to identify the best nutrient dosage which will result in enhancement of vegetative growth of the plants.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Developments in the cultivation of orchids, one of the most valuable of cut flowers has been facilitated about by mass multiplication through *in vitro* techniques which has been suitably used in seed and meristem culture. Modern methods of *in vitro* propagation have brought orchid cultivation on par with other commercial crops.

Research by Poole and Seeley (1984) had shown the balancing of the elements in orchid nutrition plays a key part in optimum plant growth and that balance will vary from genera to genera and stage of growth. This necessitates that nutrient dosages must be accurately formulated for the new varieties of orchids for the pre and post floral stages.

The nature of the media commonly used for cultivation of epiphytic orchids and their supportive rather than nutritive role specifies that nutrients are to be supplied to plants at frequent rather than infrequent intervals.

2.1 Nutrition of plantlets during the early *ex vitro* phase

The tissue cultured plantlets during their early *ex vitro* phase, are very tender and become slowly acclimatized to the autotrophic state. Many workers concentrated on the management of growing conditions for the establishment and growth. Even with all favourable conditions the growth of the plants will be very slow and a very dilute fertilizer spray can improve the growth rate and vigour of the plants. Bose and Bhattacharjee (1972) reported benefit from feeding with a weak concentration of fertilizer solution for orchids during their early *ex vitro* phase. The choice of nitrogen source to be used in nutrient solutions is critical for orchid seedlings and mericlones. Arditti and Ernst (1981) reported, ammonium nitrate as the best source of N during the early *ex vitro* stage and Seeni and Latha (1990) reported that a mixture of diammonium phosphate and potassium nitrate promotes rapid growth of *Phalaenopsis* seedlings.

Wang (1986) recommends addition of 3 g of Nutricate (14 : 14 : 14 NPK) to each pot on the week after transplanting to get healthier *in vitro* banana plantlets for planting in the mainfield. The necessity of having a correctly balanced solution during the hardening stage was also emphasised by Marchal (1990) ; Seeni and Latha (1990).

Dewald *et al.* (1988) emphasised the initial application of fertilizer biweekly followed by 10 per cent MS salt solution in the later stages for optimum growth of pineapple plantlets.

Nutrition of the micropropagules during rooting and hardening had been shown to be species dependent and Scott (1987) had shown that inclusion of fertilizer during hardening can be detrimental for kalmia and improve plant quality of Rhododendron and Magnolia. Kim *et al.* (1988) reported in *Cymbidium* kanran seedlings that those fed with MS nutrient solution grew better than those fed with Kundson C solution. Whereas Agarwal *et al.* (1992) reported better establishment and further growth with kundson C nutrient medium applied on alternate days during hardening stage in *Vanila walkereal.*

Ramesh (1990) reported application of half strength MS basal medium is the best for maximum survival of jack plantlets whereas, a negative influence of nutrient solution in *Anthurium* was reported by Sreelatha (1992) and in *Dendrobium* Sonia - 17 by Sherly (1997).

2.2 Role of nutrients in plant growth

Under natural conditions, orchids get their necessary inorganic nutrients from the soil or the bark upon which they are growing and also the atmosphere washed down by rain. When under cultivation all these should be supplied to the orchid regularly, particularly if it is growing in media other than Osmunda fibre for lack of nutrients in them and lack of nutrient holding capacity.

Since the orchids are very slow growing plants, the popular NPK mixtures, combined with organic feeding is enough to meet their requirements. The proportion of one mineral to another should of course be adjusted according to age and growth rate of the plant. The growth of orchids are markedly improved by regular schedule of fertilizing the plants in liquid form (Bose and Bhattacharjee, 1980). The beneficial effects of N, P and K in improving the growth of orchids have been reported by Kang (1979) ; Fitch (1981) and Yadav and Bose (1989). Cibes *et al.* (1949) reported increase in

Vanilla growth with high N and K levels. Henderson (1953) reported, weekly application of an NPK mixture to orchid seedlings 1 to 8 cm tall resulted in marked growth increase compared with controls receiving water only. Davidson (1960) observed in gravel culture that deficiencies of N and P limited growth of *Cattleya* more drastically than did K and that plants were more likely to respond to fertilization with N of P or a combination of two. He also reasoned that the plants are capable of translocating K from old tissues and reutilizing it to meet most of the growth requirements of new organs.

Sheehan (1961) reported that best growth of *Phalaenopsis* seedlings occurred at the higher N levels when grown in different bark media. He also reported that P and K have no significant influence on seedlings. N promoting vegetative growth was also reported by Lunt and Kofranek (1961) ; Abraham and Vatsala (1981) and Singh (1992) whereas, Sheehan (1980) reported best growth of mericloned *cattleya* plants by higher levels of K at low P levels.

Sagarik and Siripong (1963) reported that the growth of young *Dendrobium* hybrid plants was best when they were provided with a complete inorganic fertilizer in 20 per cent coconut milk. Among the several nutrient solutions recommended for orchids the Ohio WP solution containing major and minor element nutrients has been reported to be suitable for seedlings and mericlones of a large number of orchids, including epiphytes (Northen, 1970 ; Singh, 1992 and KAU, 1996). Zakrejs (1976) using the nutrient ratios established by Penningfeld and Fast (1970 and 1973), found that a ratio of 1.25

N : 0.40 P_2O_5 : 0.75 K_2O was the optimal level and further increase in N did not affect growth.

Nutrient culture studies of *cattleya, cymbidium* and *phalaenopsis* undertaken by Poole and Seeley (1978) revealed that N concentration was the most important factor determining growth of all three orchid genera. For *Phalaenopsis* and *Cymbidium* 100 ppm and for *Cattleya* 50 ppm N found to be optimum. The K level had virtually no effect on the growth and 50 ppm K level proved adequate for good vegetative growth. However Gomi *et al.* (1980) recommends a higher concentration ie. 200 ppm N for good vegetative growth of four year old *Phalaenopsis* hybrids. Banfiled (1981) have recommended fertilizers containing high N doses for *Paphilopedilum* spp during growing season. Similarly many others Sessler (1978), Boodley (1981) ; Linda (1987) ; Steward (1988) ; Marguerite (1989) and Peter (1990) recommends a fertilizer mixture (30 : 10 : 10 NPK) rich in nitrogen for good vegetative growth of orchids.

Schenk and Brundert (1983) observed N deficiency in *Phalaenopsis* plants receiving 60 mg per litre and damage of plants with 240 mg per litre. The favourable effect of N on the vegetative growth was also reported by Bhattattacharjee (1981), Braem (1995) and Thompson (1996).

Reyes *et al.* (1990) obtained best quality *Epipremnum aureum* plants with 42 mg N per pot. Kovalskaya and Zaimenko (1991) reported in

Dendrobium phalaenopsis hybrid seedlings that the growth is better with MS nutrient solution. Improvement in the growth of *Phalaenepsis* with N increase from 70 to 200 ppm was reported by Wu *et al.* (1994).

The ratio of nutrients applied plays an important role in influencing the growth. The ratio can be varied according to the nutrient content of the media used. N, P and K in the proportion 1 : 1 : 1 for plants grown in osmunda fibre and in the proportion 3 : 1:1 for those grown in tree bark was recommended by Sheehan (1966). However in *Brassolaeliocattleya* Dinh Thwy Yen "Carmela Orchids", Campell and Mathes (1989) reccomends a balanced nutrient mix (Peters Orchid Special- 18 : 18 : 18 of NPK). Singh (1992) also reccomends a fertilizer mixture with equal proportion of N, P and K. Bilton, (1998) reported that a concentration of 1000 micro semens fertilizer solution is good for plants growing in ideal conditions.

2.2.1 Plant height

Nutrient application plays an important role in increasing the height of the plant. Sagarak and Siripong (1963) reported in young *Dendrobium* hybrids that greater height was obtained with complete inorganic fertilizer. Increments of N found to have favourable effect on height. When N was increased above the optimum level stunting of the plants was observed with 200 ppm N in *Cymbidium* and *Phalaenopsis* (Poole and Seeley, 1978) and with 48 mg N per pot in *Epipremum aureum* (Reyes *et al.*, 1990). Whereas Yoneda *et al.* (1997) reported stunting of the plants with P deficiency.

Frequency of application having favourable effect on plant height was reported by Khaw and Chew (1980). Three fertilization per week found to have maximum height in *Aranda* Noorah 'Alsagoff'. In *Vanda* Miss Joaquim plant height was maximum with 150 kg N, 200 kg P and 275 K per ha (Higaki and Imamura, 1987). Uesato *et al.* (1987) reported influence on stem length in *Ceratobium phalaenanthe* types *Dendrobium* with 50 to 300 ppm N and 25 to 150 ppm p.

2.2.2 Leaf growth

The number and total area of leaf plays important role in the photosynthetic efficiency of the plant. The applied nutrition can influence the leaf number, size, colour and other characteristics.

Cibes and Childers (1947) reported in *Vanilla fragrans*, that an organic mulch (forest litter) with distilled water had larger leaves than those grown in gravel with a full nutrient solution. Cibes *et al.* (1949) again reported that nitrogen deficiency caused a reduction of leaf size. Sagarik and Siripong (1963) reported that maximum number of leaves produced with a complete inorganic fertilizer in 20 % coconut milk. Enhancement of leaf area with increase in N levels from 50 ppm to 1000 ppm was reported in *Phalaenopsis* 'pink chiffon' by Sheehan (1966). Poole (1971) reported that the source of N used have effect on the leaf area with NH_4 receiving plants had greater leaf area than those receiving NO_3 in *Cattleya*.

Generally increments of added N result in increased growth upto a point when the N concentration in the tissues becomes toxic or other factors necessary for good growth become limiting. Poole and Seeley (1978) reported fewer leaf number when the concentration is 200 ppm than those given 100 ppm N. The lower N concentration of 50 ppm produced N deficiency symptoms in *Cymbidium* and *Phalaenopsis.* However in *Cattleya* the reduction in leaf number observed with still lower concentrations of 50 or 100 ppm N and larger leaves observed with 50 ppm. A favourable effect on leaf production was reported in *Aranda* Noorah 'Asagoff' with 20.9 mg N, 5.0 mg P and 21.8 mg K (Khaw and Chew, 1980).

The favourable effect of K_2O on the leaf production was reported by Bhattacharjee (1981). The beneficial effect was however restricted to 500 ppm. The interaction of N and P_2O_5 was also observed on the number of leaves. Johnson (1984 a) reported leaf drop in *Cymbidium* with excessive nutrition coupled with reduced watering of plants and Johnson (1984 b) recommends a nutrient solution containing 100 ppm N, 20 ppm P, 75 ppm K and trace elements for *Cymbidium* and *Cattleya.* Seeni and Latha (1990) reported diammonium phosphate and ammonium nitrate (20 : 10 : 10 NPK) promotes rapid leaf growth of axenic seedlings of Fire Water Prince (*Phalaenopsis* hybrids) during their post transplantation stage. Kubota and Yoneda (1994) reported expansion of leaf blade with N application and the effect of nutrients can be observed only after a particular period and the duration also depends on the season of application .

Yoneda *et al.* (1997) reported in *Phalaenopsis* that when no N was supplied, the number and size of fully developed leaves was reduced and defoliation increased resulting in considerable reduction in total leaf area. In P deficient plants, defoliation increased and the production of new leaves was curtailed. No significant difference in new leaf formation or defoliation was observed among plants supplied with or denied K. However the surface area of fully developed leaves tended to become smaller in plants lacking K.

Schum and Fischer (1985) reported greater number of leaves with N and K in the ratio of 1 : 1.

2.2.3 Shoot growth

Well balanced nutrition is necessary for the good clump production. The stem diameter was affected when there is nitrogen deficiency with 0 or 10 ppm N (Cibes *et al.*, 1949). Increasing N level above 50 ppm affected the pseudobulb growth in *Cattleya* was reported by Poole and Seeley (1978). Excess fertilizer application resulting in bursting of pseudobulbs and sheaths was reported (Sessler, 1978).

Sheehan (1980) reported that the number of clumps was found to be higher in the treatment with 17 : 17 : 17 (at 1 per cent) fertilizer mixture at 7 days interval. Sakai *et al.* (1982) reported that when varying amounts of nitrogen were applied (0 to 48 mg pot^{-1} $month^{-1}$) the height of the pseudobulbs increased with the amount of fertilizer. The shoot formation was also increased and fertilizer application was more effective with the appearance of new pseudobulbs in *Dendrobium nobile*. Bik and Van den Berg (1984) also reported improved shoot formation with increasing N rates from 2.0 to 8.0 m mol l^{-1} in miniature *Cymbidium* and withholding N for 2 months reduced shoot formation. N and K influencing the number of shoots was reported by Sabina (1996).

Higaki and Imamura (1987) reported limiting of stem diameter with K and greatest stem diameter was obtained with 275 kg K and 150 kg N per ha. However very small differences in plant diameter were observed when the N rates were high and indicated luxury consumption of N in *Phalaenopsis* hybrids "Sylba, Nopsya and Abylos" (Ochsenbauer, 1996).

Constant fertilizer application promoting the early emergence and development of the second pseudobulb reported by Wang (1995) in *Dendrobium* and *Phalaenopsis*.

2.2.4 Root growth

Vigorous and healthy root system in epiphytic orchids is the first step towards ensuring maximum growth and favourable nutrient supply. A study conducted on the effect of N, P and K deficiencies on the root growth of Vanilla by Cibes and Childers (1947) revealed that a deficiency of P resulted in poor growth and dying of roots. N and K deficiency also reduced root growth but not upto the extent of P. Good root growth was obtained in plants grown in mulch (forest litter) and irrigated with distilled water whereas, Chin (1996) reported in *Dendrobium phalaenopsis* hybrid seedlings that the root development of plant growing in the media deficient in N, P and K was more vigorous than in the complete nutrient solution.

Poole and Seeley (1978) reported in *Cattleya* that increasing N levels above 50 ppm decreased root growth more severely than that of leaves or pseudobulbs. The 1 N : 3 K_2O treated substrate had the highest salt concentration of 0.97 g l^{-1} and it produced the most roots in *Phalaenopsis* was reported by Schum and Fischer (1985).

The length and volume of main roots was found to be increased by increasing fertilization on *Aranda* Noorah Alsagoff (Khaw and Chew, 1980). Tanaka *et al.* (1988 b) reported increased root growth with 308, 62 and 156.4 ppm of N, P and K.

In seedlings of *Dactylorhiza fuchsii* Mekendrick (1997) reported marked reduction in root growth with fertilizer application . Also Yoneda *et al.*(1997) observed new root formation with potassium deficiency.

2.3 Role of nutrients on fresh and dry weights of plants

Nutrient application plays an important role in the fresh and dry weights of the plants. Chin (1966) found that omission of N, P and K severely affected dry weights of *Dendrobium phalaenopsis* hybrid seedlings. The N deficiency causing reduction in fresh and dry weights was reported by Cibes *et al.* (1949). Poole (1971) reported variation in dry weight was observed with the source of fertilizer used. In *Cattleya* NH_4 fertilization weekly had greater fresh and dry weights of roots than those receiving NO_3.

Poole and Sheehan (1973) reported in *Cattleya* that the dry weight varies from 7.3 to 11.4 per cent in leaves with the youngest and oldest leaves being lowest. Dry matter content of pseudobulbs ranged from 6.4 to 8.8 per cent but did not vary with age as much as did the leaves. In *Phalaenopsis* Poole and Sheehan (1974) reported that the dry weight of leaves varied from 5.5 to 7.5 per cent and roots from 7.5 to 10.8 per cent.

In *Odontoglossum* seedlings fresh weight increase with increase in N application from 0 to 100 ppm was observed whereas K rates appeared to have no effect. With slightly younger seedlings the plant fresh weight was considerably higher, where P_2O_5 was added to N (Gething, 1974).

Poole and Seeley (1978) reported in *Cattleya* that plants receiving 50 ppm N had greater dry weight of leaves and roots than plants grown with 100 or 200 ppm. Increase in fresh weight of *Cattleya* and *Phalaenopsis* was observed with incremental doses of N, P and K (77 to 308 ppm, 15.50 to 62.00 ppm and 39.10 to 156.40 ppm respectively) (Tanaka *et al.*, 1981, 1988 a, 1988 b and 1989).

Schum and Fischer (1985) reported in *Phalaenopsis* that highest fresh weight was observed when the N and K_2O was applied in the ratio of 1 : 2. K deficiency resulting in reduction of dry weight was reported by Yoneda *et al.* (1997).

2.4 Nutrient composition of plants

In orchids, the composition of nutrient elements in the plant parts was decided by the age of the plant and the dosage of nutrients received by the plants. Increasing substrate levels of N, P and K increased plant tissue concentration of these nutrients in the plants. Withner and Vancamp (1948) reported in seedlings of hybrid Lc. *Canhamiana alba* X *C. eucharis* that plants grown in Osmunda had greater N, P and K level (1.18, 0.17 and 2.13 per cent respectively) than those grown in Haydite (1.07, 0.16 and 1.41 per cent respectively of N, P and K). The N and K content of *Cattleya* leaves decreasing with age was reported by Erickson (1957). Similar effect of N and K was also reported by Davidson (1961) and Poole and Sheehan (1973). Poole and Sheehan (1970) reported, N content of roots plus rhizomes to be 1.5 and 2.0 per cent dry weight in mericloned *Cattleya* hybrid plants. Poole and Sheehan (1973) also reported N accumulation in older pseudobulbs. P level was found to increase with age. Again Poole and Sheehan (1974) reported the levels of three major nutrients decreased with age of the leaves.

Yamaguchi (1979) reported the mineral composition of various plant parts of *Dendrobium nobile* as detected by neutron activation analysis. They appear to be much lower than would be expected based upon spectrographic analysis of other orchid genera.

In *Cattleya* N and P levels were nearly same for leaves pseudobulbs and roots. K levels were highest in the leaves and lowest in roots. (Poole, 1974 and Poole and Seeley, 1978). The chemical composition of *Cymbidium* leaves and roots is very similar to that of *Cattleya*. Leaves had higher levels of N and lower levels of K than *Cattleya* leaves. N and K content of *Phalaenopsis* leaves decreased dramatically with age. Highest levels of N were found in youngest leaves.

Lower N, P and K content of Leelia plants under cultivation than in plants grown in host tree was observed by Carlucci *et al.* (1980). Poole and Sheehan (1982) reported higher levels of K in the leaves of *Cattleya*, *Cymbidium* and *phalaenopsis*.

Increase in N and K contents of the leaves of *Cattleya* and *Phalaenopsis* was observed with increments of N, P and K (Tanaka *et al.*, 1988 a and 1988 b) whereas, Uesato *et al.* (1987) reported in *Dendrobium* cv Lim Hepa that there is no obvious difference in leaf composition of plants receiving 50 ppm or 300 ppm N.

Hew and Ng (1996) reported in *Oncidium goldiana* that the net accumulation of N, P and K occurred only during the period of pseudobulb development. The remobilization of stored mineral nutrients from older pseudobulbs was indicative of demand for mineral nutrients by developing pseudobulbs.

The application of higher doses of N, P and K was found to enhance the concentration of the respective nutrients in the plants was reported by Gomi *et al.* (1980) ; Khaw and Chew (1980) ; Tanaka *et al.* (1988a and b) and Sabina (1996).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was carried out to find out the optimum dose of inorganic fertilizer required by the tissue-cultured plantlets (*ex vitro established*) of *Dendrobium* Sonia-17. The materials utilized and methods followed are reported hereunder.

3.1 Experimental site

The study was conducted at the College of Agriculture, Vellayani, Thiruvananthapuram, which is geographically situated at an altitude of 29 m above MSL, at the latitude 8^0 N and longitude 76^0 E.

3.2 Climate

The experimental site enjoyed a humid tropical climate. The data on weather parameters recorded during the experimental period are presented in Table 1. The highest mean maximum temperature and the lowest mean minimum temperature were 14^0 C and 23.11^0 C respectively. The mean monthly rainfall recorded varied from 2 to 270 mm and mean relative humidity varied from 75.85 to 85.95 %.

3.3 Duration of the experiment

The experiment was carried out from October 1997 to June 1998, for a period of nine months.

Table 1. Weather data recorded during the experimental period

Month	Mean temperature (^{0}C)		Rainfall (mm)	Mean RH (%)
	Maximum	Minimum		
1997				
Oct.	-	23.73	200.20	81.69
Nov.	30.85	23.74	234.70	85.99
Dec.	30.98	23.11	75.00	83.11
1998				
Jan.	31.80	23.11	2.00	79.67
Feb.	32.13	23.71	18.80	78.88
Mar.	33.30	24.21	-	75.85
Apr.	34.14	25.38	49.30	78.07
May	32.85	25.90	213.00	83.50
June	30.67	24.60	270.10	85.13

3.4 Materials utilized

3.4.1 Variety

The orchid cultivar chosen for the experiment was *Dendrobium* Sonia-17 a commercially important variety of Kerala.

3.4.2 Planting material

Ex-vitro established, 3 months old tissue cultured *Dendrobium* Sonia -17 plants were used as planting material. Uniform sized plantlets with an average height of 2.25 cm and having a single shoot and two leaves were chosen.

3.4.3 Container

Since the plants were very small, they were planted in plastic pots of size 7 x 8 cm initially. Five months later, they were transplanted into clay pots of size 15 x 10 cm with drainage holes at the bottom and at the sides.

3.4.4 Potting media

A mixture of coconut husk, charcoal and brick pieces were used in equal proportion as the potting medium. The media components were washed thoroughly before mixing.

3.4.5 Shading

The plants were grown under 75 % shade provided by black high density polyethylene net.

3.4.6 Fertilizers and manures

Ammonium Nitrate (33.5 % N) was used as the source of nitrogen, super phosphate (16 % P_2O_5) as the source of phosphorus and muriate of potash (50 % K_2O) as the source of potassium. For T_{28} (control 1) OHIO WP solution having the following composition was used at half strength

Potassium nitrate	-	2.63 g
Ammonium sulphate	-	0.44 g
Magnesium sulphate	-	2.04 g
Monocalcium phosphate	-	1.09 g
Calcium sulphate	-	4.86 g
Iron sulphate (chelated)	-	0.50 g
Manganese sulphate (1 %)	-	2.50 ml
Water	-	1.00 gallon

3.5 Methods

3.5.1 Design of the experiment

The experiment was laid out in 3^3 + 2 Factorial CRD with six replications and two plants per plot. Plants of two replications were uprooted at 90 DAP for observations and the experiment was continued with four replications.

3.5.2 Nutrient treatments

The nutrient treatments consisted of three levels of N, P and K viz., 2, 6 and 10 mg per plantlet. Ohio WP solution at half strength and a water spray were the control treatment. Treatment details are presented in Table 2.

Table 2. Nutrient treatments

Notation	N (mg / plant)	P (mg / plant)	K (mg / plant)
$N_1P_1K_1$	2	2	2
$N_1P_1K_2$	2	2	6
$N_1P_1K_3$	2	2	10
$N_1P_2K_1$	2	6	2
$N_1P_2K_2$	2	6	6
$N_1P_2K_3$	2	6	10
$N_1P_3K_1$	2	10	2
$N_1P_3K_2$	2	10	6
$N_1P_3K_3$	2	10	10
$N_2P_1K_1$	6	2	2
$N_2P_1K_2$	6	2	6
$N_2P_1K_3$	6	2	10
$N_2P_2K_1$	6	6	2
$N_2P_2K_2$	6	6	6
$N_2P_2K_3$	6	6	10
$N_2P_3K_1$	6	10	2
$N_2P_3K_2$	6	10	6
$N_2P_3K_3$	6	10	10
$N_3P_1K_1$	10	2	2
$N_3P_1K_2$	10	2	6
$N_3P_1K_3$	10	2	10
$N_3P_2K_1$	10	6	2
$N_3P_2K_2$	10	6	6
$N_3P_2K_3$	10	6	10
$N_3P_3K_1$	10	10	2
$N_3P_3K_2$	10	10	6
$N_3P_3K_3$	10	10	10
Control 1	OHIO WP Solution		
Control 2	0	0	0

3.5.3 Preparation and planting

Plantlets were dipped in 0.2 % Indofil M-45 for 10 minutes and then planted in the centre of the pots filled with media.

3.5.4 Nutrient application

The treatments were applied as whole plant spray at weekly intervals from October 1997 to June 1998. A total of 36 applications were given during the experimental period. The treatments were given to the plants after allotting them random numbers as per Fisher and Yates (1963). The volume of spray fluid applied per plant was 10 ml. Stock solutions of the fertilizers and Ohio WP solution were prepared in distilled water and made up to the required concentration. The plots were shielded to avoid spray drift.

3.5.5 Plant protection

At monthly intervals Indofil M-45 was sprayed on the plants and media as a prophylactic measure.

3.6 Observations

Observations on plant growth was recorded at the time of planting and continued at 15 day intervals from October 1997 to June 1998. All the plantlets served as observation plants.

3.6.1 Plant height

The length of the growing shoots from their collar region to the base of the emerging leaf was recorded as the height of the shoots, at 15 day interval upto 270 days after planting (DAP).

3.6.2 Number of leaves

The total number of green leaves present on the plants was recorded from 15 to 270 DAP.

3.6.3 Leaf area

The maximum length and breadth of all the leaves were recorded and the total leaf area was computed using a constant derived from a sample of 50 stratified leaves. Using the formula, total leaf area = k x n c l x b, where l was the average length of the leaves, b the average breadth of the leaves, n the number of leaves per plant and k the derived constant which was equal to 0.7225.

3.6.4 Stem girth

The maximum stem girth of the plants was recorded upto 270 DAP.

3.6.5 Number of shoots

The number of shoots per plant was recorded upto 270 DAP.

3.6.6. Number of backbulbs

The number of leaves less pseudobulbs per plantlet was recorded up 270 DAP.

3.6.7 Number and length of roots

The number and length of roots per plant was recorded at the time of planting,at 90 DAP and at the completion of the experiment (270 DAP).

3.6.8 Fresh and dry weight of the plants

The fresh and dry weights of plants were recorded at the start of the experiment, at 90 DAP and at 270 DAP.

3.6.8 Number of keikis

No keiki or offshoot formation was observed in the plants during the period of experimentation.

3.6.9 Time taken for the shoots to become backbulbs

The number of days taken from shoot emergence to shedding of all the leaves, forming backbulbs was recorded as the time taken, for shoots to become backbulbs.

3.7 Chemical analysis of plant samples

Analysis of the N, P and K content of the plantlets as a whole was done as per the standard procedures (Jackson, 1973) and expressed as percentage on dry weight basis.

3.8 Statistical analysis

The experimental data were analysed by the Analysis of Variance technique as per Panse and Sukhatme (1967).

RESULTS

4. RESULTS

The results of the experiment depicting the effects of nutrients on the growth characters and the nutrient content of the plants are presented in this chapter.

4.1 Growth characters

4.1.1 Plant height

4.1.1.1 The effect of N

The effect of N on plant height was found to be significant from 90 to 270 DAP (Table 3).

At 90 DAP (Table 3), the height was maximum (3.09 cm)in the plants receiving 6 mg of N (N_2) which was significantly greater than those receiving 2 mg of N (N_1).

At 105, 120 and 135 DAP, the N3 plants recorded a significantly greater height ie., 3.79, 4.25 and 4.69 cm, respectively than the N2 and N1 plants (Table 3).

At 150, 165, 180 and 195 DAP too, the N_3 plants recorded a significantly greater height ie., 5.33, 5.93, 6.47 and 7.13 cm, respectively, than the N_2 and N_1 plants (Table 3).

Table 3. Effect of N and P and their interaction on the height (cm) of the plants

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	2.30	2.36	2.44	2.55	2.67	2.88	3.07	3.52	3.63
N_2	2.29	2.41	2.53	2.61	2.84	3.09	3.44	3.98	4.37
N_3	2.24	2.34	2.49	2.60	2.80	3.02	3.79	4.25	4.69
F	0.50	0.68	1.48	0.60	2.95	3.62	28.76	26.59	46.35
C.D. (0.05)	-	-	-	-	-	0.159	0.191	0.204	0.225
P_1	2.33	2.41	2.50	2.62	2.78	3.00	3.38	3.87	4.16
P_2	2.30	2.40	2.51	2.62	2.82	3.05	3.37	3.96	4.34
P_3	2.20	2.31	2.45	2.53	2.72	2.94	3.55	3.92	4.19
F	2.28	1.85	0.67	1.56	0.90	0.99	2.02	0.32	1.45
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	2.40	2.43	2.48	2.64	2.66	2.84	3.06	3.60	3.72
N_1P_2	2.39	2.42	2.49	2.60	2.75	2.93	3.00	3.54	3.69
N_1P_3	2.12	2.24	2.34	2.42	2.60	2.85	3.13	3.41	3.48
N_2P_1	2.32	2.40	2.45	2.54	2.81	3.02	3.33	3.77	4.05
N_2P_2	2.34	2.49	2.64	2.77	2.96	3.23	3.45	4.29	4.90
N_2P_3	2.21	2.34	2.51	2.53	2.76	3.02	3.56	3.87	4.17
N_3P_1	2.27	2.39	2.56	2.68	2.87	3.15	3.76	4.26	4.72
N_3P_2	2.18	2.28	2.40	2.50	2.74	2.98	3.68	4.04	4.43
N_3P_3	2.27	2.35	2.50	2.63	2.80	2.94	3.95	4.47	4.92
F	1.58	1.24	2.16	2.84	0.85	1.00	0.33	4.09	6.80
C.D. (0.05)	-	-	-	0.206	-	-	-	0.353	0.390

Table 3 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	3.68	3.83	4.06	4.59	5.47	6.67	8.01	9.22	10.11
N_2	4.78	5.25	5.61	6.12	7.23	8.27	9.19	10.44	11.59
N_3	5.33	5.93	6.47	7.13	7.62	8.38	9.11	10.05	11.01
F	70.62	97.83	113.07	127.08	88.23	63.64	15.30	7.33	10.29
C.D. (0.05)	0.280	0.304	0.323	0.323	0.353	0.337	0.475	0.647	0.654
P_1	4.52	4.94	5.39	5.85	6.70	7.60	8.52	9.72	10.62
P_2	4.69	5.09	5.44	5.93	6.78	7.90	8.86	10.09	11.09
P_3	4.57	4.98	5.31	6.06	6.84	7.82	8.93	9.90	10.99
F	0.78	0.52	0.36	0.84	0.310	1.78	1.68	0.66	1.16
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	3.77	3.97	4.51	4.99	5.70	6.52	7.53	8.81	9.29
N_1P_2	3.75	3.93	3.97	4.40	5.24	6.56	8.05	9.14	10.12
N_1P_3	3.54	3.60	3.71	4.38	5.47	6.93	8.46	9.72	10.92
N_2P_1	4.30	4.71	5.03	5.58	6.75	7.67	8.67	9.84	10.90
N_2P_2	5.45	5.98	6.52	6.75	7.80	8.87	9.32	10.66	11.80
N_2P_3	4.58	5.06	5.30	6.04	7.14	8.25	9.58	10.82	12.06
N_3P_1	5.50	6.14	6.65	6.98	7.65	8.59	9.37	10.50	11.66
N_3P_2	4.88	5.37	5.84	6.65	7.30	8.28	9.21	10.48	11.37
N_3P_3	5.61	6.27	6.92	7.75	7.91	8.29	8.76	9.17	10.00
F	8.64	9.73	13.89	9.82	4.40	4.26	2.28	3.04	5.02
C.D. (0.05)	0.485	0.527	0.559	0.552	0.612	0.584	-	1.121	1.132

At 210 and 225 DAP the N_3 and N_2 plants recorded greater height (7.62 and 8.38 cm and 7.23 and 8.27 cm, respectively than the N_1 plants. At 240, 225 and 270 DAP, the N_2 and N_3 plants recorded greater heights of 9.19, 10.44 and 11.59 cm and 9.11, 10.05 and 11.01 cm, respectively than the N_1 plants (Table 3).

4.1.1.2 The effect of P

The direct effect of P on plant height was not found to be significant throughout the experimental period (Table 3).

4.1.1.3 The effect of K

The direct effect of K on height of the plants was found to be significant form 15 to 240 DAP (Table 4).

At 15 DAP, the plants receiving 2 mg of K (K_1) were found to have a greater height (2.38 cm) than those receiving 6 mg (K_2) and 10 mg (K_3) of K. From 30 to 150 DAP, the K_1 and K_2 plants recorded significantly greater heights than the K_3 plants. Plant height in the K_1 and K_2 plants were respectively, 2.47 and 2.38 cm at 30 DAP, 2.68 and 2.61 cm at 60 DAP, 2.89 and 2.77 cm at 75 DAP, 3.13 and 3.01 cm at 90 DAP, 3.62 and 3.52 cm at 105 DAP, 4.16 and 4.07 cm at 120 DAP, 4.49 and 4.42 cm at 135 DAP and 4.88 and 4.84 cm at 150 DAP (Table 4).

At 165 and 180 DAP, the K_2 and K_1 plants recorded greater height (5.32 and 5.78 cm ; 5.27 and 5.5.0 cm, respectively) than the K_3 plants (Table 4).

At 195 and 210 DAP the K_2 plants had a greater height (6.12 and 7.07 cm, respectively) than those receiving K_1 and K_3 (Table 4).

At 225 DAP, the K_2 and K_1 plants had a greater height (8.02 and 7.81 cm, respectively) than the K_3 plants whereas at 240 DAP the K_2 and K_3 plants recorded a greater height (9.09 and 8.89 cm, respectively) than the K_1 plants (Table 4).

4.1.1.4 The effect of N P interaction

A significant interaction between N and P doses applied influencing the height of the plants was observed at 60, 120, 135, 150, 165, 189, 195, 210, 225, 255 and 270 DAP (Table 3).

AT 60 DAP (Table 3) the plants receiving N_2 P_2, N_3 P_1, N_1 P_1, N_3 P_3 and N_1 P_2 had greater height (2.77, 2.68, 2.64, 2.63 and 2.60 cm, respectively) than those receiving N_2 P_1, N_2 P_3, N_3 P_2 or N_1 P_3. Among the N_1 plants, those receiving P_1 and P_2 had greater height (2.64 and 2.60 cm, respectively) than those receiving P_3. Among the N_2 plants those receiving P_2 had greater height (2.77 cm) than those receiving P_1 and P_3. Among the N_3 plants, significant differences in plant height was not noticed in those receiving P_1, P_2 or P_3.

At 120 DAP (Table 3) plants receiving N_3 P_3, N_2 P_2 or N_3 P_1 had greater height (4.47, 4.29 and 4.06 cm, respectively) than those receiving N_3 P_2, N_2 P_3, N_2 P_1, N_1P_1, N_1P_2 or N_1P_3. Among the N_1 plants, plant height was not significantly different in those receiving P_1, P_2 or P_3. Among the N_2 plants, those receiving P_2 had a greater height (4.29 cm) than those receiving P_3 or P_1. Among the N_3 plants those receiving P_3 or P_1 had greater height (4.47 and 4.26 cm, respectively) than those receiving P_2.

At 135 DAP (Table 3) the plants receiving N_3P_3, N_2P_2, N_3P_1 and N_3P_2 had a greater height (4.92, 4.90, 4.72 and 4.43 cm, respectively) than those receiving N_3P_2, N_2P_3, N_2P_1, N_1P_1, N_1P_2 or N_1P_3. However among the N_1 plants, those receiving P_1 and P_2 had greater height (3.72 and 3.69 cm, respectively) than those receiving P_3. Among the N_2 plants those receiving P2 had greater height (4.90 cm) than those receiving P_1 or P_3. Among the N_3 plants, those receiving P_3 and P_1 had greater height (4.92 and 4.72 cm, respectively) than those receiving P_2.

At 150 DAP (Table 3) plants receiving N_3P_3, N_3P_1 or N_2P_2 had a greater height (5.61, 5.50 and 5.45 cm, respectively) than those receiving N_3P_2, N_2P_3, N_2P_1, N_1P_1, N_1P_2 or N_1P_3. Among the N_2 plants, those receiving P_2 had a greater height (5.45 cm) than those receiving P_1 and P_3. Among the N_3 plants, those receiving P_3 and P_1 had greater height (5.61 and 5.50 cm, respectively) than those receiving P_2.

At 165 DAP (Table 3) plants the N_3P_3, N_3P_1 and N_2P_2 plants had greater height (6.27, 6.14 and 5.98 cm, respectively) than the others. Among the N_2 plants those receiving P_2 had a greater height (5.98 cm) than those receiving P_1 or P_2. Among the N_3 plants those receiving P_3 or P_1 had greater height (6.27 and 6.14 cm, respectively) than those receiving P_2.

At 180 DAP (Table 3) plants receiving N_3P_3, N_3P_1 or N_2P_2 had greater height (6.92, 6.65 and 6.52 cm, respectively) than those receiving the other treatments. Among the N_1 plants those receiving P_1 and P_2 had greater height (4.51 and 3.97 cm, respectively) than those receiving P_3. Among the N_2 plants, those receiving P_2 had a greater height (6.52 cm) than those receiving P_1 or P_3. Among the N_3 plants, those receiving P_3 had a greater height (6.92 cm) than those receiving P_1 or P_2.

At 195 DAP (Table 3) plants receiving N_3P_3 had a greater height (7.75 cm) than those receiving other treatments. Among the N_1 plants, those receiving P_1 had greater height (4.99 cm) than those receiving P_2 and P_3. Among the N_2 plants, those receiving P_2 had a greater height (6.75 cm) than those receiving P_1 and P_3. Among the N_3 plants, those receiving P_3 had a greater height (7.75 cm) than those receiving P_1 and P_2.

At 210 DAP (Table 3) plants receiving N_3P_3, N_2P_2, N_3P_1 and N_3P_2 had greater height (7.91, 7.80, 7.65 and 7.30 cm, respectively) than those receiving N_2P_3, N_2P_1, N_1P_1, N_1P_3 and N_1P_2. Among the N_2 plants, those receiving P_2 had a greater height (7.80 cm) than those receiving P_1 and P_3. There was no significant difference in height between the plants receiving N_1 and N_3 in combination with P_1 , P_2 or P_3.

At 225 DAP (Table 3) plants receiving N_2P_3, N_2P_2, N_3P_1 and N_3P_2 had greater height (10.82, 10.66, 10.50 and 10.48 cm, respectively) than those receiving N_2P_1, N_1P_3, N_3P_3, N_1P_2 and N_1P_1. Among the N_2 plants, those receiving P_2 and P_3 had a greater height (8.87 cm) than those receiving P_1.

At 255 DAP (Table 3) plants receiving N_2P_3, N_2P_2, N_3P_1 and N_3P_2 had greater height (10.82, 10.66, 10.50 and 10.48 cm, respectively) than those receiving N_2P_1, N_1P_3, N_3P_3, N_1P_2 and N_1P_1. Among the N_3 plants those receiving P_1 and P_2 had greater height (10.50 and 10.48 cm, respectively) than those receiving P_3.

At 270 DAP (Table 3) plants receiving N_2P_3, N_2P_2, N_3P_1 and N_3P_2 had greater (12.06, 11.80, 11.66 and 11.37 cm, respectively) than those receiving N_1P_3, N_2P_1, N_1P_2, N_3P_3 and N_1P_1. Among the N_1 plants, those receiving P_3 and P_2 had greater height (10.92 and 10.12 cm, respectively) than those receiving P_1. Among the N_2 plants, those receiving P_3 and P_2 had greater height, (12.06 and 11.80 cm, respectively) than those receiving P_1. Among the N_3 plants, those receiving P_1 and P_2 had greater height (11.66 and 11.37 cm, respectively) than those receiving P_3.

4.1.1.5 The effect of N K interaction

The effect of interaction between the N and K doses on the height of the plants was significant at 150, 165, 180 and 195 DAP (Table 4).

At 150 DAP (Table 4), plants receiving N_3K_1 and N_3K_2 had greater height (5.86 and 5.68 cm, respectively) than those receiving the other N K combinations. Among the N_2 plants, those receiving K_2 and K_1 had greater height (5.03 and 4.96 cm, respectively) than those receiving K_3. Among the N_3 plants, those receiving K_1 and K_2 had greater height (5.86 and 5.68 cm, respectively) than those receiving K_3.

At 165 DAP (Table 4), plants receiving N_3K_1 and N_3K_2 had greater height (6.45 and 6.43 cm, respectively) than those receiving the other N K combinations. Among the N_2 plants, those receiving K_2 and K_1 had greater height (5.53 and 5.50 cm, respectively) than those receiving K_3. Among the N_3 plants, those receiving K_1 and K_2 had greater height (6.45 and 6.43 cm, respectively) than those receiving K_3.

At 180 DAP (Table 4), plants receiving N_3K_2 and N_3K_1 had greater height (6.97 and 6.85 cm, respectively) than those receiving the other N K combinations. Among the N_2 plants, those receiving K_2 and K_1 had greater height (6.13 and 5.61 cm, respectively) than those receiving K_3. Among the N_3 plants, those receiving K_2 and K_1 had greater height (6.97 and 6.85 cm, respectively) than those receiving K_3.

Table 4. Effect of K and its interaction with N and P on the height (cm) of the plants

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	2.38	2.47	2.56	2.68	2.89	3.13	3.62	4.16	4.49
K_2	2.24	2.38	2.50	2.61	2.77	3.01	3.52	4.07	4.42
K_3	2.21	2.27	2.39	2.47	2.66	2.85	3.16	3.52	3.78
F	4.06	5.99	4.68	6.27	4.56	5.64	12.31	23.07	23.93
C.D. (0.05)	0.125	0.113	0.110	0.119	0.145	0.159	0.191	0.204	0.225
N_1K_1	2.37	2.45	2.49	2.62	2.70	2.91	3.10	3.69	3.76
N_1K_2	2.28	2.36	2.46	2.58	2.71	2.94	3.18	3.56	3.75
N_1K_3	2.26	2.28	2.35	2.45	2.59	2.77	2.91	3.30	3.38
N_2K_1	2.44	2.57	2.71	2.82	3.09	3.36	3.69	4.21	4.64
N_2K_2	2.24	2.40	2.53	2.61	2.82	3.09	3.54	4.17	4.49
N_2K_3	2.18	2.25	2.35	2.41	2.62	2.81	3.10	3.56	3.99
N_3K_1	2.33	2.37	2.49	2.60	2.87	3.10	4.05	4.59	5.06
N_3K_2	2.21	2.38	2.50	2.65	2.78	2.99	3.85	4.47	5.04
N_3K_3	2.18	2.27	2.48	2.55	2.77	2.98	3.48	3.70	3.98
F	0.32	0.75	1.70	1.67	1.45	1.71	0.94	1.44	0.54
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	2.50	2.58	2.63	2.76	2.92	3.16	3.75	4.20	4.45
P_1K_2	2.28	2.40	2.52	2.64	2.84	3.06	3.42	4.02	4.37
P_1K_3	2.21	2.25	2.34	2.45	2.59	2.79	2.98	3.40	3.67
P_2K_1	2.38	2.47	2.59	2.74	3.02	3.24	3.42	4.17	4.62
P_2K_2	2.29	2.44	2.55	2.67	2.79	3.04	3.62	4.19	4.57
P_2K_3	2.23	2.28	2.39	2.46	2.64	2.87	3.09	3.51	3.84
P_3K_1	2.26	2.35	2.48	2.54	2.72	2.98	3.68	4.13	4.40
P_3K_2	2.16	2.29	2.42	2.53	2.80	2.92	3.54	3.98	4.33
P_3K_3	2.18	2.28	2.45	2.51	2.76	2.91	3.42	3.64	3.84
F	0.50	0.96	1.09	1.16	1.79	0.88	2.35	0.69	0.28
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 4 continued

Treatments	Days after planting								
	150	165	180	195	210	225	240	255	270
K_1	4.88	5.27	5.50	5.84	6.87	7.81	8.33	9.90	10.87
K_2	4.84	5.32	5.78	6.21	7.07	8.02	9.09	9.99	11.09
K_3	4.07	4.42	4.86	5.80	6.38	7.49	8.89	9.82	10.75
F	20.63	22.13	17.12	3.91	8.03	4.80	5.38	0.14	0.53
C.D. (0.05)	0.280	0.304	0.323	0.319	0.353	0.337	0.475	-	-
N_1K_1	3.82	3.87	4.04	4.49	5.38	6.45	7.61	8.83	9.64
N_1K_2	3.80	4.01	4.26	4.93	5.69	6.87	8.24	9.37	10.48
N_1K_3	3.44	3.62	3.89	4.35	5.34	6.69	8.18	9.47	10.21
N_2K_1	4.96	5.50	5.61	5.56	7.47	8.50	8.49	10.75	11.99
N_2K_2	5.03	5.53	6.13	6.09	7.52	8.56	9.53	10.45	11.69
N_2K_3	4.34	4.73	5.10	6.72	6.70	7.74	9.53	10.13	11.09
N_3K_1	5.86	6.45	6.85	7.47	7.75	8.49	8.90	10.13	10.99
N_3K_2	5.68	6.43	6.97	7.59	8.01	8.61	9.48	10.55	10.09
N_3K_3	4.44	4.90	5.59	6.32	7.10	8.05	8.96	9.86	10.95
F	2.88	3.61	2.62	10.00	0.91	1.55	0.75	0.71	0.97
C.D. (0.05)	0.485	0.527	0.559	0.552	-	-	-	-	-
P_1K_1	4.83	5.14	5.47	5.63	6.63	7.50	8.00	9.74	10.47
P_1K_2	4.79	5.39	5.88	6.21	7.16	7.97	8.71	9.56	10.52
P_1K_3	3.94	4.29	4.84	5.72	6.13	7.32	8.86	9.86	10.87
P_2K_1	4.85	5.22	5.50	5.56	6.83	7.85	8.28	10.02	11.16
P_2K_2	5.06	5.48	5.98	6.25	7.21	8.33	9.50	10.52	11.56
P_2K_3	4.17	4.57	4.85	5.99	6.31	7.53	8.80	9.74	10.56
P_3K_1	4.95	5.45	5.54	6.34	7.15	8.09	8.73	9.95	10.98
P_3K_2	4.66	5.10	5.50	6.15	6.85	7.75	9.06	9.89	11.18
P_3K_3	4.11	4.39	4.88	5.68	6.52	7.64	9.00	9.86	10.83
F	0.62	0.96	0.64	2.43	1.12	1.45	0.94	0.51	0.75
C.D. (0.05)	-	-	-	-	-	-	-	-	-

At 195 DAP (Table 4), plants receiving N_3K_2 and N_3K_1 had greater height (7.59 and 7.47 cm, respectively) than those receiving the other N K combinations. Among the N_1 plants, those receiving K_2 and K_1 had greater height (4.93 and 4.49 cm, respectively) than those receiving K_3. Among the N_2 plants, those receiving K_3 had greater height (6.72 cm) than those receiving K_1 and K_2. Among the N_3 plants, those receiving K_2 and K_1 had greater height (7.59 and 7.47 cm, respectively) than those receiving K_3.

4.1.1.6 The effect of P K interaction

The effect of P K interaction on the height of the plants was not significant throughout the experimental period (Table 4).

4.1.1.7 The effect of NPK interaction

The effect of NPK interaction on the height of the plants was found to be significant at 180, 195 and 225 DAP (Tables 5).

At 180 DAP (Table 5), plants receiving $N_3P_1K_2$, $N_2P_2K_2$, $N_3P_3K_1$, $N_3P_3K_2$ and $N_2P_3K_2$ had greater height (7.70, 7.59, 7.26, 7.13 and 7.13 cm, respectively) than the others. Among the N_1 plants, those receiving P_1K_3 had greater height (4.59 cm) than those receiving P_2K_3 and P_3 K_3. Among the N_2 plants, those receiving P_2K_2 had a greater height (7.59 cm) than the others. Among the N_3 plants those receiving P_1K_2, P_1K_1 and P_3K_2 had greater height (7.70, 7.13 and 7.13 cm, respectively) than the others.

Table 5 Interaction of N, P and K on the height (cm) of the plants

Treat-ments	Days After Planting 15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	2.58	2.61	2.56	2.73	2.75	2.89	3.15	3.71	3.88
$N_1P_1K_2$	2.33	2.43	2.53	2.69	2.72	2.97	3.24	3.66	3.75
$N_1P_1K_3$	2.30	2.26	2.33	2.48	2.53	2.68	2.80	3.43	3.53
$N_1P_2K_1$	2.43	2.53	2.65	2.77	2.88	3.00	3.00	3.88	3.93
$N_1P_2K_2$	2.43	2.43	2.51	2.58	2.77	2.93	3.00	3.45	3.77
$N_1P_2K_3$	2.30	2.30	2.33	2.44	2.60	2.87	3.00	3.29	3.38
$N_1P_3K_1$	2.09	2.22	2.27	2.35	2.48	2.85	3.16	3.48	3.49
$N_1P_3K_2$	2.08	2.22	2.34	2.47	2.66	2.93	3.31	3.56	3.71
$N_1P_3K_3$	2.19	2.27	2.40	2.43	2.66	2.77	2.93	3.19	3.25
$N_2P_1K_1$	2.52	2.63	2.72	2.83	3.01	3.32	3.93	4.23	4.36
$N_2P_1K_2$	2.21	2.31	2.31	2.39	2.77	2.96	3.09	3.78	3.99
$N_2P_1K_3$	2.23	2.26	2.33	2.40	2.65	2.77	2.96	3.30	3.80
$N_2P_2K_1$	2.43	2.60	2.73	2.93	3.20	3.62	3.56	4.40	5.21
$N_2P_2K_2$	2.38	2.60	2.80	2.95	2.98	3.27	3.85	4.79	5.27
$N_2P_2K_3$	2.21	2.27	2.38	2.43	2.53	2.81	2.93	3.69	4.22
$N_2P_3K_1$	2.38	2.49	2.69	2.72	2.88	3.16	3.58	4.00	4.35
$N_2P_3K_2$	2.15	2.29	2.48	2.48	2.71	3.04	3.68	3.94	4.21
$N_2P_3K_3$	2.09	2.22	2.35	2.40	2.68	2.85	3.43	3.68	3.94
$N_3P_1K_1$	2.40	2.49	2.62	2.72	2.99	3.27	4.18	4.65	5.10
$N_3P_1K_2$	2.31	2.47	2.71	2.85	3.03	3.25	3.93	4.64	5.38
$N_3P_1K_3$	2.10	2.23	2.37	2.46	2.59	2.92	3.19	3.48	3.69
$N_3P_2K_1$	2.28	2.28	2.38	2.52	2.81	3.11	3.69	4.23	4.73
$N_3P_2K_2$	2.07	2.29	2.34	2.48	2.62	2.91	4.00	4.33	4.66
$N_3P_2K_3$	2.18	2.26	2.48	2.50	2.78	2.93	3.34	3.56	3.91
$N_3P_3K_1$	2.30	2.34	2.48	2.57	2.80	2.93	4.30	4.90	5.36
$N_3P_3K_2$	2.26	2.38	2.44	2.63	2.68	2.80	3.63	4.45	5.08
$N_3P_3K_3$	2.27	2.33	2.59	2.70	2.93	3.10	3.91	4.05	4.33
C_1	2.16	2.24	2.32	2.42	2.51	2.56	3.58	3.77	3.95
C_2	2.28	2.28	2.39	2.44	2.51	2.86	3.20	3.30	3.54
F	0.41	0.38	1.38	1.12	0.76	0.44	1.85	1.17	1.18
CD (0.05)	-	-	-	-	-	-	-	-	-

Table 5 continued

Treat-ments	Days After Planting								
	150	165	180	195	210	225	240	255	270
$N_1P_1K_1$	3.94	3.98	4.43	5.08	5.69	6.25	6.90	7.63	8.00
$N_1P_1K_2$	3.83	4.00	4.51	5.24	5.95	6.56	7.33	8.13	8.70
$N_1P_1K_3$	3.54	3.93	4.59	4.65	5.48	6.75	8.35	10.69	11.18
$N_1P_2K_1$	3.98	4.01	4.05	4.20	5.00	6.19	7.86	8.90	9.96
$N_1P_2K_2$	3.79	4.20	4.26	4.90	5.41	7.06	8.64	9.90	11.04
$N_1P_2K_3$	3.49	3.56	3.60	4.11	5.31	6.44	7.64	8.61	9.35
$N_1P_3K_1$	3.54	3.61	3.65	4.20	5.46	6.92	8.08	9.95	10.95
$N_1P_3K_2$	3.78	3.84	4.00	4.66	5.71	6.99	8.75	10.08	11.70
$N_1P_3K_3$	3.30	3.36	3.48	4.29	5.23	6.89	8.55	9.13	10.11
$N_2P_1K_1$	4.52	4.78	4.85	4.77	6.38	7.50	7.86	10.31	11.40
$N_2P_1K_2$	4.27	4.98	5.42	5.41	7.27	8.35	8.85	10.18	11.16
$N_2P_1K_3$	4.10	4.39	4.80	6.56	6.59	7.17	9.31	9.04	10.15
$N_2P_2K_1$	5.36	5.88	6.29	5.58	8.03	9.08	8.23	11.06	12.33
$N_2P_2K_2$	6.31	6.73	7.59	6.81	8.48	9.27	9.94	10.42	11.86
$N_2P_2K_3$	4.69	5.33	5.68	7.87	6.90	8.27	9.79	10.50	11.21
$N_2P_3K_1$	4.99	5.84	5.70	6.34	8.01	8.93	9.39	10.88	12.24
$N_2P_3K_2$	4.50	4.88	5.38	6.05	6.80	8.06	9.88	10.75	12.04
$N_2P_3K_3$	4.24	4.48	4.81	5.72	6.61	7.76	9.48	10.84	11.90
$N_3P_1K_1$	6.04	6.67	7.13	7.02	7.84	8.75	9.23	11.28	12.01
$N_3P_1K_2$	6.28	7.19	7.70	7.98	8.25	8.99	9.96	10.38	11.70
$N_3P_1K_3$	4.19	4.56	5.13	5.95	6.86	8.04	8.91	9.86	11.28
$N_3P_2K_1$	5.21	5.76	6.16	6.90	7.45	8.30	8.74	10.10	11.20
$N_3P_2K_2$	5.08	5.53	6.08	7.05	7.74	8.66	9.92	11.24	11.78
$N_3P_2K_3$	4.34	4.83	5.29	5.99	6.73	7.86	8.98	10.10	11.13
$N_3P_3K_1$	6.33	6.90	7.26	8.49	7.98	8.41	8.74	9.02	9.75
$N_3P_3K_2$	5.70	6.59	7.13	7.75	8.04	8.19	8.54	8.85	9.80
$N_3P_3K_3$	4.80	5.33	6.36	7.03	7.73	8.26	8.99	9.63	10,46
C_1	4.16	4.31	4.50	4.88	5.59	6.69	7.58	8.51	9.73
C_2	3.83	4.08	4.19	4.44	4.75	5.86	6.75	7.60	8.10
F	1.88	1.95	2.03	2.48	1.26	0.59	0.92	2.06	1.76
CD (0.05)	-	-	0.969	0.957	-	-	-	1.942	-

At 195 DAP (Table 5), the plants receiving $N_3P_3K_1$, $N_3P_1K_2$, $N_2P_2K_3$ and $N_3P_3K_2$ had greater height (8.49, 7.98, 7.87 and 7.75 cm, respectively) than the others. Among the N_1 plants, those receiving P_1K_2, P_1K_1, P_2K_2, P_3K_2, P_1K_3 and P_3K_3 had greater height (5.24, 5.08, 4.90, 4.66, 4.65 and 4.29 cm, respectively) than those receiving P_2K_1, P_3K_1 or P_2K_3. Among the N_2 plants, those receiving P_2K_3 had greater height (7.87 cm) than the others. Among the N_3 plants those receiving P_3K_1, P_1K_2 and P_3K_2 had greater height (8.49, 7.89 and 7.75 cm, respectively) than the others.

At 255 DAP (Table 5) the plants receiving $N_3P_1K_2$, $N_3P_1K_1$, $N_3P_2K_2$, $N_2P_2K_1$, $N_2P_3K_1$, $N_2P_3K_3$, $N_2P_3K_2$, $N_1P_1K_3$, $N_2P_2K_3$, $N_2P_2K_2$, $N_2P_1K_1$, $N_2P_1K_2$, $N_3P_2K_1$, $N_3P_2K_3$, $N_1P_3K_2$, $N_1P_3K_1$, $N_1P_2K_2$, $N_3P_1K_3$ and $N_3P_3K_3$ had greater height *viz*., 11.38, 11.28, 11.24, 11.06, 10.88, 10.84, 10.75, 10.69, 10.50, 10.42, 10.31, 10.18, 10.10, 10.10, 10.08, 9.95, 9.86 and 9.63 cm, respectively than the others. Among the N_1 plants, those receiving P_1K_3, P_3K_2, P_3K_1, P_2K_2, P_3K_3 and P_2K_1 had greater height (10.69, 10.08, 9.95, 9.90, 9.13 and 8.92 cm, respectively) than the others. Among the N_2 plants plant height was significantly lower in those receiving P_1K_3 than in the others. Among the N_3 plants those receiving P_3K_1 or P_3K_2 had a lesser height than the others.

Height of the plants were significantly greater in the treatment plants than in the controls at 75, 120 and from 135 to 270 DAP (Tables 5). However there was no significant difference in height between the ohio WP treated and the tap water sprayed plants (control 1 and 2 respectively) throughout the experimental period.

4.1.2 Number of leaves

4.1.2.1 The effect of N

The effect of N on the number of leaves produced per plant was found to be significant at 60, 75 and 90 DAP and from 120 to 270 DAP (Table 6). At 60 DAP plants receiving N_3 and N_2 had a greater number of leaves (2.11 and 1.99 respectively) than those receiving N_1.

At 75, 90 and 120 DAP (Table 6) plants receiving N_2 and N_3 had a greater number of leaves, ie., 2.55 and 2.54 at 75 DAP, 3.02 and 2.99 at 90 DAP and 3.63 and 3.29 at 120 DAP.

The N_2 plants also had a greater number of leaves at 135 DAP (3.97), 150 DAP (4.04), 165 DAP (4.24), 180 DAP (4.36), 195 DAP (4.53), 210 DAP (4.56), 225 DAP (4.65), 240 DAP (4.71), 255 DAP (4.71) and 270 DAP (4.57) (Table 6) than the N_3 and N_1 plants.

4.1.2.2 The effect of P

The direct effect of P on the number of leaves was not found to be significant throughout the experimental period (Table 6).

4.1.2.3 The effect of K

The effect of K was found to be significant at 165, 180, 195, 210, 225, 240 and 270 DAP (Table 7). The plants receiving K_1 had greater number of

Table 6. Effect of N, P and their interaction on the number of leaves produced per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	1.62	1.68	1.75	1.83	2.19	2.63	2.90	2.99	3.13
N_2	1.62	1.73	1.88	1.99	2.55	3.02	3.32	3.63	3.97
N_3	1.66	1.68	1.83	2.11	2.54	2.99	3.13	3.29	3.54
F	0.09	0.21	0.99	4.41	7.31	8.67	2.79	6.63	11.47
C.D. (0.05)	-	-	-	0.184	0.206	0.204	-	0.349	0.352
P_1	1.62	1.69	1.80	1.95	2.37	2.79	3.08	3.22	3.49
P_2	1.59	1.62	1.77	2.03	2.44	2.90	3.08	3.28	3.44
P_3	1.69	1.77	1.90	1.95	2.47	2.95	3.18	3.40	3.71
F	0.46	1.12	1.07	0.42	0.48	1.33	0.20	0.56	1.29
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	1.53	1.61	1.72	1.83	2.08	2.31	2.67	2.71	2.92
N_1P_2	1.58	1.61	1.61	1.81	2.06	2.61	2.83	2.92	2.96
N_1P_3	1.75	1.81	1.92	1.86	2.44	2.97	3.21	3.33	3.50
N_2P_1	1.64	1.83	1.92	1.92	2.53	2.92	3.29	3.50	3.75
N_2P_2	1.64	1.69	1.86	2.14	2.69	3.11	3.29	3.65	3.79
N_2P_3	1.58	1.67	1.86	1.92	2.42	3.03	3.38	3.75	4.38
N_3P_1	1.69	1.64	1.75	2.11	2.50	3.14	3.29	3.46	3.79
N_3P_2	1.56	1.56	1.83	2.14	2.56	2.97	3.13	3.29	3.58
N_3P_3	1.72	1.83	1.92	2.08	2.56	2.86	2.96	3.13	3.25
F	0.53	0.83	0.69	0.47	1.81	3.65	1.04	1.29	2.58
C.D. (0.05)	-	-	-	-	-	0.354	-	-	0.610

Table 6 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	3.29	3.42	3.47	3.51	3.54	3.61	3.71	3.74	3.82
N_2	4.04	4.24	4.36	4.53	4.56	4.65	4.71	4.71	4.57
N_3	3.71	3.85	3.88	4.13	4.10	4.10	4.15	4.17	4.08
F	11.77	15.56	19.89	19.52	16.58	16.34	10.29	7.58	5.98
C.D. (0.05)	0.308	0.292	0.281	0.325	0.351	0.363	0.440	0.498	0.439
P_1	3.64	3.76	3.79	3.89	3.92	3.96	4.00	4.03	4.04
P_2	3.57	3.81	3.88	4.03	4.04	4.10	4.21	4.15	4.13
P_3	3.83	3.93	4.04	4.25	4.24	4.31	4.36	4.43	4.31
F	1.56	0.70	1.63	2.49	1.67	1.84	1.35	1.36	0.75
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	3.04	3.17	3.17	3.08	3.13	3.17	3.25	3.29	3.38
N_1P_2	3.08	3.25	3.29	3.38	3.46	3.58	3.75	3.63	3.83
N_1P_3	3.75	3.83	3.96	4.08	4.04	4.08	4.13	4.29	4.25
N_2P_1	3.96	4.08	4.17	4.29	4.33	4.42	4.46	4.46	4.42
N_2P_2	3.92	4.29	4.46	4.58	4.58	4.63	4.75	4.75	4.54
N_2P_3	4.25	4.33	4.46	4.71	4.75	4.92	4.92	4.92	4.75
N_3P_1	3.92	4.04	4.04	4.29	4.29	4.29	4.29	4.33	4.33
N_3P_2	3.71	3.88	3.88	4.13	4.08	4.08	4.13	4.08	4.00
N_3P_3	3.50	3.63	3.71	3.96	3.92	3.92	4.04	4.08	3.92
F	2.48	2.64	3.16	2.98	2.32	4.18	1.12	1.10	1.28
C.D. (0.05)	0.534	0.506	0.486	0.563	-	-	-	-	-

Table 7. Effect of K and its interaction with N and P on the number of leaves per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	1.56	1.66	1.78	1.99	2.45	2.82	3.18	3.39	3.67
K_2	1.71	1.77	1.87	2.02	2.53	2.94	3.14	3.32	3.58
K_3	1.62	1.66	1.81	1.93	2.30	2.87	3.03	3.19	3.39
F	1.14	0.84	0.50	0.51	2.54	0.68	0.40	0.63	1.30
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.50	1.58	1.64	1.86	2.25	2.58	2.92	3.00	3.13
N_1K_2	1.69	1.75	1.75	1.81	2.25	2.69	2.92	3.00	3.17
N_1K_3	1.67	1.69	1.86	1.83	2.08	2.61	2.88	2.96	3.08
N_2K_1	1.50	1.69	1.81	1.92	2.58	2.94	2.29	3.58	3.96
N_2K_2	1.78	1.86	2.03	2.14	2.78	3.08	3.38	3.63	4.00
N_2K_3	1.58	1.64	1.81	1.92	2.28	3.03	3.29	3.67	3.96
N_3K_1	1.69	1.69	1.89	2.19	2.53	2.94	3.33	3.58	3.92
N_3K_2	1.67	1.69	1.83	2.11	2.56	3.03	3.13	3.33	3.58
N_3K_3	1.61	1.64	1.78	2.03	2.53	2.97	2.92	2.96	3.13
F	0.55	0.13	0.97	0.66	0.94	0.02	0.29	0.78	1.06
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	1.53	1.72	1.78	2.08	2.58	2.86	3.04	3.21	3.42
P_1K_2	1.67	1.67	1.81	1.89	2.39	2.75	3.17	3.33	3.71
P_1K_3	1.67	1.69	1.81	1.89	2.14	2.75	3.04	3.13	3.33
P_2K_1	1.61	1.67	1.83	2.14	2.53	2.86	3.13	3.42	3.67
P_2K_2	1.64	1.67	1.72	2.00	2.53	3.00	3.21	3.33	3.46
P_2K_3	1.53	1.53	1.75	1.94	2.25	2.83	2.92	3.08	3.21
P_3K_1	1.56	1.58	1.72	1.75	2.25	2.75	3.38	3.54	3.92
P_3K_2	1.83	1.97	2.08	2.17	2.67	3.08	3.04	3.29	3.58
P_3K_3	1.67	1.79	1.89	1.94	2.50	3.03	3.13	3.38	3.63
F	0.42	1.12	1.14	2.25	2.35	1.01	0.42	0.38	0.68
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 7 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
K_1	3.85	3.97	4.08	4.26	4.33	4.33	4.46	4.44	4.39
K_2	3.69	3.92	3.97	4.17	4.13	4.19	4.21	4.25	4.25
K_3	3.50	3.61	3.65	3.74	3.74	3.83	3.90	3.90	3.83
F	2.53	3.50	5.02	5.91	5.91	4.01	3.17	2.43	3.43
C.D. (0.05)	-	0.292	0.281	0.325	0.351	0.363	0.440	-	0.439
N_1K_1	3.33	3.29	3.46	3.46	3.54	3.54	3.71	3.63	3.92
N_1K_2	3.33	3.58	3.63	3.71	3.71	3.79	3.71	3.88	3.88
N_1K_3	3.21	3.38	3.33	3.38	3.38	3.50	3.71	3.77	3.67
N_2K_1	4.13	4.38	4.54	4.75	4.83	4.92	5.04	5.04	4.79
N_2K_2	4.04	4.25	4.29	4.50	4.54	4.63	4.67	4.67	4.63
N_2K_3	3.96	4.08	4.25	4.33	4.29	4.42	4.42	4.42	4.29
N_3K_1	4.08	4.25	4.25	4.58	4.63	4.54	4.63	4.67	4.46
N_3K_2	3.91	3.92	4.00	4.29	4.13	4.17	4.25	4.25	4.25
N_3K_3	3.33	3.38	3.38	3.50	3.54	3.58	3.58	3.58	3.54
F	0.86	1.94	1.67	1.89	11.28	1.22	0.99	0.99	0.43
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	3.63	3.38	3.88	3.96	4.00	3.96	4.08	4.25	4.21
P_1K_2	3.83	4.00	4.00	4.17	4.21	4.29	4.29	4.25	4.33
P_1K_3	3.46	3.46	3.50	3.54	3.54	3.63	3.63	3.58	3.58
P_2K_1	3.79	4.04	4.13	4.38	4.42	4.46	4.58	4.33	4.42
P_2K_2	3.54	3.88	3.96	4.13	4.08	4.13	4.17	4.21	4.13
P_2K_3	3.38	3.50	3.54	3.58	3.63	3.71	3.88	3.92	3.83
P_3K_1	4.13	4.04	4.25	4.46	4.58	4.58	4.71	4.75	4.54
P_3K_2	3.71	3.88	3.96	4.21	4.08	4.17	4.17	4.33	4.29
P_3K_3	3.67	3.88	3.92	4.08	4.04	4.17	4.21	4.21	4.08
F	0.73	0.77	0.69	0.81	0.96	1.11	0.69	6.25	0.33
C.D. (0.05)	-	-	-	-	-	-	-	-	-

leaves ie., 3.97, 4.08, 4.26, 4.33, 4.33, 4.46 and 4.39, followed by the K_2 plants ie., 3.92, 3.97, 4.17, 4.13, 4.19, 4.21 and 4.25 respectively, than the K_3 plants.

4.1.2.4 The effect of NP interaction

Interaction between the N and P doses was found to be significant at 90, 135, 150, 165, 180 and 195 DAP (Table 6). At 90 DAP (Table 6), plants receiving N_3P_1, N_2P_2, N_2P_3, N_3P_2, N_1P_3, N_2P_1 and N_3P_3 had greater number of leaves (3.14, 3.11, 3.03, 2.97, 2.97, 2.92 and 2.86 respectively) than those receiving N_1P_1 and N_1P_2. Among the N_1 plants, those receiving P_3 and P_2 had a greater number of leaves (2.97 and 2.61 respectively) than those receiving P_1. Significant difference in the number of leaves was not observed among the N_2 and N_3 plants receiving P_1, P_2 or P_3.

At 135 DAP (Table 6) plants receiving N_2P_3, N_3P_1 and N_2P_2 had greater number of leaves (4.38, 3.79 and 3.79 respectively) than the others. Among the N_2 plants, those receiving P_3 and P_2 had greater number of leaves (4.38 and 3.79 respectively) than those receiving P_1. Significant difference in the number of leaves was not observed among the N_1 or the N_3 plants receiving P_1, P_2 or P_3.

At 150 DAP (Table 6), plants receiving N_2P_3, N_2P_1, N_2P_2, N_3P_1 and N_1P_3 had greater number of leaves (4.25, 3.96, 3.92, 3.92 and 3.75 respectively) than those receiving N_3P_2, N_3P_3, N_1P_2 and N_1P_1. Among the N_1

plants, those receiving P_3 had greater number of leaves (3.75) than those receiving P_1 and P_2. Significant difference in the number of leaves was not observed in the N_2 plants or N_3 plants receiving P_1, P_2 or P_3.

At 165 DAP (Table 6), plants receiving N_2P_3, N_2P_2, N_2P_1, N_3P_1, N_3P_2 and N_1P_3 had greater number of leaves (4.33, 4.29, 4.08, 4.04, 3.88 and 3.83 respectively) than those receiving N_3P_3, N_1P_2 and N_1P_1. Among the N_1 plants, those receiving P_3 and P_2 had greater number of leaves (3.83 and 3.25 respectively) than those receiving P_1. Significant effect on the number of leaves was not observed among the N_2 plants receiving P_1, P_2 or P_3 and the N_3 plants receiving P_1, P_2 or P_3.

At 180 DAP (Table 6) plants receiving N_2P_3, N_2P_2, N_2P_1 and N_3P_1 had greater number of leaves (4.46, 4.46, 4.17 and 4.04 respectively) than those receiving N_1P_3, N_3P_2, N_3P_3, N_1P_2 and N_1P_1. Among the N_1 plants, those receiving P_3 had greater number of leaves (3. 96) than those receiving P_2 and P_1. Significant differences in leaf number was not observed among the N_2 plants receiving P_1P_2 or P_3 and among the N_3 plants receiving P_1, P_2 or P_3.

At 195 DAP (Table 6), plants receiving N_2P_3, N_2P_2, N_2P_1 and N_3P_1 had greater number of leaves (4.71, 4.58, 4.29 and 4.29 respectively) than those receiving N_3P_2, N_1P_1, N_3P_3, N_1P_2 and N_1P_1. Among the N_1 plants those receiving P_3 had a greater number of leaves (4.08) than those receiving P_1 and

Table 8. Interaction of N, P and K on the number of leaves per plant

Treat-ments	Days After Planting								
	15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	1.42	1.50	1.67	2.00	2.33	2.42	2.50	2.63	2.63
$N_1P_1K_2$	1.67	1.75	1.75	1.67	2.00	2.17	2.63	2.75	3.00
$N_1P_1K_3$	1.50	1.58	1.75	1.83	1.92	2.33	2.88	2.75	3.13
$N_1P_2K_1$	1.58	1.75	1.67	1.92	2.17	2.50	2.75	2.88	3.00
$N_1P_2K_2$	1.58	1.58	1.50	1.67	2.08	2.92	3.13	3.13	3.25
$N_1P_2K_3$	1.58	1.50	1.67	1.83	1.92	2.42	2.63	2.75	2.63
$N_1P_3K_1$	1.50	1.50	1.58	1.67	2.25	2.83	3.50	3.50	3.75
$N_1P_3K_2$	1.83	1.92	2.00	2.08	2.67	3.00	3.00	3.13	3.25
$N_1P_3K_3$	1.92	2.00	2.17	1.83	2.42	3.08	3.13	3.38	3.50
$N_2P_1K_1$	1.50	2.00	1.83	1.83	2.67	2.83	3.13	3.25	3.50
$N_2P_1K_2$	1.67	1.67	2.00	2.00	2.83	2.92	3.38	3.50	3.88
$N_2P_1K_3$	1.75	1.83	1.92	1.92	2.08	3.00	3.88	3.75	3.88
$N_2P_2K_1$	1.67	1.67	1.92	2.33	2.92	3.33	3.13	3.63	3.88
$N_2P_2K_2$	1.75	1.83	1.83	2.08	2.75	3.08	3.50	3.75	3.88
$N_2P_2K_3$	1.50	1.58	1.83	2.00	2.42	2.92	3.25	3.50	3.63
$N_2P_3K_1$	1.33	1.42	1.67	1.58	2.17	2.67	3.63	3.88	4.50
$N_2P_3K_2$	1.92	2.08	2.25	2.33	2.75	3.25	3.25	3.63	4.25
$N_2P_3K_3$	1.50	1.50	1.67	1.83	2.33	3.17	3.25	3.75	4.38
$N_3P_1K_1$	1.67	1.67	1.83	2.42	2.75	3.33	3.50	3.75	4.13
$N_3P_1K_2$	1.67	1.58	1.67	2.00	2.33	3.17	3.50	3.75	4.25
$N_3P_1K_3$	1.75	1.67	1.75	1.92	2.42	2.92	2.88	2.88	3.00
$N_3P_2K_1$	1.58	1.58	1.92	2.17	2.50	2.95	3.50	3.75	4.13
$N_3P_2K_2$	1.58	1.58	1.83	2.25	2.75	3.00	3.00	3.13	3.25
$N_3P_2K_3$	1.50	1.50	1.75	2.00	2.42	3.17	2.88	3.00	3.38
$N_3P_3K_1$	1.83	1.83	1.92	2.00	2.33	2.75	3.00	3.25	3.50
$N_3P_3K_2$	1.75	1.92	2.00	2.08	2.58	3.00	2.88	3.13	3.25
$N_3P_3K_3$	1.58	1.75	1.83	2.17	2.75	2.83	3.00	3.00	3.00
C_1	1.50	1.42	1.92	2.25	2.67	2.75	3.13	3.25	3.25
C_2	1.50	1.42	1.75	2.00	2.25	2.50	2.75	2.88	2.63
F	0.40	0.72	0.39	0.73	0.46	1.15	0.47	0.39	0.71
CD (0.05)	-	-	-	-	-	-	-	-	-

Table 8 continued

Treat-ments	Days After Planting 150	165	180	195	210	225	240	255	270
$N_1P_1K_1$	2.75	2.75	2.88	2.75	2.75	2.63	2.88	3.00	3.13
$N_1P_1K_2$	3.13	3.38	3.38	3.25	3.38	3.50	3.88	3.38	3.50
$N_1P_1K_3$	3.25	3.38	3.25	3.25	3.25	3.38	3.50	3.50	3.50
$N_1P_2K_1$	3.13	3.25	3.38	3.50	3.62	3.75	3.88	3.50	4.13
$N_1P_2K_2$	3.38	3.63	3.63	3.75	3.75	3.88	3.75	3.75	3.75
$N_1P_2K_3$	2.75	2.88	2.88	2.88	3.00	3.13	3.63	3.63	3.63
$N_1P_3K_1$	4.13	3.88	4.13	4.13	4.25	4.25	4.28	4.38	4.50
$N_1P_3K_2$	3.50	3.75	3.88	4.13	4.00	4.00	4.00	4.50	4.38
$N_1P_3K_3$	3.63	3.88	3.88	4.60	3.88	4.00	4.00	4.00	4.38
$N_2P_1K_1$	3.88	4.25	4.38	4.50	4.50	4.63	4.75	4.75	4.50
$N_2P_1K_2$	4.00	4.13	4.13	4.25	4.38	3.38	4.50	4.50	4.63
$N_2P_1K_3$	4.00	3.88	4.00	4.13	4.13	4.25	4.13	4.13	4.13
$N_2P_2K_1$	4.00	4.50	4.63	4.75	4.88	5.00	5.13	5.13	5.00
$N_2P_2K_2$	4.00	4.38	4.50	4.75	4.75	4.75	4.88	4.88	4.63
$N_2P_2K_3$	3.75	4.00	4.25	4.25	4.13	4.13	4.25	4.25	4.00
$N_2P_3K_1$	4.50	4.38	4.63	5.00	5.13	5.13	5.25	5.25	4.88
$N_2P_3K_2$	4.13	4.25	4.25	4.50	4.50	4.75	4.63	4.63	4.63
$N_2P_3K_3$	4.13	4.38	4.50	4.63	4.63	4.88	4.88	4.88	4.75
$N_3P_1K_1$	4.25	4.50	4.38	4.63	4.75	4.63	4.63	5.00	5.00
$N_3P_1K_2$	4.38	4.50	4.50	5.00	4.88	5.00	5.00	4.88	4.88
$N_3P_1K_3$	3.13	3.13	3.25	3.25	3.25	3.25	3.25	3.13	3.13
$N_3P_2K_1$	4.25	3.38	4.38	4.88	4.55	4.63	4.75	4.38	4.13
$N_3P_2K_2$	3.25	3.63	3.75	3.88	3.75	3.75	3.88	4.00	4.00
$N_3P_2K_3$	3.63	3.63	3.50	3.63	3.75	3.88	3.75	3.88	3.88
$N_3P_3K_1$	3.75	3.88	4.00	4.25	4.38	4.38	4.50	4.63	4.25
$N_3P_3K_2$	3.50	3.63	3.75	4.00	3.75	3.75	3.88	3.88	3.88
$N_3P_3K_3$	3.25	3.38	3.38	3.63	3.63	3.63	3.78	3.75	3.63
C_1	3.50	3.38	3.63	3.88	3.88	3.75	3.75	3.50	3.50
C_2	2.75	3.00	3.13	3.25	3.50	3.38	3.25	3.25	3.00
F	1.21	1.03	0.69	1.05	0.84	1.04	0.50	0.50	0.79
CD (0.05)	-	-	-	-	-	-		-	-

P_2. Significant differences in leaf number was not observed among the N_2 plants receiving P_1, P_2 or P_3 and among the N_3 plants receiving P_1, P_2 of P_3.

4.1.2.5 The effect of NK, PK and NPK interaction

The interaction effects of NK, Pk and NPK on leaf number were not found to be significant throughout the experimental period (Tables 7 and 8). Difference in the effects of treatments and control plants were significant at 90, 150, 165, 180, 240, 255 and 270 DAP. However between the two controls, there was no significant difference in leaf number throughout the experiment period (Table 8).

4.1.3 Leaf area per plant

4.1.3.1 The effect of N

The effect of N on the leaf area of the plants was found to be significant throughout the experimental period except at 30 DAP (Table 9).

At 15, 45 and 60 DAP (Table 9) the plants receiving N_3 and N_2 recorded significantly greater leaf area than the N_1 plants. Leaf area in the N_3 and N_2 plants were respectively 2.13 and 1.89 sq cm at 15 DAP, 2.42 and 2.27 sq cm at 45 DAP and 2.80 and 2.55 sq. cm at 60 DAP.

At 75, 90, 105, 120 and 135 DAP (Table 9), the N_2 and N_3 plants recorded greater leaf area (3.93, 5.24, 7.12, 9.69 and 12.89 sq cm and 3.82, 5.04, 6.52, 8.43 and 11.64 sq. cm, respectively) than the N_1 plants.

Table 9. Effect of N and P and their interaction on the leaf area (sq cm) per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	1.78	1.88	1.97	2.19	2.94	3.98	5.20	6.78	8.27
N_2	1.89	2.05	2.27	2.55	3.93	5.24	7.12	9.69	12.89
N_3	2.13	2.15	2.42	2.80	3.82	5.04	6.52	8.43	11.64
F	3.30	1.88	5.68	7.79	13.42	13.98	10.98	16.35	23.86
C.D. (0.05)	0.268	-	0.263	0.305	0.408	0.503	0.833	1.016	1.375
P_1	1.94	2.00	2.22	2.47	3.56	4.75	6.71	8.61	11.17
P_2	1.91	2.04	2.23	2.50	3.66	4.80	6.06	8.24	10.79
P_3	1.95	2.05	2.22	2.56	3.47	4.71	6.07	8.04	10.84
F	0.04	0.08	0.00	0.17	0.42	0.08	1.60	0.64	0.17
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	1.56	1.66	1.86	1.98	2.59	3.33	4.56	5.94	7.42
N_1P_2	1.91	2.04	2.11	2.42	2.99	4.08	5.10	6.88	8.01
N_1P_3	1.87	1.95	1.95	2.18	3.25	4.52	5.95	7.51	9.39
N_2P_1	1.95	2.10	2.33	2.56	4.12	5.35	7.71	10.05	12.33
N_2P_2	1.82	2.06	2.12	2.26	4.09	5.24	6.75	9.67	12.68
N_2P_3	1.91	1.99	2.36	2.82	3.56	5.14	6.91	9.34	13.66
N_3P_1	2.32	2.22	2.46	2.88	3.96	5.56	7.87	9.85	13.75
N_3P_2	2.00	2.03	2.45	2.84	3.90	5.09	6.33	8.16	11.68
N_3P_3	2.06	2.20	2.35	2.69	3.60	4.46	5.34	7.27	9.48
F	1.20	0.88	0.70	1.77	1.65	3.39	3.72	2.83	4.15
C.D. (0.05)	-	-	-	-	-	0.872	1.443	1.706	2.382

Table 9 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	10.21	13.61	14.79	16.48	16.97	17.33	18.10	18.42	18.57
N_2	15.77	19.18	21.43	24.42	27.11	27.90	29.03	29.58	28.16
N_3	14.41	17.45	19.97	22.81	24.25	25.81	26.64	27.06	26.21
F	23.21	14.95	18.98	17.09	22.96	16.07	15.47	12.77	13.59
C.D. (0.05)	1.692	2.075	2.255	2.856	3.070	3.929	4.111	4.607	3.873
P_1	13.98	16.80	18.72	20.66	22.22	23.55	23.58	24.30	23.52
P_2	12.94	16.48	18.91	21.69	22.97	24.36	24.87	25.37	24.59
P_3	13.47	16.17	18.55	21.37	23.15	23.13	25.05	25.39	24.83
F	0.75	0.11	0.05	0.27	0.20	0.20	0.20	0.15	0.26
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	8.80	11.73	12.91	13.48	13.62	14.03	14.10	13.67	13.82
N_1P_2	10. 01	13.16	14.61	16.92	17.22	18.61	19.23	19.76	20.53
N_1P_3	11.83	15.95	16.84	19.05	20.09	19.36	20.98	21.84	21.35
N_2P_1	16.29	19.05	21.26	23.61	27.03	28.63	29.04	29.76	28.42
N_2P_2	14.73	19.04	21.64	25.09	27.23	27.93	28.30	29.68	27.11
N_2P_3	16.29	19.45	21.39	24.57	27.08	27.94	29.74	29.29	28.97
N_3P_1	16.85	19.61	21.98	24.88	26.02	28.00	28.43	29.46	28.32
N_3P_2	14.08	17.24	30.49	23.06	24.46	26.54	27.07	28.68	26.15
N_3P_3	12.29	15.51	17.43	20.49	22.29	22.89	24.44	25.03	24.16
F	3.51	2.67	2.39	2.02	1.87	1.25	1.26	1.36	1.83
C.D. (0.05)	2.931	3.593	-	-	-	-	-	-	-

These plants also recorded a greater leaf area than the N_1 plants from 150 to 270 DAP. The leaf area in the N_2 and N_3 plants were respectively 15.77 and 14.41 sq. cm at 150 DAP, 19.18 and 17.45 sq cm at 165 DAP, 21.43 and 19.97 sq cm at 180 DAP, 24.42 and 22.81 sq cm at 195 DAP, 27.11 and 24.25 sq cm at 210 DAP, 27.90 and 25.81 aq cm at 225 DAP, 29.03 and 26.64 sq cm at 240 DAP, 29.58 and 27.06 sq cm at 255 DAP and 28.16 and 26.21 sq cm at 270 DAP (Table 9).

4.1.3.2 The effect of P and K

The effect of P and K on the leaf area of the plants was not found to be significant throughout the experimental period (Tables 9 and 10).

4.1.3.3 The effect of NP interaction

Interaction between the N and P doses on the leaf area of plants was found to be significant at 90, 105, 120, 135, 150 and 165 DAP (Table 9).

At 90 DAP (Table 9), the plants receiving N_3P_1, N_2P_1, N_2P_2, N_2P_3 and N_3P_2 had a greater leaf area (5.56, 5.35, 5.24, 5.14 and 5.09 sq cm, respectively) than those receiving N_1P_3, N_3P_3, N_1P_2 and N_1P_1. Among the N_1 plants, those receiving P_3 or P_2 had a greater leaf area (4.52 and 4.08 sq cm, respectively) than those receiving P_1. Among the N_2 plants there was no significant difference in leaf area between the plants receiving P_1, P_2 or P_3. Among the N_3 plants those receiving P_1 and P_2 had a greater leaf area (5.56 and 5.09 sq cm, respectively) than those receiving P_1, P_2 or P_3.

Table 10. Effect of K and its interaction with N and P on the leaf are (sq cm) per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	1.83	1.89	2.10	2.58	3.57	4.64	6.31	8.28	11.24
K_2	2.03	2.15	2.30	2.52	3.69	4.79	6.20	8.21	11.00
K_3	1.94	2.05	2.27	2.45	3.43	4.83	6.33	8.40	10.56
F	1.09	1.78	1.30	0.35	0.81	0.32	0.06	0.07	0.51
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.66	1.76	1.90	2.24	3.07	3.91	5.04	6.62	8.11
N_1K_2	1.90	2.03	2.08	2.27	3.14	4.21	5.31	6.76	8.26
N_1K_3	1.78	1.86	1.94	2.06	2.63	3.81	5.25	6.94	8.45
N_2K_1	1.77	1.90	2.13	2.66	3.93	5.10	6.90	9.17	12.33
N_2K_2	2.03	2.20	2.37	2.38	4.23	5.27	6.87	9.30	12.83
N_2K_3	1.89	2.05	2.31	2.66	3.61	5.36	7.59	10.59	13.50
N_3K_1	2.06	2.00	2.26	2.89	3.70	4.90	6.99	9.04	13.29
N_3K_2	2.17	2.21	2.44	2.90	3.71	4.89	6.40	8.57	11.91
N_3K_3	2.15	2.24	2.55	2.62	4.05	5.32	6.15	7.67	9.71
F	0.07	0.12	0.19	0.65	1.23	0.46	0.68	1.40	2.29
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	1.80	1.76	2.07	2.46	3.94	4.81	6.42	8.17	10.43
P_1K_2	1.88	2.02	2.16	2.47	3.47	4.64	6.72	8.63	12.00
P_1K_3	2.15	2.21	2.42	2.50	3.26	4.80	7.00	9.03	11.07
P_2K_1	1.90	2.07	2.20	2.84	3.58	4.68	6.35	8.44	12.26
P_2K_2	2.00	2.10	2.28	2.42	4.01	4.91	6.09	8.10	9.88
P_2K_3	1.84	1.95	2.19	2.25	3.39	4.83	5.73	8.17	10.23
P_3K_1	1.79	1.83	2.01	2.43	3.18	4.43	6.17	8.23	11.04
P_3K_2	2.21	2.32	2.45	2.67	3.60	4.82	5.77	7.89	11.13
P_3K_3	1.84	1.99	2.19	2.60	3.63	4.87	6.26	8.01	10.36
F	1.13	1.17	0.88	1.34	1.79	0.26	0.44	0.28	1.46
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 10 continued

Treat-ments	Days after planting								
	150	165	180	195	210	225	240	255	270
K_1	13.75	17.35	18.99	21.75	23.84	24.68	25.50	26.17	24.91
K_2	13.61	17.45	19.27	22.00	23.18	24.67	25.24	25.55	25.00
K_3	13.03	15.44	17.92	19.90	21.32	21.70	23.04	23.33	23.03
F	0.41	2.36	0.79	1.18	1.44	1.51	0.86	0.83	0.65
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	10.23	12.43	14.51	15.24	16.31	16.60	17.18	17.55	17.22
N_1K_2	10.16	14.82	15.15	17.04	17.82	18.10	18.41	19.22	19.72
N_1K_3	10.25	13.58	14.69	17.18	16.80	17.30	18.71	18.51	18.76
N_2K_1	14.69	19.33	21.36	25.27	28.07	29.55	30.76	31.74	28.82
N_2K_2	16.23	19.77	21.99	24.60	27.21	28.98	29.18	29.30	28.61
N_2K_3	16.40	18.44	20.94	23.40	26.05	25.18	27.14	27.69	27.06
N_3K_1	16.35	20.30	21.11	24.74	27.15	27.88	28.55	29.25	28.69
N_3K_2	14.45	17.75	20.67	24.36	24.51	26.93	28.13	28.13	26.67
N_3K_3	12.43	14.31	18.13	19.33	21.10	22.62	23.26	28.80	23.28
F	1.98	2.17	0.38	1.21	0.79	0.45	0.55	0.40	0.55
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	12.87	16.13	17.15	18.58	20.71	21.13	22.13	23.77	22.74
P_1K_2	15.01	18.63	21.31	23.77	24.56	26.86	27.25	27.27	26.31
P_1K_3	14.06	15.58	17.69	19.63	21.40	22.68	22.18	21.85	21.52
P_2K_1	14.36	18.93	20.71	25.47	26.83	28.98	29.43	29.11	27.71
P_2K_2	12.10	15.34	17.39	19.88	21.55	22.42	22.78	23.02	22.89
P_2K_3	12.37	15.17	18.63	19.72	20.52	21.72	22.39	23.99	23.19
P_3K_1	14.03	17.01	19.12	21.19	24.00	23.96	22.94	25.64	24.28
P_3K_2	13.73	18.32	19.11	22.34	23.43	24.72	22.69	26.36	25.80
P_3K_3	12.65	15.58	17.44	20.57	22.03	20.71	24.54	24.16	24.39
F	1.27	1. 62	1.91	2.49	1.62	1.74	1.50	0.80	0.93
C.D. (0.05)	-	-	-	4.947	-	-	-	-	-

At 105 DAP (Table 9) plants receiving N_3P_1, N_2P_1, N_2P_3 and N_2P_2 had greater leaf area (7.87, 7.71, 6.91 and 6.75 sq cm, respectively) than those receiving N_1P_1, N_1P_3, N_3P_2 and N_3P_3: Significant difference in leaf area was not observed among the N_1 plants receiving P_1, P_2 and P_3 and among the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants, those receiving P_1 had a greater leaf area (7.87 sq cm) than those receiving P_2 or P_3.

At 120 DAP (Table 9) plants receiving N_2P_1, N_3P_1, N_2P_2 and N_2P_3 had a greater leaf area (10.05, 9.85, 9.67 and 9.34 sq cm, respectively) than those receiving N_1P_1, N_1P_2, N_1 P_3, N_3P_2 and N_3P_3. Significant differences in leaf area was not observed among the N_1 plants receiving P_1, P_2 or P_3, the N_2 plant receiving P_1, P_2 or P_3 and among the N_3 plants receiving P_1, P_2 or P_3.

At 135 DAP (Table 9) plants receiving N_3P_1, N_2 P_3, N_2P_2, N_2P_1 and N_3P_2 had greater leaf area (13.75, 13.66, 12.68, 12.33 and 11.68 sq cm, respectively) than those receiving N_1P_1, N_1P_1, N_1P_3 and N_3P_3. Significant difference in leaf area was not observed among the N_1 plants receiving P_1, P_2 or P_3 and the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants, those receiving P_1 and P_2 had a greater leaf area (13.75 and 11.68 sq cm, respectively) than those receiving P_3.

At 150 DAP (Table 9), the plants receiving N_3P_1, N_2P_1, N_2P_3, N_2P_2 and N_3P_2 had a greater leaf area (16.85, 16.29, 16.29, 14.73 ad 14.08 sq cm, respectively) than those receiving N_3P_3, N_1P_3, N_1P_2 or N_1P_1. Among the N_1

plants, those receiving P_3 and P_2 had greater leaf area (11.83 and 10.01 sq cm, respectively) than those receiving P_1. Significant difference in leaf area was not observed among the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants, those receiving P_1 and P_2 had greater leaf area (16.85 and 14.08 sq cm, respectively) than those receiving P_3.

At 165 DAP (Table 9), plants receiving N_3P_1, N_2P_3, N_2P_1, N_2P_2 and N_3P_2 had a greater leaf area (19.61, 19.45, 19.05, 19.04 and 17.24 sq cm respectively) than those receiving N_1P_3, N_3P_3, N_1P_2 and N_1P_1. Among the N_1 plants, those receiving P_2 and P_2 had a greater leaf area (15.95 and 13.16 sq cm, respectively) than those receiving P_1. Significant difference in leaf area was not observed among the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants, those receiving P_1 and P_2 had a greater leaf area (19.61 and 17.24 sq cm, respectively) than those receiving P_3.

4.1.3.4 The effect of NK interaction

Significant interaction between the N and K doses influencing the leaf area of plants was throughout the experimental period (Table 10).

4.1.3.5 The effect of PK interaction

Interaction between the p and K doses on the leaf area of the plants was found to be significant at 195 DAP (Table 10). At that stage, plants receiving P_2K_1, P_1K_2, P_3K_2, P_3K_1 and P_3K_3 had greater leaf area (25.47, 23.77, 22.34, 21.19 and 20.57 sq cm, respectively) than those receiving P_2K_2, P_2K_3, P_1K_3 and

Table 11. Interaction of N, P and K on the leaf area (sq cm) produced per plants

Treat-ments	Days After Planting								
	15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	1.45	1.53	1.80	2.27	3.08	3.64	4.36	5.54	5.93
$N_1P_1K_2$	1.71	1.85	1.97	1.77	2.49	3.21	4.32	6.04	7.91
$N_1P_1K_3$	1.52	1.64	1.80	1.90	2.23	3.15	5.00	6.23	8.43
$N_1P_2K_1$	2.00	2.24	2.25	2.69	3.13	3.95	4.84	6.75	8.48
$N_1P_2K_2$	1.81	2.02	2.00	2.31	3.10	4.52	5.43	6.48	7.47
$N_1P_2K_3$	1.91	1.86	2.10	2.25	2.73	3.78	5.02	7.40	8.08
$N_1P_3K_1$	1.53	1.52	1.65	1.77	2.99	4.14	5.94	7.59	9.91
$N_1P_3K_2$	2.18	2.23	2.28	2.74	3.81	4.91	6.19	7.77	9.41
$N_1P_3K_3$	1.91	2.10	1.92	2.03	2.93	4.51	5.72	7.19	8.86
$N_2P_1K_1$	1.88	1.85	2.26	2.28	4.41	4.75	6.24	7.84	9.76
$N_2P_1K_2$	1.77	2.04	2.19	2.48	4.44	5.45	7.56	9.43	12.62
$N_2P_1K_3$	2.20	2.41	2.55	2.92	3.50	5.86	9.33	12.88	14.61
$N_2P_2K_1$	1.80	2.08	2.06	2.53	4.12	5.68	6.89	10.03	14.18
$N_2P_2K_2$	1.91	2.05	2.17	2.30	4.63	5.37	7.09	9.81	11.87
$N_2P_2K_3$	1.76	2.04	2.12	1.95	3.53	4.67	6.30	9.18	11.99
$N_2P_3K_1$	1.63	1.76	2.06	2.98	3.27	4.86	7.58	9.64	13.06
$N_2P_3K_2$	2.40	2.51	2.75	2.37	3.63	5.00	5.99	8.65	14.00
$N_2P_3K_3$	1.71	1.69	2.27	3.10	3.80	5.56	7.15	9.72	13.92
$N_3P_1K_1$	2.06	1.90	2.16	2.82	4.34	6.09	8.66	11.13	15.60
$N_3P_1K_2$	2.17	2.17	2.31	3.16	3.47	5.26	8.28	10.43	15.46
$N_3P_1K_3$	2.72	2.60	2.90	2.67	4.07	5.39	6.68	7.98	10.19
$N_3P_2K_1$	1.90	1.90	2.30	3.31	3.48	4.39	7.33	8.52	14.13
$N_3P_2K_2$	2.27	2.24	2.68	2.66	4.30	4.84	5.80	8.02	10.29
$N_3P_2K_3$	1.84	1.94	2.35	2.53	3.92	6.05	5.87	7.94	10.63
$N_3P_3K_1$	2.22	2.21	2.34	2.53	3.28	4.28	4.99	7.46	10.15
$N_3P_3K_2$	2.06	2.21	2.33	2.89	3.36	5.56	5.14	7.25	9.98
$N_3P_3K_3$	1.89	2.18	2.39	2.66	4.15	4.54	5.90	7.11	8.31
C_1	1.88	1.75	2.10	2.61	3.44	3.53	4.63	6.64	9.24
C_2	1.79	1.61	1.97	2.22	2.99	3.62	4.50	5.63	7.07
F	0.85	0.80	0.63	1.21	0.53	1.27	1.20	1.38	0.94
CD (0.05)	-	-	-	-	-	-	-	-	-

Table 11 continued

Treat-ments	Days After Planting 150	165	180	195	210	225	240	255	270
$N_1P_1K_1$	7.00	8.89	10.01	9.77	9.93	9.59	10.44	11.42	10.24
$N_1P_1K_2$	9.59	13.75	15.34	15.18	16.51	17.48	16.73	15.32	16.13
$N_1P_1K_3$	9.80	12.55	13.38	15.09	14.41	15.03	15.11	14.26	15.09
$N_1P_2K_1$	10.68	13.46	15.75	18.32	18.61	20.82	20.60	21.26	21.60
$N_1P_2K_2$	9.34	12.09	12.89	15.17	15.97	16.74	16.03	16.54	19.45
$N_1P_2K_3$	10.03	13.92	15.18	17.28	17.07	18.27	21.08	21.49	20.54
$N_1P_3K_1$	13.01	14.95	17.79	17.62	20.39	19.38	20.52	19.93	19.83
$N_1P_3K_2$	11.56	18.63	17.22	20.35	20.98	20.08	22.48	25.79	23.58
$N_1P_3K_3$	10.92	14.26	15.52	19.17	18.90	18.61	19.94	19.79	20.64
$N_2P_1K_1$	13.02	17.55	19.02	21.86	23.77	25.04	26.33	27.13	24.69
$N_2P_1K_2$	16.67	19.48	23.05	24.78	28.06	29.68	31.25	32.02	31.16
$N_2P_1K_3$	19.19	20.13	21.70	24.20	29.25	31.15	29.53	30.12	29.40
$N_2P_2K_1$	15.23	22.06	23.92	28.76	32.29	34.55	35.66	35.81	32.80
$N_2P_2K_2$	14.67	18.10	20.59	23.81	26.40	26.32	27.01	26.38	25.66
$N_2P_2K_3$	14.30	16.96	20.40	22.71	23.15	22.91	22.25	26.84	22.86
$N_2P_3K_1$	15.81	18.39	21.13	25.19	28.16	29.06	30.30	32.28	28.97
$N_2P_3K_2$	17.35	21.73	22.33	25.22	27.32	30.90	29.29	29.49	29.02
$N_2P_3K_3$	15.72	18.23	20.72	23.29	25.76	21.47	29.64	26.11	28.91
$N_3P_1K_1$	18.60	21.93	22.40	24.11	28.42	28.75	29.62	32.75	32.28
$N_3P_1K_2$	18.76	22.83	25.55	30.94	29.10	33.41	33.78	34.47	31.63
$N_3P_1K_3$	13.19	14.06	18.00	19.59	20.53	21.85	21.89	21.17	20.06
$N_3P_2K_1$	17.17	21.27	22.47	29.34	29.60	31.44	32.03	30.27	28.73
$N_3P_2K_2$	12.30	15.84	18.69	20.67	22.45	24.21	25.31	26.14	23.55
$N_3P_2K_3$	12.79	14.63	20.31	19.17	21.33	23.96	23.86	23.65	26.16
$N_3P_3K_1$	13.27	17.69	18.45	20.76	23.44	23.45	23.91	24.72	24.06
$N_3P_3K_2$	12.29	14.59	17.77	21.46	21.99	23.18	25.30	23.78	24.82
$N_3P_3K_3$	11.37	14.24	16.07	19.24	21.43	22.06	24.03	26.58	23.62
C_1	11.74	12.62	15.70	18.42	19.21	18.91	19.17	17.49	17.41
C_2	8.22	10.59	11.77	14.71	16.33	16.37	16.18	16.99	17.65
F	0.80	0.84	0.36	0.36	0.52	0.59	0.44	0.57	0.73
CD (0.05)	-	-	-	-	-	-	-	-	-

P_1K_1. Among the P_1 plants, those receiving K_2 and K_3 had a greater leaf area (23.77 and 19.63 sq cm, respectively) than those receiving K_1. Among the P_2 plants those receiving K_1 had greater leaf area (25.47 sq cm) than those receiving K_1 and K_3. Significant effect on plant height was not observed among the P_3 plants r receiving K_1, K_2 or K_3.

4.1.3.5 The effect of NPK interaction

Interaction between the N, P and K doses on the leaf area of the plants was not significant throughout the experiment period (Table 11). The leaf area of the treatment plants were found to be significantly greater than the controls from 90 to 210 DAP and from 240 to 270 DAP.

However there was no significant difference between the two controls in leaf area throughout the experimental period (Table 11).

4.1.4 Stem girth

4.1.4.1 The effect of N

The effect of N on stem girth was found to be significant at 15. 60, 105, 120, 135, 150, 165, 180, 195, 210, 225, 240, 255 and 270 DAP (Table 12) and at 15 DAP plants receiving N_1 had greater stem girth (1.11 cm) than those receiving N_2 and N_3.

At 60 DAP (Table 12), plants receiving N_1 and N_2 had greater stem girth (1.34 and 1.33 cm) than those receiving N_2.

Table 12. Effect of N,P and their interaction on the stem girth (cm) of the plants

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	1.11	1.11	1.13	1.33	1.34	1.37	1.53	1.65	1.81
N_2	1.05	1.06	1.10	1.25	1.31	1.43	1.70	1.83	1.97
N_3	1.04	1.08	1.15	1.34	1.34	1.42	1.67	1.80	1.89
F	3.57	1.72	1.48	4.83	1.06	2.26	31.22	25.24	9.23
C.D. (0.05)	0.054	-	-	0.062	-	-	0.048	0.055	0.073
P_1	1.07	1.08	1.12	1.27	1.28	1.37	1.56	1.69	1.83
P_2	1.05	1.08	1.12	1.33	1.36	1.44	1.66	1.80	1.93
P_3	1.07	1.09	1.14	1.32	1.35	3.42	1.68	1.78	1.92
F	0.27	0.08	0.44	1.95	3.96	3.63	12.75	8.10	5.84
C.D. (0.05)	-	-	-	-	0.058	0.055	0.048	0.055	0.073
N_1P_1	1.14	1.14	1.17	1.27	1.28	1.31	1.38	1.51	1.66
N_1P_2	1.07	1.08	1.11	1.42	1.43	1.45	1.60	1.74	1.88
N_1P_3	1.10	1.12	1.12	1.31	1.32	1.36	1.59	1.68	1.89
N_2P_1	1.04	1.05	1.09	1.21	1.25	1.36	1.65	1.78	1.92
N_2P_2	1.07	1.08	1.10	1.28	1.34	1.45	1.71	1.86	2.00
N_2P_3	1.03	1.05	1.10	1.27	1.34	1.48	1.75	1.86	1.99
N_3P_1	1.03	1.05	1.10	1.35	1.32	1.43	1.66	1.80	1.88
N_3P_2	1.01	1.08	1.14	1.30	1.31	1.41	1.67	1.80	1.92
N_3P_3	1.05	1.11	1.20	1.39	1.40	1.43	1.69	1.79	1.89
F	1.09	0.96	1.18	2.32	2.05	2.12	4.10	3.13	1.78
C.D. (0.05)	-	-	-	-	-	-	0.082	0.096	-

Table 12 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	1.97	2.12	2.14	2.18	2.25	2.27	2.28	2.28	2.29
N_2	2.20	2.47	2.63	2.65	2.68	2.71	2.75	2.75	2.82
N_3	2.08	2.28	2.47	2.51	2.53	2.57	2.60	2.61	2.66
F	10.04	12.11	22.96	20.36	15.36	14.33	15.30	14.28	17.12
C.D. (0.05)	0.103	0.141	0.146	0.150	0.160	0.169	0.174	0.181	0.184
P_1	2.03	2.20	2.37	2.39	2.41	2.44	2.47	2.45	2.50
P_2	2.13	2.35	2.42	2.49	2.52	2.54	2.56	2.60	2.64
P_3	2.10	2.32	2.45	2.46	2.54	2.57	2.59	2.60	2.64
F	1.97	2.42	0.60	1.01	1.55	1.13	1.01	1.75	1.64
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	1.84	1.97	2.03	2.04	2.05	2.09	2.10	2.10	2.11
N_1P_2	2.03	2.18	2.09	2.19	2.19	2.20	2.21	2.22	2.23
N_1P_3	2.04	2.25	2.30	2.31	2.50	2.51	2.52	2.53	2.54
N_2P_1	2.19	2.45	2.62	2.65	2.68	2.70	2.75	2.68	2.77
N_2P_2	2.24	2.53	2.63	2.66	2.71	2.74	2.76	2.85	2.87
N_2P_3	2.18	2.43	2.62	2.64	2.67	2.70	2.74	2.75	2.83
N_3P_1	2.06	2.19	2.45	2.47	2.50	2.54	2.56	2.58	2.60
N_3P_2	2.11	2.37	2.55	2.62	2.68	2.67	2.70	2.73	2.83
N_3P_3	2.07	2.29	2.42	2.43	2.46	2.48	2.52	2.53	2.55
F	0.90	0.90	1.15	1.11	2.41	2.05	1.90	1.80	2.06
C.D. (0.05)	-	-	-	-	-	-	-	-	-

At 105 DAP (Table 12) plants receiving N_2 and N_3 had greater stem girth (1.70 and 1.67 cm, respectively) than those receiving N_1.

Plants receiving N_2 and N_3 recorded significantly greater stem girth than the N_1 plants at 120 DAP (1.83 and 1.80 cm, respectively) (Table 21) and at 150 DAP (2.2 and 2.08 cm, respectively) (Table 22).

At 135, 165 and 180 DAP the plants receiving N_2 had greater stem girth (1.97 and 2.47 cm. respectively) than those receiving N_3 and N_1 (Table 12).

From 195 to 270 DAP the N_2 and N_3 plants recorded significantly greater stem girth than the N_1 palntlets. Stem girth in the N_2 and N_3 plants were respectively 2.65 and 2.51 cm at 195 DAP, 2.68 and 2.53 cm at 210 DAP, 2.75 cm at 225 DAP, 2.75 and 2.60 cm at 240 DAP and 2.82 and 2.66 cm at 270 DAP (Table 22).

4.1.4.2 The effect of P

Effect of P on the stem girth of the plants was found to be significant at 75, 90, 105, 120 and 135 DAP (Tables 12).

At 75, 90, 105, 120 and 135 DAP (Table 12) the P_2 and P_3 plants recorded greater stem girth (ie. 1.36, 1.44, 1.68, 1.80 and 1.93 cm respectively in the P_2 plants and 1.35, 1.42, 1.66, 1.78 and 1.92 cm, respectively in the P_3 plants) than in the P_1 plants.

4.1.4.3 The effect of K

The direct effect of K on the stem girth of the plants was not found to be significant throughout the experimental period (Table 13).

4.1.4.4 The effect of NP interaction

Significant interaction between the N and P doses on the stem girth of the plants was found at 105 and 120 DAP (Table 12).

At 120 DAP (Table 12) plants receiving N_2P_2, N_2P_3, N_3 P_1, N_3P_2, N_3P_3 and N_2P_1 had greater stem girth (1.86, 1.86, 1.80, 1.80, 1.79 and 1.78 cm, respectively) than those receiving N_1K_1, N_2K_2 and N_2K_3. Among the N_1 plants, those receiving P_2 and P_3 had greater stem girth than those receiving P_1. Significant differences in stem girth was not observed among the N_2 plants receiving P_1, P_2 or P_3 and the N_3 plants receiving P_1, P_2 or P_3.

4.1.4.5 The effect of NK interaction

Interaction between the N and K doses on the stem girth of the plants was found to be significant at 60, 75, 90, 105, 120 and 135 DAP (Table 13).

At 60 DAP (Table 13) plants receiving N_1K_3, N_3K_3, N_3K_2 and N_1K_1 had greater stem girth (1.42, 1.39, 1.35 and 1.33 cm, respectively) than those receiving N_2K_2, N_3K_1, N_1K_2, N_2K_1 and N_2K_3. Among the N_1 plants those receiving K_3 and K_1 had greater stem girth (1.42 and 1.33 cm, respectively)

Table 13. Effect of K and its interaction with N and P on the stem girth (cm) of the plants

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	1.09	1.11	1.15	1.29	1.32	1.40	1.65	1.78	1.92
K_2	1.07	1.08	1.13	1.30	1.32	1.40	1.61	1.73	1.86
K_3	1.04	1.06	1.10	1.34	1.35	1.43	1.64	1.76	1.89
F	1.76	1.32	1.29	1.11	0.80	0.83	1.43	1.97	1.33
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.17	1.17	1.15	1:33	1.34	1.36	1.56	1.65	1.80
N_1K_2	1.08	1.08	1.12	1.25	1.26	1.29	1.42	1.55	1.70
N_1K_3	1.07	1.09	1.12	1.42	1.43	1.48	1.60	1.74	1.91
N_2K_1	1.05	1.07	1.11	1.24	1.31	1.44	1.69	1.85	2.01
N_2K_2	1.07	1.08	1.12	1.31	1.34	1.47	1.74	1.84	1.96
N_2K_3	1.03	1.03	1.06	1.21	1.27	1.38	1.68	1.80	1.93
N_3K_1	1.05	1.07	1.18	1.30	1.31	1.40	1.70	1.85	1.95
N_3K_2	1.06	1.09	1.15	1.35	1.36	1.44	1.67	1.80	1.90
N_3K_3	1.01	1.06	1.12	1.39	1.36	1.43	1.65	1.75	1.84
F	0.82	0.79	0.22	3.16	3.26	4.79	5.11	4.50	2.71
C.D. (0.05)	-	-	-	0.108	0.100	0.094	0.082	0.096	0.126
P_1K_1	1.07	1.06	1.13	1.27	1.29	1.34	1.53	1.70	1.84
P_1K_2	1.09	1.09	1.13	1.25	1.26	1.37	1.59	1.68	1.81
P_1K_3	1.06	1.09	1.09	1.30	1.30	1.39	1.58	1.70	1.81
P_2K_1	1.06	1.09	1.15	1.28	1.32	1.43	1.68	1.82	1.97
P_2K_2	1.06	1.09	1.13	1.33	1.34	1.41	1.62	1.80	1.93
P_2K_3	1.03	1.06	1.08	1.39	1.41	1.47	1.68	1.78	1.91
P_3K_1	1.13	1.16	1.16	1.32	1.36	1.43	1.74	1.82	1.96
P_3K_2	1.05	1.08	1.14	1.33	1.36	1.41	1.62	1.71	1.85
P_3K_3	1.02	1.03	1.13	1.32	1.34	1.43	1.67	1.80	1.96
F	0.84	1.42	0.18	1.70	0.70	0.37	2.56	0.92	0.67
C.D. (0.05)	-	-	-	-	-	-	0.082	-	-

Table 13 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
K_1	2.11	2.36	2.50	2.53	2.56	2.59	2.59	2.63	2.64
K_2	2.03	2.26	2.34	2.38	2.47	2.50	2.55	2.53	2.54
K_3	2.11	2.25	2.40	2.42	2.44	2.46	2.48	2.50	2.59
F	1.64	1.56	2.29	2.08	2.41	1.14	0.72	1.10	0.60
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.95	2.10	2.13	2.15	2.16	2.19	2.2	2.21	2.23
N_1K_2	1.87	2.02	1.98	2.08	2.26	2.29	2.30	2.30	2.31
N_1K_3	2.09	2.25	2.30	2.31	2.32	2.33	2.33	2.34	2.35
N_2K_1	2.28	2.58	2.77	2.81	2.85	2.89	2.92	2.93	2.94
N_2K_2	2.22	2.50	2.61	2.63	2.67	2.69	2.75	2.75	2.76
N_2K_3	2.11	2.33	2.49	2.51	2.53	2.55	2.59	2.60	2.77
N_3K_1	2.10	2.41	2.59	2.63	2.66	2.68	2.64	2.75	2.77
N_3K_2	2.00	2.26	2.43	2.44	2.46	2.51	2.61	2.54	2.55
N_3K_3	2.14	2.18	2.40	2.45	2.48	2.51	2.53	2.55	2.66
F	2.15	2.20	2.33	1.85	1.68	1.45	1.16	1.27	0.70
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	2.05	2.26	2.43	2.46	2.48	2.51	2.53	2.55	2.56
P_1K_2	1.97	2.24	2.38	2.39	2.42	2.46	2.51	2.52	2.54
P_1K_3	2.07	2.11	2.30	2.31	2.32	2.35	2.37	2.30	2.39
P_2K_1	2.18	2.46	2.56	2.60	2.63	2.65	2.68	2.70	2.71
P_2K_2	2.13	2.33	2.37	2.47	2.50	2.52	2.54	2.55	2.56
P_2K_3	2.08	2.25	2.35	2.40	2.43	2.43	2.45	2.55	2.65
P_3K_1	2.10	2.38	2.51	2.53	2.57	2.59	2.55	2.64	2.66
P_3K_2	2.00	2.21	2.28	2.29	2.48	2.50	2.60	2.52	2.53
P_3K_3	2.20	2.39	2.55	2.56	2.58	2.60	2.63	2.65	2.73
F	1.04	1.00	1.31	1.20	0.44	0.44	0.59	0.70	0.63
C.D. (0.05)	-	-	-	-	-	-	-	-	-

than those receiving K_2. Significant difference in stem girth was not observed among the N_2 plants receiving K_1K_2 or K_3 and N_3 plants receiving K_1, K_2 or K_3.

At 75 DAP (Table 13) plants receiving N_1K_3, N_3K_3, N_3K_2, N_2K_2 and N_1K_1 had greater stem girth (1.43, 1.36, 1.36, 1.34 and 1.34 cm, respectively) than those receiving N_3K_1, N_2K_1, N_2K_3 and N_1K_2. Among the N_1 plants those receiving K_3 and K_1 had greater stem girth (1.43 and 1.34 cm, respectively) than those receiving K_2. significant differences in stem girth was not observed among the N_2 plants receiving K_1, K_2 or K_3 and N_3 plants receiving K_1, K_2 or K_3.

At 90 DAP (Table 13) plants receiving N_1K_3, N_2K_2, N_2K_1, N_3K_2, N_3K_3 and N_3K_1 had greater stem girth (1.48, 1.47, 1.44, 1.44, 1.43 and 1.40 cm, (respectively) than those receiving N_2K_3, N_1K_1 and N_1K_2. Among the N_1 plants, those receiving K_3 had greater stem girth (1.48 cm) than those receiving K_1 and K_2. Significant difference in the stem girth was not observed among the N_2 plants receiving P_1, P_2 or P_3 and the N_3 plants receiving P_1, P_2 or P_3.

At 105 DAP (Table 13) the plants receiving N_2K_2, N_3K_1, N_2K_3 and N_3K_2 had greater stem girth (1.74, 1.70, 1.69, 1.68 and 1.67 cm, respectively) than those receiving N_1K_1, N_1K_2, N_1K_3 and N_3K_3. Significant difference in stem girth was not observed among the N_1 plants receiving K_1, K_2 or K_3 and N_3

plants receiving K_1, K_2 or K_3. Among the N_2 plants those receiving K_2 had greater stem girth (1.42 cm) than those receiving K_1 and K_3.

At 120 DAP (Table 13) plants receiving N_2K_1, N_3K_1, N_2K_2, N_2K_3 and N_3K_2 had greater stem girth (1.85, 1.85, 1.84, 1.80 and 1.80 cm, respectively) than those receiving N_3K_3, N_1K_3, N_1K_1 and N_1K_2. Among the N_1 plants, those receiving K_3 and K_1 had greatest stem girth (1.74 and 1.65 cm, respectively) those receiving K_2. Significant difference in the stem girth was not observed among the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants those receiving K_1 and K_2 had greater stem girth (1.85 and 1.80 cm, respectively) than those receiving K_3.

At 135 DAP (Table 13) plants receiving N_2K_1, N_2K_2, N_3K_1, N_2K_3 and N_3K_2 had greater stem girth (2.01, 1.96, 1.95, 1.93 and 1.91 and 1.90 cm respectively) than those receiving N_3K_3, N_1K_1 and N_1K_2. Among the N_1 plants, those receiving K_3 and K_1 had greater stem girth (1.91 and 1.80 cm, respectively) than those receiving K_2. Significant difference in the stem girth was not observed among the N_2 plants receiving K_1, K_2 or K_3 and the N_3 plants receiving K_1, K_2 or K_3.

4.1.4.6 The effect of PK interaction

Interaction between the P and K doses on the stem girth of the plants was found to be significant at 105 DAP (Table 13).

The plants receiving P_3K_1, P_2K_1, P_2K_3 and P_3K_3 had greater stem girth (1.74, 1.68, 1.68 and 1.67 cm, respectively) than those receiving P_2K_2, P_3K_2, P_1K_2, P_1K_3 and P_1K_1. Significant differences in stem girth was not observed among the P_1 plants receiving K_1, K_2 or K_3 and the P_2 plants receiving K_1, K_2 or K_3. Among the P_3 plants those receiving K_1 had greater stem girth (1.74 cm) than those receiving K_2 and K_3.

4.1.4.7 The effect of NPK interaction

Interaction of N, P and K on the stem girth of the plants found to be significant at 105 DAP (Table 14).

At 105 DAP, plants receiving $N_2P_2K_1$, $N_1P_2K_3$, $N_2P_3K_3$, $N_2P_2K_2$, $N_2P_3K_1$, $N_1P_3K_1$, $N_2P_3K_2$, $N_2P_1K_2$, $N_3P_3K_1$, $N_3P_1K_2$, $N_3P_2K_1$, $N_3P_3K_2$, $N_2P_1K_3$, $N_3P_1K_1$, $N_3P_2K_3$ and $N_3P_3K_3$ had greater stem girth (1.79, 1.76, 1.76, 1.75, 1.75, 1.75, 1.74, 1.72, 1.71, 1.70, 1.70, 1.69, 1.69, 1.68, 1.68 and 1.66 cm, respectively) than the others. Among the N_1 plants, those receiving $N_1P_2K_3$ and $N_1P_3K_1$ had greater stem girth (1.76 and 1.75 cm, respectively) than the others. Among the N_2 plants, those receiving P_2K_1, P_3K_3, P_2K_2, P_3K_1, P_3K_2, P_1K_2 and P_1K_3 had greater stem girth (1.79, 1.76, 1.75, 1.75, 1.74, 1.72 and 1.69 cm, respectively) than those receiving P_1K_1 and P_2K_3. Significant difference in stem girth was not observed in the N_3 plants receiving the combinations of P and K.

Table 14. Interaction of N, P and K on the stem girth (cm) of the shoots

Treat-ments	Days After Planting								
	15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	1.13	1.13	1.17	1.25	1.25	1.28	1.38	1.50	1.61
$N_1P_1K_2$	1.12	1.12	1.15	1.20	1.22	1.26	1.34	1.41	1.60
$N_1P_1K_3$	1.18	1.18	1.18	1.35	1.38	1.39	1.44	1.62	1.78
$N_1P_2K_1$	1.08	1.08	1.12	1.37	1.38	1.40	1.55	1.70	1.90
$N_1P_2K_2$	1.10	1.10	1.13	1.29	1.29	1.31	1.49	1.68	1.81
$N_1P_2K_3$	1.03	1.05	1.07	1.61	1.61	1.65	1.76	1.85	1.94
$N_1P_3K_1$	1.29	1.30	1.17	1.38	1.38	1.39	1.75	1.75	1.90
$N_1P_3K_2$	1.02	1.02	1.09	1.27	1.28	1.29	1.44	1.55	1.75
$N_1P_3K_3$	1.00	1.03	1.12	1.29	1.31	1.39	1.59	1.75	2.01
$N_2P_1K_1$	1.04	1.04	1.10	1.32	1.34	1.35	1.55	1.73	1.94
$N_2P_1K_2$	1.07	1.07	1.12	1.20	1.22	1.39	1.72	1.80	1.94
$N_2P_1K_3$	1.01	1.04	1.06	1.11	1.18	1.33	1.69	1.80	1.89
$N_2P_2K_1$	1.05	1.07	1.10	1.15	1.23	1.47	1.79	1.91	2.06
$N_2P_2K_2$	1.09	1.11	1.11	1.44	1.45	1.52	1.75	1.91	2.04
$N_2P_2K_3$	1.07	1.06	1.09	1.25	1.32	1.37	1.59	1.75	1.89
$N_2P_3K_1$	1.05	1.10	1.13	1.26	1.35	1.51	1.75	1.91	2.04
$N_2P_3K_2$	1.03	1.05	1.13	1.29	1.36	1.49	1.74	1.81	1.91
$N_2P_3K_3$	0.99	0.99	1.04	1.26	1.30	1.43	1.76	1.86	2.01
$N_3P_1K_1$	1.03	1.02	1.12	1.25	1.27	1.38	1.68	1.88	1.96
$N_3P_1K_2$	1.07	1.08	1.13	1.36	1.36	1.16	1.70	1.83	1.90
$N_3P_1K_3$	0.99	1.04	1.04	1.43	1.33	1.45	1.61	1.69	1.76
$N_3P_2K_1$	1.06	1.12	1.23	1.32	1.33	1.42	1.70	1.85	1.94
$N_3P_2K_2$	1.00	1.05	1.13	1.26	1.29	1.42	1.63	1.80	1.93
$N_3P_2K_3$	0.98	1.07	1.07	1.32	1.31	1.39	1.68	1.75	1.90
$N_3P_3K_1$	1.05	1.09	1.18	1.33	1.33	1.40	1.71	1.81	1.94
$N_3P_3K_2$	1.11	1.15	1.19	1.43	1.43	1.43	1.69	1.76	1.88
$N_3P_3K_3$	1.06	1.07	1.23	1.41	1.43	1.46	1.66	1.80	1.85
C_1	0.99	1.08	1.06	1.22	1.27	1.40	1.62	1.83	1.96
C_2	0.99	1.10	1.17	1.30	1.31	1.35	1.45	1.61	1.65
F	1.33	1.00	0.55	2.28	1.86	0.91	3.04	1.08	0.39
CD (0.05)	-	-	-	0.187	-	-	0.143	-	-

Table 14 continued

Treat-ments	150	165	180	195	210	225	240	255	270
				Days After Planting					
$N_1P_1K_1$	1.78	1.88	1.93	1.94	1.95	1.99	2.00	2.00	2.01
$N_1P_1K_2$	1.79	1.93	2.03	2.03	2.04	2.09	2.09	2.10	2.11
$N_1P_1K_3$	1.95	2.10	2.15	2.16	2.18	2.20	2.21	2.21	2.21
$N_1P_2K_1$	2.08	2.19	2.23	2.24	2.24	2.25	2.28	2.29	2.30
$N_1P_2K_2$	1.95	2.06	1.86	2.14	2.14	2.15	2.16	2.16	2.16
$N_1P_2K_3$	2.08	2.19	2.19	2.20	2.20	2.20	2.20	2.21	2.23
$N_1P_3K_1$	2.01	2.24	2.25	2.28	2.30	2.33	2.33	2.34	2.36
$N_1P_3K_2$	1.88	2.06	2.06	2.08	2.61	2.63	2.65	2.65	2.66
$N_1P_3K_3$	2.24	2.46	2.58	2.58	2.58	2.58	2.58	2.60	2.60
$N_2P_1K_1$	2.23	2.48	2.68	2.71	2.74	2.78	2.80	2.80	2.81
$N_2P_1K_2$	2.25	2.55	2.69	2.71	2.75	2.76	2.89	2.89	2.90
$N_2P_1K_3$	2.09	2.32	2.50	2.51	2.54	2.55	2.58	2.35	2.60
$N_2P_2K_1$	2.39	2.75	2.85	2.80	2.94	2.99	3.01	3.04	3.04
$N_2P_2K_2$	2.30	2.63	2.70	2.71	2.78	2.80	2.81	2.81	2.84
$N_2P_2K_3$	2.04	2.23	2.35	2.39	2.41	2.43	2.45	2.70	2.73
$N_2P_3K_1$	2.23	2.51	2.79	2.82	2.88	2.91	2.94	2.95	2.98
$N_2P_3K_2$	2.10	2.34	2.45	2.46	2.49	2.51	2.54	2.54	2.55
$N_2P_3K_3$	2.11	2.44	2.63	2.63	2.65	2.69	2.74	2.75	2.98
$N_3P_1K_1$	2.15	2.43	2.68	2.73	2.76	2.79	2.80	2.84	2.85
$N_3P_1K_2$	1.86	2.24	2.44	2.44	2.48	2.54	2.56	2.58	2.60
$N_3P_1K_3$	2.16	1.91	2.24	2.25	2.25	2.31	2.33	2.33	2.36
$N_3P_2K_1$	2.08	2.44	2.60	2.68	2.70	2.73	2.74	2.76	2.80
$N_3P_2K_2$	2.13	2.31	2.54	2.55	2.58	2.61	2.65	2.68	2.68
$N_3P_2K_3$	2.13	2.35	2.50	2.63	2.66	2.68	2.71	2.75	3.01
$N_3P_3K_1$	2.06	2.38	2.49	2.50	2.53	2.54	2.39	2.64	2.65
$N_3P_3K_2$	2.03	2.23	2.33	2.33	2.34	2.38	2.63	2.38	2.39
$N_3P_3K_3$	2.14	2.26	2.45	2.48	2.51	2.54	2.56	2.59	2.60
C_1	2.14	2.30	2.50	2.55	2.55	2.56	2.59	2.60	2.61
C_2	1.74	1.91	1.91	1.91	1.93	1.94	1.95	1.95	1.95
F	0.62	0.58	0.55	0.50	0.80	0.65	0.87	0.67	0.85
CD (0.05)	-	-	-	-	-	-	-	-	-

Significant difference in stem girth of the plants was observed in the treatment plants, compared to the controls at 105, 210, 240, 255 and 270 DAP. Between the two controls, significant difference in stem girth was observed at 105, 120, 135, 150, 180, 195, 210, 240, 255, 270 DAP (Tables 25 and 26). In the plants treated with Ohio WP solution (control 1) had greater stem girth (1.62, 1.83, 1.96, 2.14, 2.50, 2.55, 2.55, 2.56, 2.59, 2.60 and 2.61 cm, respectively) than those the tap water treated (control 2) plants.

4.1.5 Number of shoots

4.1.5.1 The effect of N

The effect of N on the number of shoots produced per plants was found to be significant at 15, 30 and 45 DAP (Table 15).

At 15 DAP, the plants receiving N_3 had greater number of shoots (1.05) than those receiving N_2 and N_1.

At 30 and 45 DAP (Table 15) the plants recorded a significantly greater number of shoots than the N_1 plants. The number in the N_3 and N_2 plants were respectively 1.05 and 1.01 at 30 DAP and 1.13 and 1.07 at 45 DAP.

4.1.5.2 Effect of P and K

Direct effect of P and K on the number of shoots per plants was not significant throughout the experimental period (Tables 15 and 16).

Table 15. Effect of N,P and their interaction on the number of shoots per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	1.00	1.00	1.01	1.09	1.12	1.22	1.22	1.28	1.33
N_2	1.01	1.06	1.07	1.10	1.22	1.31	1.29	1.33	1.31
N_3	1.05	1.11	1.13	1.16	1.19	1.29	1.29	1.43	1.47
F	3.76	7.63	6.26	1.35	1.35	1.17	0.59	1.49	1.38
C.D. (0.05)	0.035	0.056	0.067	-	-	-	-	-	-
P_1	1.03	1.05	1.07	1.09	1.19	1.22	1.21	1.25	1.32
P_2	1.01	1.06	1.08	1.14	1.23	1.30	1.26	1.33	1.28
P_3	1.05	1.06	1.06	1.12	1.20	1.30	1.33	1.46	1.51
F	0.54	0.21	0.34	0.60	0.41	1.12	1.39	2.74	2.75
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	1.00	1.00	1.03	1.06	1.17	1.17	1.21	1.21	1.38
N_1P_2	1.00	1.00	1.00	1.11	1.25	1.25	1.21	1.25	1.17
N_1P_3	1.00	1.00	1.00	1.11	1.22	1.25	1.25	1.38	1.46
N_2P_1	1.03	1.06	1.08	1.11	1.19	1.28	1.21	1.38	1.25
N_2P_2	1.00	1.08	1.11	1.11	1.22	1.33	1.29	1.38	1.25
N_2P_3	1.00	1.03	1.03	1.08	1.25	1.31	1.38	1.29	1.42
N_3P_1	1.06	1.08	1.11	1.11	1.19	1.22	1.21	1.38	1.33
N_3P_2	1.03	1.11	1.14	1.19	1.22	1.31	1.29	1.63	1.42
N_3P_3	1.06	1.14	1.14	1.17	1.14	1.33	1.38	0.41	1.67
F	0.27	0.53	0.49	0.27	0.35	0.10	0.16	0.41	0.41
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 15 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	1.38	1.40	1.42	1.42	1.42	1.42	1.40	1.39	1.39
N_2	1.38	1.35	1.43	1.40	1.44	1.43	1.44	1.46	1.43
N_3	1.49	1.46	1.47	1.44	1.40	1.36	1.35	1.32	1.28
F	0.77	0.50	0.13	0.07	0.07	0.21	0.42	0.80	1.07
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1	1.36	1.36	1.40	1.40	1.39	1.36	1.35	1.33	1.28
P_2	1.33	1.31	1.35	1.36	1.36	1.36	1.36	1.35	1.33
P_3	1.54	1.54	1.57	1.50	1.51	1.49	1.49	1.49	1.49
F	2.39	2.46	2.11	0.75	0.97	0.82	1.04	1.19	1.99
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1P_1	1.42	1.42	1.42	1.42	1.42	1.42	1.38	1.33	1.29
N_1P_2	1.21	1.29	1.29	1.29	1.29	1.25	1.21	1.17	1.21
N_1P_3	1.50	1.50	1.54	1.45	1.54	1.58	1.63	1.67	1.67
N_2P_1	1.33	1.33	1.42	1.38	1.42	1.38	1.38	1.42	1.38
N_2P_2	1.29	1.25	1.29	1.38	1.38	1.38	1.46	1.50	1.46
N_2P_3	1.50	1.46	1.58	1.46	1.54	1.54	1.50	1.46	1.46
N_3P_1	1.33	1.33	1.38	1.42	1.33	1.29	1.29	1.25	1.17
N_3P_2	1.50	1.38	1.46	1.42	1.42	1.46	1.42	1.38	1.33
N_3P_3	1.63	1.67	1.58	1.50	1.46	1.33	1.33	1.33	1.13
F	0.55	0.25	0.21	0.12	0.18	0.76	1.02	1.36	1.03
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 16. Effect of K and its interaction with P and K on the number of shoots per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	1.02	1.06	1.07	1.12	1.23	1.32	1.28	1.33	1.29
K_2	1.02	1.06	1.07	1.13	1.20	1.26	1.21	1.29	1.35
K_3	1.02	1.05	1.06	1.10	1.19	1.23	1.32	1.42	1.47
F	0.00	0.21	0.05	0.22	0.41	1.38	1.12	1.01	1.48
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.00	1.00	1.03	1.11	1.28	1.31	1.21	1.29	1.21
N_1K_2	1.00	1.00	1.00	1.11	1.22	1.19	1.21	1.25	1.33
N_1K_3	1.00	1.00	1.00	1.06	1.14	1.17	1.21	1.29	1.46
N_2K_1	1.00	1.03	1.03	1.06	1.22	1.33	1.29	1.38	1.25
N_2K_2	1.03	1.11	1.11	1.14	1.22	1.31	1.21	1.21	1.21
N_2K_3	1.00	1.03	1.08	1.11	1.22	1.28	1.29	1.42	1.46
N_3K_1	1.06	1.17	1.17	1.19	1.19	1.33	1.33	1.33	1.42
N_3K_2	1.03	1.06	1.11	1.14	1.17	1.28	1.21	1.42	1.50
N_3K_3	1.06	1.11	1.11	1.14	1.19	1.25	1.46	1.54	1.50
F	0.54	2.12	0.49	0.60	0.44	0.12	0.19	0.48	0.30
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	1.03	1.03	1.08	1.14	1.25	1.28	1.21	1.29	1.29
P_1K_2	1.03	1.06	1.06	1.08	1.14	1.22	1.21	1.25	1.33
P_1K_3	1.03	1.06	1.08	1.06	1.17	1.17	1.21	1.21	1.33
P_2K_1	1.00	1.08	1.08	1.14	1.22	1.36	1.29	1.29	1.17
P_2K_2	1.00	1.08	1.11	1.17	1.25	1.28	1.21	1.29	1.33
P_2K_3	1.03	1.03	1.06	1.11	1.22	1.25	1.29	1.42	1.33
P_3K_1	1.03	1.08	1.06	1.08	1.22	1.33	1.33	1.42	1.42
P_3K_2	1.03	1.03	1.06	1.14	1.22	1.28	1.21	1.33	1.38
P_3K_3	1.00	1.06	1.06	1.14	1.17	1.28	1.46	1.63	1.75
F	0.54	0.74	0.27	0.55	0.38	0.07	0.50	0.72	0.76
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table. 16 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
K_1	1.35	1.36	1.44	1.44	1.43	1.38	1.40	1.40	1.35
K_2	1.38	1.36	1.38	1.39	1.40	1.40	1.38	1.35	1.36
K_3	1.51	1.49	1.50	1.43	1.43	1.43	1.42	1.42	1.39
F	1.49	0.84	0.62	0.12	0.04	0.12	0.08	0.22	0.08
C.D. (0.05)	-	-	-	-	-	-	-	-	-
N_1K_1	1.29	1.33	1.38	1.33	1.33	1.38	1.42	1.33	1.29
N_1K_2	1.29	1.33	1.33	1.38	1.38	1.38	1.33	1.38	1.38
N_1K_3	1.54	1.54	1.54	1.54	1.54	1.50	1.46	1.46	1.50
N_2K_1	1.38	1.33	1.42	1.56	1.54	1.42	1.50	1.50	1.46
N_2K_2	1.33	1.33	1.38	1.33	1.42	1.46	1.38	1.38	1.38
N_2K_3	1.42	1.38	1.50	1.38	1.38	1.42	1.46	1.50	1.46
N_3K_1	1.38	1.42	1.54	1.50	1.42	1.33	1.29	1.38	1.29
N_3K_2	1.50	1.42	1.42	1.46	1.42	1.38	1.42	1.29	1.33
N_3K_3	1.58	1.54	1.46	1.38	1.38	1.38	1.33	1.29	1.29
F	1.30	0.12	0.22	0.52	0.48	0.11	0.32	0.21	0.46
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	1.33	1.29	1.38	1.42	1.38	1.29	1.29	1.25	1.13
P_1K_2	1.38	1.42	1.42	1.46	1.46	1.42	1.38	1.38	1.38
P_1K_3	1.38	1.38	1.42	1.33	1.33	1.38	1.38	1.38	1.33
P_2K_1	1.21	1.25	1.33	1.33	1.33	1.33	1.42	1.38	1.38
P_2K_2	1.33	1.25	1.29	1.33	1.38	1.42	1.38	1.38	1.38
P_2K_3	1.46	1.42	1.42	1.42	1.38	1.33	1.29	1.29	1.25
P_3K_1	1.50	1.54	1.63	1.58	1.58	1.50	1.50	1.58	1.54
P_3K_2	1.42	1.42	1.42	1.38	1.38	1.38	1.38	1.29	1.33
P_3K_3	1.71	1.67	1.67	1.54	1.58	1.58	1.58	1.58	1.58
F	0.46	0.36	0.28	0.39	0.45	0.39	0.47	0.88	1.13
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 17. Interaction of N, P and K on the number of shoots per plant

Treat-ments	Days After Planting 15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	1.00	1.00	1.08	1.08	1.25	1.25	1.25	1.25	1.25
$N_1P_1K_2$	1.00	1.00	1.00	1.08	1.17	1.17	1.25	1.25	1.50
$N_1P_1K_3$	1.00	1.00	1.00	1.00	1.08	1.08	1.13	1.13	1.38
$N_1P_2K_1$	1.00	1.00	1.00	1.17	1.25	1.33	1.25	1.25	1.13
$N_1P_2K_2$	1.00	1.00	1.00	1.08	1.25	1.17	1.13	1.25	1.13
$N_1P_2K_3$	1.00	1.00	1.00	1.08	1.25	1.25	1.25	1.25	1.25
$N_1P_3K_1$	1.00	1.00	1.00	1.17	1.33	1.33	1.13	1.38	1.25
$N_1P_3K_2$	1.00	1.00	1.00	1.08	1.25	1.25	1.25	1.25	1.38
$N_1P_3K_3$	1.00	1.00	1.00	1.08	1.08	1.17	1.38	1.50.	1.75
$N_2P_1K_1$	1.00	1.00	1.00	1.08	1.25	1.25	1.13	1.25	1.25
$N_2P_1K_2$	1.08	1.17	1.17	1.17	1.17	1.33	1.25	1.13	1.00
$N_2P_1K_3$	1.00	1.00	1.08	1.08	1.17	1.25	1.25	1.38	1.50
$N_2P_2K_1$	1.00	1.08	1.08	1.08	1.17	1.42	1.38	1.50	1.25
$N_2P_2K_2$	1.00	1.17	1.17	1.17	1.25	1.33	1.25	1.38	1.38
$N_2P_2K_3$	1.00	1.00	1.08	1.08	1.25	1.25	1.25	1.25	1.13
$N_2P_3K_1$	1.00	1.00	1.00	1.00	1.25	1.33	1.50	1.38	1.25
$N_2P_3K_2$	1.00	1.00	1.00	1.08	1.25	1.25	1.13	1.13	1.25
$N_2P_3K_3$	1.00	1.08	1.08	1.17	1.25	1.33	1.50	1.63	1.75
$N_3P_1K_1$	1.08	1.08	1.17	1.25	1.25	1.33	1.25	1.38	1.38
$N_3P_1K_2$	1.00	1.00	1.00	1.00	1.08	1.17	1.13	1.38	1.50
$N_3P_1K_3$	1.08	1.17	1.17	1.08	1.25	1.17	1.25	1.13	1.13
$N_3P_2K_1$	1.00	1.17	1.17	1.17	1.25	1.33	1.25	1.13	1.13
$N_3P_2K_2$	1.00	1.08	1.17	1.25	1.25	1.33	1.25	1.25	1.50
$N_3P_2K_3$	1.08	1.08	1.08	1.17	1.17	1.25	1.38	1.75	1.63
$N_3P_3K_1$	1.08	1.25	1.17	1.17	1.08	1.33	1.38	1.50	1.75
$N_3P_3K_2$	1.08	1.08	1.17	1.17	1.17	1.33	1.25	1.63	1.50
$N_3P_3K_3$	1.00	1.08	1.08	1.17	1.17	1.33	1.50	1.75	1.75
C_1	1.00	1.00	1.08	1.17	1.25	1.25	1.25	1.13	1.25
C_2	1.08	1.00	1.08	1.08	1.17	1.25	1.25	1.13	1.13
F	1.07	1.06	0.75	0.50	0.36	0.31	0.45	0.95	0.91
CD (0.05)	-	-	-	-	-	-	-	-	-

Table 17 continued

Treat-ments	Days After Planting 150	165	180	195	210	225	240	255	280
$N_1P_1K_1$	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.13	1.00
$N_1P_1K_2$	1.50	1.50	1.38	1.38	1.38	1.28	1.25	1.25	1.25
$N_1P_1K_3$	1.50	1.50	1.63	1.63	1.63	1.63	1.63	1.63	1.63
$N_1P_2K_1$	1.13	1.25	1.25	1.13	1.25	1.25	1.25	1.16	1.13
$N_1P_2K_2$	1.00	1.13	1.13	1.25	1.25	1.25	1.25	1.25	1.25
$N_1P_2K_3$	1.50	1.50	1.50	1.50	1.38	1.25	1.13	1.13	1.25
$N_1P_3K_1$	1.50	1.50	1.63	1.63	1.50	1.63	1.75	1.75	1.75
$N_1P_3K_2$	1.38	1.38	1.50	1.50	1.50	1.50	1.50	1.63	1.63
$N_1P_3K_3$	1.63	1.63	1.50	1.50	1.63	1.63	1.63	1.63	1.63
$N_2P_1K_1$	1.38	1.25	1.38	1.38	1.38	1.25	1.25	1.25	1.13
$N_2P_1K_2$	1.25	1.38	1.50	1.50	1.63	1.63	1.63	1.75	1.75
$N_2P_1K_3$	1.38	1.38	1.38	1.25	1.25	1.25	1.25	1.25	1.25
$N_2P_2K_1$	1.38	1.38	1.38	1.63	1.50	1.38	1.63	1.63	1.63
$N_2P_2K_2$	1.38	1.25	1.25	1.25	1.38	1.38	1.25	1.25	1.25
$N_2P_2K_3$	1.13	1.13	1.25	1.25	1.25	1.38	1.50	1.63	1.50
$N_2P_3K_1$	1.38	1.38	1.50	1.50	1.75	1.63	1.63	1.63	1.63
$N_2P_3K_2$	1.38	1.38	1.38	1.25	1.25	1.38	1.25	1.13	1.13
$N_2P_3K_3$	1.75	1.63	1.88	1.63	1.63	1.63	1.63	1.63	1.63
$N_3P_1K_1$	1.38	1.38	1.50	1.63	1.50	1.38	1.38	1.38	1.25
$N_3P_1K_2$	1.38	1.38	1.38	1.50	1.38	1.25	1.25	1.13	1.13
$N_3P_1K_3$	1.25	1.25	1.25	1.13	1.13	1.24	1.25	1.25	1.13
$N_3P_2K_1$	1.13	1.13	1.38	1.25	1.25	1.38	1.38	1.38	1.38
$N_3P_2K_2$	1.63	1.38	1.50	1.50	1.50	1.63	1.63	1.63	1.63
$N_3P_2K_3$	1.75	1.63	1.50	1.50	1.50	1.38	1.25	1.13	1.00
$N_3P_3K_1$	1.63	1.75	1.75	1.63	1.50	1.25	1.13	1.38	1.25
$N_3P_3K_2$	1.50	1.50	1.38	1.38	1.38	1.25	1.38	1.13	1.25
$N_3P_3K_3$	1.75	1.75	1.63	1.50	1.50	1.50	1.50	1.50	1.50
C_1	1.25	1.38	1.38	1.38	1.50	1.50	1.38	1.25	1.38
C_2	1.13	1.25	1.25	1.25	1.25	1.13	1.13	1.13	1.13
F	0.84	0.46	0.53	0.66	0.46	0.40	0.95	1.28	1.39
CD (0.05)	-	-	-	-	-	-	-	-	-

4.1.5.3 Effect of NP, NK, PK and NPK interaction

Interaction of NP, NK, PK and NPK were not found to be significant throughout the experimental period (Tables 15, 16 and 17).

Significant difference in the number of shoots produced per plant was not observed among the treatment plants when compared to the control plants and between the two controls (Tables 17).

4.1.6 Number of back bulbs

4.1.6.1 The effect of N

Effect of N on the number of back bulbs produced per plant was found to be significant at 60, 75, 90, 165, 210, 225, 240, 255 and 270 DAP (Table 18).

At 60 and 90 DAP (Table 18) the N_3 and N_2 plants recorded greater number of back bulbs (0.44 and 0.56) respectively for N_3 and 0.32 and 0.46 (respectively for N_2) than the N_1 plants.

At 75 DAP (Table 18) plants receiving N_3 had greater number of back bulbs (0.50) than the N_2 and N_1 plants.

At 165, 210, 225 and 240 DAP (Table 18) the N_3 and N_2 plants recorded significantly greater number of back bulbs than the N_1 plants.

Table 18. Effect of N,P and their interaction on the number of backbulbs per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
N_1	0.10	0.16	0.18	0.24	0.30	0.31	0.40	0.47	0.51
N_2	0.07	0.19	0.26	0.32	0.36	0.46	0.49	0.53	0.58
N_3	0.09	0.19	0.31	0.44	0.50	0.56	0.57	0.61	0.67
F	0.29	0.25	2.54	5.00	5.00	6.28	2.26	1.58	1.76
C.D. (0.05)	-	-	-	0.121	0.128	0.134	-	-	-
P_1	0.05	0.08	0.13	0.17	0.22	0.28	0.33	0.39	0.46
P_2	0.11	0.19	0.28	0.37	0.44	0.49	0.56	0.61	0.61
P_3	0.11	0.25	0.33	0.46	0.49	0.56	0.57	0.61	0.69
F	2.02	6.87	6.53	12.06	9.73	9.46	5.71	5.32	4.30
C.D. (0.05)	-	0.090	0.114	0.121	0.128	0.134	0.156	0.157	0.162
N_1P_1	0.00	0.08	0.06	0.06	0.08	0.11	0.17	0.25	0.29
N_1P_2	0.14	0.19	0.22	0.28	0.36	0.39	0.50	0.58	0.58
N_1P_3	0.17	0.19	0.25	0.39	0.44	0.44	0.54	0.58	0.67
N_2P_1	0.03	0.06	0.11	0.11	0.19	0.28	0.33	0.38	0.46
N_2P_2	0.11	0.22	0.36	0.47	0.50	0.53	0.58	0.63	0.63
N_2P_3	0.08	0.28	0.31	0.39	0.39	0.58	0.54	0.58	0.67
N_3P_1	0.11	0.11	0.22	0.33	0.39	0.44	0.50	0.54	0.63
N_3P_2	0.08	0.17	0.25	0.36	0.47	0.56	0.58	0.63	0.63
N_3P_3	0.08	0.28	0.44	0.61	0.64	0.67	0.63	0.67	0.75
F	1.40	0.49	0.95	1.67	1.11	0.29	0.63	0.52	0.66
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 18 continued

Treat-ments	Days after planting 150	165	180	195	210	225	240	255	270
N_1	0.58	0.64	0.74	0.74	0.79	0.86	0.90	0.96	1.00
N_2	0.61	0.71	0.78	0.81	0.94	1.07	1.15	1.17	1.28
N_3	0.76	0.86	0.92	0.97	1.15	1.26	1.38	1.49	1.67
F	2.69	3.27	1.61	2.48	4.43	4.27	5.89	7.82	12.80
C.D. (0.05)	-	0.177	-	-	0.242	0.274	0.274	0.268	0.263
P_1	0.49	0.64	0.72	0.75	0.89	1.00	1.10	1.17	1.29
P_2	0.68	0.72	0.81	0.83	0.96	1.10	1.15	1.21	1.31
P_3	0.79	0.85	0.90	0.93	1.04	1.10	1.18	1.24	1.35
F	6.81	2.78	1.47	1.37	0.79	0.33	0.19	0.14	0.10
C.D. (0.05)	0.167	-	-	-	-	-	-	-	-
N_1P_1	0.33	0.46	0.54	0.54	0.58	0.71	0.75	0.83	0.88
N_1P_2	0.67	0.67	0.83	0.83	0.88	0.92	0.96	1.00	1.00
N_1P_3	0.75	0.79	0.83	0.83	0.92	0.96	1.00	1.04	1.13
N_2P_1	0.38	0.54	0.63	0.67	0.88	1.04	1.13	1.17	1.33
N_2P_2	0.71	0.75	0.75	0.79	0.92	1.00	1.04	1.08	1.17
N_2P_3	0.75	0.83	0.96	0.96	1.04	1.17	1.29	1.25	1.33
N_3P_1	0.75	0.92	1.00	1.04	1.21	1.25	1.42	1.50	1.67
N_3P_2	0.67	0.75	0.83	0.88	1.08	1.38	1.46	1.54	1.75
N_3P_3	0.88	0.92	0.92	1.00	1.17	1.17	1.25	1.42	1.58
F	1.43	1.15	1.18	0.92	0.61	0.47	0.72	0.36	0.56
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Number of back bulbs in the N_3 and N_2 plants were respectively 0.86 and 0.71 at 165 DAP, 1.15 and 0.94 at 210 DAP, 1.26 and 1.07 at 225 DAP and 1.38 and 1.15 at 240 DAP.

At 255 and 270 DAP (Table 18) the plants receiving N_3 had greater number of back bulbs (1.49 and 1.67 respectively) than the N_2 and N_1 plants.

4.1.6.2 The effect of P

Effect of P on the number of back bulbs produced per plant was found to be significant from 30 to 150 DAP (Tables 18). The P_3 and P_2 plants recorded significantly greater number of backbulbs than the P_1 plants. Number of backbulbs in the P_3 and P_2 plants were respectively 0.25 and 0.19 at 30 DAP, .033 and .028 at 45 DAP, 0.46 and 0.37 at 60 DAP, 0.49 and 0.44 at 75 DAP, 0.56 and 0.49 at 90 DAP, 0.57 and 0.56 at 105 DAP, 0.61 and 0.61 at 120 DAP, 0.69 and 0.61 at 135 DAP and 0.79 and 0.69 at 150 DAP.

4.1.6.3 The effect of K

The effect of K was significant at 30, 45, 60, 75, 90, 105, 120 and 150 DAP (Table 19).

At 30 and 45 DAP (Table 19) the K_3 and K_1 plants recorded greater number of back bulbs than the P_1 plants. The number of back bulbs in K_3 and K_1 plants were respectively, 0.23 and 0.19 at 30 DAP and 0.33 and 0.23 at 45 DAP.

Table 19. Effect of K and its interaction with N and P on the number of backbulbs per plant

Treat-ments	Days after planting 15	30	45	60	75	90	105	120	135
K_1	0.08	0.19	0.23	0.29	0.32	0.40	0.44	0.47	0.57
K_2	0.06	0.11	0.18	0.23	0.30	0.39	0.40	0.47	0.50
K_3	0.12	0.23	0.33	0.48	0.54	0.55	0.61	0.67	0.69
F	1.16	3.52	0.75	9.05	8.19	3.32	3.95	4.07	2.91
C.D. (0.05)	-	0.090	0.114	0.121	0.128	0.134	0.156	0.157	-
N_1K_1	0.08	0.17	0.17	0.19	0.19	0.22	0.33	0.38	0.29
N_1K_2	0.11	0.11	0.11	0.17	0.28	0.31	0.38	0.42	0.58
N_1K_3	0.11	0.19	0.25	0.36	0.42	0.41	0.50	0.63	0.67
N_2K_1	0.08	0.22	0.25	0.31	0.33	0.44	0.46	0.50	0.46
N_2K_2	0.03	0.11	0.22	0.28	0.33	0.50	0.46	0.54	0.63
N_2K_3	0.11	0.22	0.31	0.39	0.42	0.44	0.54	0.54	0.67
N_3K_1	0.08	0.17	0.28	0.36	0.44	0.53	0.54	0.54	0.63
N_3K_2	0.06	0.11	0.19	0.25	0.28	0.36	0.38	0.46	0.63
N_3K_3	0.14	0.28	0.44	0.69	0.78	0.78	0.79	0.83	0.75
F	0.35	0.33	0.37	1.42	2.18	2.21	0.94	1.05	1.35
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	0.06	0.11	0.14	0.14	0.14	0.22	0.29	0.29	0.46
P_1K_2	0.03	0.06	0.11	0.11	0.17	0.22	0.25	0.33	0.38
P_1K_3	0.06	0.08	0.14	0.25	0.36	0.39	0.46	0.54	0.54
P_2K_1	0.11	0.19	0.25	0.28	0.39	0.47	0.50	0.58	0.58
P_2K_2	0.06	0.11	0.19	0.25	0.31	0.36	0.46	0.50	0.50
P_2K_3	0.17	0.28	0.39	0.58	0.64	0.64	0.71	0.75	0.75
P_3K_1	0.08	0.25	0.31	0.44	0.44	0.50	0.54	0.54	0.67
P_3K_2	0.11	0.17	0.22	0.33	0.42	0.58	0.50	0.58	0.63
P_3K_3	0.14	0.33	0.47	0.61	0.61	0.61	0.67	0.71	0.79
F	0.41	0.57	0.72	0.65	0.30	0.62	0.06	0.21	0.08
C.D. (0.05)	-	-	-	-	-	-	-	-	-

Table 19 continued

Treat-ments	15	30	45	60	75	90	105	120	135
	Days after planting								
K_1	0.65	0.76	0.83	0.86	0.99	1.04	1.08	1.14	1.26
K_2	0.54	0.67	0.75	0.79	0.92	1.04	1.14	1.19	1.32
K_3	0.76	0.78	0.85	0.88	0.99	1.11	1.21	1.28	1.36
F	3.52	0.93	0.50	0.46	0.22	0.17	0.41	0.54	0.27
C.D. (0.05)	0.167	-	-	-	-	-	-	-	-
N_1K_1	0.54	0.58	0.71	0.71	0.79	0.83	0.83	0.92	1.00
N_1K_2	0.50	0.63	0.71	0.71	0.79	0.88	0.96	1.00	1.04
N_1K_3	0.71	0.71	0.79	0.79	0.79	0.88	0.92	0.96	0.96
N_2K_1	0.71	0.79	0.79	0.79	0.96	1.04	1.08	1.08	1.17
N_2K_2	0.50	0.67	0.79	0.79	0.88	1.04	1.13	1.08	1.21
N_2K_3	0.63	0.67	0.75	0.83	1.00	1.13	1.25	1.33	1.46
N_3K_1	0.71	0.92	1.00	1.08	1.21	1.25	1.33	1.42	1.63
N_3K_2	0.61	0.71	0.75	0.83	1.08	1.21	1.33	1.50	1.71
N_3K_3	0.96	0.96	1.00	1.00	1.17	1.33	1.46	1.54	1.61
F	0.77	0.68	0.46	0.30	0.07	0.04	0.09	0.22	0.40
C.D. (0.05)	-	-	-	-	-	-	-	-	-
P_1K_1	0.54	0.75	0.79	0.83	1.00	1.04	1.08	1.17	1.29
P_1K_2	0.33	0.54	0.63	0.63	0.75	0.88	1.00	1.08	1.21
P_1K_3	0.58	0.63	0.75	0.79	0.92	1.08	1.21	1.25	1.38
P_2K_1	0.67	0.75	0.83	0.88	1.00	1.08	1.13	1.17	1.33
P_2K_2	0.58	0.63	0.75	0.75	0.96	1.13	1.21	1.29	1.38
P_2K_3	0.79	0.79	0.83	0.88	0.92	1.08	1.13	1.17	1.21
P_3K_1	0.75	0.79	0.88	0.88	0.96	1.00	1.04	1.08	1.17
P_3K_2	0.71	0.83	0.88	0.96	1.04	1.13	1.21	1.21	1.38
P_3K_3	0.+92	0.92	0.96	0.96	1.03	1.17	1.29	1.42	1.50
F	0.19	0.49	0.12	0.32	0.45	0.27	0.31	0.48	0.68
C.D. (0.05)	-	-	-	-	-	-	-	-	-

The plants receiving K_3 had greater number of back bulbs ie, 0.48, 0.54, 0.55, 0.61 and 0.61 at respectively, 45, 60, 75, 90, 105 and 120 DAP (Table 19).

At 150 DAP (Table 19), K_3 and K_1 plants recorded greater number of pseudobulbs (0.76 and 0.65, respectively) than those receiving K_2.

4.1.6.4 The effect of NP, NK and PK interaction

The effect of NP, NK and PK interaction on the number of back bulbs produced per plant was not found to be significant throughout the experimental period (Tables 18 and 19).

4.1.6.5 The effect of NPK interaction

Interaction between the N, P and K doses was observed to be significant at 30 and 75 DAP (Table 20).

At 30 DAP (Table 20) plants receiving $N_2P_3K_3$, $N_2P_2K_1$, $N_1P_2K_3$, $N_3P_2K_3$, $N_3P_3K_1$, $N_3P_3K_3$ and $N_1P_3K_1$ had greater number of backbulbs (0.50, 0.42, 0.33, 0.33, 0.33, 0.33 and 0.25, respectively) than those others. Among the N_1 plants, those receiving P_2K_3, P_3K_1, P_1K_1, P_3K_2, P_3K_3, P_2K_1, P_2K_2 and P_1K_3 had greater number of backbulbs (0.33, 0.25, 0.17, 0.17, 0.17, 0.17, 0.08 and 0.08, respectively) than those receiving P_1K_2. Among the N_2 plants, those receiving P_3K_3 and P_2K_1 had greater number of backbulbs (0.50 and 0.42, respectively) than those receiving the other PK combinations. Significant

Table 20. Interaction of N, P and K on the number of backbulbs per plant

Treat-ments	Days After Planting								
	15	30	45	60	75	90	105	120	135
$N_1P_1K_1$	0.00	0.17	0.08	0.08	0.08	0.08	0.13	0.13	0.25
$N_1P_1K_2$	0.00	0.00	0.00	0.00	0.00	0.08	0.13	0.13	0.13
$N_1P_1K_3$	0.00	0.08	0.08	0.08	0.17	0.17	0.25	0.50	0.50
$N_1P_2K_1$	0.08	0.08	0.17	0.17	0.17	0.25	0.38	0.50	0.50
$N_1P_2K_2$	0.17	0.17	0.17	0.17	0.33	0.33	0.50	0.50	0.50
$N_1P_2K_3$	0.17	0.33	0.33	0.50	0.58	0.58	0.63	0.75	0.75
$N_1P_3K_1$	0.17	0.25	0.25	0.33	0.33	0.33	0.50	0.50	0.63
$N_1P_3K_2$	0.17	0.17	0.17	0.33	0.50	0.50	0.50	0.63	0.63
$N_1P_3K_3$	0.17	0.17	0.33	0.50	0.50	0.50	0.63	0.63	0.75
$N_2P_1K_1$	0.08	0.08	0.17	0.17	0.17	0.33	0.38	0.38	0.63
$N_2P_1K_2$	0.00	0.08	0.17	0.17	0.33	0.33	0.38	0.50	0.50
$N_2P_1K_3$	0.00	0.00	0.00	0.00	0.08	0.17	0.25	0.25	0.25
$N_2P_2K_1$	0.17	0.42	0.42	0.42	0.50	0.50	0.50	0.63	0.63
$N_2P_2K_2$	0.00	0.08	0.33	0.50	0.50	0.58	0.63	0.63	0.63
$N_2P_2K_3$	0.17	0.17	0.33	0.50	0.50	0.50	0.63	0.63	0.63
$N_2P_3K_1$	0.00	0.17	0.17	0.33	0.33	0.50	0.50	0.50	0.75
$N_2P_3K_2$	0.08	0.17	0.17	0.17	0.17	0.58	0.38	0.50	0.50
$N_2P_3K_3$	0.17	0.50	0.58	0.67	0.67	0.67	0.78	0.75	0.75
$N_3P_1K_1$	0.08	0.08	0.17	0.17	0.17	0.25	0.38	0.38	0.50
$N_3P_1K_2$	0.08	0.08	0.17	0.17	0.17	0.25	0.25	0.38	0.50
$N_3P_1K_3$	0.17	0.17	0.33	0.67	0.83	0.83	0.88	0.88	0.88
$N_3P_2K_1$	0.08	0.33	0.17	0.25	0.50	0.67	0.63	0.63	0.63
$N_3P_2K_2$	0.00	0.17	0.08	0.08	0.08	0.17	0.25	0.38	0.38
$N_3P_2K_3$	0.17	0.08	0.50	0.75	0.83	0.83	0.88	0.88	0.88
$N_3P_3K_1$	0.08	0.08	0.50	0.67	0.67	0.67	0.63	0.63	0.63
$N_3P_3K_2$	0.08	0.33	0.33	0.50	0.58	0.67	0.63	0.63	0.75
$N_3P_3K_3$	0.08	0.33	0.50	0.67	0.67	0.67	0.63	0.75	0.88
C_1	0.08	0.16	0.16	0.33	0.42	0.42	0.50	0.50	0.50
C_2	0.00	0.08	0.08	0.16	0.16	0.16	0.13	0.13	0.25
F	0.54	2.04	1.05	1.63	2.39	1.23	1.05	0.69	0.60
CD (0.05)	-	0.269	-	-	0.383	-	-	-	-

Table 20 continued

Treat-ments	Days After Planting								
	150	165	180	195	210	225	240	255	270
$N_1P_1K_1$	0.38	0.50	0.63	0.63	0.75	0.75	0.75	0.88	1.00
$N_1P_1K_2$	0.13	0.38	0.38	0.38	0.38	0.63	0.75	0.88	0.88
$N_1P_1K_3$	0.50	0.50	0.63	0.63	0.63	0.75	0.75	0.75	0.75
$N_1P_2K_1$	0.63	0.63	0.75	0.75	0.75	0.75	0.75	0.75	0.75
$N_1P_2K_2$	0.63	0.63	0.88	0.88	1.00	1.00	1.13	1.13	1.13
$N_1P_2K_3$	0.75	0.75	0.88	0.88	0.88	1.00	1.00	1.13	1.13
$N_1P_3K_1$	0.63	0.63	0.75	0.75	0.88	1.00	1.00	1.13	1.25
$N_1P_3K_2$	0.75	0.88	0.88	0.88	1.00	1.00	1.00	1.00	1.13
$N_1P_3K_3$	0.88	0.88	0.88	0.88	0.88	0.88	1.00	1.00	1.00
$N_2P_1K_1$	0.63	0.75	0.75	0.75	1.13	1.25	1.25	1.25	1.38
$N_2P_1K_2$	0.25	0.50	0.63	0.63	0.63	0.75	0.75	0.75	0.88
$N_2P_1K_3$	0.25	0.38	0.50	0.63	0.88	1.13	1.38	1.50	1.75
$N_2P_2K_1$	0.63	0.75	0.75	0.75	0.88	1.00	1.00	1.00	1.13
$N_2P_2K_2$	0.75	0.75	0.75	0.75	1.00	1.13	1.25	1.38	1.50
$N_2P_2K_3$	0.75	0.75	0.75	0.88	0.88	1.88	0.88	0.88	0.88
$N_2P_3K_1$	0.88	0.88	0.88	0.88	0.88	0.88	1.00	1.00	1.00
$N_2P_3K_2$	0.50	0.75	1.00	1.00	1.00	0.25	1.38	1.13	1.25
$N_2P_3K_3$	0.88	0.88	1.00	1.00	1.25	1.38	1.50	1.63	1.75
$N_3P_1K_1$	0.63	1.00	1.00	1.13	1.13	1.13	1.25	1.38	1.50
$N_3P_1K_2$	0.63	0.75	0.88	0.88	1.25	1.25	1.50	1.63	1.88
$N_3P_1K_3$	1.00	1.00	1.13	1.13	1.25	1.38	1.50	1.50	1.63
$N_3P_2K_1$	0.75	0.88	1.00	1.13	1.38	1.50	1.63	1.75	2.13
$N_3P_2K_2$	0.38	0.50	0.63	0.63	0.88	1.25	1.25	1.38	1.50
$N_3P_2K_3$	0.88	0.88	0.88	0.88	1.00	1.38	1.50	1.50	1.63
$N_3P_3K_1$	0.75	0.88	1.00	1.00	1.13	1.13	1.13	1.13	1.25
$N_3P_3K_2$	0.88	0.88	0.75	1.00	1.13	1.13	1.25	1.50	1.75
$N_3P_3K_3$	1.00	1.00	1.00	1.00	1.25	1.25	1.38	1.63	1.75
C_1	0.50	0.50	0.50	0.50	0.75	0.75	0.88	1.13	1.13
C_2	0.38	0.38	0.38	0.38	0.50	0.50	0.63	0.75	0.75
F	0.91	0.21	0.21	0.18	0.58	0.44	0.64	1.05	1.75
CD (0.05)	-	-	-	-	-	-	-	-	-

differences in the number of backbulbs produced per plant was not observed among the N_3 plants receiving the PK combinations.

At 75 DAP (Table 20) plants receiving $N_3P_1K_3$, $N_3P_2K_3$, $N_3P_3K_1$, $N_3P_3K_3$, $N_2P_3K_3$, $N_3P_3K_2$, $N_1P_2K_3$, $N_1P_3K_2$, $N_1P_3K_3$, $N_1P_2K_1$, $N_1P_2K_2$, $N_1P_2K_3$ and $N_3P_2K_1$ had greater number of pseudobulbs (0.83, 0.83, 0.67, 0.67, 0.67, 0.58, 0.50, 0.50, 0.50, 0.50, 0.50 and 0.50, respectively) than the others. Among the N_1 plants those receiving P_2K_3, P_3K_2, P_3K_3, P_2K_2 and P_3K_1 had greater number of backbulbs (0.58, 0.50, 0.50, 0.33 and 0.33, respectively) than those receiving P_1K_1, P_1K_3 and P_3K_2. Among the N_3 plants, those receiving P_1K_3, P_2K_3, P_3K_1, P_3K_3, P_3K_2 and P_2K_1 had greater number of back bulbs (0.83, 0.83, 0.67, 0.67, 0.58 and 0.50, respectively) than those receiving P_1K_1, P_1K_2 and P_2K_2.

The number of backbulbs produced was significantly greater in the treatment plants than in the control plants at 180, 195 and 225 DAP. Significant differences on the number of backbulbs produced per plant was not observed between the two controls (Table 20).

4.1.7. Number of roots

4.1.7.1 The effect of N

Effect of N was found to be significant at 270 DAP (Table 21). The N_2 followed by N_1 plants had a greater number of roots (7.47 and 6.83, respectively) than the N_3 plants.

Table 21 Effect of N, P and their interaction on the number and length of roots (cm) per plant

Treatments	Number of roots		Length of roots	
	90 DAP	270 DAP	90 DAP	270 DAP
N_1	5.78	6.83	5.93	7.64
N_2	6.08	7.47	6.91	7.02
N_3	5.67	6.58	6.49	6.50
F	1.08	3.11	3.55	2.11
C.D. (0.05)	-	0.762	0.763	-
P_1	5.75	7.17	6.52	6.87
P_2	5.89	6.56	6.11	6.84
P_3	5.89	7.17	6.20	7.45
F	0.15	1.84	0.67	0.77
C.D. (0.05)	-	-	-	-
N_1P_1	5.75	6.92	5.63	6.91
N_1P_2	6.17	6.42	6.47	7.85
N_1P_3	5.42	7.17	5.71	8.17
N_2P_1	5.75	7.58	6.98	6.93
N_2P_2	6.00	7.42	6.99	7.05
N_2P_3	6.50	7.42	6.77	7.08
N_3P_1	5.75	7.00	6.95	6.77
N_3P_2	5.50	5.83	6.38	5.63
N_3P_3	5.75	6.92	6.13	7.11
F	1.12	0.51	0.66	0.73
C.D. (0.05)	-	-	-	-

4.1.7.2 The effect of P

Effect of P on the number of roots was not found to be significant (Table 21).

4.1.7.3 The effect of K

Effect of K on the number of roots produced was found to be significant at 270 DAP (Table 22), the plants receiving K_3 and K_2 had greater number of roots (7. 58 and 7.14, respectively) than those receiving K_1.

4.1.7.4 The effect of NP, NK, PK and NPK interaction

Interaction effect of NP, NK, PK and NPK was not found to be significant on the number of roots produced (at 90 and 270 DAP) (Tables 21, 22 and 23).

The treated plants recorded a greater number of shoots than the control plants at 270 DAP. Between the two controls there was no significant difference in the number of shoots produced.

4.1.8 Length of the roots

4.1.8.1 The effect of N

Effect of N on the length of the roots produced by the plants was found to be significant at 90 DAP (Table 21). The plants receiving N_2 and N_3 had greater root length (6.91 and 6.49 cm, respectively) than those receiving N_1.

Table 22 Effect of K and its interaction with N and P on the number and length of the roots (cm) per plant

Treat-ments	Number of roots 90 DAP	Number of roots 270 DAP	Length of roots 90 DAP	Length of roots 270 DAP
K_1	5.81	6.17	6.26	7.09
K_2	6.08	7.14	6.76	7.12
K_3	5.64	7.58	6.31	6.96
F	1.17	7.77	1.15	0.05
C.D. (0.05)	-	0.762	-	-
N_1K_1	5.50	6.25	5.48	8.17
N_1K_2	5.67	6.42	6.13	7.45
N_1K_3	6.17	7.33	6.19	7.30
N_2K_1	6.17	6.83	7.18	6.78
N_2K_2	6.50	7.50	6.70	7.23
N_2K_3	5.56	8.08	6.86	7.05
N_3K_1	5.75	5.42	6.11	6.32
N_3K_2	6.08	7.00	7.47	6.66
N_3K_3	5.17	7.33	5.88	6.53
F	1.15	0.40	1.75	0.30
C.D. (0.05)	-	-	-	-
P_1K_1	5.17	6.58	6.70	6.68
P_1K_2	6.50	7.33	6.81	7.15
P_1K_3	5.58	7.58	6.04	6.77
P_2K_1	6.25	5.42	5.94	7.34
P_2K_2	5.75	7.17	7.06	6.65
P_2K_3	5.67	7.08	6.83	6.53
P_3K_1	6.00	6.50	6.13	7.23
P_3K_2	6.00	6.92	6.42	7.55
P_3K_3	5.67	8.08	6.02	7.58
F	1.74	0.85	0.80	0.29
C.D. (0.05)	-	-	-	-

Table 23. Interaction of N, P and K on the number of roots and length of the roots (cm) per plant

Treatments	Number of roots		Length of roots	
	90 DAP	270 DAP	90 DAP	270 DAP
$N_1P_1K_1$	5.25	6.75	6.03	7.03
$N_1P_1K_2$	6.25	7.00	6.08	6.70
$N_1P_1K_3$	5.75	7.00	4.78	7.00
$N_1P_2K_1$	6.00	5.50	5.80	9.43
$N_1P_2K_2$	6.00	7.00	6.90	7.03
$N_1P_2K_3$	6.50	6.75	6.70	7.10
$N_1P_3K_1$	5.25	6.50	4.63	8.05
$N_1P_3K_2$	4.75	6.75	5.40	8.65
$N_1P_3K_3$	6.25	8.25	7.10	7.80
$N_2P_1K_1$	5.75	6.50	7.20	6.68
$N_2P_1K_2$	6.50	7.50	6.30	7.15
$N_2P_1K_3$	5.00	8.75	7.43	6.75
$N_2P_2K_1$	6.25	6.75	6.78	7.30
$N_2P_2K_2$	6.00	8.25	7.18	7.35
$N_2P_2K_3$	5.75	7.25	7.03	6.50
$N_2P_3K_1$	6.50	7.25	7.55	6.35
$N_2P_3K_2$	7.00	6.75	6.63	7.20
$N_2P_3K_3$	6.00	8.25	6.13	7.70
$N_3P_1K_1$	4.50	6.50	6.88	6.35
$N_3P_1K_2$	6.75	7.50	8.05	7.00
$N_3P_1K_3$	6.00	7.00	5.93	6.35
$N_3P_2K_1$	6.50	4.00	5.25	5.30
$N_3P_2K_2$	5.25	6.25	7.10	5.58
$N_3P_2K_3$	4.75	7.25	6.78	6.00
$N_3P_3K_1$	6.25	5.75	6.20	7.30
$N_3P_3K_2$	6.25	7.25	7.25	6.80
$N_3P_3K_3$	4.75	7.75	4.95	7.23
C_1	5.75	5.75	5.13	6.75
C_2	6.00	4.75	5.08	5.50
F	1.07	0.76	1.24	0.33
CD (0.05)	-	-	-	-

4.1.8.2 The effect of P and K

Effect of P and K on the length of the roots was not found to be significant (Tables 21 and 22).

4.1.8.3 The effect of NP, NK, PK and NPK interaction

Interaction effect of NP, NK, PK and NPK interaction had no significant effect on the length of the roots produced (Tables 21, 22 and 23). The treated plants recorded greater root length than the control plants at 90 DAP. No significant difference was observed between the two controls (Table 23).

4.1.9. Fresh weight

4.1.9.1 The effect of N and P

Effect of N on the fresh weight of the plants was found to be significant at 270 DAP (Table 24). The plants receiving N_3 and N_2 had a greater fresh weight (12.21 and 11.53 g, respectively) than those receiving N_1. Effect of P was found to be significant at 270 DAP (Table 24). The plants receiving P_3 had a greater weight (11.83 g) than those receiving P_2 and P_3.

4.1.9.2 The effect of P, K, NP, NK, PK and NPK

The direct effect of P and K and interaction of NP, NK, PK and NPK on the fresh weight of the plants was not found to be significant (Tables 24, 25 and 26). Significant difference in fresh weight between the treatment and the control plants was observed at 270 DAP, with the treatment plants recorded

Table 24. Effect of N, P and their interaction on the fresh and dry weight (g) of the plants

Treatments	Fresh weight		Dry weight	
	90 DAP	270 DAP	90 DAP	270 DAP
N_1	1.05	9.71	0.09	0.86
N_2	1.05	11.53	0.09	1.02
N_3	1.05	12.21	0.08	1.11
F	0.02	20.93	0.83	28.40
C.D. (0.05)	-	0.818	-	0.068
P_1	1.04	10.48	0.08	0.93
P_2	1.05	11.14	0.09	0.99
P_3	1.06	11.83	0.08	1.08
F	0.17	5.70	1.79	11.12
C.D. (0.05)	-	0.818	-	0.068
N_1P_1	1.01	8.97	0.08	0.79
N_1P_2	1.06	9.57	0.09	0.84
N_1P_3	1.07	10.59	0.09	0.96
N_2P_1	1.05	10.49	0.08	0.91
N_2P_2	1.08	11.94	0.09	1.06
N_2P_3	1.04	12.16	0.09	1.10
N_3P_1	1.07	11.97	0.08	1.09
N_3P_2	1.00	11.91	0.08	1.06
N_3P_3	1.08	12.74	0.09	1.19
F	0.69	0.70	0.71	1.35
C.D. (0.05)	-	-	-	-

Table 25. Effect of K and its interaction with N and P on the fresh and dry weight (g) of the plants

Treat-ments	Fresh weight		Dry weight	
	90 DAP	270 DAP	90 DAP	270 DAP
K_1	1.06	10.90	0.09	0.99
K_2	1.06	11.58	0.08	1.04
K_3	1.04	10.96	0.09	0.97
F	0.13	1.78	0.34	2.37
C.D. (0.05)	-	-	-	-
N_1K_1	1.04	9.52	0.09	0.85
N_1K_2	1.05	9.89	0.08	0.89
N_1K_3	1.05	9.72	0.09	0.84
N_2K_1	1.05	11.38	0.09	1.02
N_2K_2	1.07	11.92	0.09	1.05
N_2K_3	1.04	11.28	0.08	0.99
N_3K_1	1.07	11.81	0.09	1.09
N_3K_2	1.04	12.94	0.08	1.17
N_3K_3	1.04	11.88	0.08	1.07
F	0.13	0.27	0.57	0.13
C.D. (0.05)	-	-	-	-
P_1K_1	1.05	10.10	0.08	0.91
P_1K_2	1.06	11.04	0.08	0.97
P_1K_3	1.02	10.29	0.09	0.90
P_2K_1	1.04	10.91	0.09	0.96
P_2K_2	1.06	11.42	0.08	1.01
P_2K_3	1.04	11.09	0.09	0.99
P_3K_1	1.08	11.70	0.09	1.10
P_3K_2	1.05	12.29	0.09	1.13
P_3K_3	1.06	11.49	0.09	1.02
F	0.17	0.12	0.56	0.55
C.D. (0.05)	-	-	-	-

greater fresh weights. Significant difference between the two controls was also recorded at 270 DAP (Table 26). The control plants receiving Ohio WP Solution (Control 1) recorded greater fresh weight (10.89 g) than the tap water treated (Control 2) plants.

4.1.10 Dry matter content

4.1.10.1 The effect of N

Effect of N on the dry matter content of the plants was found to be significant at 270 DAP (Table 24). The plants receiving N_3 had a greater dry matter content (1-11 g) than those receiving N_2 and N_1 (1.02 and 0.86 g, respectively).

4.1.10.2 The effect of P

The effect of P on the dry matter content of the plants was found to be significant at 270 DAP (Table 24) plants receiving P_3 had a greater dry matter content (1.08 g) than those receiving P_2 and P_1.

4.1.10.3 The effect of K, NP, NK, PK and NPK

The direct of effect of K and the interaction effects of NP, NK, PK and NPK was not found to be significant at 90 and 270 DAP (Tables 24, 25 and 26).

Significant differences in dry matter content between the treatment plants and control plants was observed at 90 and 270 DAP. However there

Table 26. Interaction of N, [illegible]d K on the fresh and dry weight (g) of the plant

Treatments	F[illegible] weight		Dry weight	
	90 DAP	270 DAP	90 DAP	270 DAP
$N_1P_1K_1$	1.00	8.81	0.08	0.77
$N_1P_1K_2$	1.01	8.94	0.08	0.79
$N_1P_1K_3$	1.03	9.14	0.10	0.80
$N_1P_2K_1$	1.06	9.23	0.10	0.82
$N_1P_2K_2$	1.08	9.35	0.09	0.82
$N_1P_2K_3$	1.05	10.12	0.09	0.89
$N_1P_3K_1$	1.06	10.50	0.10	0.97
$N_1P_3K_2$	1.07	11.37	0.09	1.07
$N_1P_3K_3$	1.07	9.89	0.09	0.85
$N_2P_1K_1$	1.04	9.85	0.08	0.87
$N_2P_1K_2$	1.11	11.06	0.09	0.95
$N_2P_1K_3$	0.99	10.58	0.08	0.90
$N_2P_2K_1$	1.07	11.85	0.08	1.04
$N_2P_2K_2$	1.10	12.58	0.09	1.11
$N_2P_2K_3$	1.07	11.38	0.08	1.03
$N_2P_3K_1$	1.05	12.45	0.09	1.15
$N_2P_3K_2$	1.01	12.12	0.08	1.10
$N_2P_3K_3$	1.06	11.90	0.09	1.05
$N_3P_1K_1$	1.11	11.62	0.08	1.08
$N_3P_1K_2$	1.06	13.12	0.09	1.18
$N_3P_1K_3$	1.03	11.18	0.08	1.00
$N_3P_2K_1$	1.00	11.65	0.08	1.02
$N_3P_2K_2$	1.00	12.32	0.08	1.10
$N_3P_2K_3$	1.01	11.77	0.08	1.05
$N_3P_3K_1$	1.11	12.15	0.09	1.17
$N_3P_3K_2$	1.05	13.38	0.09	1.24
$N_3P_3K_3$	1.06	12.70	0.09	1.16
C_1	0.98	10.89	0.08	0.95
C_2	0.91	8.25	0.07	0.77
F	0.14	0.46	0.71	0.64
CD (0.05)	-	-	-	-

was no significant difference in dry matter content between the two controls (Table 26).

4.1.11 Number of Keikis

No keiki formation was observed during the period of experimentation.

4.1.12 Time taken for the shoots to become backbulbs

The period of time taken for shoots to become backbulbs was not significantly influenced by the nutrient treatments and their interactions.

4.2 Nutrient composition of the plants

4.2.1 The nitrogen content

4.2.1.1 The effect of N, P and K

The effect of N doses received by the plants on the nitrogen content of the plants was found to be significant (Table 27). The N content was higher in the plants receiving N_3 (2.69 %) than those receiving N_2 and N_1.

The effect of P and K doses received by the plants on the nitrogen content of the plant was not significant (Tables 27 and 28).

4.2.1.2 The effect of NP, NK, PK and NPK interaction

The effect of NP, NK, PK and NPK on the nitrogen content of the plants was not significant (Tables 27, 28 and 29). However the N content was significantly greater in the treatment plants than in the control plants (Table 29). There was no significant difference between the two controls.

Table 27. Effect of N, P and their interaction the nutrient (per cent) of the plants

Treatments	N %	P %	K %
N_1	1.61	0.33	1.66
N_2	2.09	0.48	2.09
N_3	2.69	0.45	2.12
F	39.77	6.94	12.03
C.D. (0.05)	0.251	0.088	0.216
P_1	1.99	0.38	2.06
P_2	2.15	0.45	1.68
P_3	2.20	0.48	2.13
F	2.31	3.11	10.92
C.D. (0.05)	-	0.088	0.216
N_1P_1	1.49	0.28	1.53
N_1P_2	1.50	0.29	1.42
N_1P_3	1.83	0.48	2.03
N_2P_1	1.94	0.42	2.26
N_2P_2	2.11	0.46	1.95
N_2P_3	2.22	0.49	2.05
N_3P_1	2.54	0.44	2.39
N_3P_2	2.83	0.46	1.66
N_3P_3	2.70	0.48	2.31
F	0.61	0.94	3.51
C.D. (0.05)	-	-	0.374

4.2.2 The phosphorus content

4.2.2.1 The effect of N, P and K

The effect of N and P doses received by the plants on the phosphorus content of the plants was significant. The P content was higher in the plants receiving N_2 and N_3 (0.48 and 0.45 % respectively) than in those rèceiving N_1, (Table 27 and 28). Also the P content was higher in the plants receiving P_3 and P_2 (0.48 and 0.45 per cent respectively) than the P_1 plants.The direct effect of P and K doses received by the plants on the phosphorus content of the plants was not significant.

4.2.2.2 The effect of NP, NK, PK and NPK interaction

The effect of NP, NK, PK and NPK interaction on the phosphorus content of the plants was not significant (Tables 27, 28 and 29). However the treatment plants as a whole recorded a significantly greater phosphorus content than the control plants. There is no significant difference among the two controls.

4.2.3 The potassium content

4.2.3.1 The effect of N, P and K

The effect of P and K doses given to the plants on the potassium content of the plants was significant (Table 27 and 28). Plants receiving N_3 and N_2 had a higher K content (2.12 and 2.09 per cent respectively) than those

Table 28. Effect of K and its interaction with N and P on the nutrient status (per cent) of the plants

Treatments	N %	P %	K %
K_1	2.15	0.44	1.80
K_2	2.08	0.37	1.78
K_3	2.16	0.45	2.29
F	0.24	1.84	15.49
C.D. (0.05)	-	-	0.216
N_1K_1	1.59	0.33	1.51
N_1K_2	1.56	0.31	1.43
N_1K_3	1.68	0.36	2.05
N_2K_1	2.20	0.46	1.80
N_2K_2	2.09	0.44	1.91
N_2K_3	1.98	0.46	2.56
N_3K_1	2.65	0.51	2.09
N_3K_2	2.59	0.36	2.00
N_3K_3	2.82	0.48	2.26
F	0.57	0.45	1.51
C.D. (0.05)	-	-	-
P_1K_1	2.02	0.39	1.89
P_1K_2	1.92	0.34	2.01
P_1K_3	2.03	0.41	2.27
P_2K_1	2.12	0.43	1.43
P_2K_2	2.20	0.33	1.49
P_2K_3	2.12	0.46	2.11
P_3K_1	2.31	0.48	2.07
P_3K_2	2.12	0.44	1.83
P_3K_3	2.32	0.43	2.49
F	0.31	0.57	1.16
C.D. (0.05)	-	-	-

Table 29 Interaction of N, P and K on the nutrient status (per cent) of the plants

Treatments	N	P	K
$N_1P_1K_1$	1.51	0.35	1.37
$N_1P_1K_2$	1.62	0.19	1.40
$N_1P_1K_3$	1.34	0.29	1.81
$N_1P_2K_1$	1.62	0.24	1.17
$N_1P_2K_2$	1.37	0.25	1.19
$N_1P_2K_3$	1.51	0.39	1.91
$N_1P_3K_1$	1.62	0.39	1.98
$N_1P_3K_2$	1.68	0.48	1.70
$N_1P_3K_3$	2.18	0.40	2.42
$N_2P_1K_1$	2.27	0.40	2.02
$N_2P_1K_2$	1.74	0.42	2.16
$N_2P_1K_3$	1.82	0.44	2.59
$N_2P_2K_1$	1.99	0.46	1.56
$N_2P_2K_2$	2.35	0.41	1.78
$N_2P_2K_3$	1.99	0.51	2.52
$N_2P_3K_1$	2.35	0.53	1.81
$N_2P_3K_2$	2.18	0.50	1.78
$N_2P_3K_3$	2.13	0.44	2.57
$N_3P_1K_1$	2.27	0.43	2.29
$N_3P_1K_2$	2.41	0.39	2.47
$N_3P_1K_3$	2.94	0.51	2.41
$N_3P_2K_1$	2.74	0.57	1.55
$N_3P_2K_2$	2.88	0.34	1.51
$N_3P_2K_3$	2.86	0.48	1.91
$N_3P_3K_1$	2.94	0.52	2.43
$N_3P_3K_2$	2.49	0.34	2.02
$N_3P_3K_3$	2.66	0.45	2.47
C_1	1.96	0.31	1.98
C_2	1.37	0.20	1.41
F	1.22	0.56	0.07
SE	0.257	0.090	0.221
CD (0.05)	-	-	-

receiving P_2. Plants receiving K_3 had higher potassium content (2.29 per cent) than those receiving K_1 and K_2.

4.2.3.2 The effect of NP interaction

The effect of NP interaction on the potassium content of the plants was significant (Table 27). Plants receiving N_3P_1, N_3P_3, N_2P_1, N_2P_3 and N_1P_3 had a greater potassium content (2.39, 2.31, 2.26, 2.05 and 2.03 per cent respectively) than those receiving N_1P_1, N_1P_2, N_2P_2 and N_3P_2. Among the N_1 plants those receiving P_3 had a higher potassium content (2.03 %) than those receiving P_1 and P_2.

Significant effect on the potassium content was not observed among the N_2 plants receiving P_1, P_2 or P_3. Among the N_3 plants those receiving P_1 and P_3 had greater potassium content (2.39 and 2.31 per cent respectively) than those receiving P_2 (Table 27).

4.2.3.3 The effect of NK, PK and NPK interaction

Interaction of NK, PK and NPK were not found to be significant on the potassium content of the plants (Tables 28and 29).

Significant differences in the potassium content of the plants was not observed among the treatment plants when compared to the control and between the two controls (Table 29).

Plate 1. *Dendrobium* Sonia-17 plant at the start of the experiment (3 months after transplanting)

Plate 2.
T_{13} plant receiving 6.0, 6.0 and 2.0mg of N,P and K at 270 DAP.

Plate 3.
T_{11} plant receiving 6.0, 2.0 and 6.0 mg of N, P and K at 270 DAP.

Plate 4. T_{20} plant receiving 10.0, 2.0 and 6.0 mg of N,P and K at 270 DAP.

Plate 5. Over all view of the experimental plot

DISCUSSION

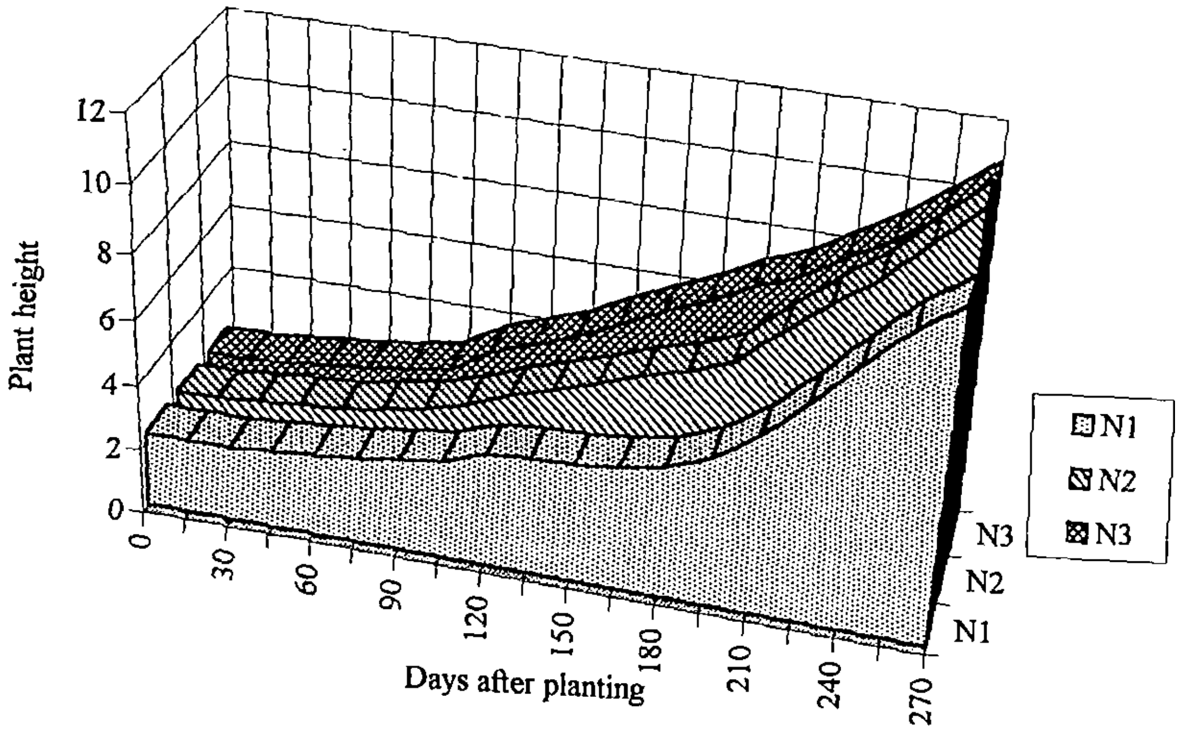
DISCUSSION

The *ex vitro* stage of tissue / meristem cultured plants is characterised by gradual acclimatization to the *ex vitro* environment and transformation into complete autotrophs accompanied by anatomical and physiological changes which complement the process.

Therefore, nutrient uptake and utilization are determined by the rate of growth and dry matter accumulation, which differs with the plant species and in turn determines the time taken to attain reproductive capacity. In orchids, the time taken by tissue-cultured plants to produce marketable flowers ranges from 24 to 30 months. Hence, nutrient management of acclimatized plants with a view to promote growth and development is of considerable significance.

In the present study, *Dendrobium* Sonia - 17 plants, three months after acclimatization in green house conditions at 25 per cent light intensity were subjected to the nutrient treatments which constituted N, P and K at three levels *viz.*, 2.0, 6.0 and 10.0 mg per plant given as whole plant spary at weekly intervals with Ohio WP solution at half strength and tap water spray as the controls. The results obtained revealed that the treatments influenced vegetative growth, dry matter accumulation and nutrient composition of the plants during the period of experimentation.

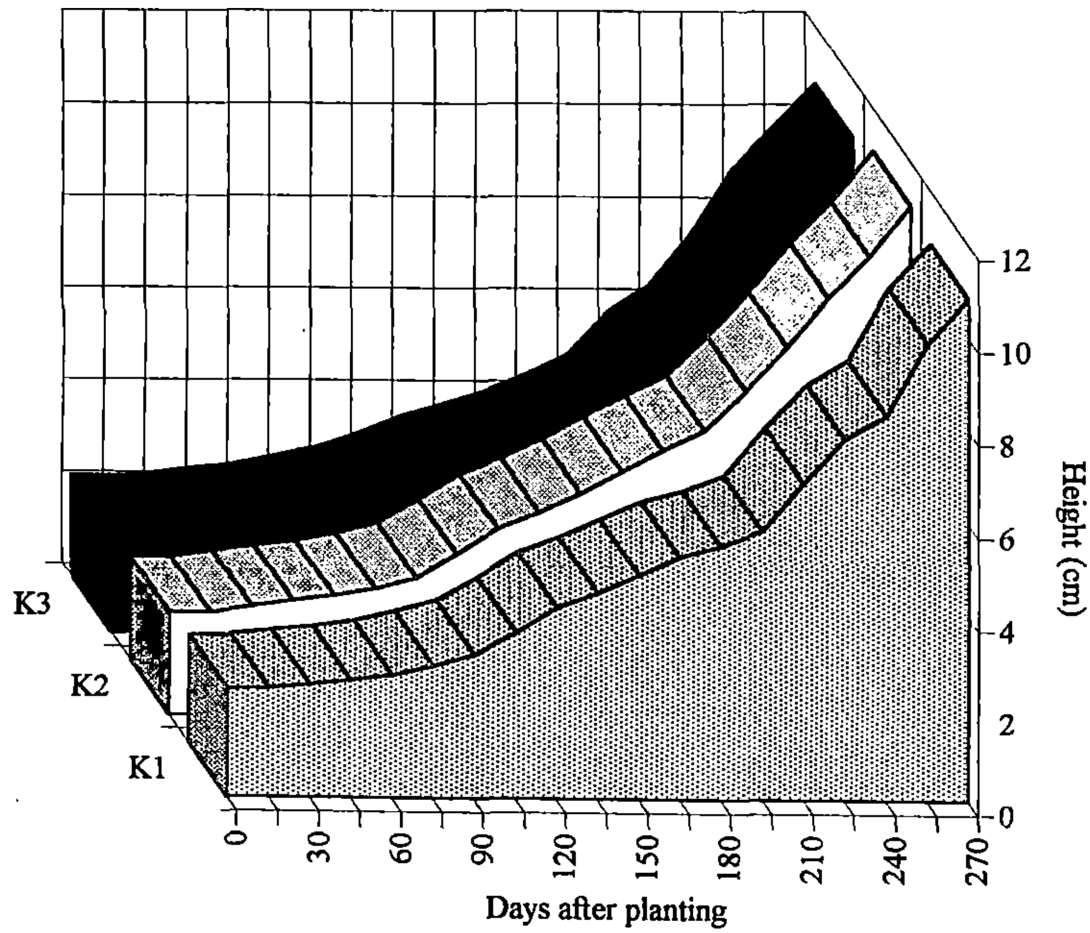
Fig. 1 Effect of N dosages on the height (cm) of the plants



The growth was slow during the early stage upto 90 DAP. Then there was a rapid increase in shoot length, leaf number, leaf area, stem girth and number of shoots. Among the biometric characters, plant height was influenced by the N and K levels. At 90 and 105 DAP the plants receiving 6.0 or 10.0 mg of nitrogen had a significantly greater height than those receiving 2.0 mg. At 120 to 195 DAP, the 10.0 mg dose was found to be superior and at 210, 225, 240, 255 and 270 DAP both 6.0 and 10.0 mg nitrogen promoted plant height (Tables 3 and Figure 1). In contrast, a dramatic reduction in growth of *Cattleya* by increasing nitrogen levels was reported by Poole and Seeley (1978).

The effect of K was observed from 15 DAP onwards, while the plants receiving 2.0 mg K was found to have a greater height at 15 DAP. From 30 to 150 DAP and at 165 and 180 DAP, the 6.0 mg dosage also was found to be equally effective. At 210 DAP, the plants receiving 6.0 mg K and at 225 DAP those receiving 2.0 or 6.0 mg recorded greater heights. However at 240 DAP the effect of 6.0 and 10.0 mg K on height was significantly promotive. (Table 5 and Figure 2) Yoneda *et al.* (1997) reported stunted growth of shoots in *Phalaenopsis* due to deficiency of K. Poole and Seeley (1978) in a comprehensive investigation on the nutrition of seedlings and mericlones of three orchid genera viz., *Cattleya, Cymbidium* and *Phalaenopsis* found that in nutrient culture the N and K levels influenced growth at constant level of P. The most responsive dosage of N and K for greater vegetative growth was found to be 10.5 mg and 5.25 mg with 2.1 mg P per week for *Cymbidium* and

Fig. 2 Effect of K on the height (cm) of the plants



Phalaenopsis plantlets, and 5.25 mg each of N and K with 2.1 mg P per week for *Cattleya* plantlets during the first nine months of their *ex vitro* life.

In the present study, direct effect of P nutrition on plant height, number of leaves, leaf area, number of shoots, number and length of roots was not observed. However, significant effects of P on stem girth and back bulb production and interaction with N for plant height, number of leaves, leaf area and stem girth was observed. Concurrent to the observed effect Bhattacharjee (1981) reported that P_2O_5 alone have no effect but P_2O_5 with N have influence on growth of the plant.

A short term influence of P K interaction was also observed for leaf area and stem girth. Interaction of NP and NK influenced plant height at respectively 60 DAP, from 120 to 270 DAP and at 150, 165, 180 and 195 DAP. The responsive doses influencing increase in height were 2.0 mg of N with 2.0 mg of P or 6.0 mg of N with 6.0 or 10.0 mg of P and 10.0 mg of N with 10.0 mg of P at 60, 120, 135, 150, 165, 180, 195 and 210 DAP. Towards the later stages (at 225, 255 and 270 DAP) 6.0 mg each of N and P or 10.0 mg N with 2.0 mg of P were found to be effective in increasing the plant height (Tables 3).

Interaction effects of N and K showed that plants receiving 10.0 mg per plant of nitrogen and 2.0 mg per plant of potassium found to have greater height at 150, 165, 180 and 195 DAP (Table 4).

In *Phalaenopsis*, the number of leaves and leaf shedding reported to be influenced by the nitrogen nutrition of plants (Yoneda *et al.* 1997). In the present study both nitrogen and potassium could directly increase the number of leaves produced by the plants. The dosage of 6.0 mg N per plant was found to increase the number of leaves consistently from 120 to 270 DAP and 10.0 mg per plant was equally effective at 60, 75, 90 and 120 DAP (Table 6 and Figure 3). Similarly higher dosage of N (200 ppm) produced fewer leaves than 100 ppm N in *Cymbidium* was reported by Poole and Seeley (1978). They also reported fewer leaves with 200 ppm K than with 50 or 100 ppm K. In the present study also higher dosage of K found to reduce the number of leaves. 2.0 or 6.0 mg per plant of K was found to result in greater leaf number from 165 to 270 DAP (Tables 7 and Figure 4).

Interaction effects revealed that plants receiving 6.0 mg N with 2.0 or 6.0 mg P per plant (at 90, 135, 150, 165, 180 and 195 DAP) and also 10.0 mg N with 2.0 mg P per plant (at 90 DAP) could result in greater number of leaves (Table 6).

A direct effect on leaf area per plant was observed with the N dosages of 6.0 and 10.0 mg per plant were equally effective in maintaining a greater leaf area (Table 9 and Figure 5) at 15 and from 45 to 270 DAP. Similar increase in leaf area with increasing levels of N was reported in *phalaenopsis* seedlings by Sheehan (1966).

Fig. 3 Effect of N dosages on the number of leaves produced per plant

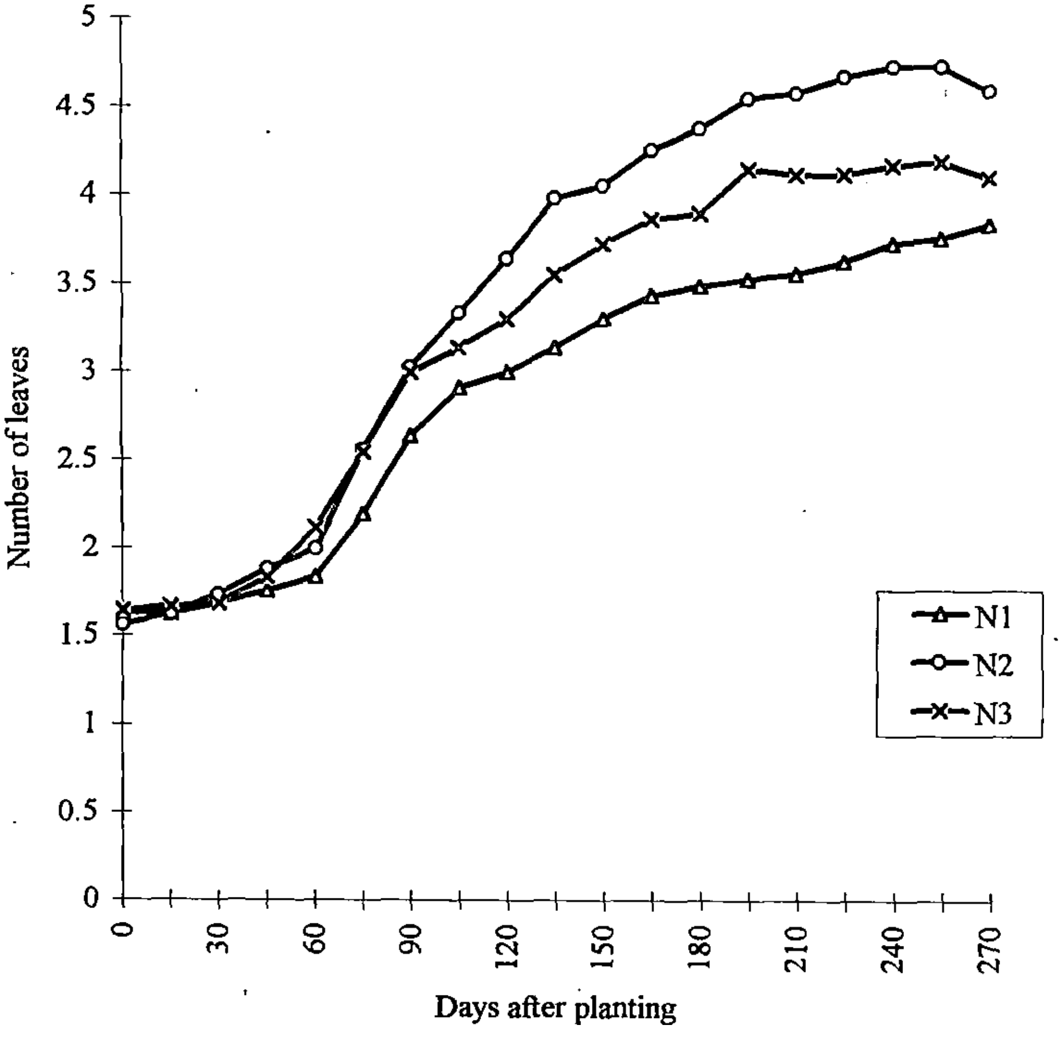
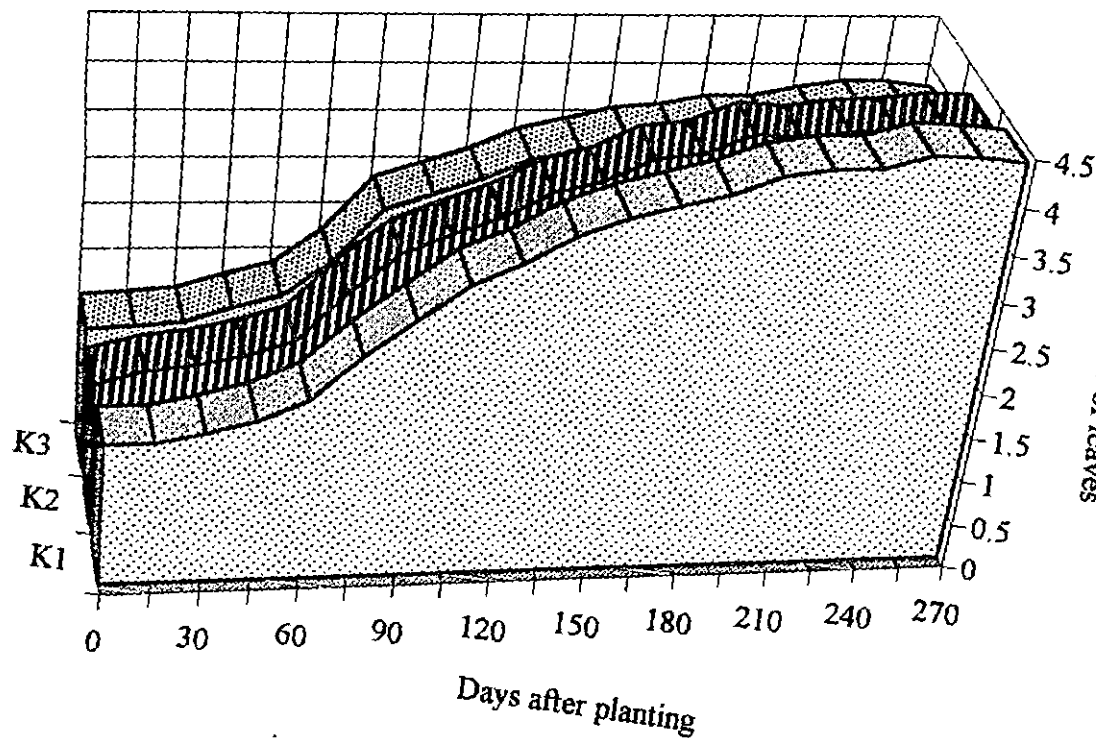


Fig. 4 Effect of K on the number of leaves produced per plant

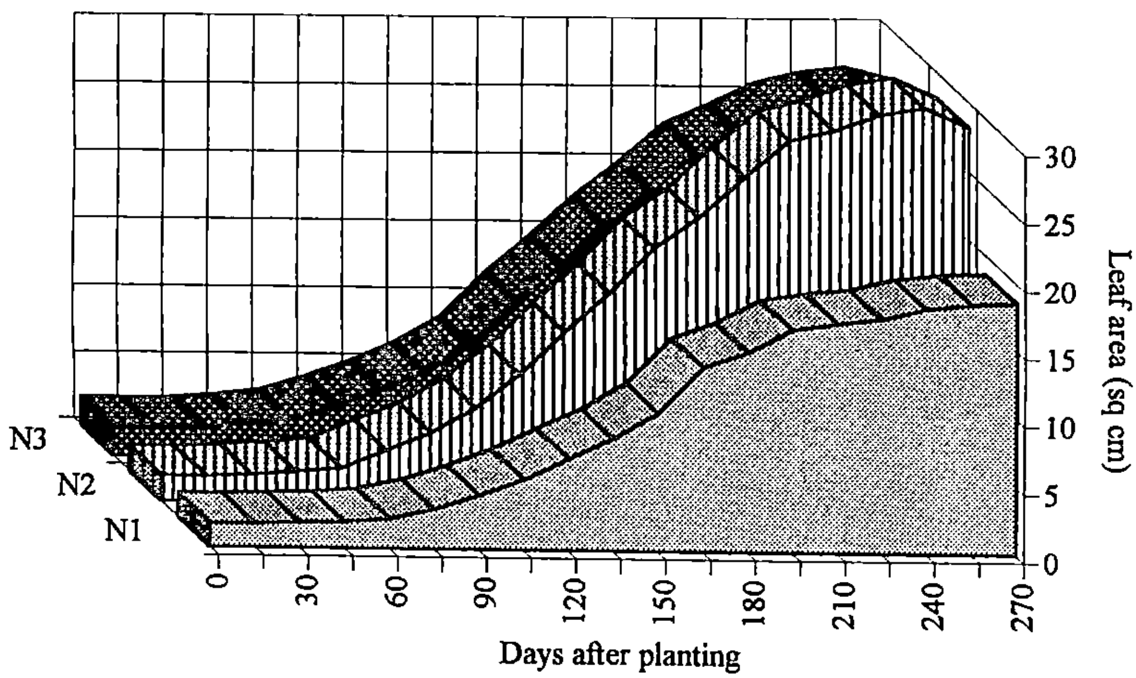


The observed effect of leaf area enhancement may due to a greater number of leaves observed with the higher doses of N and also due to a greater leaf size as deficient levels of N have been reported to reduce leaf size and consequently leaf area in *Vanilla fragrans* (Cibes *et al.*, 1949) and in *Phalaenopsis* (Yoneda *et al.*, 1997).

Interaction effects of N with P showed that 6.0 mg N with 2.0, 6.0 or 10.0 mg P and 10.0 mg N with 2.0 or 6.0 mg P resulted in greater leaf area at 90 to 165 DAP (Tables 9). A short term interaction between the P and K levels influencing leaf area was observed at 195 DAP, when 2.0 mg P with 6.0 mg K or *vice versa* and 10.0 mg P with either 2.0, 6.0, 10.0 mg K were found to result in greater leaf area. There was no considerable increase in leaf area with increase in P and plants receiving 2.0 mg of N with 2.0, 6.0 or 10.0 mg per plant of K has lower leaf area.

Among the nutrients, nitrogen and phosphorus were found to influence the stem girth of plants. At the early stages (15 and 60 DAP) the lower levels of N (2.0 mg per plant) was observed to be sufficient while the higher levels, 6.0 and 10.0 mg was found to result in greater girth at the later stages (105 to 270 DAP) (Table 12). In the present study, increasing the dosages of N found to decrease the stem girth of the plants at elder stages whereas, Cibes *et al.* (1949) reported reduction of stem diameter in N deficient *Vanilla fragrans* plants under gravel culture and Ochsenbauer (1996) could not detect

Fig. 5 Effect of N on the leaf area (sq cm) of the plants



considerable difference in plant diameter of three *phalaenopsis* hybrids (Sylba, Nopsya and Abylos) at high rates of N nutrition.

Phosphorus was found to influence the stem girth from 75 to 135 DAP with 6.0 or 10.0 mg per plant. The NP, NK and PK interaction effects also confirm the beneficial effect of 6.0 mg each of N and P in combination with 2.0 mg K per plant. 6.0 or 10.0 mg N with the same dosage of P resulted in greater stem girth at 105 and 120 DAP (Table 12). Also 6.0 or 10.0 mg per plant of N with 2.0 or 6.0 mg of K had greater stem girth at 75, 105 and 120 DAP. PK interaction had a short term influence at 105 DAP with 6.0 mg each of N and K and 10.0 mg of N with 2.0 mg of K having greater stem girth.

The number of leafy shoots on the plants was influenced by nitrogen among the nutrients upto 45 DAP. The number was higher in the plants receiving 10.0 mg N per plant at 15 DAP and 6.0 or 10.0 mg per plant at 30 and 45 DAP (Table 15).

Improvement in shoot formation was reported by increasing the N rates from 24 to 120 mg per clump by Bik (1982) and by increasing the dosage from 2.0 to 48 m mol l^{-1} by Bik and Van den Berg (1984) in miniature *Cymbidium*. However the leafless backbulbs were greater in the plants receiving 6.0 or 10.0 mg per plant of N and lower in those plants receiving 2.0 mg per plant of N at 60, 90 and from 165 to 240 DAP and 10.0 mg N at 15, 255 and 270 DAP

(Tables 18). The greater number of leaf less backbulbs at the higher dosages of N and higher dosages of P suggest a greater tendency of leaf shedding.

Plants receiving well balanced nutrient solution foliarly applied may not need a well developed root system for that they need not depend only on the nutrients absorbed by the roots. The nutrients will be readily available to the plants foliarly may not divert the carbohydrates for the development of extensive root system (Mekendrick, 1997). The number of roots produced per plant was influenced by N and K dosages at 270 DAP. N doses of 2.0 or 6.0 mg per plant was found to result in a greater number of roots (Table 21) The K doses of 2.0 or 10.0 mg per plant were equally effective in increasing the number of roots at 270 DAP. The number of roots not influenced by nutrients at 90 DAP reveals the requirement of only minimal quantity of nutrients for optimum growth.

A short term influence on the root length was observed with the N doses at 90 DAP (Table 21) greater in the plants receiving 6.0 or 10.0 mg per plant.

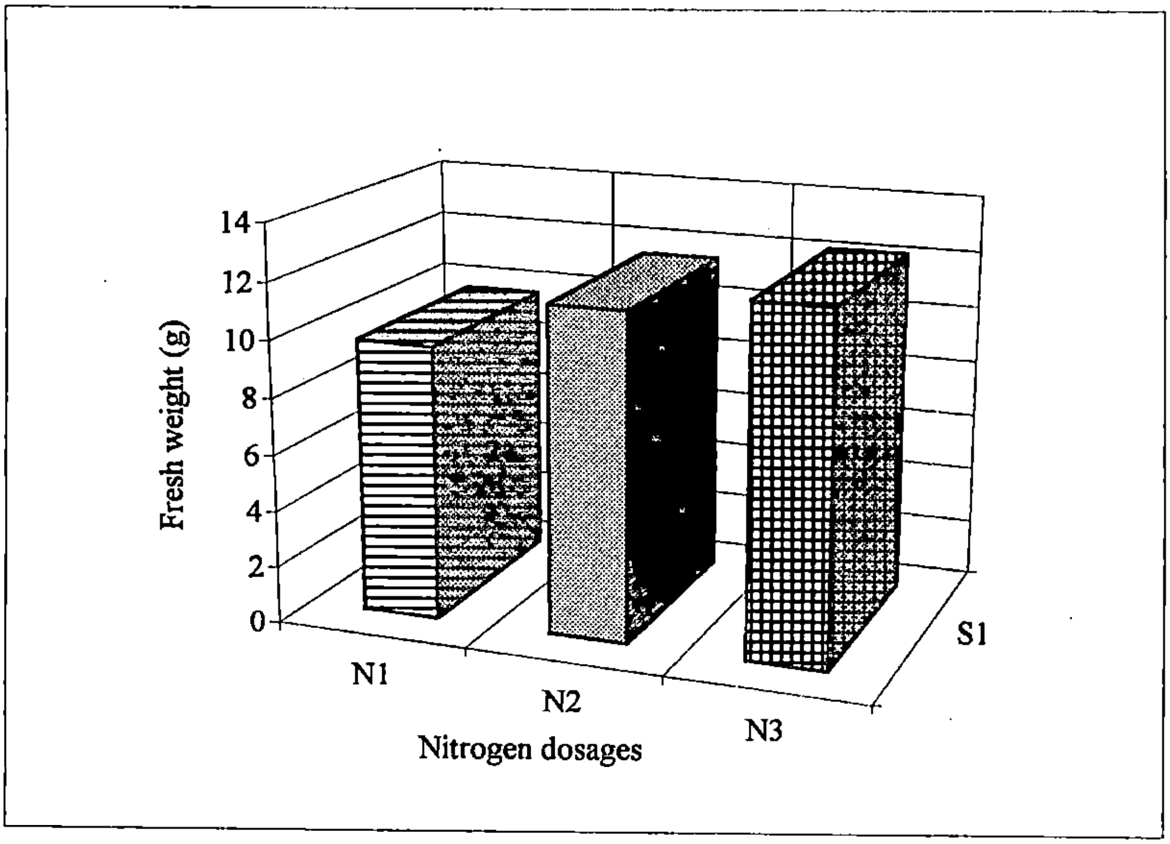
Effect of applied nutrients on root production and root growth had been reported in several orchids. The production of new roots in *phalaenopsis* was reported to be influenced by the K doses given (Yoneda *et al.*, 1997). Root growth enhancement was reported in seedlings of *Dactylorrhiza fuchsii* by applied nutrients (Mekendrick, 1997). In the present study the observed effects indicate that a positive response on root growth could be obtained at the later stages of growth when the plants were atleast 1 year old.

Similarly nutrient effects on the fresh and dry weights of the plants were limited to the later stages (270 DAP). Greater fresh weights were observed in the plants receiving 6.0 or 10.0 mg N and in those receiving 6.0 or 10.0 mg of P. Increase in fresh weight with N doses in *Odontoglossum* seedlings was reported by Gething (1974). Greater dry weights were observed in those receiving the highest dose of N and P (Table 24, Figure 6). This indicates that 10.0 mg per plant each of N and P could effectively result in greater dry matter production at 270 DAP, though fresh weight increase could be obtained with the 6.0 mg dosage too (Table 24, Figures 6 and 7). Concurrent to the observed results Chin (1966) observed that omission of N, P and K severely affected the dry weights of *Dendrobium phelaenopsis* hybrid seedlings.

The dry matter content of plants observed (9.09 per cent) at the effective doses (at 10.0 mg per plant of N) and 9.13 per cent (at 10.0 mg per plant of P) (Table 24) appear to conform that reported in mature plants of other genera such as 6.4 to 8.8 per cent in the pseudobulbs of cattleya (Poole and Sheehan, 1973) and 13.4 per cent in the stem of phalaenopsis plants (Poole and Sheehan, 1974).

The content of the N, P and K nutrients in the plants was influenced by the applied doses of nutrients. The N content of the plants was greater in

Fig. 6 Effect of N on the fresh and dry weight (g) of the plants



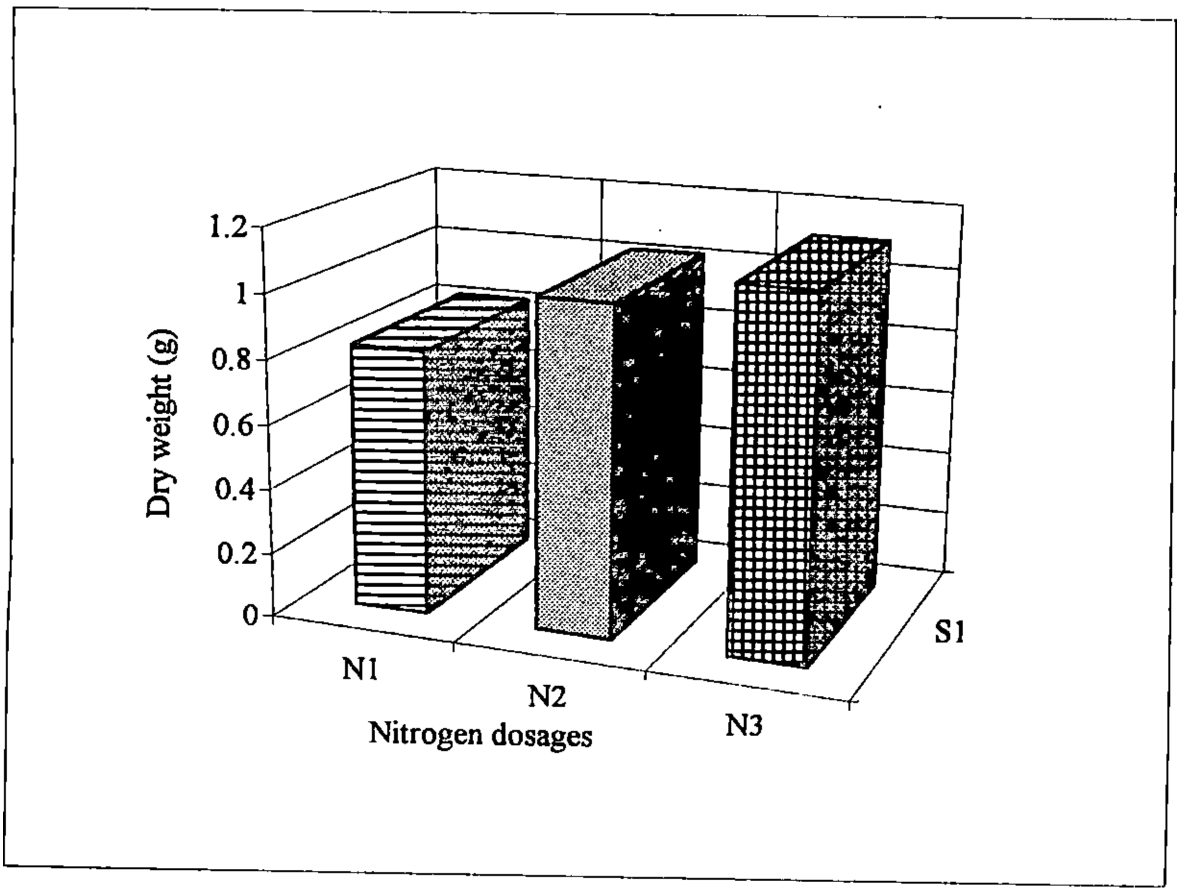
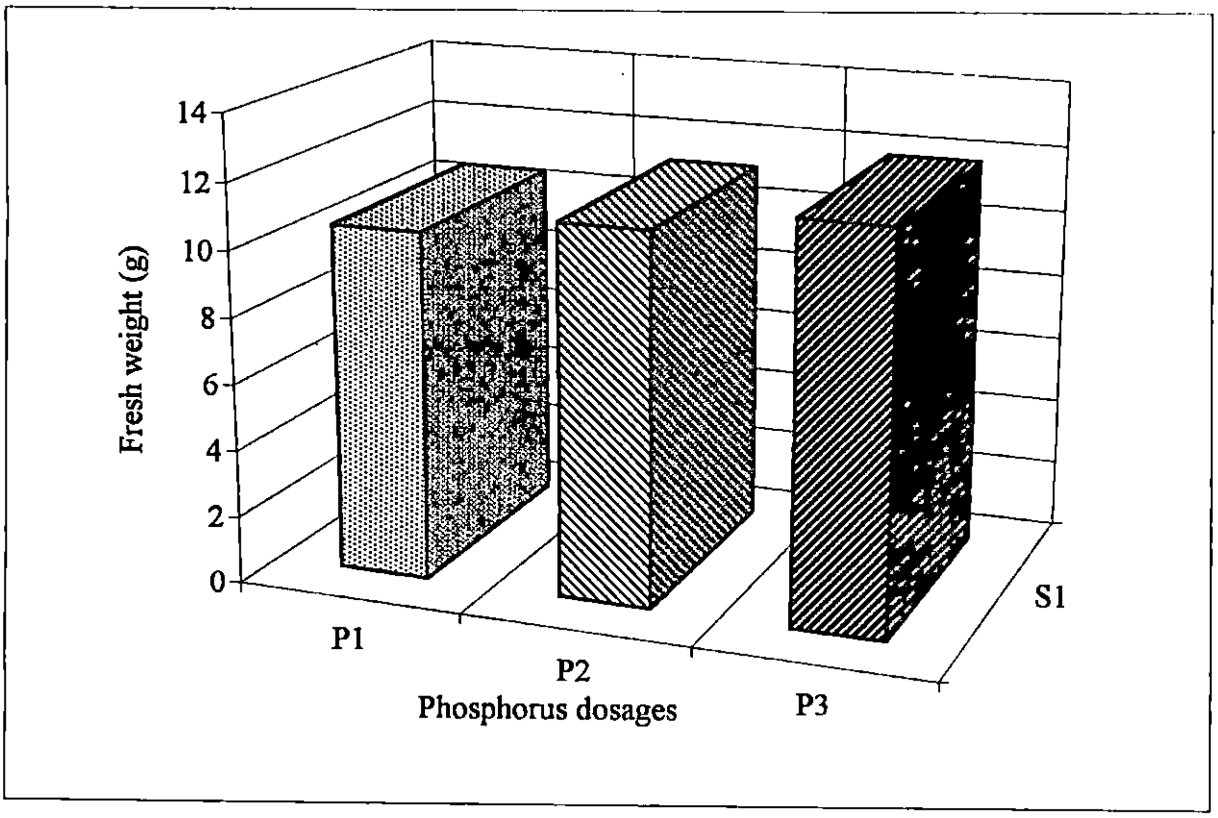
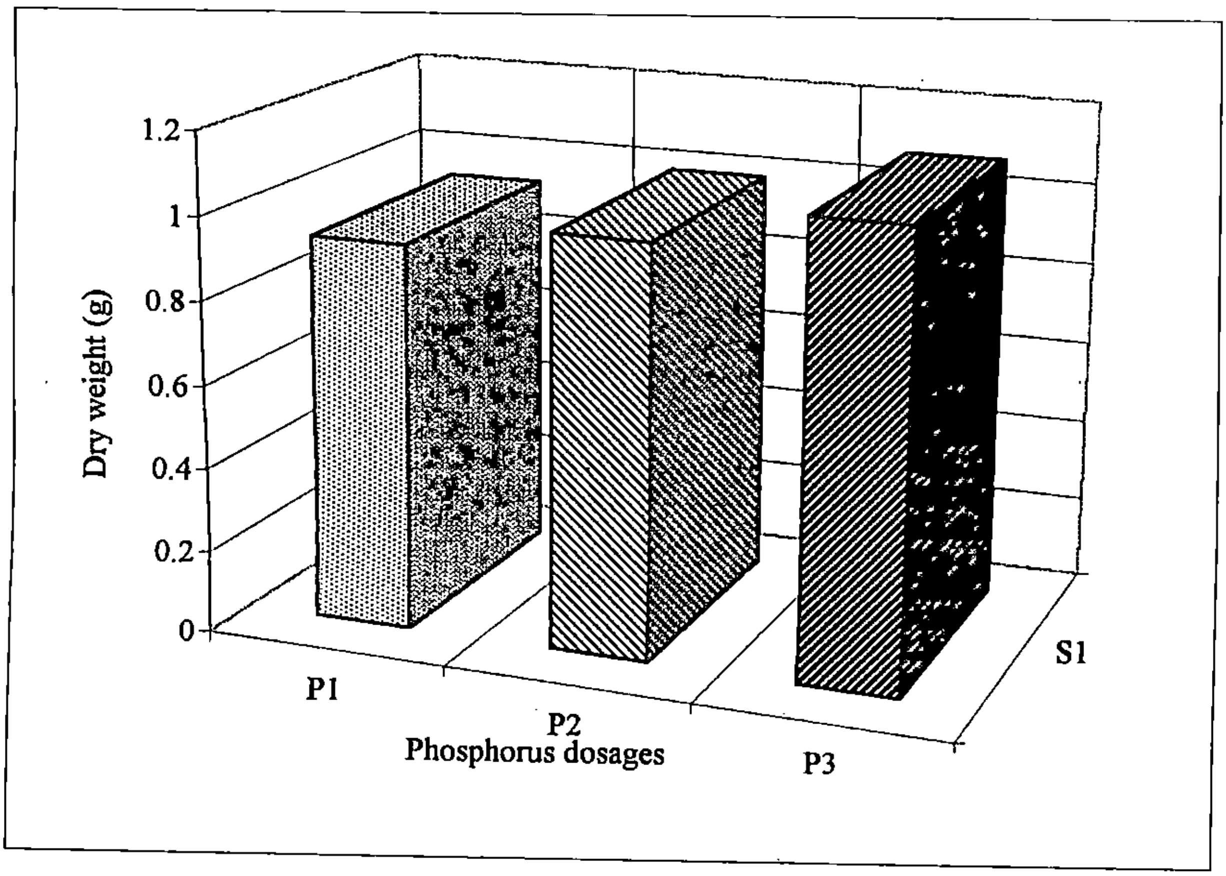


Fig. 7 Effect of P on the fresh and dry weight (g) of the plants





those receiving 10.0 mg N with 2.69 per cent N and P content was the highest (0.48 and 0.45 per cent) in the plants receiving 6.0 or 10.0 mg P respectively (Table 27).

The K content of the plants were greater in the plants receiving 6.0 or 10.0 mg of N, 2.0 or 6.0 mg of P and in those receiving 10.0 mg of K. This enhanced accumulation may be a luxury consumption by the plants with availablility. Similar increase in the plant tissue concentration of N, P and K with increase in the substrate concentration of these nutrients was reported by Poole and Seeley (1978) in *Cymbidium* and *Phalaenopsis*, Gomi *et al.* (1980), Khaw and Chew (1980) in *Aranda* Noorah Alsagoff, Tanaka (1988 b) in *Cattleya* and *Phalaenopsis* and Sabina (1996) in *Dendrobium* Sonia - 16.

Interaction effects resulted in greater K content in the plants. Plants receiving 2.0, 6.0 or 10.0 mg of N with 10.0 mg of P and 6.0 or 10.0 mg of N with 2.0 mg of P had greater K content (Table 28).

The vegetative growth response of the plants to applied doses of nutrients were found to differ during the period of experimentation. For three to six months old plants (up to 90 days after the start of experiment) 2.0 mg each of N, P and K can be recommended. For six to nine months old plants 6.0, 2.0 and 2.0 mg of N, P and K found to have the most favourable effect. For nine to twelve months old plants 6.0 mg of N, 2.0 to 6.0 mg of P and 2.0 mg of K found to enhanced growth and for the plants above one year age 6.0, 6.0 and 2.0 mg of N, P and K can be recommended for maximum vegetative growth.

SUMMARY

SUMMARY

To standardise the nutrient dosages for the tissue cultured and *ex-vitro* established plants of *Dendrobium* Sonia - 17, study was conducted at College of Agriculture, Vellayani in 1997-98. The performance of the cultivar under three dosages 2.0, 6.0 and 10.0 mg at different combinations of N, P and K was studied. Ohio WP solution at half strength and tap water spray were the two controls selected.

The nutrient treatments influenced vegetative growth of the plants. The growth increment was slow for the first 3 months after planting. Then the shoot growth, leaf production and leaf area increased rapidly.

Nitrogen could make a significant increase in height of the shoots from 90 to 270 DAP and K from 30 to 270 DAP. Plants receiving 6.0 or 10.0 mg per plant N found to have greater height. The K doses of 2.0 or 6.0 mg was found to be more responsive.

Interaction of NP was significant at 60 DAP and from 120 to 270 DAP. Plants receiving 10.0 mg of N with 10.0 or 6.0 mg of P or 6.0 mg of N with 6.0 or 10.0 mg of P had greater height. Interaction NK was significant at 150, 165, 180 and 195 DAP. Plants receiving 10.0 mg of N with 2.0 or 6.0 mg of K had the greater height.

Nitrogen and potassium could make a significant increase in the number of leaves produced. 6.0 or 10.0 mg per plant of N influence the number of leaves at 60, 75, 90 and 120 DAP and 6.0 mg per plant influence the number of leaves from 135 to 270 DAP. The K doses of 2.0 to 6.0 mg per plant found to have greater number of leaves.

Number of leaves was also influenced by the NP interaction at 90, 135, 150, 165, 180 and 195 DAP. 6.0 or 10.0 mg of N with 2.0 or 6.0 mg of P per plant had greater number of leaves.

Leaf area per plant was influenced by the N dosages. 6.0 or 10.0 mg per plant of N found to be effective in influencing leaf area. Interaction of NP was influenced from 90 to 165 DAP and PK at 195 DAP. 6.0 mg of N with 2.0, 6.0 or 10.0 mg per plant of P and 10.0 mg per plant of N with 2.0 or 6.0 mg of P found to have greater leaf area. Treatment receiving 6.0, 6.0 and 2.0 mg of N, P and K had greatest leaf area consistently from 210 to 270 DAP. The average effect of treatment over the control was significant from 90 to 270 DAP.

Stem girth was influenced by N and P doses at 15 and 60 DAP, 2.0 mg per plant, and from 105 to 270 DAP. 6.0 or 10.0 mg per plant found to influence the stem girth. The P doses of 6.0 or 10.0 mg per plant found to influence the stem girth. The P doses of 6.0 or 10.0 mg per plant was found to influence the stem girth form 75 to 135 DAP.

Interaction of NP was influenced by 6.0 or 10.0 mg of N with 6.0 or 10.0 mg per plant of P had greater stem girth. 6.0 mg N with 2.0, 6.0 of 10.0 mg of K or 10.0 mg of N with 2.0 or 6.0 mg of K had greater stem girth at 60, 75, 105, 120 and 135 DAP. PK interaction was significant at 105 DAP.

The number of shoots produced per plant was found to be influenced by 6.0 mg per plant of N at 15 DAP and 6.0 or 10.0 mg / plant of N at 30 and 45 DAP. 6.0 or 10.0 mg per plant of P had greater number of shoots at 75, 90, 105, 120 and 135 DAP.

Increasing the dosage of N, P and K was found to increase the number of backbulbs produced. Nitrogen at 6.0 or 10.0 mg per plant was found to influence the number of blackbulbs at 60, 90 and from 165 to 240 DAP. 10.0 mg per plant of N influence the number of balckbulbs at 75, 225 and 270 DAP. 6.0 or 10.0 mg per plant of P was found to influence the number of backbulbs from 30 to 150 DAP. 10.0 mg per plant of K had more influence on the number of backbulbs produced at 30, 45, 60, 75, 90, 105, 120 and 150 DAP.

Number of roots produced per plant was influenced by N and K. N doses of 2.0 or 6.0 mg per plant was found to influence the number of roots at 270 DAP. 10.0 mg of K influenced number of roots at 270 DAP. The length of roots was influenced by 6.0 or 10.0 mg per plant of N at 90 DAP.

The fresh weight of the plants was influenced by 10.0 or 6.0 mg of N and P at 270 DAP.

Significant difference in fresh weight between the treatment and controls was observed at 270 DAP with the treated plants recording greater fresh weight.

Nitrogen and Phosphorus dosages found to influence the dry weight of the plants. Plants receiving 10.0 mg per plant of N had a greater dry weight (1.11 g) than those receiving 6.0 or 2.0 mg at 270 DAP. Also 10.0 mg of P per plant had influence on the dry weight (1.08 g) of the plants at 270 DAP.

No keiki formation was observed during the experimental period. The time taken for the shoots to became backbulbs was not significantly influenced by the nutrient treatments.

The nutrient composition of the plants was influenced by the nutrient treatments. The N content was higher in the plants receiving 10.0 mg of N (having 2.69 per cent N) than those receiving 6.0 or 2.0 mg. The N content was significantly greater in the treated plants than in the control plants.

The P dosages on the P content of the plants was significant. Plants receiving 6.0 or 10.0 mg of P had greater P content (0.48 and 0.45 per cent respectively).

The N, P and K dosages given to the plant on the potassium content of the plants was significant. Plants receiving 10.0 or 6.0 mg of N, 10.0 or 2.0 mg of P or 10.0 mg of K had higher K content.

Significant N P interaction showed 10.0 mg of N with 2.0, 6.0 or 10.0 mg of P enhanced the K content of the plants.

The vegetative growth response of the plants to applied doses of nutrients were found to differ during the period of experimentation. From three to six months age of the plants 2.0 mg each of N, P and K found to be effective. For six to nine months age of the plants 6.0, 2.0 and 2.0 mg of N, P and K was found to have favourable effect. For nine to twelve months age of plants 6.0 mg of N, 2.0 to 6.0 mg of P and 2.0 mg of K had maximum vegetative growth and for above one year aged plants 6.0, 6.0 and 2.0 mg of N, P and K can be recommended.

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NUTRITION OF TISSUE - CULTURED PLANTS OF *Dendrobium* SONIA - 17

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ABSTRACT OF THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE
MASTER OF SCIENCE IN HORTICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

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1999

ABSTRACT

The present study was undertaken to evolve the nutrient dosage combination which will produce maximum vegetative growth of tissue-cultured and *ex vitro* established *Dendrobium* Sonia - 17 plants. The experiment was conducted from October 1997 to June 1998. The varying nutrient dosages selected were 2.0, 6.0 and 10.0 mg of N, P and K at different combinations.

Nitrogen at 6.0 mg per plant increased the plant height, number of leaves, leaf area, number of backbulbs and length of roots. Upto 90 DAP 2.0 mg of N found to increase the stem girth and after that 6.0 mg found to be favourable. Number of roots was greater with 2.0 mg of N. Phosphorus had less influence on growth. 6.0 mg of P increases the stem girth and number of backbulbs at early stages. 2.0 mg of potassium had influence on the plant height, number of leaves, number of backbulbs and number of roots. Interaction between the nutrient were also observed.

6.0 mg of N and P influenced the fresh weight and 10.0 mg of N and P the dry weight. The nutrient composition of the plants was enhanced by 10.0 mg of N, 6.0 mg of P and 10.0 mg of K.

Based on the observed effects of nutrition on *Dendrobium* Sonia - 17 plants, a nutrient dosage of 2.0 mg each of N, P and K from three to six months age of *ex vitro* stage, 6.0, 2.0 and 2.0 mg of N, P and K from six to nine months age, 6.0 mg of N, 2.0 to 6.0 mg of P and 2.0 mg of K from nine to twelve months age can be recommended. For plants above one year age a dosage of 6.0, 6.0 and 2.0 mg of N, P and K can be recommended for maximum vegitative growth.