NUTRITIONAL REQUIREMENT OF BUSH PEPPER UNDER DIFFERENT LIGHT INTENSITIES

By

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THESIS

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1997

DECLARATION

I hereby declare that this thesis entitled **"Nutritional requirement of bush pepper under different light intensities"** 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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Certified that this thesis entitled **"Nutritional requirement of bush pepper under different light intensities"** is a record of research work done independently by Smt. **MADHURA DEVADAS** 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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TO MY PARENTS

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LIST OF ABBREVIATIONS

%	-	Per cent
AOAC	-	Association of Official Agricultural Chemists
CD	-	Critical difference at 5%
cm	-	Centimetre
DOES	-	Directorate of Economics and Statistics
FYM	-	Farm yard manure
g	-	gram
g $bush^{-1}$	-	gram per bush
KAU	-	Kerala Agricultural University
m	-	metre
MAP	-	Months after planting
mg	-	milligram
t	-	Tonne
t ha^{-1}	-	Tonnes per hectare

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INTRODUCTION

INTRODUCTION

Of the gifts of nature that enliven our day to day life, spices constitute a fantastically fascinating group. These are a group of plants endowed with the much preferred characteristic flavour, pungency and aroma. Derived from the perennial vine (*Piper nigrum* L.) black pepper with its charismatic and turbulent heritage, invigorating and piquant properties and tremendous utility is the most outstanding of all the spices, and is rightly crowned the 'king of spices'. By virtue of its position as the largest foreign exchange earner among spices, black pepper enjoys a strategic position in our national economy.

Among the pepper producing countries in the world, India was holding a near monopoly both in production and export. But now her predominance in world trade is diminishing consequent to rapid pace of growth of this plantation industry in countries like Indonesia, Malaysia and Brazil. Besides, our production remained rather static without matching increase with world demand.

India accounts for 50 per cent of world area, but only 23 per cent of the global production. Pepper production in India during 1994-95 was 48,000 t from a total cultivated area of 1.74 lakh ha. Kerala accounts for nearly 97 per cent of the total area (1.69 lakh ha) and 98 per cent of the total production (47000 t). Eventhough we are the pioneers in pepper production our productivity is too low, 310 kg ha^{-1} in India and 299 kg ha^{-1} in Kerala as against 2600, 1500 and 500 kg ha^{-1} in Malaysia, Brazil and Indonesia respectively (DOES, 1994).

The expected global demand for black pepper by 2000 AD is 1,85,000 t which include 30,000 t for internal consumption. To capture at least 50 per cent of the global market, India should increase its production to three times the present level. One of the suggestions to bridge the gap between demand and supply is by growing pepper in pots, which is an attractive advantage for the urban areas, as otherwise the trailing nature of the crop limits its cultivation to rural areas only. Bush pepper raised from the spike bearing branches of pepper can be grown in pots and hence is gaining popularity in urban horticulture.

Studies conducted at NRCS, Calicut (1992) showed that yield of four year old plants raised from laterals was the highest compared to those grown from runners or hanging shoots.

However no attempt have so far been made to compare the growth and yield of bush pepper as influenced by inorganic fertilization. Since bush pepper is recommended for the urban areas the performance of this crop under open as well as shaded conditions needs investigation. Hence this experiment is taken with an objective to study the influence of NPK fertilizers under different light intensities on the growth, yield and quality of bush pepper.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Pepper vines are usually grown with standards which supports its vertical growth. This method is adopted in large plantations where the target of production is mainly for commercial scales. But in urban areas and small homesteads where the availability of cultivable areas is limited, pepper could be successfully grown to meet the household requirement in the form of bush pepper.

Bush pepper, as the name indicate is a method of cultivating the vine in the form of a bush. All existing varieties can be used for bush pepper. The method of cultivation of bush pepper as described by Sherif (1993) is described below. Instead of runner shoots, the lateral branches or plagiotropes (which usually bear fruits) are taken from the mother plant as the planting material. one year lateral branch with 3-4 nodes are to be planted in nursery during March – April. Before planting, the cuttings are to be dipped in 1000 ppm solution of IBA for 45 seconds as pre-rooting treatment. The treated cutting may be kept in a humid chamber for better rooting.

The rooted cuttings thus obtained could be planted either in a flower pot or in small pits taken on the ground. Flower pots with 30 cm diameter filled in with potting mixture may be planted with two or three rooted cuttings of the vine. If on the ground, 50 cm^3 pits are to be taken and filled with potting mixture before planting the cuttings. Irrigation and partial shade during summer months should be given adequately in the initial stages. Once the plant gets established, fertilizer doses may be applied @ Urea (5 g), Super phosphate (15 g) and MOP (18 g) once in 3 months. The fertilizers are to be applied near the basin so that the leaves or stem of the plant do not come in direct contact with it. Irrigation should be given after fertilizer application and should be continued for atleast five days.

In addition to the chemical fertilizers, those plants on the ground may be given 5 kg of well rotten FYM at the onset of monsoon. Plants kept in pots may be repotted atleast once in two years. Under average management, a good bush pepper plant may yield 1.5 kg green pepper in a span of 2-3 years.

The available literature on aspects pertaining to this study is classified under two sections. The first part deals with the response of crops to varying intensities of light and the second part to major plant nutrients. Since literature on bush pepper is limited similar studies conducted on other crops are also reviewed.

2.1 Response to light

2.1.1 Growth characters

2.1.1.1 Length of branches

Panicker *et al.* (1969) reported that in tobacco the length increased by 35.2 per cent under shade as compared to unshaded plants.

Ross (1976) brought out the effect of light intensity on growth of house plants. The plants grown in full sun appeared stunted with stiff branches and sparse foliage but were tall and lanky with abundant foliage as shade increased.

In *Mentha piperita* length of branches under 44 per cent day light was significantly greater than that under 100 or 14 per cent day light (Virzo and Alfani, 1980).

Senanayake and Kirthisinghe (1983) reported longest shoot length in black pepper under 50 per cent light compared to 75 and 25 per cent light.

In *Synchonium podophyllum* plants grown under 20 per cent light were taller than those grown under 53 per cent light (Chase and Poole, 1987).

Cooper (1966) reported that the length of branches decrease proportionately with decreasing intensity of light in alfalfa.

In tea the length of branches was greatest under 60 per cent light and least under 10 per cent light (Kulasegaram and Kathiravet Pillai, 1980).

2.1.1.2 Number of branches

Deli and Tiessen (1969) reported that chilli plants produced more branches when exposed to low light intensity of 800 ft. candles than at 1600 ft. candles. In cowpea increased light intensity decreased the number of branches (Tarila, 1977).

Khosien (1977) noticed reduction in branching in bean plants due to high light intensity.

Senanayake and Kirthisinghe (1983) reported better production of laterals in black pepper at 50 per cent light than at 75 and 25 per cent light.

Mathai and Sasthry (1988) reported that pruning the support trees of black pepper thereby regulating light intensity increased the number of laterals.

2.1.1.3 Internodal length

Plants grown under shade recorded increased internodal length compared to sunplants (Ross, 1976).

Black pepper grown at 50 per cent and 70 per cent light had longer internodes compared to plants grown in full sunlight (Senanayake and Kirthisinghe, 1983) and Seneviratne *et al*., 1985).

2.1.1.4 Number of leaves

Nair (1964) reported that the production as well as the retention of leaves will be more under shade than in the open, in peppermint.

Senanayake and Kirthisinghe (1983) reported maximum number of leaves in black pepper under 50 per cent light compared to 75 and 25 per cent light.

Aasha (1986) reported that the number of leaves in open condition will be less as compared to that under shade in Begonia. The best growth of plants was obtained under 50 per cent day light.

2.1.1.5 Total leaf area

Panickar *et al*. (1969) observed that in tobacco length and breadth of leaves increased by 15.1 and 17.6 per cent respectively under shade as compared to unshaded plants.

Attridge (1990) reported that under shade plants produce more leaves and leaf area and this is an adaptation to expose larger photosynthetic surface under limited illumination.

Tarila *et al*. (1977) reported an increase in leaf area and plant size of cowpea at a higher light intensity.

2.1.2 Chlorophyll

Shirley (1929) reported that shaded leaves have more chlorophyll per unit weight.

Increasing shade intensity increased chlorophyll content in *Ficus benjamina* (Collard *et al*., 1977).

Hilton (1983) pointed out that in barley under shaded conditions, the efficiency of photosynthesis was maintained by the absorption of more light by the accessory pigments and by increasing the amount of chlorophyll 'b'.

Ramanujam and Jose (1984) found that cassava leaves grown under low light (6000 lux) recorded higher concentration of total chlorophyll per unit leaf weight.

The leaves of black pepper showed yellowing followed by the formation of necrotic patches, when grown in full sunlight. The chlorophyll content of exposed leaves was 44 per cent below the content of shaded leaves (Vijayakumar *et al*., 1985).

In ginger and turmeric total chlorophyll and its fractions increased steadily with increasing levels of shade chlorophyll a to chlorophyll 'b' ratio was not found to be markedly affected by shading (Joseph, 1992).

2.1.3 Flowering

Pepper (*Capsicum annum* L.) when grown under 50 per cent light flowered earlier than at 100 per cent light (Mathi and Bahadli, 1989).

Hong *et al*. (1986) reported that Geranium flowered earlier at 50 per cent light than at 88 per cent light.

2.1.4 Dry matter production

Monteith (1969) reported that the maximum amount of dry matter production by a crop was strongly correlated with the amount of light intercepted by its foliage.

Lalithabai (1981) reported reduction in drymatter production by shading in crops like ginger, turmeric and colocasia.

Ramanujam and Jose (1984) stated that the photosynthetic apparatus per unit leaf area was curtailed under low light intensity.

Senanayake and Kirthisinghe (1983) observed that in black pepper 50 per cent light enhanced DMP.

Seneviratne *et al*. (1985) reported that 75 per cent and 50 per cent shade profoundly increased the plant growth and DMP in black pepper.

Increased DMP in ginger under shaded condition was reported by Ravisankar and Muthuswamy (1986) and Joseph (1992).

2.1.5 Yield

Senanayake and Kirthisinghe (1983) reported increased yield of pepper under 50 per cent light as compared to 75 per cent and 25 per cent light.

Mathai and Sasthry (1988) reported that pruning the support trees of pepper thereby regulating light produce more number of laterals and spikes thereby increasing yield.

Karimunda yields well under shade in coconut garden (KAU, 1994).

Pepper yields well when trained shade tress like Pongalyam and Azhanthal (KAU, 1994).

2.1.6 Quality of the produce

Light regimes received by a plant determine the productivity and quality of the produce. Graded shade levels of 20, 47, 63, 80 and 93 per cent were found to have little effect on quality parameters of soybean viz. oil and protein content of seeds except at 93 per cent shade where the protein content was the highest and oil content the lowest (Wahua and Miller, 1978). An (1982) studied the effect of light intensity on groundnut and observed that shade increased the oil content of kernel Ginger cultivar Rio-de-Janeiro grown as an intercrop in a six year old arecanut plantation recorded highest volatile oil and NVEE compared to those grown in the open as pure crop (Ravisankar and Muthuswamy, 1986). Ginger showed a steady decrease in the oleoresin content upto 50 per cent level of shade (Varughese, 1989).

2.1.7 Uptake of nutrients

In *Mentha piperita* under shaded conditions leaves contained significantly higher levels of N and K than leaves of sun plants (Virzo and Alfani, 1980).

According to Lalithabai (1981) contents of N, P and K in all the plant components of ginger and turmeric increased with increase in shade.

In Cacao leaf nitrogen and phosphorus contents were found to be influenced by shading. Shading increased leaf N whereas it decreased leaf P (Maliphant, 1959).

2.2 Response to major plant nutrients

2.2.1 Growth characters

2.2.1.1 Length of branches

Joseph (1982) in an experiment on chilli concluded that incremental doses of N increased the length of branches at all the stages studied.

Geetha and Aravindakshan (1992) reported that length of branches in bush pepper increased with increasing N dose.

Joseph (1982) reported increased length of branches with P application in chilli.

In a study on bush pepper Geetha and Aravnindakshan (1992) obtained increased length of branches with the application of P.

Joseph (1982) in an experiment on chilli observed that length of branches was significantly increased by the application of potash.

Shukla *et al*. (1987) showed that length of branches was not affected by potassium fertilization.

Geetha and Aravindakshan (1992) reported significant effect of potash on the length of branches in bush pepper.

2.2.1.2 Number of branches

Mehrotra *et al*. (1968) observed a significant reduction in branching in chilli crop by the deficiency of N. Kunju (1968) reported that branching was significantly increased by N application.

Geetha and Aravindakshan (1992) observed that the number of primary as well as secondary branches of bush pepper were increased by the application of higher levels of N.

P application increased the number of branches per plant in chilli (Joseph, 1982).

Higher doses of P increased the number of primary and secondary branches in bush pepper (Geetha and Aravindakshan, 1992).

According to Singh *et al.*, (1986) potassium significantly increased the number of branches per plant in chilli.

Geetha and Aravindakshan (1992) reported significant effect of potassium on branching in bushpepper.

2.2.1.3 Internodal length

Internodal length is an indication of vegetative growth. The vegetative parts are definitely the photosynthetic factory of the plants and the internodal length of the vines decide the length of the branches total number of leaves produced, flowering and yield (Tisdale *et al.* 1995, Russel, 1973).

Nybe and Nair (1989) reported longer shoots with longer internodes in black pepper with the application of nitrogen. Application of higher doses of nitrogen increased the internodal length in snakegourd (Haris, 1989).

2.2.1.4 Number of leaves

Geetha and Aravindakshan (1992) in their experiment on pepper concluded that there was significant effect of N, P and K fertilizers on leaf development.

2.2.2 Flowering

Iuanic (1957) observed that N delayed flowering and prolonged the growing season in chillies. Gill *et al*. (1974) revealed that number of days to flowering was increased by nitrogen fertilization. Rajagopal (1977) indicated that N influenced the duration to flowering since it prolonged the vegetative phase.

Gill *et al*. (1974) showed that P doses decreased the mean days required for flowering in chillies. Similar results were reported by Joseph (1982) and Khan and Suryanarayana (1977).

Pimpini (1967) observed that application of potassium promotes earliness in flowering. However Mohamed Kunju (1968) observed that application of potassium had no significant influence on the time of flowering. Similar effects of potassium on the time of flowering were reported by a number of workers. (Khan and Suryanarayana, 1977 and Chougule and Mahajan, 1979).

2.2.3 Drymatter production (DMP)

Kunju (1968) showed that higher doses of N and P significantly increased the total weight of drymatter produced in chilli.

Geetha and Aravindakshan (1992) reported increased DMP in bushpepper due to the application of N, P and K. Maximum drymatter was produced at N:P:K 120:45:120 kg ha^{-1}.

2.2.4 Yield and yield attributes

Ward and Sutton (1960) reported that maximum yields with NPK in pepper when applied at 240 kg N, 120 kg P_2O_5 and 340 kg K_2O ha^{-1} in Malaysia.

Pillai and Sasikumaran (1976) reported that 100 g N, 40 g P_2O_5 and 140 g K_2O per vine is optimum for the pepper variety Panniyur-1.

Pillai *et al.* (1979) reported that continuous application of 60, 120 and 180 g of N per plant per year in conjunction with constant levels of P (40 g) and K (140 g) increased the spike production and yield of pepper. 60 g N was found optimum, higher levels of N reduced the yield.

Cheeran (1981) conducted a study on the nutrient requirement of pepper vines trained on dead standards and reported that their requirement was adequately met with 75 g N and 50 g $P_2O_5^{-1}$ vine^{-1} year. Higher levels of N (150 g and 225 g) reduced the yield.

Chepote (1986) studied the effect of NPK fertilization on the production of *Piper nigrum* in Southern Bahia. The mean yield of dry pepper ranged from 2883 kg ha^{-1} in unfertilized plots to 7413 kg ha^{-1} in plots receiving N:P:K at 200:240:180 kg ha^{-1}.

Pillai *et al*. (1987) reported that N dose of 50 kg ha^{-1} along with 100 kg P_2O_5 and 200 kg P_2O_5 ha^{-1} is optimum for Pepper var. Panniyur-1. The study also showed that there is a reduction in yield with increase in levels of nitrogen.

Sushama (1987) found significant positive correlation of yield with P and K of leaf whereas N content failed to establish significant positive correlation with yeild.

The economically optimum dose of N, P, K for the two popular varieties of pepper viz. Karimunda and Arakulam munda was 50 g N, 50 g P_2O_5 and 100 g K_2O^{-1} vine^{-1} year (KAU, 1989).

In a study to find out the nutrient requirement of bushpepper, it was found that bimonthly application of NPK at the rate of 1, 0.5, 2.0 g bush^{-1} grown in pots (10 kg soil) was optimum (NRCS, 1992).

Sadanandan (1993) reviewed an exhaustive series of fertilizer trials with pepper in major pepper growing countries in the world and reported that the levels of fertilizer used in India is very low and is perhaps one of the reasons for poor yield in India. Studies conducted in farmers field over a period of four years (1979-84) showed that there was 250 per cent increase in pepper yield due to the application of NPK fertilisers at 100 kg N, 40 kg P_2O_5 and 140 kg $K_2O.ha^{-1}$.

Sherif (1993) reported that application of urea 5g, superphosphate 15g and MOP 18g once in three months give optimum yield in bush pepper.

2.2.5 **Quality**

Nair and Das (1982) found that planofix alone as well as the combinations of 2 per cent urea and 400 ppm planofix led to greater accumulation of olesresin, though urea alone failed to produce any significant result.

Rao *et al.* (1983) opined that N has considerable influence on the yield of coriander seed and its essential oil content.

According to Rahman *et al.* (1990) essential oil content of coriander seeds was found to be increasing with the increase in N application from 0 to 60 kg ha^{-1}.

2.6.6 Uptake of Major Nutrients

Waard and Sutton (1960) reported that maximum uptake of NPK occured when applied at 240 kg N, 120 kg P_2O_5 and 340 kg K_2O ha^{-1} in Malaysia.

According to Waard (1964) the nutrient removal of the variety kutching (1729 vines/ha) was 252.04 kg N, 31.75 kg P_2O_5 and 224.04 kg K_2O per hectare.

Waard (1969) worked out the critical levels of N, P and K as 2.7, 0.1 and 2.0 per cent respectively on dry weight basis below which deficiencies of the concerned elements are expected to occur.

Removal of inorganic nutrients from soil by seventeen year old vines was reported by Sim (1971) as 233 kg N, 39 kg P_2O_5 and 270 kg K_2O ha^{-1}.

Nagarajan and Pillai (1975) reported that Panniyur-1 is more nutrient exhaustive than Kalluvally for N, P and K after analysing the lateral fruiting shoots of one year growth from mature pepper vines. One hectare of pepper vines (Numbering 1200) with an average yield of 1 kg dry pepper per vine removed 3.4 kg N, 3.5 kg P_2O_5 and 3.2 kg K_2O for the production of berries in Panniyur-1 (Pillai and Sasikumaran, 1976).

Investigations on pepper variety Panniyur-1 in laterite soil showed that application of 140 g N, 55 g P_2O_5 and 270 g K_2O $vine^{-1}$ $year^{-1}$ resulted in significant increase in the availability of N, P and K in the soil and resulted in higher uptake of nutrients by the pepper vine (Sivaraman *et al.*, 1987).

Wahid (1987) reported that the foliar concentration of N and K increased following their application.

In an experiment on bush pepper it was found that absorption of N increased with increasing levels of N application. N application increased the uptake of not only N but also P and K. Phosphorus application enhanced the uptake of N and K. Potassium absorption by the plants increased with increasing levels of K applied (Geetha, 1990).

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials utilized and the methodology followed for the experiment are presented in this chapter.

3.1 Experimental site

The pot culture experiment was conducted at the Farming Systems Research Station, Sadanandapuram, 5 km east to Kottarakkara town, along the M.C. road in Kollam district. It is located at 76°36' E longitude, 9°16'N latitude and at an elevation of 100 m above MSl.

3.2 Season

The experiment was conducted from 1995 June to 1996 July. The meteorological data for the season are given in Appendix I and Fig. 1.

3.3 Materials

3.3.1 Potting mixture

The experiment was conducted with potting mixture prepared by mixing sand, soil and FYM in 1:1:1 proportion. The important physical and chemical properties are given in Table 1.

Fig 1 Weather parameters during crop period (1995-1996)

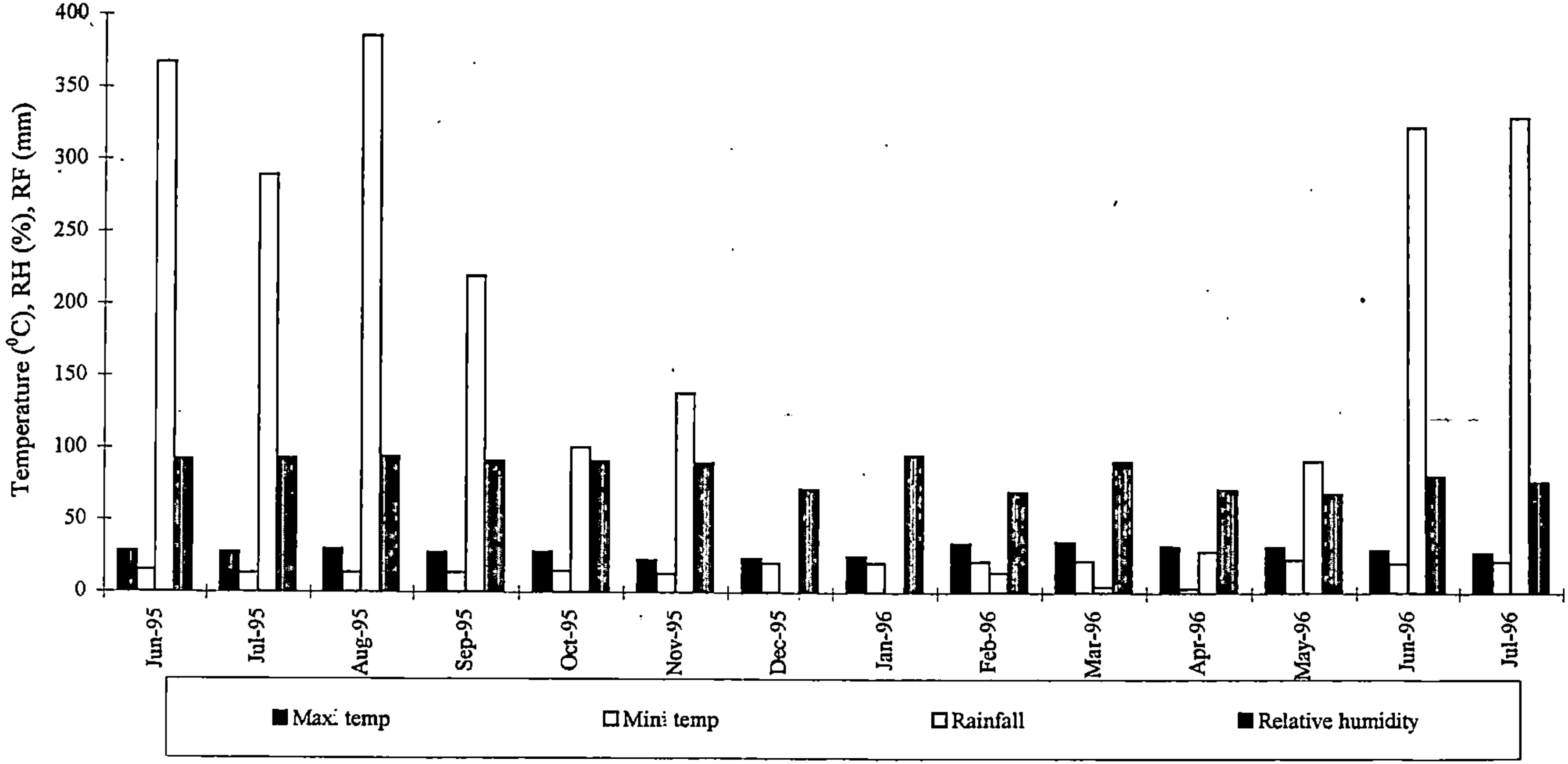


Table 1. Chemical properties of potting mixture

Constituent	Content	Rating	Method used
Organic C (%)	0.2	low	Walkley and Black's rapid titration method (Jackson, 1973)
Available N (%)	0.0086	low	Alkaline potassium permanganate method (Subbaiah and Asija, 1956)
Avilable P_2O_5 (%)	0.0007	Medium	Bray colorimetric method (Jackson, 1973)
Available K_2O (%)	0.0049	low	Ammonium acetate method (Jackson, 1973)

3.3.2 Pots

Mud pots of size 30 x 35 cm were used for the experiment.

3.3.3 Planting material

One year old bush pepper plants (variety - Karimunda) obtained from the State Farm, Kottukkal were used for planting.

3.3.4 Fertilizers

Fertilizers with the following grades were used for the study.

Urea	-	46% N
Mussoriephos	-	22% P_2O_5
Muriate of potash	-	60% K_2O

3.3.5 Shade material

Black high density polyethylene net fabricated for 50% and 75% light intensity were used for the experiment. The nets were spread at a height of 2.5m from the ground level and supported on G.I. pipes.

3.4 Methods

3.4.1 Design and layout

The experiment was laid out in split plot design with 3 replications. Light was assigned to the main plot and nutrient levels to the subplot. The layout of the experiment is presented in Fig.2.

3.4.2 Treatments

A. Light levels

100% light	-	L_1
75% light	-	L_2
50% light	-	L_3

B. Nutrient levels

Nitrogen	25 g $bush^{-1}$	- N_1
	37.5 g $bush^{-1}$	- N_2
	50 g $bush^{-1}$	- N_3
Phosphorus	25 g $bush^{-1}$	- P_1
	37.5 g $bush^{-1}$	- P_2
	50 g $bush^{-1}$	- P_3
Potassium	50 g $bush^{-1}$	- K_1
	75 g $bush^{-1}$	- K_2
	100 g $bush^{-1}$	- K_3

Treatment combinations

$L_1N_1P_1K_1$ - T_1	$L_2N_1P_1K_1$ - T_{28}	$L_3N_1P_1K_1$ - T_{55}
$L_1N_1P_1K_2$ - T_2	$L_2N_1P_1K_2$ - T_{29}	$L_3N_1P_1K_2$ - T_{56}
$L_1N_1P_1K_3$ - T_3	$L_2N_1P_1K_3$ - T_{30}	$L_3N_1P_1K_3$ - T_{57}
$L_1N_1P_2K_1$ - T_4	$L_2N_1P_2K_1$ - T_{31}	$L_3N_1P_2K_1$ - T_{58}
$L_1N_1P_2K_2$ - T_5	$L_2N_1P_2K_2$ - T_{32}	$L_3N_1P_2K_2$ - T_{59}
$L_1N_1P_2K_3$ - T_6	$L_2N_1P_2K_3$ - T_{33}	$L_3N_1P_2K_3$ - T_{60}
$L_1N_1P_3K_1$ - T_7	$L_2N_1P_3K_1$ - T_{34}	$L_3N_1P_3K_1$ - T_{61}
$L_1N_1P_3K_2$ - T_8	$L_2N_1P_3K_2$ - T_{35}	$L_3N_1P_3K_2$ - T_{62}
$L_1N_1P_3K_3$ - T_9	$L_2N_1P_3K_3$ - T_{36}	$L_3N_1P_3K_3$ - T_{63}
$L_1N_2P_1K_1$ - T_{10}	$L_2N_2P_1K_1$ - T_{37}	$L_3N_2P_1K_1$ - T_{64}
$L_1N_2P_1K_2$ - T_{11}	$L_2N_2P_1K_2$ - T_{38}	$L_3N_2P_1K_2$ - T_{65}
$L_1N_2P_1K_3$ - T_{12}	$L_2N_2P_1K_3$ - T_{39}	$L_3N_2P_1K_3$ - T_{66}
$L_1N_2P_2K_1$ - T_{13}	$L_2N_2P_2K_1$ - T_{40}	$L_3N_2P_2K_1$ - T_{67}
$L_1N_2P_2K_2$ - T_{14}	$L_2N_2P_2K_2$ - T_{41}	$L_3N_2P_2K_2$ - T_{68}
$L_1N_2P_2K_3$ - T_{15}	$L_2N_2P_2K_3$ - T_{42}	$L_3N_2P_2K_3$ - T_{69}
$L_1N_2P_3K_1$ - T_{16}	$L_2N_2P_3K_1$ - T_{43}	$L_3N_2P_3K_1$ - T_{70}
$L_1N_2P_3K_2$ - T_{17}	$L_2N_2P_3K_2$ - T_{44}	$L_3N_2P_3K_2$ - T_{71}
$L_1N_2P_3K_3$ - T_{18}	$L_2N_2P_3K_3$ - T_{45}	$L_3N_2P_3K_3$ - T_{72}
$L_1N_3P_1K_1$ - T_{19}	$L_2N_3P_1K_1$ - T_{46}	$L_3N_3P_1K_1$ - T_{73}
$L_1N_3P_1K_2$ - T_{20}	$L_2N_3P_1K_2$ - T_{47}	$L_3N_3P_1K_2$ - T_{74}
$L_1N_3P_1K_3$ - T_{21}	$L_2N_3P_1K_3$ - T_{48}	$L_3N_3P_1K_3$ - T_{75}
$L_1N_3P_2K_1$ - T_{22}	$L_2N_3P_2K_1$ - T_{49}	$L_3N_3P_2K_1$ - T_{76}
$L_1N_3P_2K_2$ - T_{23}	$L_2N_3P_2K_2$ - T_{50}	$L_3N_3P_2K_2$ - T_{77}
$L_1N_3P_2K_3$ - T_{24}	$L_2N_3P_2K_3$ - T_{51}	$L_3N_3P_2K_3$ - T_{78}
$L_1N_3P_3K_1$ - T_{25}	$L_2N_3P_3K_1$ - T_{52}	$L_3N_3P_3K_1$ - T_{79}
$L_1N_3P_3K_2$ - T_{26}	$L_2N_3P_3K_2$ - T_{53}	$L_3N_3P_3K_2$ - T_{80}
$L_1N_3P_3K_3$ - T_{27}	$L_2N_3P_3K_3$ - T_{54}	$L_3N_3P_3K_3$ - T_{81}

Fig 2. Lay out of the experiment

Replication I

T_{11}	T_{15}	T_{6}	T_{68}	T_{63}	T_{69}	T_{38}	T_{30}	T_{33}
T_{16}	T_{13}	T_{10}	T_{71}	T_{56}	T_{60}	T_{42}	T_{48}	T_{37}
T_{7}	T_{22}	T_{2}	T_{55}	T_{62}	T_{80}	T_{34}	T_{29}	T_{41}
T_{12}	T_{17}	T_{24}	T_{61}	T_{70}	T_{67}	T_{28}	T_{46}	T_{53}
T_{1}	T_{26}	T_{5}	T_{64}	T_{74}	T_{59}	T_{43}	T_{32}	T_{36}
T_{18}	T_{14}	T_{19}	T_{72}	T_{57}	T_{78}	T_{40}	T_{44}	T_{50}
T_{27}	T_{3}	T_{9}	T_{76}	T_{65}	T_{73}	T_{52}	T_{31}	T_{54}
T_{8}	T_{25}	T_{20}	T_{58}	T_{81}	T_{77}	T_{35}	T_{45}	T_{51}
T_{21}	T_{23}	T_{4}	T_{75}	T_{79}	T_{66}	T_{39}	T_{47}	T_{49}

Replication II

T_{55}	T_{58}	T_{63}	T_{1}	T_{14}	T_{5}	T_{41}	T_{36}	T_{28}
T_{79}	T_{68}	T_{71}	T_{19}	T_{9}	T_{22}	T_{46}	T_{40}	T_{45}
T_{67}	T_{76}	T_{61}	T_{115}	T_{23}	T_{13}	T_{35}	T_{29}	T_{34}
T_{70}	T_{78}	T_{56}	T_{25}	T_{2}	T_{18}	T_{50}	T_{47}	T_{39}
T_{62}	T_{66}	T_{80}	T_{10}	T_{17}	T_{8}	T_{30}	T_{38}	T_{33}
T_{72}	T_{57}	T_{64}	T_{3}	T_{6}	T_{21}	T_{42}	T_{52}	T_{44}
T_{59}	T_{77}	T_{74}	T_{27}	T_{12}	T_{4}	T_{37}	T_{48}	T_{32}
T_{65}	T_{69}	T_{81}	T_{7}	T_{24}	T_{26}	T_{53}	T_{31}	T_{54}
T_{73}	T_{75}	T_{60}	T_{16}	T_{20}	T_{11}	T_{51}	T_{43}	T_{49}

Replication III

T_{35}	T_{40}	T_{30}	T_{112}	T_{8}	T_{3}	T_{62}	T_{59}	T_{57}
T_{46}	T_{28}	T_{37}	T_{16}	T_{2}	T_{18}	T_{75}	T_{66}	T_{71}
T_{31}	T_{43}	T_{45}	T_{7}	T_{11}	T_{5}	T_{72}	T_{56}	T_{79}
T_{53}	T_{39}	T_{34}	T_{26}	T_{21}	T_{15}	T_{60}	T_{70}	T_{74}
T_{36}	T_{48}	T_{42}	T_{4}	T_{1}	T_{25}	T_{81}	T_{76}	T_{61}
T_{52}	T_{29}	T_{50}	T_{23}	T_{27}	T_{10}	T_{55}	T_{73}	T_{78}
T_{32}	T_{54}	T_{44}	T_{13}	T_{20}	T_{22}	T_{67}	T_{69}	T_{65}
T_{47}	T_{38}	T_{49}	T_{17}	T_{6}	T_{24}	T_{63}	T_{58}	T_{77}
T_{41}	T_{51}	T_{33}	T_{19}	T_{9}	T_{14}	T_{68}	T_{64}	T_{80}

3.4.3 Planting

The pots were filled with potting mixture to one fourth of the volume prior to planting of the rooted cuttings. The rooted cuttings were then removed from the polybags and one rooted cutting each was transplanted to the pots. The container was then filled to capacity with potting mixture to give a final volume of 10 kg potting mixture per pot.

3.4.4 Shading

Artificial shade to the required level as per the treatment was provided.

3.4.5 Fertilizer application

Fertilizers were applied in 12 equal splits at monthly intervals. They were mixed well with the soil on the pots.

3.4.6 After cultivation

3.4.6.1 Weeding

Weeding was done before each fertilizer application. Hanging shoots were removed as and when noted.

3.4.6.2 Plant protection

Monocrotophos 0.05 per cent was sprayed to control thrips and 1 per cent Bordeaux mixture was sprayed on the crop as a prophylatic measure against quick wilt during May-June and September-October.

3.4.7 Harvesting

Harvesting of pepper was started 9 MAP. During the period under study, altogther four harvestings were done.

3.5 Observations

Observations on growth characters were taken at monthly intervals

3.5.1 Growth characters

3.5.1.1 Length of primary branches

The length from the base of the branch to the base of the youngest fully opened leaf in the branch was measured and expressed in cm.

3.5.1.2 Length of secondary branches

The length from the base of the secondary branch to the base of the youngest fully opened leaf was measured and expressed in cm.

3.5.1.3 Number of primary branches

The number of primary branches were counted and recorded.

3.5.1.4 Number of secondary branches

The total number of secondary branches were counted and recorded.

3.5.1.5 Internodal length

The distance between consecutive nodes of the vine was measured and the mean length was expressed in cm.

3.5.1.6 Number of leaves

The total number of fully opened leaves on the plant were counted and recorded.

3.5.1.7 Total leaf area

The leaf area for individual leaf was calculated as the product of the length and breadth and a factor 0.71 as suggested by Mohanakumaran and Prabhakaran (1980). The average leaf area was worked out for 5 randomly selected leaves in a plant. This was multiplied by the number of leaves to get total leaf area and expressed in cm^2.

3.5.2 Yield and yield attributes

3.5.2.1 Days to flower

The number of days taken from planting to the opening of the first flower in each treatment was recokoned as the days taken for flowering.

3.5.2.2 Dry matter production

Drymatter production was calculated at the time of harvest. The plants were uprooted, cleaned, chopped, air dried, oven dried and weighed. Dry matter production was expressed as g $bush^{-1}$.

3.5.2.3 Number of spikes

The number of spikes in each bush was counted and was expressed as the total number.

3.5.2.4 Number of developed berries

The number of fully set berries in each spike was counted and recorded as the total number per bush.

3.5.2.5 Number of undeveloped berries

The number of undeveloped berries in each spike was counted and recorded as the total number per bush.

3.5.2.6 Fresh weight of berries

The berries were separated from the spikes and then fresh weight was taken and recorded in g.

3.5.2.7 Dry weight of berries

The berries were first dried under the sun then oven dried and dry weight was expressed in g.

3.6 Chemical analysis

3.6.1 Plant analysis

Plant samples were analysed for N, P and K at harvest by adopting standard procedures. The samples were chopped and dried in an air oven at 70±2°C till constant weights were obtained. Samples were then passed through a 0.5 mm mesh in a willey mill.

N content was estimated using Microkjeldahl method (Jackson, 1973) P content using Vanadomolybdophosphoric yellow colour method (Jackson, 1973) and K content using flame photometer (Piper, 1966).

3.6.1.1 Nutrient uptake

The total uptake of N, P and K were calculated as the product of percentage content of nutrient in the plant samples and dry weight. N and K uptake were expressed as g bush^{-1} and P as mg bush^{-1}.

3.6.1.2 Chlorophyll content

Chlorophyll a, Chlorophyll b and total chlorophyll content of leaves were estimated at 4, 8 and 12 months after planting by the spectrophotmetric method suggested by Starnes and Hadley (1965).

3.6.2 Quality parameters

3.6.2.1 Volatile oil

The content of volatile oil was estimated by Clevenger distillation method (A.O.A.C., 1973) and expressed as percentage on dry weight basis.

3.6.2.2 Oleoresin

The content was estimated by Soxhlet distillation method and expressed as percentage on dry weight basis (A.O.A.C., 1975)

3.6.3 Chemical properties of soil

Available nutrient status was determined before and after the experiment using standard procedures given in Table 1.

3.7. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for split plot design (Panse and Sukhatme, 1995). CD values were provided only for those tables when the F-test was significant.

RESULTS

RESULTS

Results obtained from the experiment to study the influence of NPK fertilizers under different light intensities on the growth, yield and quality of bush pepper are presented in this chapter.

4.1 Growth characters

4.1.1 Length of primary branches

The increase in the length of primary branches due to treatments are presented in table 2.

The length of primary branches in bush pepper was unaffected by light in the early stages of growth ie, 4 and 8 MAP, but after 12 months it was found to be significant. Maximum length of 28.43 cm was attained under L_3 and the minimum length of 16.21 cm under L_1.

Nutrient application was also found to have significant effect on this character. N levels showed significant influence throughout the growth period. After 4 months the length of branches decreased with increasing levels of N but from 8 month onwards, the length increased upto N_2 level. Among the different P levels tried, P_2 was the best. The effect of K was not significant.

Light x nutrient interaction (Table 3) showed that L_2N_1, L_2P_2 and L_2K_1 were the best combinations upto 8 months. After 12 months the combination L_3N_1 and L_3P_2 were found to be superior and all the L_3K combinations were on par and superior to all others, P_2 under L_3 was on par with P_1. Under L_1, plants receiving N_2, P_1 and K_1 level of nutrients recorded maximum length of branches and under L_2 plants receiving N_2, P_2 and K_1 level of nutrients performed better than the others 12 MAP, N_2 was on par with N_1.

4.1.2 Length of secondary branches

Light intensities and nutrient levels significantly influenced the length of secondary branches (Table 2).

Maximum length of secondary branch (29.28 cm) was recorded under L_3 which was significantly superior to L_1 and L_2. Among the nutrient levels N_1, P_3 and K_1 were found to be superior.

The interaction of light with different levels of the three nutrients was found significant (Table 3). N_1, P_3 and K_1 under L_3 recorded the maximum length of branches. Under L_1 and L_2 plants receiving N_1, P_3, K_1 and N_3, P_1, K_1 respectively attained the maximum length of secondary branches 12 MAP, N_3 under L_2 was on par with N_1.

Table 2 Effect of light and nutrient levels on the length (cm) of primary and secondary branches

Light levels	Length of primary branches			Length of secondary branches		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1	9.49	11.88	16.21	4.09	9.16	16.00
L_2	10.61	14.76	21.70	6.84	13.84	23.52
L_3	8.26	14.35	28.43	10.53	18.19	29.28
F	NS	NS	S	S	S	S
SE(±M)	0.985	0.989	1.29	0.251	0.334	0.744
CD (0.05)	-	-	4.47	0.87	1.16	2.58
Nutrient levels						
N_1	10.22	14.15	22.90	7.42	14.15	23.73
N_2	10.19	15.34	24.60	6.78	13.52	22.47
N_3	7.95	11.49	18.83	7.26	13.52	22.61
F	S	S	S	NS	NS	S
P_1	8.86	12.77	21.36	6.82	13.74	23.02
P_2	9.76	14.71	23.48	6.46	12.82	21.74
P_3	9.74	13.49	21.49	8.19	14.63	24.04
F	NS	NS	S	S	S	S
K_1	10.16	14.23	22.90	8.16	15.09	24.66
K_2	9.17	13.20	21.30	6.89	13.06	22.61
K_3	9.03	13.56	22.13	6.41	13.04	21.54
F	NS	NS	NS	S	S	S
SE (±M)	0.592	0.604	0.696	0.197	0.225	0.218
CD (0.05)	1.64	1.68	1.93	0.55	0.624	0.604

Table 3 Effect of interaction of light with N, P and K on the length (cm) of primary and secondary branches

Treatment	Length of primary branches			Length of secondary branches		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1N_1	8.82	10.79	15.36	3.89	8.70	16.96
L_1N_2	12.13	15.46	20.21	4.11	9.30	16.04
L_1N_3	7.53	9.38	13.06	4.26	9.48	15.00
L_2N_1	12.67	16.34	23.17	7.52	14.74	23.74
L_2N_2	10.78	16.30	23.85	6.00	13.26	22.78
L_2N_3	8.39	11.64	18.08	7.00	13.52	24.04
L_3N_1	9.19	15.33	30.17	10.85	19.00	30.48
L_3N_2	7.66	14.26	29.76	10.22	18.00	28.59
L_3N_3	7.93	13.44	25.35	10.52	17.56	28.77
F	S	NS	S	NS	S	S
L_1P_1	9.70	12.09	16.46	3.59	8.78	16.42
L_1P_2	9.13	11.68	15.72	3.07	7.56	13.35
L_1P_3	9.64	11.85	16.44	5.59	11.15	18.23
L_2P_1	9.11	12.76	19.51	6.00	13.67	24.25
L_2P_2	11.76	16.90	24.63	7.15	14.44	23.63
L_2P_3	10.98	14.62	20.96	7.37	13.41	22.67
L_3P_1	7.78	13.47	28.11	10.85	18.78	28.38
L_3P_2	8.40	15.55	30.10	9.15	16.44	28.24
L_3P_3	8.60	14.01	27.08	11.59	19.33	31.22
F	NS	NS	S	S	S	S
L_1K_1	9.99	12.34	16.84	4.33	9.41	16.60
L_1K_2	9.13	11.58	15.97	4.00	9.41	16.40
L_1K_3	9.36	11.71	15.80	3.93	8.67	15.00
L_2K_1	11.37	15.59	22.35	7.96	15.52	25.40
L_2k_2	10.14	13.76	21.45	6.44	12.15	22.01
L_2K_3	10.33	14.93	21.29	6.11	13.85	23.15
L_3K_1	9.13	14.75	29.54	12.19	20.33	31.99
L_3K_2	8.25	14.25	26.46	10.22	17.63	29.41
L_3K_3	7.40	14.03	29.28	9.19	16.59	26.45
F	NS	NS	S	S	S	S
SE(±M)	1.025	1.047	1.205	0.341	0.390	0.377
CD (0.05)	2.842	-	3.340	0.944	1.081	1.046

Table 4 Effect of NP, NK and PK interaction of the length (cm) of secondary branches

Treatment	4 MAP	8 MAP	12 MAP
N_1P_1	7.00	14.26	23.98
N_1P_2	6.89	13.15	22.76
N_1P_3	8.37	15.04	24.44
N_2P_1	6.07	12.48	21.66
N_2P_2	5.30	12.59	21.46
N_2P_3	8.96	15.48	24.28
N_3P_1	7.37	14.48	23.42
N_3P_2	7.19	12.70	21.00
N_3P_3	7.22	13.37	23.29
F	S	S	S
N_1K_1	8.44	15.48	25.40
N_1K_2	6.89	13.22	23.11
N_1K_3	6.93	13.74	22.67
N_2K_1	8.19	16.44	26.27
N_2K_2	6.67	12.59	21.78
N_2K_3	5.48	11.52	19.35
N_3K_1	7.85	13.33	22.31
N_3K_2	7.11	13.37	22.93
N_3K_3	6.82	13.85	22.58
F	NS	S	S
P_1K_1	7.26	14.48	24.83
P_1K_2	7.37	13.48	22.61
P_1K_3	5.82	13.26	21.62
P_2K_1	7.30	13.79	23.03
P_2K_2	6.04	12.52	22.26
P_2K_3	6.04	12.15	19.94
P_3K_1	9.93	17.00	26.13
P_3K_2	7.26	13.19	22.95
P_3K_3	7.37	13.70	23.04
F	S	S	S
SE(±M)	0.341	0.390	0.377
CD(0.05)	0.944	1.081	1.046

Table 5 Effect of interaction of light with NPK on the length (cm) of secondary branches

Treatment	8 MAP				12 MAP			
	L_1	L_2	L_3	Mean NPK	L_1	L_2	L_3	Mean NPK
$N_1P_1K_1$	11.67	14.00	17.33	14.33	21.33	24.00	28.10	24.48
$N_1P_1K_2$	7.33	14.67	20.00	14.00	16.00	24.67	31.33	24.00
$N_1P_1K_3$	10.33	15.33	17.67	14.44	20.67	23.93	25.80	23.47
$N_1P_2K_1$	7.00	14.33	19.33	13.56	12.33	24.00	33.47	23.27
$N_1P_2K_2$	8.00	15.67	14.00	12.56	17.00	25.67	26.00	22.89
$N_1P_2K_3$	4.67	16.67	18.67	13.33	9.00	26.33	31.00	22.11
$N_1P_3K_1$	12.00	17.33	26.33	18.56	23.67	24.73	36.93	28.44
$N_1P_3K_2$	9.33	13.33	16.67	13.11	16.33	22.67	28.33	22.44
$N_1P_3K_3$	8.00	11.33	21.00	13.44	16.33	17.67	33.33	22.44
$N_2P_1K_1$	6.00	16.00	21.67	14.56	14.00	27.67	33.33	25.00
$N_2P_1K_2$	8.00	10.00	18.00	12.00	15.67	21.00	26.93	21.20
$N_2P_1K_3$	4.67	11.33	16.67	10.89	9.13	22.00	25.17	18.77
$N_2P_2K_1$	11.67	17.33	14.67	14.56	21.00	26.50	26.00	24.50
$N_2P_2K_2$	12.33	12.67	15.33	13.44	19.53	22.67	27.20	23.13
$N_2P_2K_3$	5.67	8.67	15.00	9.78	10.00	16.33	23.93	16.76
$N_2P_3K_1$	10.67	22.33	27.67	20.22	16.00	32.50	39.47	29.32
$N_2P_3K_2$	10.33	7.00	19.67	12.33	16.33	13.67	33.00	21.00
$N_2P_3K_3$	14.33	14.00	13.33	13.89	22.67	22.67	22.27	22.53
$N_3P_1K_1$	12.00	12.67	19.00	14.56	19.67	24.33	31.00	25.00
$N_3P_1K_2$	10.00	11.67	21.67	14.44	15.67	23.00	29.20	22.62
$N_3P_1K_3$	9.00	17.33	17.00	14.44	15.67	27.61	24.53	22.62
$N_3P_2K_1$	2.00	16.67	21.00	13.22	5.67	25.03	33.23	21.31
$N_3P_2K_2$	7.67	13.00	14.00	11.56	12.57	23.33	26.33	20.74
$N_3P_2K_3$	9.00	15.00	16.00	13.33	13.07	22.83	27.00	20.97
$N_3P_3K_1$	11.67	9.00	16.00	12.22	15.73	19.90	26.33	20.62
$N_3P_3K_2$	11.67	11.33	19.33	14.11	18.47	21.43	36.33	25.41
$N_3P_3K_3$	12.33	15.00	14.00	13.78	18.50	28.93	25.00	24.14
Mean L	9.16	13.84	18.19		16.00	23.52	29.28	
F	L - S	NPK-S	LNPK-S		L - S	NPK-S	LNPK-S	
SE(±M)	0.334	0.675	1.170		0.744	0.653	1.132	
CD(0.05)	1.156	1.872	3.242		2.58	1.811	3.137	

NP, NK and PK interaction was also significant. N_1P_3, N_2K_1 and P_3K_1 recorded the maximum values (Table 4).

The interaction of light with NPK (Table 5) showed that maximum length of secondary branch (39.47 cm) was recorded by the treatment combination $L_3N_2P_3K_1$, which was on par with $L_3N_1P_3K_1$. Under L_1 and L_2 maximum length was attained for the combinations $N_1P_3K_1$ and $N_2P_3K_1$ respectively after 12 months of planting.

4.1.3 Number of primary branches

The difference in the number of primary branches due to treatments are presented in Table 6.

The number of primary branches increased with decreasing light intensities at all the growth stages studied and differed significantly from each other. Maximum number of primary branches (3.28) were recorded at L_3 and minimum (1.74) at L_1 12 MAP.

Effect of different nutrient levels was also significant. P and K levels had significant influence throughout the growth period but the effect of N was significant only after 8 and 12 months of planting. Increasing levels of N increased the number of branches upto N_2 level. At N_3 there was a significant reduction in the number of branches produced. With increasing levels of P the number of branches decreased. P_1 was significantly superior to P_2 and P_3 at all stages of growth.

Application of K increased the branches upto K_2 level. After this level, the number of primary branches showed a declining trend.

Interaction between light intensities and nutrient levels was significant only after 12 months of planting. At all light intensities nitrogen at N_2 level, phosphorus at P_1 level and potassium at K_2 level recorded highest values (Table 7) under L_1, K_2 was on par with K_1.

NP and NK interactions were found significant at 8 and 12 MAP (Table 8). N_2P_1 and N_2K_2 recorded the maximum values. PK interaction was not significant.

NPK interaction showed that $N_2P_3K_2$ was the best treatment. The interaction of light with NPK showed that the combination $N_2P_1K_2$ under L_2 recorded the maximum number of branches (9.0) which was significantly superior to all others. Under L_1 and L_3 $N_2P_1K_1$ and $N_2P_3K_2$ respectively proved to be the best combinations (Table 9).

4.1.4 Number of secondary branches

Light intensities showed significant influence only after 12 months of planting (Table 6). Maximum number of branches (10.89) were produced at L_3 and minimum (6.14) at L_1.

N application had significant effect throughout the crop growth period. P fertilization had effect only after 12 months. N_2 and P_2 were the superior levels at all stages of growth. K application was not significant at any of the growth stage studied (Table 6).

Light x nutrient interaction showed significant effect after 12 months (Table 7). N_2 and P_2 under L_3 recorded maximum number of secondary branches, but L_3P_2 was on par with L_3P_1. The different K levels under L_3 were on par and superior to others. Under L_1 and L_2 also plants receiving N_2 and P_2 levels of nutrients recorded the maximum number of branches. N_2 under L_1 and P_2 under L_2 were on par with N_1 and P_1 respectively. Among K levels K_3 performed better under L_1 and K_1 under L_2. K_3 under L_1 was on par with K_1.

NP and NK interactions were significant only after 12 months of planting. N_2P_2 and N_2K_1 were the superior combinations. N_2P_2 was on par with N_2P_1 (Table 8).

PK and NPK interactions were not significant.

The interaction of light with NPK showed that the combination $L_3N_2P_1K_1$ recorded the maximum number of secondary branches (13.33). Under L_1 and L_2 plants receiving $N_2P_2K_3$ and $N_2P_2K_1$ respectively produced maximum number of branches (Table 9).

Table 6 Effect of light and nutrient levels on the number of primary and secondary branches

Light levels	Number of primary branches			Number of secondary branches		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1	0.91	1.38	1.74	0.75	3.38	6.14
L_2	1.25	2.63	3.09	0.52	3.94	8.47
L_3	1.17	2.64	3.28	1.01	4.72	10.89
F	NS	S	S	NS	NS	S
SE(±M)	0.141	0.235	0.257	0.176	0.329	0.276
CD(0.05)	0.489	0.812	0.891	-	-	0.956
Nutrient levels						
N_1	1.06	2.03	2.38	0.61	3.98	8.21
N_2	1.22	2.68	3.37	0.90	4.46	9.14
N_3	1.05	1.95	2.36	0.78	3.61	8.15
F	NS	S	S	S	S	S
P_1	1.30	2.70	3.26	0.68	3.95	8.32
P_2	1.09	2.25	2.75	0.75	4.19	8.84
P_3	0.95	1.74	2.10	0.85	3.90	8.33
F	S	S	S	NS	NS	S
K_1	1.15	2.10	2.51	0.67	3.99	8.57
K_2	1.25	2.40	3.03	0.78	4.05	8.28
K_3	0.94	2.16	2.58	0.84	4.00	8.63
F	S	S	S	NS	NS	NS
SE(±M)	0.078	0.099	0.104	0.080	0.149	0.131
CD(0.05)	0.217	0.275	0.288	0.221	0.414	0.363

Table 7 Effect of interaction of light with N, P and K on the number of primary and secondary branches 12 MAP

Treatment	Number of primary branches	Number of secondary branches
L_1N_1	1.41	6.11
L_1N_2	2.15	6.59
L_1N_3	1.67	5.70
L_2N_1	2.39	8.19
L_2N_2	3.89	9.00
L_2N_3	3.00	8.22
L_3N_1	3.37	10.33
L_3N_2	4.07	11.82
L_3N_3	2.41	10.52
F	S	S
L_1P_1	2.26	5.67
L_1P_2	1.59	6.44
L_1P_3	1.37	6.30
L_2P_1	3.74	8.33
L_2P_2	3.37	8.74
L_2P_3	2.15	8.33
L_3P_1	3.78	10.96
L_3P_2	3.30	11.33
L_3P_3	2.78	10.37
F	S	S
L_1K_1	1.85	6.15
L_1K_2	1.93	5.63
L_1K_3	1.44	6.63
L_2K_1	2.78	8.67
L_2K_2	3.48	8.26
L_2K_3	3.00	8.48
L_3K_1	2.89	10.89
L_3K_2	3.67	10.89
L_3K_3	3.30	10.89
F	S	S
SE(±M)	0.180	0.227
CD(0.05)	0.499	0.628

Table 8 Effect of NP and NK interaction on the number of primary and secondary branches

Treatment	Number of primary branches		Number of secondary branches	
	8 MAP	12 MAP	8 MAP	12 MAP
N_1P_1	2.44	2.93	3.59	7.59
N_1P_2	2.00	2.30	4.30	8.44
N_1P_3	1.63	1.93	4.04	8.59
N_2P_1	3.33	4.19	4.41	9.37
N_2P_2	2.41	3.00	4.52	9.59
N_2P_3	2.30	2.93	4.44	8.44
N_3P_1	2.22	2.67	3.85	8.00
N_3P_2	2.33	2.96	3.74	8.48
N_3P_3	1.30	1.44	3.22	7.96
F	S	S	NS	S
N_1K_1	2.15	2.52	3.85	7.85
N_1K_2	2.00	2.37	3.93	8.00
N_1K_3	1.93	2.26	4.15	8.78
N_2K_1	2.19	2.74	4.37	9.41
N_2K_2	3.30	4.30	4.74	8.78
N_2K_3	2.56	3.07	4.26	9.22
N_3K_1	1.96	2.26	3.74	8.44
N_3K_2	1.89	2.41	3.48	8.00
N_3K_3	2.00	2.41	3.59	8.00
F	S	S	NS	S
SE(±M)	0.172	0.180	0.259	0.227
CD(0.05)	0.477	0.499	-	0.628

Table 9 Effect of interaction of light with NPK on the number of primary and secondary branches 12 MAP

	Number of primary branches				Number of secondary branches			
	L_1	L_2	L_3	Mean NPK	L_1	L_2	L_3	Mean NPK
$N_1P_1K_1$	1.67	4.33	4.33	3.44	5.33	7.33	9.67	7.44
$N_1P_1K_2$	1.33	2.67	2.33	2.11	4.33	7.33	10.00	7.22
$N_1P_1K_3$	1.33	3.00	5.33	3.22	6.33	7.33	10.67	8.11
$N_1P_2K_1$	1.33	2.33	3.67	2.44	5.33	9.00	9.67	8.00
$N_1P_2K_2$	2.00	2.00	3.33	2.44	6.33	8.67	9.67	8.22
$N_1P_2K_3$	1.67	2.33	2.00	2.00	6.67	9.33	11.33	9.11
$N_1P_3K_1$	1.00	1.00	3.00	1.67	6.33	8.00	10.00	8.11
$N_1P_3K_2$	1.67	1.00	5.00	2.56	6.67	8.00	11.00	8.56
$N_1P_3K_3$	0.67	2.67	1.33	1.56	7.67	8.67	11.00	9.11
$N_2P_1K_1$	4.00	2.00	4.67	3.56	6.67	9.67	13.33	9.89
$N_2P_1K_2$	3.33	9.00	3.00	5.11	5.33	8.33	11.33	8.33
$N_2P_1K_3$	1.33	3.67	6.67	3.89	6.33	10.33	13.00	9.89
$N_2P_2K_1$	2.00	3.33	2.33	2.56	7.33	10.67	11.67	9.89
$N_2P_2K_2$	1.00	4.67	3.33	3.00	6.33	8.33	13.33	9.33
$N_2P_2K_3$	1.67	3.67	5.00	3.44	8.00	8.00	12.67	9.56
$N_2P_3K_1$	1.00	2.67	2.67	2.11	6.33	8.00	11.00	8.44
$N_2P_3K_2$	2.00	5.33	7.00	4.78	5.67	9.00	11.33	8.67
$N_2P_3K_3$	3.00	0.67	2.00	1.89	7.33	8.67	8.67	8.22
$N_3P_1K_1$	4.00	2.67	1.67	2.78	6.67	9.33	9.67	8.56
$N_3P_1K_2$	2.33	2.00	2.67	2.33	4.67	8.33	10.33	7.78
$N_3P_1K_3$	1.00	4.33	3.33	2.89	5.33	7.00	10.67	7.68
$N_3P_2K_1$	1.33	3.67	2.67	2.57	5.67	7.00	11.67	8.11
$N_3P_2K_2$	2.00	3.33	4.67	3.33	6.00	8.67	11.33	8.68
$N_3P_2K_3$	1.33	5.00	2.67	3.00	6.33	9.00	10.67	8.68
$N_3P_3K_1$	0.33	3.00	1.00	1.44	5.67	9.00	11.33	8.68
$N_3P_3K_2$	1.67	1.33	1.67	1.56	5.33	7.67	9.67	7.56
$N_3P_3K_3$	1.00	1.67	1.33	1.33	5.67	8.00	9.33	7.68
Mean L	1.741	3.086	3.284		6.136	8.469	10.889	
F	L-S	NPK-S	LNPK-S		L-S	NPK-NS	LNPK-S	
SE(±M)	0.257	0.312	0.540		0.276	0.392	0.680	
CD(0.05)	0.891	0.864	1.497		0.956	1.088	1.844	

4.1.5 Internodal length

The increase in internodal length due to treatments are presented in Table 10.

There was significant difference in the internodal length due to varying light intensities. Maximum internodal length was recorded at L_3 (4.81) and minimum at L_1 (3.07).

Nitrogen fertilization was found to be significant throughout the period under study. Among the N levels, N_1 and N_2 were on par and superior to N_3. P and K fertilization had no significant effect.

The interaction of light with nutrients was significant 8 and 12 MAP (Table 11). The combinations L_3N_1, L_3P_2 and L_3K_3 recorded maximum internodal values, L_3K_3 was on par with L_3K_2. Under L_1 and L_2 plants receiving N_2 recorded maximum internodal length than the other levels, N_2 under L_1 was on par with N_1. Among P and K levels, P_2 and K_1 performed better under L_1 and P_1 and K_2 under L_2. K_2 under L_2 was on par with K_1.

4.1.6 Number of leaves

There was significant variation in the number of leaves produced with varying light intensities 8 and 12 months after planting (Table 12).

Table 10 Effect of light and nutrient levels on the internodal length (cm)

Light levels	Internodal length		
	4 MAP	8 MAP	12 MAP
L_1	0.52	1.85	3.07
L_2	1.67	3.00	4.25
L_3	2.11	3.39	4.81
F	S	S	S
SE(±M)	0.108	0.112	0.144
CD(0.05)	0.372	0.388	0.498
Nutrient levels			
N_1	1.39	2.84	4.15
N_2	1.59	2.81	4.19
N_3	1.33	2.59	3.79
F	S	S	S
P_1	1.34	2.71	4.08
P_2	1.48	2.83	4.12
P_3	1.48	2.71	3.93
F	NS	NS	NS
K_1	1.40	2.87	4.03
K_2	1.40	2.64	3.99
K_3	1.50	2.74	4.12
F	NS	NS	NS
SE(±M)	0.078	0.092	0.101
CD(0.05)	0.215	0.254	0.281

Table 11 Effect of interaction of light with N, P and K on the internodal length (cm)

Treatment	Internodal length	
	8 MAP	12 MAP
L_1N_1	1.92	3.18
L_1N_2	1.80	3.24
L_1N_3	1.84	2.81
L_2N_1	2.92	4.24
L_2N_2	3.32	4.46
L_2N_3	2.77	4.04
L_3N_1	3.70	5.03
L_3N_2	3.32	4.87
L_3N_3	3.15	4.52
F	S	S
L_1P_1	1.86	3.03
L_1P_2	1.86	3.13
L_1P_3	1.83	3.06
L_2P_1	2.92	4.38
L_2P_2	3.05	4.22
L_2P_3	3.04	4.14
L_3P_1	3.34	4.84
L_3P_2	3.57	5.01
L_3P_3	3.56	4.58
F	S	S
L_1K_1	2.17	3.35
L_1K_2	1.66	2.87
L_1K_3	1.73	2.99
L_2K_1	3.12	4.17
L_2K_2	2.97	4.29
L_2K_3	2.92	4.29
L_3K_1	3.34	4.57
L_3K_2	3.27	4.79
L_3K_3	3.56	5.07
F	S	S
SE(±M)	0.159	0.175
CD(0.05)	0.440	0.486

Leaf number was maximum (94.68) at L_3 which was significantly superior to L_1 and L_2 at 12 months after planting. L_1 recorded the least value of 30.72 for this character.

N fertilization was found to be significant at all the three growth stages studied. Among the different levels of N, N_1 and N_2 were on par and significantly superior to N_3 upto 8 MAP, but after 12 months N_3 recorded the maximum leaf number of 64.96. The effect of P and K levels on the number of leaves was significant after 8 months. Plants receiving P_3 and K_2 recorded greater number of leaves than others at 12 MAP but these levels were on par with P_1 and K_1 respectively (Table 12).

The interaction of light with N and P was significant 8 and 12 MAP (Table 13). Maximum leaf number was recorded by L_3 plants receiving N_1 and P_2 8 MAP and N_3 and P_3 levels of nutrients 12 MAP. Under L_1, plants receiving N_1 and P_1 recorded maximum leaf number at 8 MAP and N_3 and P_1 at 12 MAP, N_3 was on par with N_1. Under L_2 level, plants receiving N_2 and P_3 produced maximum leaves 8 MAP and N_1 and P_1 levels 12 MAP.

4.1.7 Total leaf area

The data furnished in table (12) showed significant difference in leaf area due to varying light intensities 8 and 12 MAP. Maximum leaf area was attained under L_3 (5013.24 cm^2) which remained significantly superior to L_1 and L_2. L_1 recorded the lowest leaf area of 1795.17 cm^2.

Nitrogen fertilization had significant effect throughout the growth period. Leaf area decreased with increasing N levels 4 MAP, but after 8 months leaf area increased upto N_2 level and after 12 months N_3 was found to be superior to N_1 and N_2. P and K levels had influence on this character only after 12 months. P_1 and K_1 were the superior levels (Table 12).

The interaction of light with nutrients was also significant (Table 13). LN interaction was significant throughout the period under study, LP interaction after 8 months and LK interaction after 12 months. N_1 level under L_3 level performed better than others 4 and 8 MAP and after 12 months L_3N_3 was the best. Among P levels P_3 was superior under L_3. Under L_1, N_1 recorded maximum leaf area 4 and 8 MAP and after 12 months, N_2 was the best. P_1 level performed the best under L_1. Under L_2, N_3 recorded maximum leaf area 4 MAP, N_2 8 MAP and N_1 12 MAP. P_3 and P_1 levels performed better under this light level 8 and 12 MAP respectively. Among the LK interactions L_3K_1 was significantly superior. K_1 under L_1 and K_2 under L_2 performed better than the other levels (Table 13).

NP interaction was significant. N_3P_1 recorded the highest value. LNP interaction was significant 12 MAP. N_3P_1 under L_3 level recorded the maximum leaf area of 6761.45 cm^2 (Table 14).

Table 12 Effect of light and nutrient levels on the number of leaves and total leaf area (cm^2)

Light levels	Number of leaves			Total leaf area		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1	5.14	22.53	30.72	303.0	594.37	1795.17
L_2	4.75	35.37	60.41	270.44	1114.80	3314.17
L_3	2.04	44.43	94.68	415.75	1387.73	5013.24
F	NS	S	S	NS	S	S
SE(±M)	1.467	2.227	6.313	56.395	68.053	256.516
CD(0.05)		7.708	21.846		235.472	887.694
Nutrient levels						
N_1	4.82	36.11	60.91	426.72	1079.94	3250.39
N_2	3.95	35.77	59.93	317.51	1094.74	3152.27
N_3	3.16	30.46	64.96	244.98	922.22	3719.91
F	S	S	S	S	S	S
P_1	3.93	36.17	65.90	291.64	1082.85	3676.28
P_2	3.49	33.57	53.31	339.62	1023.19	2983.11
P_3	4.51	32.59	66.59	357.94	990.85	3463.19
F	NS	S	S	NS	NS	S
K_1	4.32	35.79	64.24	372.01	1072.42	3669.85
K_2	3.98	32.17	66.31	319.17	991.74	3442.11
K_3	3.63	34.37	55.26	298.01	1032.74	3010.62
F	NS	S	S	NS	NS	S
SE(±M)	1.037	1.247	1.366	32.760	39.640	76.466
CD(0.05)	2.873	3.458	3.787	90.806	109.870	211.954

Table 13 Effect of interaction of light with N, P and on the number of leaves and total leaf area (cm^2)

Light levels	Number of leaves			Total leaf area cm^2		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1N_1	12.11	27.15	30.07	449.22	710.26	1408.70
L_1N_2	9.33	24.56	29.78	306.04	646.04	2018.29
L_1N_3	4.07	15.89	32.30	153.74	426.82	1958.52
L_2N_1	6.93	32.85	71.70	221.82	1022.67	3827.48
L_2N_2	8.93	39.00	57.07	290.52	1255.82	2823.33
L_2N_3	8.30	34.26	52.44	299.00	1065.93	3291.70
L_3N_1	13.22	48.33	80.96	609.11	1506.89	4515.00
L_3N_2	10.33	43.74	92.93	355.96	1382.37	4615.19
L_3N_3	5.22	41.22	110.14	282.19	1273.93	5909.52
F	NS	S	S	S	S	S
L_1P_1	9.44	27.96	37.44	247.19	731.04	2052.67
L_1P_2	9.15	19.44	23.59	340.26	515.48	1341.85
L_1P_3	6.93	20.19	31.11	321.56	536.59	1991.00
L_2P_1	7.48	33.89	69.85	249.96	1061.93	3980.56
L_2P_2	6.82	34.33	53.41	223.78	1079.56	3173.07
L_2P_3	9.85	37.89	57.96	337.59	1202.93	2788.89
L_3P_1	9.82	46.67	90.41	377.78	1455.59	4995.63
L_3P_2	11.19	46.93	82.93	454.82	1474.56	4434.41
L_3P_3	7.79	39.70	110.74	414.67	1233.04	5609.67
F	NS	S	S	NS	S	S
L_1K_1	10.78	25.74	39.07	385.82	670.07	2078.41
L_1K_2	8.26	21.33	27.82	305.93	570.82	1730.74
L_1K_3	6.48	20.52	25.26	217.26	542.22	1576.37
L_2K_1	7.67	34.00	57.85	238.74	1058.11	3482.59
L_2K_2	8.52	34.15	68.41	305.22	1102.00	3561.29
L_2K_3	7.96	37.96	54.96	267.37	1184.29	2898.63
L_3K_1	10.48	47.63	95.78	491.48	1489.07	5448.55
L_3K_2	9.44	41.04	102.70	346.37	1302.41	5034.29
L_3K_3	8.85	44.63	85.56	409.41	1371.70	4556.85
F	NS	S	S	NS	NS	S
SE(±M)	1.795	2.161	2.366	56.742	68.652	132.44
CD(0.05)		5.989	6.558	157.280	190.29	367.124

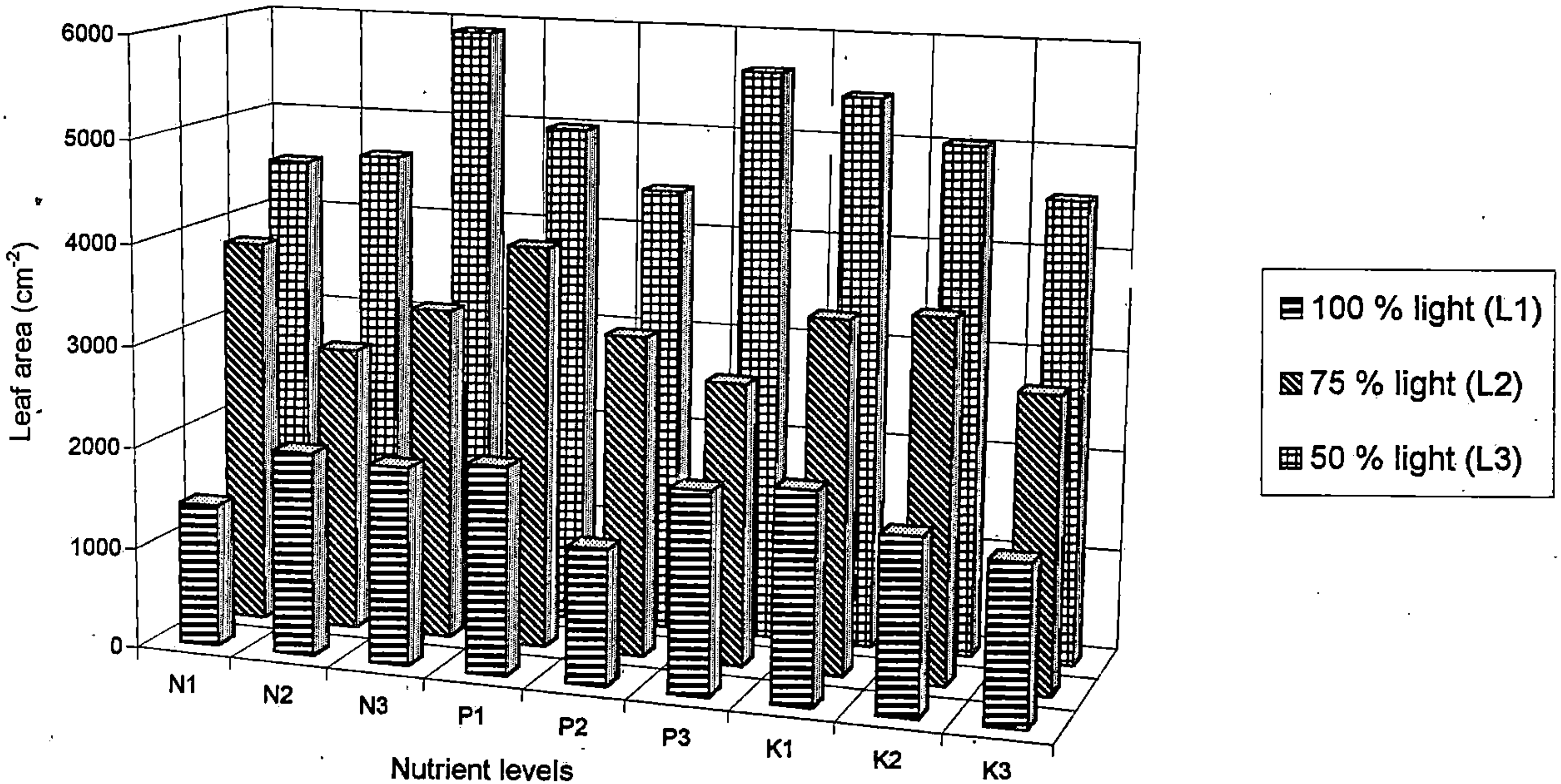
Table 14 Effect of interaction of light with NP on the total leaf area (cm^2) 12 MAP

Treatment	L_1	L_2	L_3	Mean NP
N_1P_1	1384.33	3704.22	4240.45	3109.67
N_1P_2	955.67	5135.67	3046.67	3046.00
N_1P_3	1886.11	2642.56	6257.89	3595.52
N_2P_1	2423.22	3579.89	3985.00	3329.37
N_2P_2	1221.45	2215.56	4090.67	2509.22
N_2P_3	2410.22	2674.56	5769.89	3618.22
N_3P_1	2350.44	4657.56	6761.45	4589.82
N_3P_2	1848.45	2168.00	6165.89	3394.11
N_3P_3	1676.67	3049.56	4801.22	3175.82
Mean L	415.75	1387.73	5013.24	
F	L-S	NP - S	LNP - S	
SE(±M)	256.516	132.444	229.394	
CD(0.05)	887.694	367.115	635.861	

Table 15 Effect of interaction of light with NPK on the leaf area (cm^2)

Treatment	Light intensities L_1	L_2	L_3	Mean NPK
$N_1P_1K_1$	2062.66	4857.66	4568.00	3829.44
$N_1P_1K_2$	1027.00	3534.33	4223.66	2928.33
$N_1P_1K_3$	1063.33	2720.66	3929.66	2571.22
$N_1P_2K_1$	899.00	5644.66	3046.00	3196.55
$N_1P_2K_2$	627.33	5591.00	2356.33	2858.22
$N_1P_2K_3$	1340.66	4171.33	3737.66	3083.22
$N_1P_3K_1$	1617.66	2544.66	6916.66	3693.00
$N_1P_3K_2$	2048.00	2608.00	7492.33	4049.44
$N_1P_3K_3$	1992.66	2775.00	4364.66	3044.11
$N_2P_1K_1$	2424.00	2910.00	5915.66	3749.89
$N_2P_1K_2$	2871.33	4266.33	3508.33	3548.67
$N_2P_1K_3$	1974.33	3563.33	2531.00	2689.56
$N_2P_2K_1$	1663.66	2411.00	2948.33	2341.00
$N_2P_2K_2$	1174.00	2090.00	5594.33	2952.78
$N_2P_2K_3$	826.66	2145.66	3729.33	2233.89
$N_2P_3K_1$	2339.33	2758.33	8671.66	4589.78
$N_2P_3K_2$	2269.33	2692.66	3671.00	2877.67
$N_2P_3K_3$	2622.00	2572.66	4967.00	3387.22
$N_3P_1K_1$	2668.33	4758.00	5945.00	4457.11
$N_3P_1K_2$	2737.66	4874.00	7143.33	4918.33
$N_3P_1K_3$	1645.33	4370.66	7196.00	4394.00
$N_3P_2K_1$	3026.00	3148.00	7071.66	4415.22
$N_3P_2K_2$	1304.33	1988.66	7529.33	3607.44
$N_3P_2K_3$	1215.00	1367.33	3896.66	2159.67
$N_3P_3K_1$	2005.00	2311.00	3954.00	2756.67
$N_3P_3K_2$	1517.66	4406.66	3790.00	3238.11
$N_3P_3K_3$	1507.33	2431.00	6659.66	3532.11
Mean L	1795.17	3314.17	5013.23	
F	L-S	NPK-S	LNPK-S	
SE(±M)	256.516	229.399	397.331	
CD(0.05)	887.694	635.861	1101.344	

Fig 3 Effect of nutrient levels on the total leaf area (cm^{-2}) of bush pepper under varying levels of light



LNPK interaction showed that the combination $L_3N_2P_3K_1$ was superior to others. Under L_1, $N_2P_1K_2$ and under L_2, $N_1P_2K_1$ were the best combinaions (Table 15).

4.2 Chlorophyll

Total chlorophyll and its fractions, chlorophyll 'a' and chlorophyll 'b' increased progressively with decreasing levels of light at all stages of growth. Maximum chlorophyll content was recorded at L_3 (Tables 16 and 17).

The nutrient treatments showed a general trend of increase in total chlorophyll, chlorophyll a and chlorophyll b. The ratio of chlorophyll a to b was found to be unaffected by light and nutrient levels tried.

Significant interaction was noted between light and nitrogen at all the growth stages (Table 18).

Maximum chlorophyll a and b was recorded under L_3 at N_2 level, which was on par with N_1 12 MAP. Under L_1 and L_2 levels maximum chlorophyll content was at N_3 level which was on par with N_1 12 MAP.

4.3 Yield and yield attributes

4.3.1 Number of days to flowering

Spike initiation was started three months after planting. Flowering commenced six days after spike initiation.

Table 16 Effect of light and nutrient levels on chlorophyll 'a' and chlorophyll 'b' content of leaves (mg g^{-1} fresh weight)

Light levels	Chlorophyll a			Chlorophyll b		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1	0.315	0.405	0.475	0.269	0.379	0.444
L_2	0.379	0.457	0.540	0.344	0.421	0.500
L_3	0.476	0.484	0.597	0.448	0.459	0.557
F	S	S	S	S	S	S
SE(±M)	0.014	0.005	0.006	0.013	0.004	0.004
CD(0.05)	0.047	0.018	0.021	0.045	0.015	0.014
Nutrient levels						
N_1	0.345	0.438	0.536	0.316	0.410	0.498
N_2	0.411	0.458	0.541	0.362	0.425	0.504
N_3	0.415	0.449	0.534	0.383	0.423	0.499
F	S	S	NS	S	S	NS
P_1	0.386	0.447	0.531	0.348	0.413	0.498
P_2	0.382	0.451	0.542	0.348	0.426	0.502
P_3	0.401	0.448	0.538	0.366	0.419	0.502
F	S	NS	NS	S	S	NS
K_1	0.403	0.446	0.538	0.365	0.419	0.496
K_2	0.381	0.449	0.534	0.342	0.422	0.501
K_3	0.387	0.451	0.539	0.354	0.418	0.503
F	S	NS	NS	S	NS	NS
SE(±M)	0.005	0.003	0.012	0.005	0.003	0.004
CD(0.05)	0.013	0.009	0.004	0.013	0.010	0.011

Table 17 Effect of light and nutrient levels on total chlorophyll (mg g^{-1} fresh weight) and chlorophyll (a/b)

Light levels	Chlorophyll					
	4 MAP		8 MAP		12 MAP	
	a+b	a/b	a+b	a/b	a+b	a/b
L_1	0.584	1.171	0.784	1.069	0.923	1.069
L_2	0.722	1.099	0.878	1.086	1.039	1.078
L_3	0.924	1.063	0.943	1.054	1.154	1.072
F	S	NS	S	NS	S	NS
SE($\pm$M)	0.026	0.295	0.007	0.324	0.009	0.413
CD(0.05)	0.089		0.025		0.031	
Nutrient levels						
N_1	0.661	1.696	0.848	1.068	1.034	1.076
N_2	0.773	1.494	0.884	1.080	1.045	1.073
N_3	0.798	1.394	0.872	1.060	1.033	1.070
F	S	NS	S	NS	S	NS
P_1	0.735	1.526	0.860	1.082	1.029	1.060
P_2	0.730	1.557	0.877	1.059	1.044	1.079
P_3	0.767	1.469	0.867	1.069	1.040	1.072
F	S	NS	S	NS	S	NS
K_1	0.768	1.473	0.865	1.064	1.040	1.072
K_2	0.729	1.561	0.871	1.064	1.030	1.077
K_3	0.741	1.523	0.869	1.079	1.042	1.072
F	S	NS	S	NS	S	NS
SE($\pm$M)	0.004	0.355	0.002	0.344	0.004	0.128
CD(0.05)	0.011	0.982	0.005	0.954	0.013	0.357

Table 18 Effect of interaction of light with N on chlorophyll 'a' and chlorophyll 'b' content (mg g^{-1} fresh weight) of leaves

Treatment	Chlorophyll a			Chlorophyll b		
	4 MAP	8 MAP	12 MAP	4 MAP	8 MAP	12 MAP
L_1N_1	0.241	0.407	0.469	0.211	0.379	0.439
L_1N_2	0.331	0.409	0.472	0.261	0.386	0.437
L_1N_3	0.373	0.398	0.484	0.334	0.372	0.455
L_2N_1	0.344	0.438	0.539	0.309	0.413	0.499
L_2N_2	0.377	0.463	0.544	0.345	0.411	0.501
L_2N_3	0.414	0.469	0.535	0.379	0.439	0.501
L_3N_1	0.448	0.469	0.599	0.426	0.439	0.557
L_3N_2	0.526	0.502	0.607	0.480	0.477	0.574
L_3N_3	0.456	0.481	0.584	0.438	0.460	0.541
F	S	S	S	S	S	S
SE(±M)	0.008	0.006	0.008	0.008	0.006	0.007
CD(0.05)	0.023	0.016	0.021	0.023	0.017	0.020

Flowers opened from top to bottom. In six to seven days all flowers opened.

Light and nutrient levels were found to have significant effect on the number of days taken for flowering in bush pepper (Table 19).

Early flowering was noted at L_3 level (84.90 days) followed by L_2. Among the nutrient levels, early flowering was noted at N_1, P_1 and K_3 levels, K_3 was on par with K_1.

Light x nutrient interaction was significant (Table 20). L_3N_1, L_3P_1 and L_3K_2 recorded early flowering compared to all others; L_3K_2 was on par with L_3K_1. Under L_1, plants receiving N_1, P_3 and K_3 flowered earlier, L_1P_3 and L_1K_3 were on par with L_1P_1 and L_1K_1 respectively. Under L_2 plants receiving N_1, P_1 and K_3 flowered earlier compared to others.

4.3.2 Dry matter production (DMP)

Significant variation was noticed among light intensities with respect to the dry matter production (Table 19).

DMP at L_3 (73.34 g) was found significantly superior to L_1 and L_2. There was a drastic reduction in DMP at L_1 (39.16 g).

There was significant difference among drymatter production at different N and P levels. Maximum drymatter was produced at N_2 (55.57 g) and P_1 (55.92 g) levels. N_2 was on par

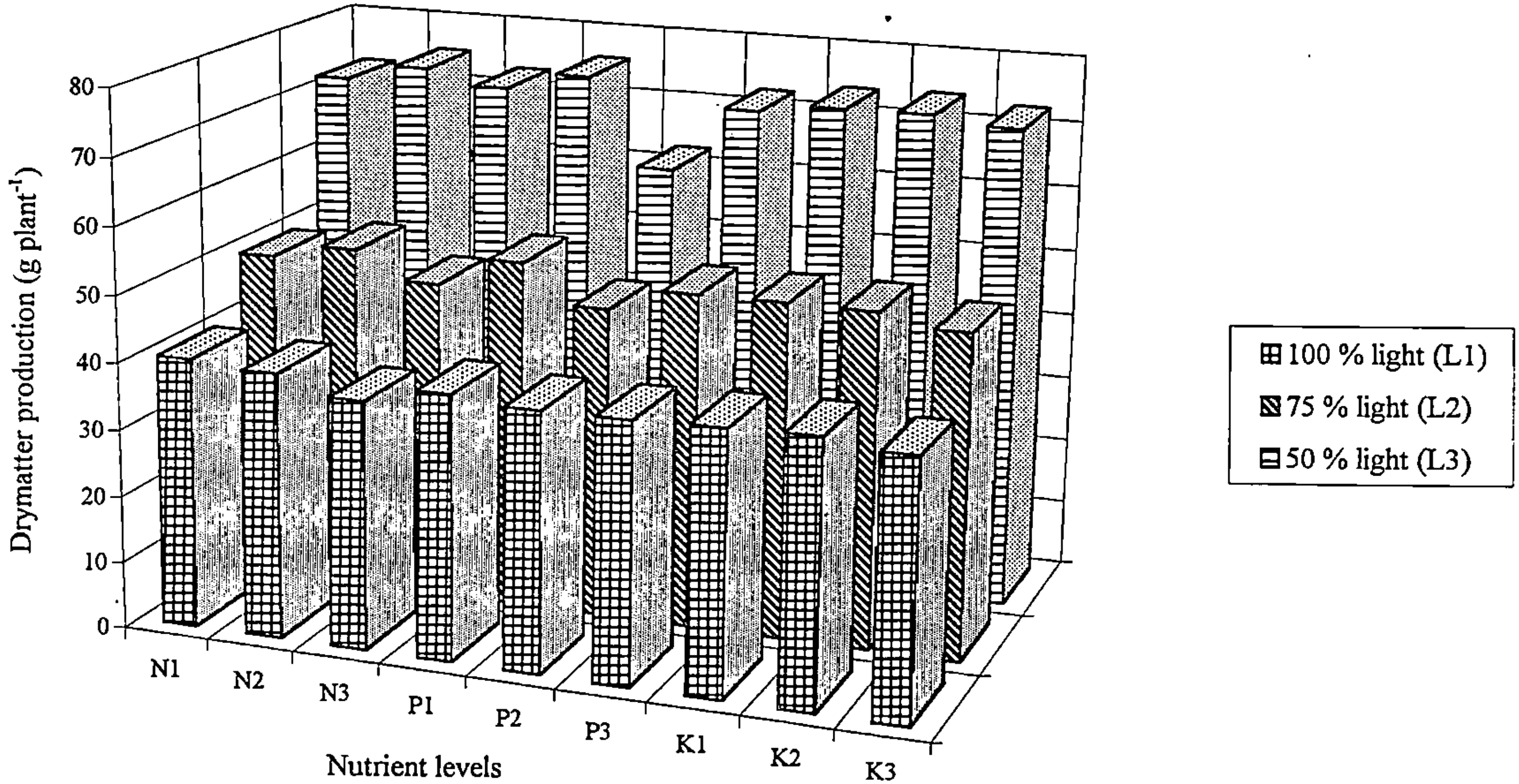
Table 19 Effect of light and nutrient levels on the mean number of days to flowering and drymatter production (g $bush^{-1}$) of the plant

Light levels	Number of days to flowering	Drymatter production (g $bush^{-1}$)
L_1	94.07	39.16
L_2	89.07	49.94
L_3	84.90	73.34
F	S	S
SE($\pm$M)	1.145	2.003
CD(0.05)	3.96	6.931
Nutrient levels		
N_1	87.13	54.22
N_2	90.13	55.57
N_3	90.80	52.65
F	S	S
P_1	88.90	55.92
P_2	89.86	51.68
P_3	89.30	54.85
F	S	S
K_1	88.90	54.45
K_2	91.60	54.67
K_3	87.47	53.32
F	S	NS
SE($\pm$M)	0.787	0.70
CD(0.05)	2.18	1.94

Table 20 Effect of interaction of light with N, P and K on the mean number of days to flowering and drymatter production (g $bush^{-1}$) of the plant

Treatment	No. of days to flowering	Drymatter production (g $bush^{-1}$)
L_1N_1	92.6	40.52
L_1N_2	95.4	39.77
L_1N_3	94.2	37.19
L_2N_1	86.4	49.79
L_2N_2	89.8	52.02
L_2N_3	91.0	47.99
L_3N_1	82.4	72.34
L_3N_2	85.2	74.91
L_3N_3	87.2	72.77
F	S	S
L_1P_1	95.2	39.66
L_1P_2	93.8	38.87
L_1P_3	93.2	38.96
L_2P_1	88.2	52.59
L_2P_2	90.8	46.87
L_2P_3	88.2	50.35
L_3P_1	83.3	75.50
L_3P_2	85.0	62.29
L_3P_3	86.5	72.24
F	S	S
L_1K_1	93.4	39.30
L_1K_2	97.8	39.64
L_1K_3	91.0	38.54
L_2K_1	89.0	50.44
L_2K_2	92.8	50.46
L_2K_3	85.2	48.72
L_3K_1	84.4	73.59
L_3K_2	84.2	73.74
L_3K_3	86.2	72.70
F	S	S
SE(±M)	1.032	1.212
CD(0.05)	2.86	3.360

Fig 4 Effect of nutrient levels on the drymatter production (g plant^{-1}) of bush pepper under varying levels of light



with N_1 (54.22 g). DMP was not affected due to potassium application (Table 19).

Light x nutrient interaction was also found significant (Table 20).

The different N, P and K levels performed better under L_3 compared to L_1 and L_2. Maximum drymatter was produced by L_3N_2, L_3P_1 and L_3K_2 levels. L_3N_2 and L_3K_2 were on par with L_3N_1 and L_3K_1 respectively. Under L_1 maximum drymatter production was recorded by the plants receiving N_1, P_1 and K_2 levels of nutrients, K_2 was on par with K_1. Under L_2 plants receiving N_2, P_1 and K_2 levels produced maximum dry matter, N_2 and K_2 were on par with N_1 and K_1 respectively.

NP, NK, PK, NPK and LNPK interactions were not significant.

4.3.3 Number of spikes

The results on the number of spikes produced (Table 21) showed that light intensities and P and K application did not have any significant effect. The effect of N levels was found to be significant. Maximum number of spikes (43.75) were produced at N_2 level.

The interaction of light levels with N (Table 22) showed that maximum number of spikes (52.52) was produced by the combination L_3N_2. Under L_1 and L_2 levels also maximum number of spikes were produced at N_2 level. LP and LK interactions were not significant.

NP interaction was significant. N_2P_2 recorded the maximum number of spikes which was on par with N_2P_1 (Table 23).

The interaction of light with NP was significant (Table 24). N_2P_2 under L_3 recorded the maximum number of spikes (55.89) but it was on par with N_2P_1 and N_1P_3 combinations. Under L_1 and L_2 maximum number of spikes were produced by N_2P_3.

4.3.4 Number of developed berries

Light intensities had no significant effect on the number of developed berries, though maximum number of developed berries (1582.06) were produced at L_3 followed by L_2 (Table 21).

N and P fertilization had significant effect. Of the different levels tried, N_2 and P_2 recorded the maximum number of developed berries (1518.09 and 1385.53) but P_2 was found to be on par with P_1. K had no significant effect on this character (Table 21).

LN, LP and LK interactions were found to have significant effect on this character (Table 22). L_3N_2 and L_3P_2 were significantly superior to other combinations. Among LK combinations L_3K_2 was found to produce maximum number of developed berries (1649.59) but it was on par with L_3K_1 (1578.74). Under L_1 level, N_1, P_1 and K_1 and under L_2 level N_1, P_2 and K_1 recorded maximum number of developed berries. Under L_2 level P_2 was on par with P_1.

NP interaction was also significant (Table 23). N_2P_2 recorded the maximum number of developed berries (1636.33).

The interaction of light with NP was significant (Table 24). $L_3N_2P_2$ recorded the maximum number of developed berries (2070) which was on par with $L_3N_2P_1$ and $L_3N_1P_3$. Under L_1 and L_2 levels, N_2P_2 produced the maximum number of berries.

4.3.5 Number of undeveloped berries

The light intensities did not have any significant influence on the number of undeveloped berries, but results presented in Table 21 showed that undeveloped berries were minimum at L_3 level (293.72) and maximum at L_1 level (375.94).

N and P fertilization had significant effect on this character. Undeveloped berries were minimum at N_2 and P_2 levels and maximum at N_3 and P_3 levels.

LN, LP and LK interactions (Table 22) were significant. L_3N_2, L_3P_2 and L_3K_2 produced the minimum number of undeveloped berries, maximum being at L_1N_3, L_1P_3 and L_1K_1. Under L_1 level minimum number of undeveloped berries were at N_2, P_2 and K_2

levels, L_1P_2 was on par with L_1P_1. Under L_2 minimum undeveloped berries were recorded at N_1, P_2 and K_3 levels, but L_2K_3 was on par with L_2K_2.

NP interaction was also significant (Table 23). N_2P_2 recorded the minimum number of undeveloped berries and N_3P_3 the maximum.

The interaction of light with NP showed that the combination N_3P_2 produced minimum number undeveloped berries of at L_3 level (Table 24). Under L_1 minimum number of undeveloped berries were produced at N_3P_3 which was on par with N_3P_2 level. Under L_2 minimum undeveloped berries were at N_3P_3 which was on par with N_1P_3.

4.3.6 Fresh weight of berries

There was variation in the fresh weight of berries under different light intensities, though not significant (Table 21). Maximum berry yield of (186.85 g) was recorded by L_3 and the lowest yield of 123.64 g by L_1.

N and P application had significant influence on this character. Maximum fresh berry yield was recorded at N_2 and P_2 levels. Higher levels of N and P reduced the berry yield. K application was not significant (Table 21).

The interaction of light with N, P and K was significant (Table 22). L_3N_2, L_3P_2 and L_3K_2 combinations recorded maximum berry yield but the combinations L_3P_2 and L_3K_2 were found to be on par with L_3P_1 and L_3K_1 respectively.

NP interaction showed that N_2P_2 was the superior combination which recorded a fresh berry yield of 191.75 g (Table 23).

The interaction of light with NP showed that highest fresh berry yield was recorded by the treatment combination N_2P_2 under L_3 (244.77 g) which was on par with $L_3N_2P_1$ and $L_3N_1P_3$ (Table 24). Lowest berry yield of 99.67 g was recorded under L_1 by the treatment combination N_3P_3. Under L_1 and L_2 maximum fresh berry yield was recorded by the combination N_2P_2.

4.3.7 Dry weight of berries

The different light intensities did not have any significant effect on the dry weight of berries (Table 21). However, maximum dry berry yield of 71.31 g was obtained under L_3 and minimum yield of 47.29 g under L_1.

N and P fertilization showed significant effect on the dry berry yield. N_2 and P_2 levels recorded the highest yields (Table 21).

The interaction effect of light and nutrient levels was also significant (Table 22). L_3N_2, L_3P_2 and L_3K_2 were the superior combinations. The combination L_3K_2 was found to be on par with L_3K_1.

Table 21 Effect of light and nutrient levels on the number of spikes, developed berries, undeveloped berries, fresh weight and dry weight of berries $bush^{-1}$

Light levels	Number of spikes	Number of developed berries	Number of undeveloped berries	Fresh weight of berries (g)	Dry weight of berries (g)
L_1	31.42	1081.81	375.94	123.64	47.29
L_2	37.72	1323.10	339.73	153.72	58.67
L_3	43.15	1582.06	293.72	186.85	71.31
F	NS	NS	NS	NS	NS
SE(±M)	6.256	245.006	51.959	25.727	8.603
Nutrient levels					
N_1	37.36	1332.58	332.83	155.22	59.36
N_2	43.75	1518.09	291.90	177.85	68.70
N_3	31.17	1136.31	384.65	131.13	49.21
F	S	S	S	S	S
P_1	38.01	1321.67	338.23	154.64	59.04
P_2	38.36	1385.53	321.54	161.62	61.36
P_3	35.91	1279.78	349.60	147.94	56.87
F	NS	S	S	S	S
K_1	38.36	1350.21	348.72	158.45	60.47
K_2	37.41	1340.94	328.41	156.22	59.76
K_3	36.52	1295.83	332.55	149.33	57.05
F	NS	NS	NS	NS	NS
SE(±M)	0.998	30.571	8.215	3.747	1.405
CD(0.05)	2.766	84.740	22.770	10.385	3.894

Table 22 Effect of interaction of light with N, P and K on the number of spikes, developed berries, undeveloped berries, fresh weight (g) and dry weight (g) of berries $bush^{-1}$

Treatment	Number of spikes	Number of developed berries	Number of undeveloped berries	Fresh weight of berries (g)	Dry weight of berries (g)
L_1N_1	32.00	1077.96	395.89	122.99	47.39
L_1N_2	35.44	1208.63	287.85	140.20	53.48
L_1N_3	26.81	958.85	444.07	107.71	41.00
L_2N_1	34.74	1274.59	317.63	149.33	56.90
L_2N_2	43.30	1479.26	319.81	171.44	66.91
L_2N_3	35.11	1215.44	381.74	140.40	52.21
L_3N_1	45.33	1645.19	284.96	193.35	73.80
L_3N_2	52.52	1866.37	268.04	221.91	85.71
L_3N_3	31.59	1234.63	328.15	145.29	54.43
F	S	S	S	S	S
L_1P_1	32.89	1122.59	366.74	128.50	49.66
L_1P_2	30.48	1061.93	362.48	122.55	46.29
L_1P_3	30.89	1060.93	398.59	119.86	45.92
L_2P_1	38.37	1320.81	346.11	153.82	58.91
L_2P_2	40.41	1413.15	315.48	164.08	62.10
L_2P_3	34.37	1235.33	357.59	143.27	55.01
L_3P_1	42.78	1521.59	301.85	181.62	68.55
L_3P_2	44.19	1681.52	280.67	198.25	75.70
L_3P_3	42.48	1543.07	292.63	180.67	69.70
F	NS	S	S	S	S
L_1K_1	33.15	1109.33	385.33	127.74	49.15
L_1K_2	30.15	1055.37	374.70	121.19	46.48
L_1K_3	30.96	1080.74	375.94	121.97	46.27
L_2K_1	39.67	1362.66	344.89	160.52	61.49
L_2K_2	36.70	1317.85	339.73	152.21	57.92
L_2K_3	36.78	1288.89	327.30	148.44	56.60
L_3K_1	42.26	1578.74	315.93	187.10	70.75
L_3K_2	45.37	1649.59	270.81	195.26	74.88
L_3K_3	41.81	1517.89	294.41	178.18	68.31
F	NS	S	S	S	S
SE(±M)		52.951	14.228	6.489	2.433
CD(0.05)		146.774	39.439	17.988	6.745

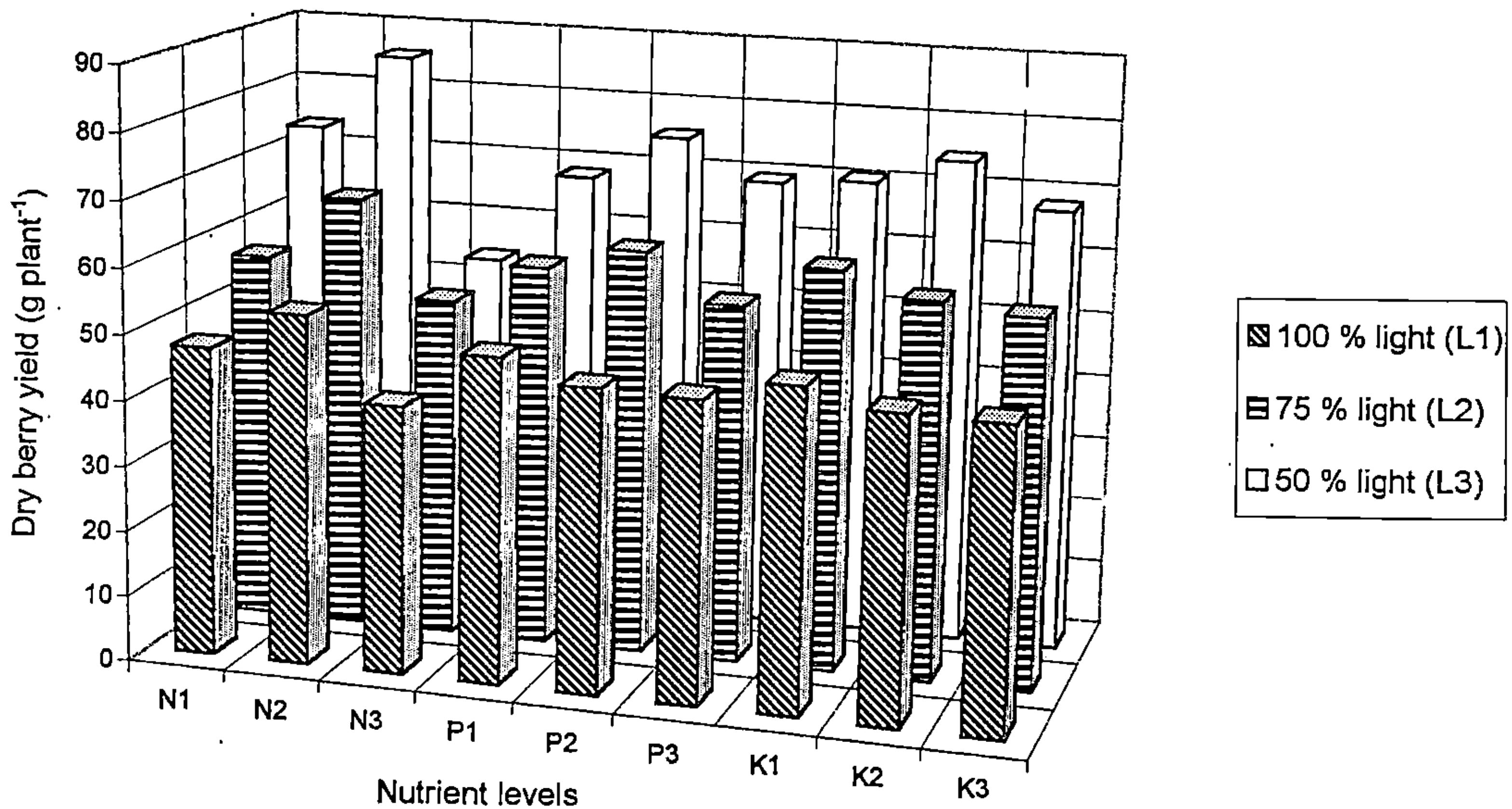
Table 23 Effect of NP interaction on the number of spikes, developed berries, undeveloped berries, fresh weight (g) and dry weight (g) of berries bush^{-1}

Treatment	No.of spikes	No.of developed berries	No. of undeveloped berries	Fresh weight (g)	Dry weight (g)
N_1P_1	36.00	1247.11	321.52	146.16	55.66
N_1P_2	37.56	1329.22	336.52	161.16	61.69
N_1P_3	38.52	1358.41	340.44	158.36	60.73
N_2P_1	42.56	1462.89	297.07	172.65	67.81
N_2P_2	45.59	1636.33	255.78	191.75	72.06
N_2P_3	43.11	1455.04	322.85	169.14	66.24
N_3P_1	35.48	1255.00	370.33	145.13	53.64
N_3P_2	31.93	1128.04	372.33	131.96	50.34
N_3P_3	26.11	1025.89	411.30	116.31	43.65
F	S	S	S	S	S
SE(±M)	1.728	52.95	14.228	6.489	2.433
CD(0.05)	4.790	146.774	39.439	17.988	6.745

Table 24 Effect of interaction of light with NP on the number of spikes, developed berries, undeveloped berries, fresh weight (g) and dry weight (g) of berries bush^{-1}

Treatment	Number of spikes	Number of developed berries	Number of undeveloped berries	Fresh wt. of berries (g)	Dry weight berries (g)
$L_1N_1P_1$	35.56	1148.67	337.00	132.04	49.59
$L_1N_1P_2$	29.89	1021.11	400.67	116.43	45.51
$L_1N_1P_3$	30.56	1064.11	450.00	120.51	47.06
$L_1N_2P_1$	32.89	1153.56	446.56	132.64	53.45
$L_1N_2P_2$	36.11	1270.33	496.11	148.56	54.17
$L_1N_2P_3$	37.33	1202.00	389.56	139.39	52.83
$L_1N_3P_1$	30.22	1065.56	316.67	120.82	45.94
$L_1N_3P_2$	25.44	894.33	299.00	102.65	39.20
$L_1N_3P_3$	24.78	916.67	257.89	99.67	37.86
$L_2N_1P_1$	34.44	1256.44	329.89	149.56	57.25
$L_2N_1P_2$	38.00	1428.22	350.11	165.01	62.51
$L_2N_1P_3$	31.78	1139.11	272.89	133.42	50.92
$L_2N_2P_1$	40.11	1351.56	353.56	158.77	63.23
$L_2N_2P_2$	44.78	1568.67	381.33	181.92	68.40
$L_2N_2P_3$	45.00	1517.56	410.33	173.62	69.12
$L_2N_3P_1$	40.56	1354.44	354.89	153.12	56.25
$L_2N_3P_2$	38.44	1242.56	341.33	145.30	55.38
$L_2N_3P_3$	26.33	1049.33	263.22	122.79	44.99
$L_3N_1P_1$	38.00	1336.22	297.67	156.87	60.14
$L_3N_1P_2$	44.78	1727.33	270.56	202.04	77.04
$L_3N_1P_3$	53.22	1872.00	286.67	221.14	84.22
$L_3N_2P_1$	54.67	1883.56	310.89	226.55	86.76
$L_3N_2P_2$	55.89	2070.00	356.44	244.77	93.62
$L_3N_2P_3$	47.00	1645.56	317.11	194.40	76.76
$L_3N_3P_1$	35.67	1345.00	297.00	161.44	58.74
$L_3N_3P_2$	31.89	1247.22	250.89	149.94	56.43
$L_3N_3P_3$	27.22	1111.67	256.22	126.48	48.11
F	S	S	S	S	S
SE(±M)	2.993	91.714	24.644	11.24	4.215
CD(0.05)	8.297	254.219	68.310	31.16	11.683

Fig. 5 Effect of nutrient levels on the dry berry yield (g plant^{-1}) of bush pepper under varying levels of light



NP interaction (Table 23) had significant effect on the dry berry yield, N_2P_2 recorded the maximum dry berry yield, but it was on par with N_2P_1.

The interaction of light with NP was also significant (Table 24). Maximum dry berry yield (93.62 g) was recorded by the combination $L_3N_2P_2$ which was on par with $L_3N_2P_1$ and $L_3N_1P_3$. Under L_1 and L_2 maximum yield was produced by the combinations N_2P_2 and N_2P_3 respectively, N_2P_3 under L_2 was on par with N_2P_2. Lowest dry berry yield of 37.86 g was recorded under L_1 by the combination N_3P_3.

4.4 Quality parameters

4.4.1 Volatile oil

The different light intensities tried did not have any influence on the volatile oil content of berries (Table 25).

N application had significant effect. Maximum volatile oil content of 3.55 per cent was at N_2 level which was on par with N_1 (3.45 per cent) (Table 25).

Light x Nitrogen interaction was also found to be significant. The combination L_3N_3 recorded the maximum volatile oil content of 3.58 per cent (Table 26). LP and LK interactions were not significant.

Table 25 Effect of light and nutrient levels on the volatile oil and oleoresin content of berries

Light levels	Volatile oil (%)	Oleoresin (%)
L_1	3.48	11.283
L_2	3.49	11.928
L_3	3.49	12.129
F	NS	NS
SE(±M)	0.094	0.217
Nutrient levels		
N_1	3.45	11.729
N_2	3.55	11.893
N_3	3.47	11.719
F	S	NS
P_1	3.47	11.574
P_2	3.52	11.829
P_3	3.48	11.937
F	NS	S
K_1	3.48	11.783
K_2	3.49	11.774
K_3	3.50	11.784
F	NS	NS
SE(±M)	0.025	0.093
CD(0.05)	0.070	0.258

Table 26 Effect of interaction of light with N on the volatile oil content (%) of berries

Treatment	volatile oil(%)
L_1N_1	3.46
L_1N_2	3.51
L_1N_3	3.46
L_2N_1	3.45
L_2N_2	3.55
L_2N_3	3.47
L_3N_1	3.45
L_3N_2	3.48
L_3N_3	3.58
F	S
SE($\pm$M)	0.044
CD	0.121

4.4.2 Oleoresin

P application alone had significant effect on the oleoresin content of berries. Maximum oleoresin content was recorded at P_3 level (11.937 per cent) which was on par with P_2 level (11.829 per cent) (Table 25).

4.5 Uptake of major nutrients

4.5.1 Nitrogen

The uptake of nitrogen increased significantly from 0.680 g to 1.082 g when light intensity decreased from L_1 to L_3 level (Table 27).

N, P and K fertilization significantly influenced the uptake of N. With each increase in N level there was significant increase in N uptake, maximum being at N_3 (0.919 g). With increase in P level also there was increase in N uptake, maximum was at P_3 level which was significantly superior to P_1 and P_2. With incremental doses of K, N uptake increased, maximum was at K_3 level but it was on par with K_2 (Table 27).

The interaction of light and nutrients was also significant. Maximum uptake was noted at L_3N_3, L_3P_3 and L_3K_3, L_3K_3 was on par with L_3K_1 and L_3K_2. Under L_1 and L_2 maximum N uptake was at N_2, P_3 and K_3 levels of nutrients (Table 28).

4.5.2 Phosphorus

The uptake of phosphorus was found to be the highest under L_3 (69.9 mg) followed by L_2 (49.5 mg). Lowest uptake of 37.2 mg was noted at L_1 (Table 27).

An increasing trend in P uptake was observed with increase in nutrient levels. Maximum P uptake was noted at N_3, P_3 and K_3 levels (Table 27).

Significant interaction was noted between light intensities and nutrient levels. Maximum P uptake was recorded by L_3N_3, L_3P_3 and L_3K_3 combinations. Under L_1 maximum P uptake was noted at N_2, P_3 and K_3 and under L_2 at N_2, P_3 and K_2 levels of nutrients (Table 28).

4.5.3 Potassium

Potassium uptake also followed the same pattern as that of nitrogen and phosphorus, maximum uptake being at L_3 (1.598 g) (Table 27).

K uptake was found to be increasing with increase in nutrient levels. N, P and K levels produced a steady increase in K uptake (Table 27).

Significant interaction was noted between light and nutrient levels. Maximum K uptake was recorded by L_3N_3, L_3P_3 and

Table 27 Effect of light and nutrient levels on the uptake of nutrients

Light levels	Uptake		
	N (g $bush^{-1}$)	P (mg $bush^{-1}$)	K (g $bush^{-1}$)
L_1	0.680	37.2	0.843
L_2	0.842	49.5	1.152
L_3	1.082	69.9	1.598
F	S	S	S
SE ±M	0.045	0.838	0.004
CD(0.05)	0.156	2.9	0.015
Nutrient levels			
N_1	0.772	40.8	0.845
N_2	0.914	56.4	1.325
N_3	0.919	59.4	1.425
F	S	S	S
P_1	0.804	47.1	1.035
P_2	0.858	53.4	1.210
P_3	0.943	56.1	1.355
F	S	S	S
K_1	0.830	48.3	1.115
K_2	0.877	53.7	1.240
K_3	0.899	54.3	1.240
F	S	S	S
SE(±M)	0.017	0.397	0.036
CD(0.05)	0.048	1.101	0.100

Table 28 Effect of interaction of light with N, P and K on the uptake of nutrients

Treatment	Uptake		
	N (g $bush^{-1}$)	P (mg $bush^{-1}$)	K (g $bush^{-1}$)
L_1N_1	0.601	34.2	0.720
L_1N_2	0.746	38.4	0.900
L_1N_3	0.695	38.4	0.910
L_2N_1	0.792	37.5	0.775
L_2N_2	0.873	55.8	1.335
L_2N_3	0.863	55.2	1.345
L_3N_1	0.922	50.4	1.040
L_3N_2	1.122	74.7	1.740
L_3N_3	1.201	84.6	2.015
F	S	S	S
L_1P_1	0.598	33.6	0.750
L_1P_2	0.708	36.9	0.805
L_1P_3	0.736	40.8	0.970
L_2P_1	0.778	43.8	0.950
L_2P_2	0.830	51.6	1.225
L_2P_3	0.919	52.8	1.275
L_3P_1	1.036	63.3	1.395
L_3P_2	0.036	71.1	1.595
L_3P_3	1.174	75.0	1.810
F	S	S	S
L_1K_1	0.603	35.4	0.835
L_1K_2	0.698	37.8	0.825
L_1K_3	0.741	38.1	0.870
L_2K_1	0.819	45.9	1.040
L_2K_2	0.849	53.1	1.245
L_2K_3	0.859	49.8	1.160
L_3K_1	1.067	64.8	1.460
L_3K_2	1.083	71.7	1.650
L_3K_3	1.096	73.8	1.685
F	S	S	S
SE(±M)	0.020	1.09	0.063
CD(0.05)	0.056	3.021	0.175

L_3K_3 combinations, L_3K_3 was on par with L_3K_2. Under L_1 maximum uptake was at N_3, P_3 and K_3 levels and under L_2 at N_3, P_3 and K_2 levels of nutrients (Table 28).

4.6 Soil NPK content

Table 29 presents data on soil NPK content as influenced by light and fertilizer treatments.

There was significant differences in N, P and K content under different light intensities. Maximum N (0.0151 per cent), P (0.00116 per cent) and K (0.0149 per cent) content was recorded under L_1 followed by L_2.

Soil N content was found to be increasing steadily with increasing N levels. With increasing P levels soil N decreased. Maximum soil N was at K_3 level which was on par with K_1. At K_2 there was a significant reduction in soil N content.

Soil P content increased significantly with increasing levels of P and K. Maximum soil P content was at N_2 level, at N_3 there was a reduction in soil P content.

Soil K content decreased with increasing levels of N. soil K content increased upto P_2 and K_2 levels and then showed a declining trend.

Table 29 Effect of light and nutrient levels on soil nutrient status

Light levels	N (%)	P (%)	K (%)
L_1	0.0151	0.00116	0.0149
L_2	0.0144	0.00107	0.0140
L_3	0.0138	0.00101	0.0135
F	S	S	S
SE(±M)	0.00005	0.00003	0.00021
CD(0.05)	0.00019	0.00009	0.00071
Nutrient levels			
N_1	0.0138	0.00109	0.0144
N_2	0.0146	0.00106	0.0142
N_3	0.0149	0.00111	0.0139
F	S	NS	S
P_1	0.0146	0.00102	0.0141
P_2	0.0144	0.00104	0.0144
P_3	0.0143	0.00119	0.0140
F	NS	S	S
K_1	0.0145	0.00102	0.0141
K_2	0.0140	0.00105	0.0143
K_3	0.0148	0.00117	0.0142
F	S	S	S
SE(±M)	0.000043	0.000022	0.00007
CD(0.05)	0.00012	0.00006	0.0002

Bush pepper plants started flowering 3 MAP. Yielding commenced from nineth month onwards. Since bush pepper plants are perennial in nature, it will take atleast two years for showing the full response of a treatment. In this study observations on growth characters and yield was recorded only upto 12 months. Hence it is too early to work out the economics of the treatments.

DISCUSSION

DISCUSSION

The economic produce of a crop plant is mainly determined by light since the energy provided by photophosphorylation plays a pivotal role in the metabolism reactions of crop plants. In general, crops differ markedly in their adaptation to light intensities. Shading of crop plants at various stages of growth is a cultural operation which influences plant growth, yield and quality of the produce.

In the present experiment an attempt has been made to compare the growth, yield and quality of bush pepper under varying light intensities as influenced by inorganic fertilization. The results obtained are discussed in the light of the research findings obtained elsewhere, under the following headings.

5.1 Light

5.1.1 Effect on growth and yield

The varying light intensities had significant influence on all the growth characters including the length and number of primary and secondary branches, internodal length, number of leaves and total leaf area.

The length of primary and secondary branches increased with decrease in light intensity from 100 to 50 per cent (Table 2). Maximum length of primary branch (28.43 cm) and secondary branch (29.28 cm) was attained under 50 per cent light. The longer vines obtained under shaded condition may be due to lesser photosynthetically active radiation obtained under this situation (Attridge, 1990). High irradiance result in high rates of transpiration which are likely to result in internal deficiencies of water and a consequent retardation of cell division or cell elongation. This may be the possible reason for reduced length of branches under open condition. Similar results were reported in Maize (Moss and Stinson, 1961), tobacco (Panicker *et al*., 1969), ginger (Aclan and Quisumbing, 1976) and pepper (Senanayake and Kirthisinghe, 1983).

The number of primary branches was significantly influenced by light at all the growth stages, but significant influence on the number of secondary branches was felt only after 6 months (Table 6). Branching was maximum under 50 per cent light. The reduction in photosynthetically active radiation received may be the reason for increased vegetative growth under partially shaded condition (Attridge, 1990). This is in agreement with the results obtained in pepper by Senanayake and Kirthisinghe (1983) and Mathai and Sasthry (1988).

Internodal length increased from 3.07 cm to 4.81 cm when light intensity decreased from 100 to 50 per cent (Table 10). Under shaded conditions the stem in general show a tendency to elongate resulting in longer internodes (Meyer and Anderson, 1952). Senanayake and Kirthisinghe (1983) reported similar results in black pepper. The internodes were shorter in full sunlight. This is in accordance with the reports of Attridge (1990).

Bush pepper produced maximum number of leaves when grown under 50 per cent light followed by plants under 75 per cent light (Table 12). Under shade the production as well as the retention of leaves was more. Under shaded conditions reduced radiation may prevent scorching or wilting of leaves caused by marked increase in temperature within the leaf tissue from strong sunlight (Aasha, 1986) and thereby increase the leaf life under shade resulting in maximum retention of leaves. This is in agreement with the findings of Nair (1964) in peppermint and Senanayake and Kirthisinghe (1983) in pepper. In the open condition the number of leaves was the minimum. This may be due to scorching and wilting of leaves under high light intensity (Aasha, 1986).

The total leaf area of plants followed the same pattern as the number of leaves, increasing from 100 per cent to 50 per cent light intensity (Table 12). The tendency of plants to increase the leaf area from no shading to moderate shading as observed in the present investigation may perhaps be a plant adaptation to expose larger photosynthetic surface under limited illumination (Attridge, 1990).

Plants under 50 per cent light flowered earlier (Table 19). Under full sunlight the vines took 94.07 days for flowering, while under 50 per cent light they took only 84.9 days. The favourable micro climate under 50 per cent light might have favoured earlier flowering. Also differentiation of photosynthates take place earlier in shade leaves compared to sunleaves (Anderson, 1955). This is in agreement with the results obtained by Mathi and Bahadli (1989) in pepper (*Capsicum annum* L.).

DMP was found to be high under shaded situation (Table 19). Maximum dry matter of 73.4 g was produced under 50 per cent light and there was a drastic reduction in dry matter production under 100 per cent light (39.16 g). The positive influence of different growth parameters like length and number of primary and secondary branches (Tables 2) number of leaves and total leaf area (Tables 12) might have reflected in the DMP of the plant. Similar increase in dry matter was reported in ginger under shaded condition by Ravisankar and Muthuswamy (1986) and Joseph (1992). Very high light intensity under open conditions may cause stomatal closure preventing entry of carbondioxide for assimilation as reported by Hardy (1958) or inactivation of enzymes due to increase in leaf temperature (Miginiac *et al.* 1990). This lead to reduction in photosynthates which has resulted in the drastic reduction of dry matter production under open condition.

Chlorophyll content increased with decreasing intensity of light (Table 16 and 17). The chlorophyll content was maximum at 50 per cent light. The increase in chlorophyll content under shaded conditions is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency (Attridge, 1990). This is in agreement with the findings of Shirley (1929), Collard *et al.* (1977), Lalithabai (1981) and Ramanujam and Jose (1984) in different crops.

The total number of spikes, number of developed and undeveloped berries, fresh weight and dry weight of berries were not significantly influenced by the varying light intensities. The vines flowered three months after planting and yielding started from nineth month onwards. So only four harvests could be recorded and that may be the reason for the nonsignificant effect of different light intensities on yield. Since bush pepper plants are perennial in nature it will take at least two years for showing the full response of a treatment.

However maximum yield was recorded under 50 per cent light followed by 75 per cent light. Minimum yield was recorded under the open condition (Table 21). Plants under 50 per cent light recorded maximum number of spikes (43.15), number of developed berries (1582.06), fresh weight of berries (186.85 g), dry weight of berries (71.31 g) and minimum number of undeveloped berries (293.72). The positive influence of number and length of secondary branches, dry matter production and flowering might have reflected in the yield of the plant. Under open condition the yield was minimum. This may be due to low leaf area exhibited by the plants throughout the growth period, which could have reduced the total photosynthates accumulated in the plant.

5.1.2 Effect on the uptake of nutrients

N, P and K uptake was found to be maximum at 50 per cent light (Table 27). The better vegetative growth of the plants under this light level and the increased dry matter production might have contributed to increased uptake of all the nutrients. Virzo and Alfani (1980) reported increased levels of N and K in the leaves of *Mentha piperita* under shaded condition compared to open condition. Lalithabai (1981) also reported increased N, P and K in all plant components of ginger and turmeric as a result of shading.

5.1.3 Effect on soil nutrient status

Light intensities showed significant influence on the soil nutrient status after the experiment (Table 29). Maximum soil nutrient content was recorded in the open condition and minimum at 50 per cent light. In the open condition transpiration rates are high. So there will not be sufficient moisture in the soil for the uptake of nutrients (Noggle and Fritz, 1992). This may be the possible reason for increased soil nutrient content under open condition. Under 50 per cent light due to adequate soil moisture and moderate light intensity there will be maximum uptake of nutrients and hence the soil nutrient content low.

5.2 Nutrients

5.2.1 Effect on growth and yield

Nutrient treatments showed significant influence on all the growth characters.

The length of primary and secondary branches was significantly influenced by nitrogen nutrition. The length of primary branch was maximum at 37.5 g N bush^{-1} and that of secondary branch at 25 g N bush^{-1} (Table 2). Influence of nitrogen in increasing the vegetative growth of plants is a universally accepted fact. The importance of nitrogen on the vegetative growth of black pepper was reported by De Waard (1989) and Nybe and Nair (1987). The positive influence of nitrogen on the length of branches is also in confirmity with the results reported by Joseph (1982), Singh *et al*. (1986) in chilli.

The results also indicated significant effect of phosphorus on the length of branches. The length of primary branches increased upto 37.5 g P (23.48 cm) and that of secondary branches upto 50 g P (21.74 cm) bush^{-1}. The increase in length may be due to the higher metabolic activity coupled with rapid cell division brought about by P (Bear, 1965). The significant effect of phosphorus on the length of branches was reported by De Waard (1969), Nybe and Nair (1987) in black pepper. Similar results were also reported by John (1989) in chilli.

Potassium fertilization had significant influence on the length of secondary branches only. Maximum length (24.66 cm) was recorded at 25 g K bush^{-1}. This indicate that the lowest level of K tried would have been sufficient for the crop. The importance of potassium on the vegetative growth of plants was reported by Tisdale *et al*. (1995). Potassium activate enzymes present in meristamatic tissue where cell division and cell elongation take place rapidly. Significant increase in the length of branches due to application of potassium has been reported by Dewaard (1969) and Nybe and Nair (1987) in black pepper and Ozaki *et al*. (1987) in chilli.

NP, NK and PK interactions showed significant effect on the length of secondary branches (Table 4). The combinations 25 g N and 50 g P bush^{-1} recorded maximum length under NP interaction, 37.5 g N and 50 g K bush^{-1} under NK interaction and

50 g P and 50 g K bush^{-1} under PK interaction. Evidently this is a case of complimentary effect of the nutrients (Tisdale *et al.*, 1995). Under NPK interaction 37.5 g N, 50 g P and 50 g K bush^{-1} recorded maximum length but 37.5 g N was on par with 25 g N bush^{-1}.

Branching was significantly influenced by the levels of nitrogen (Table 6). Increasing levels of N increased the number of branches upto 37.5 g N bush^{-1}. The number of primary branches increased from 2.38 to 3.37 and that of secondary branches from 8.21 to 9.14 with increase in the levels of nitrogen from 25 to 37.5 g bush^{-1}. The increase in the number of branches may be due to the increased nutrient absorption when the plants are fertilized as a result of which lateral meristems get stimulated and develop into branches (Tisdale *et al.*, 1995). Geetha and Aravindakshan (1992) reported increased branching with higher levels of N in bush pepper.

Application of P significantly influenced the number of branches. Maximum number of primary branches (3.26) were produced at 25 g P bush^{-1} and secondary branches at 37.5 g P bush^{-1}. Since P is a constituent of cell nucleus it is closely associated with cell division and meristamatic activity (Bear, 1965) and hence result in better branching. Geetha and Aravindakshan (1992) also reported similar results in bush pepper.

Potassium application proved significant on the production of primary branches. With increase in the level of potassium from 50 to 75 g $bush^{-1}$, the number of branches increased from 2.51 to 3.03 (Table 6). Potassium absorbed during the vegetative period of plant growth would have helped the production of maximum number of branches (Mengel and Kirbky, 1980). Singh *et al*. (1986) also reported similar results in chilli. When K level was increased to 100 g $bush^{-1}$ there was a significant reduction in the number of branches. This may be due to luxury consumption of K, without producing a corresponding increase in the number of branches. Secondary branch production was not affected by potash application. Lack of response to potassium in increasing the number of branches is in confirmity with the results of Kunju (1968) and Shukla *et al*. (1987) in chilli.

NP and NK interaction was significant on the production of branches (Table 8). The treatment combinations of 37.5 g N and 25 g P $bush^{-1}$ under NP interaction and 37.5 g N and 75 g K $bush^{-1}$ under NK interaction recorded maximum number of primary branches. Number of secondary branches were maximum at NP combination of 37.5 g each of N and P but 37.5 g P was on par with 25 g P $bush^{-1}$; and NK combination of 37.5 g N and 75 g K $bush^{-1}$. Evidently this is a case of increased metabolism resulting from the complimentary effects of these nutrients (Tisdale *et al*., 1995). Under NPK interaction the combination

37.5 g N, 25 g P and 75 g K bush^{-1} recorded maximum number of primary branches (Table 9).

N application alone had significant influence on the internodal length. Increasing doses of N increased the internodal length upto 37.5 g N. At 50 g N there was a reduction in internodal length. This indicates that 37.5 g N bush^{-1} may be sufficient for the crop. This finding is in accordance with the report of Nybe and Nair (1987) in black pepper and Haris (1989) in snakegourd.

Increasing doses of N increased the number of leaves, maximum number being at 50 g N bush^{-1}. Nitrogen being the most potential nutrient element for the vegetative growth and development of plants, its supply and availability would have helped the plant to produce more leaves. The importance of N in leaf development of pepper was reported by Nybe and Nair (1987), where more number of leaves were produced when N was supplied compared to no nitrogen application. Geetha and Aravindakshan (1992) also reported high leaf production at higher levels of N in bush pepper.

Phosphorus and potassium application also showed significant effect on the production of leaves. Maximum number of leaves were produced at 50 g P and 75 g K bush^{-1}, but they were on par with 25 g P and 50 g K bush^{-1} respectively. The increased root growth and activity resulting from the application of P and K would have encouraged extensive exploitation of both soil nutrients and moisture resulting in higher number of functional leaves. Similar results were reported by Geetha and Aravindakshan (1992) in bush pepper.

An increase in the total leaf area with increase in N application was observed 12 MAP. Thus more leaf area was made available to the crop for the various physiological activities including photosynthesis. Russel (1973) stated that for many crops the amount of leaf area available for photosynthesis is roughly proportional to the amount of N supplied. Geetha and Aravindakshan (1992) in their study on bush pepper also reported similar pronounced effect of N on leaf area.

Phosphorus and potassium application was also significant. Maximum leaf area was attained at 25 g P and 50 g K $bush^{-1}$. This may be due to the increased number of leaves at these levels. Pronounced effect of P and K on leaf area in bush pepper was reported by Geetha and Aravindakshan (1992).

NP interaction (Table 14) showed that maximum leaf area was recorded by the combination 50 g N and 25 g P $bush^{-1}$. Under NPK interaction, the combination 50 g N, 25 g P and 75 g K recorded maximum leaf area.

With increasing levels of N flowering delayed but with incremental doses of P, earliness in flowering was noted. It is a well established fact that N delays flowering while P promotes earliness in flowering (Russel, 1973). The influence of N in increasing the time of flowering is in confirmity with the results obtained in chilli by Chougule and Mahajan (1979) and Rao and Gulshanlal (1986). Results of inducing earliness in flowering due to application of higher doses of P were reported by Khan and Suryanarayana (1977) and Joseph (1982) in chilli. K application had influence on flowering. Profound influence of potassium on flowering was reported by Pimpini (1967).

Dry matter production was significantly influenced by the varying nutrient levels (Table 19). Maximum dry matter production was recorded at 37.5 g N bush^{-1}. Beyond this level DMP decreased. DMP at 37.5 g N was on par with 25 g N bush^{-1}. Among P and K levels maximum dry matter was recorded at 25 g P and 75 g K bush^{-1}, 75 g K was on par with 50 g K. Better vegetative growth of the plant at these nutrient levels might have reflected in the dry matter production. This can be attributed to the beneficial effect of fertilizers on both leaf number and leaf area under these shade levels (Tables 12 to 15). Beneficial effect of NPK fertilizers on DMP was reported by Geetha and Aravindakshan (1992) in bush pepper.

Nutrient treatments had profound influence on the chlorophyll content of the leaves. Maximum chlorophyll content was recorded at 50 g N, 50 g P and 75 g K bush^{-1}. In wheat, Moursi *et al.* (1976) and in *Ficus benjamina*, Collard *et al.* (1977) reported similar effects of fertilizer treatments on chlorophyll content.

Nitrogen and phosphorus application was found to have significant effect on yield (Tables 21 and 23). Maximum number of spikes (43.75), developed berries (1518.09), maximum fresh weight (177.85), dry weight (68.70) and minimum number of undeveloped berries (291.90) were recorded at 37.5 g each of N and P bush^{-1}. At higher level of 50 g N bush^{-1} there was a significant reduction in yield. This may be an indication that 37.5 g N bush^{-1} may be sufficient for obtaining optimum yield in bush pepper. Similar results were reported by Pillai *et al.* (1979) in the Panniyur-1 variety of black pepper. According to Pillai *et al.* (1987) higher levels of P gave higher yields in black pepper.

Potassium application did not gave any significant result. But the uptake of K increased with increased application of potassium (Table 19). In this connection it may be remembered that potassium is an element which is governed by the principle of 'luxury consumption' and as such plants may tend to absorb this element in excess of their requirement (Tisdale *et al.*, 1995).

From the foregoing discussion it has become clear that among the nutrient treatments N and P alone showed significant effect on the yield of bush pepper. N and P each at 37.5 g $bush^{-1}$ recorded maximum yield. Spike retention, berry set and number of developed berries were maximum at these levels, beyond which a declining trend was noticed. Hence 37.5 g each of N and P $bush^{-1}$ may be considered adequate for obtaining optimum yield in bush pepper.

Quality of the produce was influenced by N and P application. Nitrogen had significant effect on the volatile oil content (Table 25). Maximum volatile oil content of 3.55 per cent was recorded at 37.5 g N $bush^{-1}$, but this level was on par with 25 g N. Profound influence of N on the oil content of coriander seeds was reported by Rao *et al.*, (1983). P application showed significant influence on the oleoresin content (Table 25). Maximum oleoresin content of 11.93 per cent was recorded at 50 g P $bush^{-1}$, but this level was on par with 37.5 g P $bush^{-1}$. This indicates that 37.5 g P $bush^{-1}$ was sufficient for maximum oleoresin production.

5.2.2 Effect on uptake

There was a progressive increase in the uptake of N, P and K due to graded levels of nutrient application. Similar increase in the uptake of nutrients consequent to their application was reported by Pillai *et al*. (1987), Geetha (1990) and Sadanandan (1993).

5.2.3 Effect on soil nutrient status

There was an increase in soil N, P and K content after the experiment. This may be due to the residual effect of the nutrients. Such an increase in soil following their application was reported by many workers.

5.3 Interaction of light and nutrients

5.3.1 Effect on growth and yield

Significant interaction between light and nutrients was noted with respect to all growth characters studied viz. number and length of primary and secondary branches, internodal length, number of leaves and total leaf area.

In the open condition better expression of all growth characters was observed from low to medium level of nitrogen and phosphorus (25 to 35 g bush^{-1}). No response was obtained beyond these levels of N and P. Also the plants responded to the lowest dose of K (50 g bush^{-1}) in the open condition. Compared to plants under 75 and 50 per cent light the vegetative growth of plants in the open condition was poor. They produced comparatively less number of branches and leaves. In the open condition due to high light intensity, transpiration rates are high. So even when a plant is well watered, water stress may develop due to heat of the day if water absorption by roots fails to keep pace with transpiration (Noggle and Fritz, 1992). The poor soil moisture status and high soil temperature prevailing under direct sun might have limited the capacity of plants to utilise higher doses of nutrients.

Under 75 per cent light, better expression of all growth characters was at medium level of nitrogen (37.5 g $bush^{-1}$) except number of leaves and leaf area, where 25 g was found optimum. This may be due to the fact that the number of leaves produced and the leaf area developed by the application of 25 g N may be sufficient for intercepting 75 per cent of light. With respect of phosphorus better expression of all growth characters except length of primary branches was noted at the lowest level of P tried (25 g $bush^{-1}$). Phosphorus is an element which is involved in the early establishment of the plant (Tisdale *et al*., 1995). So higher doses of P might have not been utilized for vegetative growth. The uptake of P was also less at this level. This may be due to less moisture in the soil due to which absorption was restricted (Noggle and Fritz, 1992). All the growth characters studied responded upto 75 g K under this light intensity.

Under 50 per cent light, response to N levels was not consistent for different growth parameters. Being a perennial crop, pepper vines will take atleast two years for the full expression of all the growth characters due to treatments. This may be the reason for the non-consistent response of growth parameters to applied N.

Length of primary and secondary branches and internodal length were maximum at the lowest level of N tried (25 g $bush^{-1}$). Under shaded condition plants in general show a tendency to elongate (Attridge, 1990). So the role played by nutrients to effect increase in length is less marked compared to shade. This may be the reason for the increased length of primary and secondary branches and internodal length at the lowest dose of N. Number of leaves increased with increasing N and P doses. This may be due to better soil moisture status and moderate light intensity available to the plants which favoured increased uptake of nutrients (Table 27). Leaf area also showed the same trend as leaf number, with N application, since leaf number is the most important factor deciding the leaf area. The plants showed positive response to P and K levels from medium to highest level in terms of all growth characters. This may be due to the increased uptake of these nutrients under 50 per cent light.

Flowering was significantly influenced by the interaction of light and nutrients. Early flowering at all light intensities was recorded at the lowest level of N tried (25 g $bush^{-1}$). It is a universally accepted fact that N delays flowering since it prolongs vegetative growth (Tisdale *et al.*, 1995). This may be the reason for plants given the lowest level of N under all light intensities flowered earlier. Under shaded situation plants given 25 g p $bush^{-1}$ flowered early but in the open condition early flowering was recorded at 50 g p $bush^{-1}$. Shaded plants show a tendency to flower early, since differentiation of carbohydrates take place earlier in shade plants compared to sun plants (Anderson, 1955). So under shaded condition 25 g p $bush^{-1}$ might have been sufficient for inducing early flowering. The response to potassium was maximum at 75 per cent light followed by 50 per cent and 100 per cent light.

Under all light intensities dry matter production was more in low to medium levels of nutrients. The uptake of these nutrients also followed the same pattern (Table 28) which might have helped in increased dry matter production under these light intensities. Similar beneficial effect of nutrient treatments on dry matter production of bush pepper was reported by Geetha and Aravindakshan (1992).

The number of spikes, developed berries, undeveloped berries, fresh weight and dry weight of berries were significantly influenced by the combination effect of light, nitrogen and phosphorus. Maximum number of spikes, developed berries, maximum fresh weight and dry weight were recorded at medium level of N and P (37.5 g $bush^{-1}$). Number of undeveloped berries were also minimum at this level. This points that irrespective of the light levels 37.5 g $bush^{-1}$ of N and P was the optimum level for maximum production of berries in bush pepper. Light x potassium interaction was also significant on the number of developed and undeveloped berries, fresh weight and dry weight of berries under 50 per cent light. Medium level of K (75 g $bush^{-1}$) was found to be the best, but it was on par with 50 g $bush^{-1}$. This shows that under 50 per cent light 50 g of K $bush^{-1}$ was sufficient for the optimum production of berries in bush pepper.

5.3.2 Effect on uptake

N and P uptake under 100 per cent and 75 per cent light were maximum at medium levels of N (37.5 g $bush^{-1}$) and highest levels of P and K (50 g and 100 g $bush^{-1}$ respectively). K uptake under 100 per cent light was maximum at the highest level of K (100 g $bush^{-1}$). N, P and K uptake under 50 per cent light were at the highest levels of N, P and K. Under 75 per cent light K uptake was maximum at highest levels of N and p (50 g $bush^{-1}$) and medium level of K (75 g $bush^{-1}$). Under shaded condition, the soil moisture content will be more and this might have helped in the increased uptake of nutrients. But irrespective of the light intensities, the response in terms of yield was only upto 37.5 g N and p $bush^{-1}$.

SUMMARY

SUMMARY

An experiment was conducted at the Farming Systems Research Station, Kottarakkara to study the influence of NPK fertilizers under different light intensities on the growth, yield and quality of bush pepper. The treatments consisted of three levels of light (100, 75 and 50 per cent) and three levels each of N (25, 37.5, 50 g $bush^{-1}$), P (25, 37.5, 50 g $bush^{-1}$) and K (50, 75, 100 g $bush^{-1}$). The experiment was laid out in split plot design assigning light levels to the main plot and nutrient levels to the subplot and was replicated three times. Black high density polyethylene nets fabricated for 50 per cent and 75 per cent light intensity were used for the experiment. Nitrogen, phosphorus and potassium were supplied in the form of urea, mussoriphos and muriate of potash respectively. The salient findings of the study are summarised below.

The length of primary branches reduced significantly under open condition. Maximum length of branches was recorded under 50 per cent light by plants given 37.5 g N and 37.5 g P. All the K levels were on par. Under 75 and 100 per cent light plants given 37.5 g N and 50 g K performed better than others. Among the P levels 25 g under 100 per cent light and 37.5 g under 75 per cent light performed better than the other levels.

The length of secondary branches increased significantly as the light intensity reduced from 100 to 50 per cent. Under 100 and 50 per cent light plants receiving 25 g N, 50 g P and 50 g K recorded maximum length of branches. Under 75 per cent light plants given the lowest level of nutrients (25:25:50 g N:P:K) recorded the maximum length of branches.

The number of primary branches increased with decreasing light intensities, maximum number being at 50 per cent light. At all light intensities maximum number of primary branches were produced by plants given 37.5 g N, 25 g P and 75 g K $bush^{-1}$.

The number of secondary branches increased significantly with decrease in light intensity from 100 to 50 per cent. Maximum number of secondary branches was produced under 50 per cent light. Under all light levels plants given 37.5 g each of N and P $bush^{-1}$ recorded the maximum number. The effect of K application was not significant.

Internodal length increased with decrease in light intensity from 100 to 50 per cent. Maximum internodal length was at 50 per cent light for plants given 25 g N, 37.5 g P and 75 g K $bush^{-1}$. Under 100 per cent and 75 per cent light plants receiving 37.5 g N and 50 g K recorded maximum internodal length than the other levels. Among P levels, 37.5 performed better under 100 per cent light and 25 g under 75 per cent light.

Leaf number increased significantly as the light intensity decreased from 100 to 50 per cent. Plants under 50 per cent light given 50 g N and 50 g P recorded maximum number of leaves. Under 100 per cent and 75 per cent light plants receiving 25 g each of N and P recorded maximum leaf number.

Maximum leaf area was recorded under 50 per cent light by plants receiving 50 g N, 50 g P and 50 g K $bush^{-1}$. Under 100 per cent light plants given 37.5 g N, 25 g P and 50 g K $bush^{-1}$ and under 75 per cent light plants given 25 g N, 25 g P and 75 g K $bush^{-1}$ recorded the maximum number of leaves.

Total chlorophyll and its fractions, chlorophyll 'a' and chlorophyll 'b' increased progressively with increasing levels of shade and nutrients.

Plants under 50 per cent light flowered earlier compared to 75 per cent and 100 per cent light. Under 50 and 75 per cent light plants given 25 g N, 25 g P and 75 g K flowered earlier and under 100 per cent light plants receiving 25 g N, 50 g P and 75 g K $bush^{-1}$ flowered earlier.

The effect of light intensities on the number of developed berries was not significant. N and P fertilization showed significant influence on this character. Under all light intensities maximum number of developed berries were produced by plants receiving 37.5 g each of N and P $bush^{-1}$.

Light intensities did not have any significant influence on the number of undeveloped berries. However undeveloped berries were minimum at 50 per cent light. Under all light intensities studied, minimum number of undeveloped berries were produced at 37.5 g each of N and P bush^{-1}. The effect of K was not significant.

Fresh weight of berries was not influenced by light intensities even though maximum fresh berry yield was recorded at 50 per cent light and minimum at 100 per cent light. N and P application had significant effect on this character. Maximum fresh berry yield was at 37.5 g N and 37.5 g P bush^{-1}.

Dry berry yield was not influenced by varying light intensities. N and P fertilization showed significant effect on the dry berry yield. 37.5 g N and 37.5 g P bush^{-1} recorded the highest yields.

Dry matter production was observed to be higher under shaded situation. There was a drastic reduction in dry matter production at 100 per cent light, Under shaded condition, plants receiving 37.5 g N, 25 g P and 50 g K bush^{-1} produced maximum dry matter. In the open condition vines given 25 g N, 25 g P and 50 g K bush^{-1} produced maximum drymatter.

Maximum uptake of all the nutrients was observed at 50 per cent light. Uptake was maximum at the highest levels of each of the nutrients at 50 per cent light. Under 75 and 100 per cent light maximum N uptake was at 37.5 g N, 50 g P and 100 g K $bush^{-1}$. Under 75 per cent light maximum P uptake was at 37.5 g N, 50 g P and 75 g K $bush^{-1}$ and K uptake at the highest levels of the nutrients tried. In the open condition maximum P uptake was at 37.5 g N, 50 g P and 100 g K $bush^{-1}$ and K uptake at the highest level of N and P and 75 g K.

Volatile oil and oleoresin content were not influenced by light intensities. N showed significant effect on the volatile oil content and P on oleoresin content. Maximum volatile oil content was as 37.5 g N $bush^{-1}$ and oleoresin at 50 g $bush^{-1}$.

Soil N, P and K content was maximum in the open condition. Maximum soil N content was at 50 g N, 25 g P and 100 g K $bush^{-1}$. Soil P content increased significantly with increasing levels of N, P and K. Soil K content was maximum at 50 g N, 37.5 g P and 50 g K $bush^{-1}$.

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APPENDIX

APPENDIX - I

Weather parameters during the crop period (1995-'96)

Months	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
June 1995	28.5	15.5	92	367.2
July 1995	27.6	13.1	93	289.2
August 1995	29.8	13.6	94	385.9
September 1995	27.8	13.6	91	219.4
October 1995	25.7	14.3	91	100.5
November 1995	22.4	12.8	90	128.4
December 1995	23.6	20.6	72	-
January 1996	25.0	20.5	95	-
February 1996	34.2	21.8	70	14.0
March 1996	35.5	22.1	91	4.3
April 1996	32.6	22.9	72	228.6
May 1996	32.2	23.3	69	91.4
June 1996	30.0	20.7	81	323.0
July 1996	23.1	22.1	77	329.5

NUTRITIONAL REQUIREMENT OF BUSH PEPPER UNDER DIFFERENT LIGHT INTENSITIES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A pot culture experiment was conducted at the Farming Systems Research Station, Kottarakkara to study the influence of NPK fertilizers under different light intensities on the growth yield and quality of bush pepper. The treatments included three levels of light (100, 75 and 50 per cent) three levels of each of N, P (25, 37.5 and 50 g bush^{-1}) and K (50, 75, 100 g bush^{-1}). The experiment was laid out in split plot design with three replications.

Light intensities showed profound influence on the length and number of primary and secondary branches, number of leaves, leaf area, chlorophyll content of leaves, internodal length and drymatter production. Best expression of all these characters was under 50 per cent light. All these characters showed a declining trend as light intensity increased from 50 per cent to 100 per cent light.

In the open condition better expression of all growth characters were observed from low to medium level of nitrogen and phosphorus (25 to 37.5 g bush^{-1}). Under 75 per cent light better expression of all growth characters was at medium level of N (37.5 g bush^{-1}), K (75 g bush^{-1}) and lowest level of P (25 g bush^{-1}). Under 50 per cent light response to N levels was not

consistent for different growth parameters. The plant showed positive response to P and K from medium to highest level (37.5 to 50 g $bush^{-1}$).

Earlier flowering was observed at 50 per cent light. Under all levels of light higher levels of N delayed flowering, but incremental doses of P induced early flowering. Dry matter production at all light intensities was more in low to medium levels of nutrients.

Yield and yield attributes were not influenced by light intensities. However maximum berry yield was recorded under 50 per cent light with 37.5 g N and 37.5 g P $bush^{-1}$. Under 100 and 75 per cent light also maximum yield was recorded by plants receiving 37.5 g each of N and P $bush^{-1}$.

Quality of the produce was not significantly influenced by the varying light levels. N levels had significant effect on the volatile oil content and P levels on oleoresin content.

Maximum uptake of all the nutrients was observed under 50 per cent light. There was a steady increase in the uptake of all the nutrients with increasing dose of the three nutrients. Under 100 per cent and 75 per cent light maximum uptake was from medium to high level of the nutrients.