NUTRIENT REQUIREMENT OF GINGER (*Zingiber officinale* R.)

UNDER SHADE

By

ANCY JOSEPH

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Horticulture
COLLEGE OF AGRICULTURE
Vellayani, Thiruvananthapuram

1992

DECLARATION

I hereby declare that this thesis entitled **"Nutrient requirement of ginger** (*Zingiber officinale* R.) **under shade"**, is a bonafide record of research and that the thesis has not formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Vellayani
12-10-1992.

ANCY JOSEPH

CERTIFICATE

Certified that this thesis entitled **"Nutrient requirement of ginger** (Zingiber officinale R.) **under shade"**, is a record of research work done independently by **Smt. Ancy Joseph** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,
14-10-1992.

DR. B.K. JAYACHANDRAN
Chairman, Advisory Committee

Associate Professor,
Department of Horticulture,
College of Agriculture,
Vellayani.

APPROVED BY:

CHAIRMAN:

DR. B.K. JAYACHANDRAN

MEMBERS :

1. DR. S. RAMACHANDRAN NAIR
2. DR. N. MOHANAKUMARAN
3. DR. P. RAJENDRAN

EXTERNAL EXAMINER

Dedicated to

my loving Parents

ACKNOWLEDGEMENT

The author wishes to express her deep sense of gratitude and indebtedness to:

DR. B.K. Jayachandran, Associate Professor of Horticulture, College of Agriculture, Vellayani, Chairman of the Advisory committee for his sincere guidance, critical suggestions and constant encouragement during the course of the investigation.

DR. S. Ramachandran Nair, Professor and Head, Department of Horticulture, **DR. N. Mohanakumaran,** Associate Director, NARP (Southern region), and **DR.P. Rajendran,** Assistant Professor of Soil Science and Agricultural Chemistry for their sincere help, guidance, inspiring suggestions and encouragement.

DR. P. Saraswathy, Professor of Agricultural Statistics for her sincere and timely help in the execution of the the is and **Sri. Ajith Kumar,** Programmer for his generous help in the statistical analysis of the data.

DR. N. Saifudeen, Associate Professor of Soil Science and Agricultural Chemistry for the sincere help in the chemical analysis.

All the staff members and students of the Department of Horticulture for their encouragement throughout the experiment.

My affectionate parents, brothers, sisters and friends who were the source of inspiration and support to me during the course of this investigation.

ANCY JOSEPH

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

INTRODUCTION

The Scenario of Agriculture in Kerala presents special features with its own unique system of homestead farming predominated by a variety of crops like coconut, arecanut, mango, jack and other perennial crops which form the base crops. The vast majority of farmers in Kerala belong to the category of small and marginal farmers, as 97.3 per cent of the total holdings are having an area of less than two hectares and the average size of the holding is about 0.36 ha (Anon., 1991). It is not practicable to increase the income and employment potential of small and marginal farmers if they continue to depend on monoculture of perennial crops. The only way of augmenting both is by introducing compatible combinations of intercrops. The space below the canopy of perennial crops like coconut can accommodate intercrops to judiciously exploit soil and solar radiation.

Solar radiation is considered to be the most essential component in the photosynthetic performance of plants. Productivity of plant depends on its capacity to efficiently harvest solar energy for the metabolic production and also on the efficient partitioning of the same. Under intercropped situations, adaptation of plants for better light use efficiency may be important for attaining higher yields. Hence, identification of suitable crops and evolving suitable technologies for intercropping are likely to be the major ways of improving intercropping performance. Selection of an appropriate combination of crops for intercropping would ensure a built in insurance against price fluctuations and total crop loss. At the same time, small farmers should be provided with the right farming package for intercropping to maximise land productivity and thereby maximise income from unit land area (Balram Jakhar, 1991).

Ginger is one of the important tropical seasonal crops recommended for intercropping in coconut and arecanut gardens. This is valued as one of the important spice crop of the country. Kerala is the largest ginger producing state, accounting for about 33 per cent of the production in India (Anon., 1990 a). The area under the crop is 14,000 hectares with an annual production of 45,000 tonnes (Anon., 1991). Though the exact statistics pertaining to the distribution of the area under open and shaded conditions are not available, it is well understood that ginger under partial shade as an intercrop and as a crop component of the homestead cultivation occupies a substantial area in Kerala. However it is to be noted that there is a major proportion of land under perennial monocrops which is still unexploited. As ginger is found to perform better under partially shaded condition, by intercropping ginger, the problem of low income of small farmers and disguised unemployment of rural youth can be solved to some extent.

The ability of ginger plants to tolerate shaded conditions makes them suitable for intercropping between taller tree crops so that light filtered through the tree canopy is not wasted. Minoru and Hori(1969) observed that ginger can efficiently utilise low light intensities for photochemical reactions. A study conducted at the Philippines indicated that ginger performs best when grown under slight shade., but not in excess of 50 per cent shade (Aclan and Quisumbing, 1976). Increased efficiency to synthesise, translocate and utilize more carbohydrates, when ginger was grown under shade, was observed by Ravisankar and Muthuswamy (1987). The screening of ginger cultivars for shade tolerance at Vellanikkara revealed that most of the ginger cultivars were shade loving and gave more yield and dry matter production under 25 per cent shade and comparable yield under medium shade (Susan Varghese, 1989). However work done in Kerala to develop suitable management strategies for ginger with a view to increase productivity under varying light regimes are scanty and meagre. The shade studies conducted under the ICAR Ad-hoc scheme on turmertic, colocasia and soybean indicated the necessity for increasing fertilizer dose for plants under light shade and reducing the same at intense shade levels (Anon., 1990 b). At present, evidences are lacking for increasing or decreasing the recommended dose of fertilizers for ginger under shaded situations. Hence, the present investigation on "Nutrient requirement of ginger (Zingiber officinale R.) under shade," was taken up with the following objectives:

To determine the fertilizer requirement of ginger under varying levels of shade

To assess the influence of shade and manuring on vegetative growth, rhizome yield and quality of ginger

To estimate the uptake of major nutrients under varying levels of shade

To determine the benefit : cost ratio of the different treatments.

Review of Literature

REVIEW OF LITERATURE

This review is classified under two sections. The first section reviews the literature on the response of different crops to varying intensities of shade. The second section reviews the response to major plant nutrients both in the open and under partially shaded conditions.

A. Response of different crops to varying intensities of shade.

Plant height:

Cooper (1966) in his attempt to find out the response of birdsfoot trefoil and alfalfa to various levels of shade (51, 76 and 92 per cent shade) found that plant height was decreasing proportionately with increasing levels of shade. Panikar et al. (1969) reported that in tobacco, plant height increased by 35.2 per cent under shade as compared to unshaded plants. Ginger plants grown under full sunlight were found to be shorter compared to shaded plants (Aclan and Quisumbing, 1976). Rose (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.

Kulasegaram and Kathiravetpillai (1980) reported that plant height was greatest under 60 per cent light and least under 10 per cent sunlight in the case of young tea plants. Viburnam opulus cv. Nanum was grown in a shade house under 100, 70, 53 and 37 per cent of available sunlight. The plants receiving 70 and 53 per cent of available sunlight grew significantly larger than plants in full sunlight or heavy shade (Robinson and Hamilton, 1980).

Contradictory to Cooper's findings several other workers reported an increase in plant height with increasing levels of shade in crops like maize (Moss and Stinson, 1961), easterlily (Kohl and Nelson, 1963) and Lilium longifolium (Einert and Box, 1967). While experimenting with tuber and rhizomatous crops, Lalithabai and Nair (1982) observed positive influence of shading on plant height/vine length in ginger, coleus and sweet potato whereas height of colocasia was unaffected by shading.

In Mentha piperita, plant height under 44 per cent day light was significantly greater than that under 100 or 14 per cent daylight. Under 14 per cent daylight growth was limited (Virzo and Alfani, 1980). In Syngonium podophyllum, plant grown under 80 per cent shade were taller than those grown under 47 per cent shade. (Chase and Poole, 1987). An increase in plant height under shade was also reported in cassava (Sreekumari et al, 1988). Susan Varughese (1989) reported that in ginger, plant height increased with increase in shade intensity from zero to 75 per cent shade at 60 days after planting only after which plants grown at 25 per cent shade had the highest plant height whereas in turmeric, with increase in shade, plant height increased upto the medium shade of 50 per cent and then decreased. According to Hanada (1991) covering the leafy vegetables with plastic net or non woven fabrics reduced the radiation and prevented scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. A shade intensity of about 30 to 40 per cent seemed to be suitable for most of the leafy vegetables.

Number of tillers per plant:

Shading at the vigorous tillering stage retarded tiller formation in rice (Oshima and Murayama, 1960).

In wheat also, a reduction in the number of tillers by shading was reported by Moursi et al. (1976). According to Aclan and Quisumbing (1976), in ginger tillering was not affected by shade. Contrary to this report, Susan Varughese (1989) observed a decrease in the number of tillers with increasing levels of shade at all growth stages both in ginger and turmeric. In colocasia there was no significant difference in tiller production among different shade levels. (Prameela, 1990). In a shade experiment with turmeric, tiller production was found to be reduced under 50 and 75 per cent shade (Jayachandran et al., 1992)

Number and size of leaves:

Panikar 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. Aclan and Quisumbing (1976) reported reduced number of leaves per plant in ginger grown under full sunlight. Full sunlight was found detrimental to the growth of begonia. The leaves developed scorch marks on the margins. The best growth of plants was obtained under 50 per cent day light (Aasha, 1986). In sweet potato, leaf size increased as leaf number declined in response to higher shade levels, thus leaf areas were similar in all treatments (Laura *et al.*, 1986). In *Syngonium podophyllum*, plants grown under 80 per cent shade had fewer leaves but produced larger leaves than those grown under 47 per cent shade (Chase and Poole, 1987). Sreekumari *et al.* (1988) reported that in cassava leaf size increased, leaf number decreased and leaf longivity increased when grown under shade in a coconut garden. Contrary to the observation of Aclan and Quisumbing (1976), a decrease in number of leaves was observed at all stages by increasing the intensity of shading from zero to 75 per cent (Susan Varughese, 1989).

Chlorophyll content:

According to Shirley (1929) shaded leaves generally have enhanced chlorophyll levels per unit weight. In wheat, the total chlorophyll per unit area of leaf blade increased with increasing nitrogen., the ratio of chlorophyll 'a' to chlorophyll 'b' was constant. There was no significant interaction between the effects of nitrogen and shading on chlorophyll (Moursi *et al.*, 1976). In *Ficus benjamina* increasing shade and fertilizer levels increased chlorophyll content (Collard *et al.*, 1977). Lalithabai (1981) reported an increase in chlorophyll content with increasing shade levels (25, 50 and 75 per cent shade) in crops like ginger and turmeric.

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 the cassava leaves grown under low light (6000 lux) recorded higher concentration of total chlorophyll per unit leaf weight. They also observed that low light favoured the concentration of chlorophyll 'b' and thus the ratio of chlorophyll 'a' to chlorophyll 'b' was reduced significantly. In ginger and turmeric total chlorophyll and its fractions, chlorophyll 'a' and chlorophyll 'b' increased steadily with increasing levels of shade. Chlorophyll 'a' to chlorophyll 'b' ratio was not found to be markedly affected by shading (Susan Varughese, 1989).

Photosynthesis:

Shading either partial or complete was found to reduce the carbondioxide assimilation and thereby the available constructive material for plants

(Duggar,1903). According to Hardy (1958), shade loving plants had a threshold illumination beyond which the stomata tend to close. Gastra (1963) found a linear relationship between photosynthesis and light intensity at low intensities. Minoru and Hori (1969) observed that ginger can efficiently utilize low light intensities for photochemical reactions. In soybean the low activity of ribulose 1,5 diphosphate carboxylase had been reported at low intensities of light (30, 50 and 70 per cent light) by Bowes et al. (1972). Crockson et al. (1975) recorded 38 per cent reduction in photosynthesis of bean leaves due to shading, mainly because of increase in stomatal and mesophyll resistance to diffusion of carbon dioxide.

Photosynthesis and dry matter accumulation had been reported to be adversely affected by shade in many species of plants. But in the case of ginger and turmeric positive influence of shade was reported (Lalithabai and Nair, 1982). High light intensities warm the leaves and may increase respiration and if warming become too high the temperature rise may be sufficient to cause thermal inactivation of enzymes. This effect is reported in many plants. The chloroplastic enzyme NADP malate dehydrogenase was totally inactivated when chloroplasts of peas, maize and spinach were illuminated with high light intensity (Miginiac et al., 1990).

Growth analysis:

Leaf area indices of crops viz., ginger, turmeric and coleus were observed to be not influenced by different shade intensities (Lalithabai, 1981). Ravisankar and Muthuswamy (1988) reported that LAI was highest when ginger was grown as an intercrop in two year old arecanut plantation. According to Pushpakumari (1989) maximum leaf area index was recorded at 50 per cent shade in greater yam and at 25 per cent shade in lesser yam, tannia and elephant foot yam.

A positive correlation has been reported between net assimilation rate and irradiance (Blackman and Wilson, 1951; Newton, 1963 and Coombe, 1966). Moursi et al. (1976) noted in wheat, a reduction in NAR with increase in shade intensity from 5.7 to 3.2 and 11.9 to 0.8 g m^{-2} day^{-1} at 80-95 and 95-100 days after planting respectively. In sweet potato also NAR was found to be lower under shade (Laura et al., 1986). Tao and Zhang (1986) reported that at 28 $^{\circ}$C the net photosynthetic rate of tea plants increased with light intensity and the light saturation and compensation points of shaded tea plants were lower than that of unshaded plants. Although the photosynthetic efficiency of plants under open condition at higher light intensity was slightly above that of shaded plants their photorespiration and dark respiration at 80klx, 34-38 °C and 40-60 per cent relative humidity were higher so that the net photosynthetic rate decreased markedly.

Monteith (1978) reviewed maximum recorded crop growth rates of C_3 and C_4 plants. He suggests that a maximum for C_3 stands is in the range 34-39 g m^{-2} day $^{-1}$ compared with 50-54 g m^{-2} day^{-1} for C_4 plants. Averaged over a whole season he reports rates of 13.0 and 22.0 gm^{-2} day^{-1}, respectively. The maximum individual CGR recorded in the study conducted by Whiley (1980) in ginger was 39.6 g m^{-2} day^{-1}, C was 13.2 g m^{-2} day^{-1}.

Janardhanan and Murthy (1980) observed that in rice under low light conditions LAI was increased whereas NAR was reduced. Ramadasan and Satheesan (1980) recorded highest LAI, CGR an NAR with three turmeric cultivars grown in open conditions compared to the same under shade. Reduction in solar input upto 32 per cent reduced CGR to about half that of control in cassava

(Fukai et al., 1984). Ramanujam et al. (1984) observed that the CGR and NAR of cassava grown under shade were reduced significantly when compared to those plants grown under normal light. In sweet potato NAR and relative growth rate (RGR) tended to decline with increasing shade, lower values were recorded in 73 per cent shade. (Roberts_Nkrumah et al., 1986).

There are also reports of non significant influence on growth analysis factors due to shade. Gopinathan (1981) observed that in cocoa seedlings, NAR was not influenced by increase in shade intensity ranging from 25 to 75 per cent. Turmeric and ginger showed no general trend in NAR with increasing shade levels (Lalithabai, 1981).

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. Myhr and Saebo (1969) reported reduction in dry matter yield in Festuca rubra, Lolium perenne and Phleum pratense by shading. Similar results were reported in crops like ginger, turmeric, colocasia, coleus and sweet potato (Lalithabai, 1981).

Dry matter production of four sweet potato cultivars was not significantly affected by 25 or 55 per cent shade but was severely reduced in 73 per cent shade. (Laura et al., 1986). Ravisankar and Muthuswamy (1986) reported that dry matter production and recovery of dry ginger increased when grown as an intercrop in arecanut garden. A declining trend in total dry matter production was observed in crops like tannia, elephant foot yam (Pushpakumari, 1989) and turmeric (Susan Varughese, 1989). But in ginger dry matter production was found to be maximum under 25 per cent shade.

Yield and yield attributes:

Habfield (1968) reported that the yield of the tea bush is limited by excessive leaf temperature in unshaded conditions and by low light intensity in shaded conditions. Aclan and Quisumbing (1976) oberved no significant difference in rhizome yield among ginger plants grown under full sunlight, 25 per cent and 50 per cent shade. But heavier shading of 75 per cent reduced the yeild. Xanthosoma sagittifolium and Colocasia esculenta showed enhanced ability to survive stress condition when grown under shade but only with a low yield of edible materials (Caesar, 1980). According to Lalithabai (1981) colocasia did not show any marked decrease in yield with increase in shade upto 50 per cent of full sunlight. As opposed to these results, reduction in tuber yield due to shade was reported in tapioca (Sreekumari et al., 1988).

Studies conducted in four sweet potato cultivars showed that fresh weight of the tuber was not affected in 25 per cent shade but in 55 per cent shade, values were noticeably lower and in 73 per cent shade tuberisation was almost completely suppressed in all cultivars. The responses were resulted from slower tuber growth in 55 per cent shade and from delayed tuber initiation and slower tuber growth in 73 per cent shade (Laura et al., 1986). Roberts_Nkrumah et al. (1986) pointed out that fresh weight of the tuber in 50 per cent shade was markedly lower and little tuberisation occured in 75 per cent shade. Ravisankar and Muthuswamy (1988) observed that fresh ginger rhizome yield increased when ginger was grown as an intercrop in arecanut plantations. Pushpakumari (1989) reported that tannia (Xanthosoma sagittifolium) recorded highest yield under 25 per cent shade with an almost equal yield under

50 per cent shade. The screening of ginger cultivars for shade tolerance at Vellanikkara revealed that most of the ginger cultivars were shade loving and gave more yield and dry matter production under 25 per cent shade (Susan Varughese, 1989). In her study using turmeric a steady decrease in rhizome yield with increase in shade intensity was observed. As opposed to this, Jayachandran et al. (1992) found that the yield of turmeric at 25 per cent shade was on par with that under open condition.

Prameela (1990) reported that colocasia gave maximum tuber yield and dry matter production under 25 per cent shade followed by a reduction in yield with further increase in shade intensity. According to Hanada (1991) covering crops with plastic net or non woven fabrics, increased the yield of vegetables especially of leafy vegetables in both tropical and subtropical areas. The yield increases were found to be the combined results of shading, suppression of increases in soil temperature and conservation of soil moisture. Soil temperature at a depth of 5 cm were found to be lower by as much as 6 °C under cover with a shading intensity of more than 67 per cent compared to the control and thus produced an underground environment more suitable for root growth.

Togari (1950) reported that in shade, cambial activity and tuberisation were suppressed in sweet potato roots. Zara et al. (1982), Martin (1985) and Roberts Nkrumah et al. (1986) also reported the same effect in sweet potato.

Root and bud growth as commonly inhibited by low light intensities and this can lead to a reduction in assimilate flow to the root system (Nelson, 1964). A considerable delay in tuber initiation due to shade was reported in tapioca (Ramanujam et al., 1984). In pot experiment, shade delayed initiation of bulking by about 40 days and reduced dry matter diversion to tuberous roots in tapioca (Kasele et al., 1986)

According to Hirota and Moritani (1980) in shaded conditions top growth was maintained at the expense of root growth. Ramanujam et al. (1984) observed that most of the photosynthates of shade grown cassava plants were utilized for shoot growth at the expense of tuber growth. In ginger, haulm yield at zero and 25 per cent shade were found to be on par but significantly higher when compared to that under 50 and 75 per cent shade whereas in turmeric, a steady decrease in haulm yield was observed (Susan Varughese, 1989).

Susan Varughese (1989) reported that percentage dryage increased progressively with increase in shading both in turmeric and ginger. According to Pushpakumari (1989) the utilization index (UI) was not influenced by shade in elephant foot yam whereas in greater yam, there was marked decrease in the UI at intense shade level. In lesser yam, the highest UI was at full illumination. But in tannia, she reported that UI was maximum under intense shade. Harvest index failed to show any statistically significant difference between shade levels in turmeric whereas in ginger, plants at 25 per cent shade recorded the highest harvest index and was statistically on par with that under 50 and 75 per cent shade (Susan Varughese, 1989).

Quality of the produce:

Light regimes received by plant determine the productivity and quality of its 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 was 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 fruits. Ginger cultivar Rio de Janeiro grown as an intercrop in a six year old arecanut plantation recorded highest volatile oil and NVAE contents followed by those grown in two year old plantation compared to those grown in the open as a pure crop. (Ravisankar and Muthuswamy, 1987). Contrary to this finding, ginger showed a steady decrease in the oleoresin content upto 50 per cent level of shade (Susan Varughese, 1989).

Myhr and Saebo (1969) observed that in some grass species, fibre contents decreased by shading to 10 to 15 per cent of the light intensity. Aclan and Quisumbing (1976) reported that in ginger fibre content was not affected by shading. Ravisankar and Muthuswamy (1987) also reported the same result in ginger.

Uptake of nutrients:

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). According to Robinson and Hamilton (1980) in Viburnam opulus cv. Nanum full sum significantly decreased foliar N content from 3.7 per cent dry weight at the intermediate light levels to 3.1 and 3.5 per cent respectively, whilst P and K were contant at all light levels.

In Mentha piperita under shaded conditions leaves contained significantly higher levels on 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 coleus, colocasia, sweet potato, turmeric and ginger increased with increase in shade.

In turmeric, uptake of all the nutrients was found to decrease with shade except potassium where uptake was maximum at 50 per cent shade. In ginger, uptake of N and K increased from zero to 20 per cent shade and then showed a progressive decrease. However the uptake of phosphorus decreased with increasing shade intensities (Susan Varughese, 1989).

B. Response of different crops to varying levels of fertilizers.

Shoot growth and leaf development:

Purewal and Dargon (1957) observed that in colocasia plant height and leaf area were increased significantly with the application of nitrogen from 50 to 100 lbs acre^{-1}. However N had no effect on the number of leaves formed at various stages of growth. Nitrogen application was found to significantly increase the number of shoots per plant in ginger (Muralidharan et al., 1974). According to Aclan and Quisumbing (1976), there was a progressive increase in plant height and number of tillers per plant with an increase in the amount of N applied upto 90 kg ha^{-1}.

Container grown Ficus macrophylla was given three N levels (225, 300 and 375 g m^{-2}) and three shade levels (20,60 or 80 per cent shade). Plant height was greatest with 20 per cent shading and 300-375 g N m^{-3} (Thomas and Teoh, 1983). In sweet potato, Bourke (1985) reported that N application increased number of leaves per plant.

Juliano and Ramos (1940) reported increased number of vegetative and ear bearing tillers by the application of nitrogenous fertilizers in rice. A uniform low rate of increase in number of tillers with increasing dose of nitrogen upto 50 lbs per acre was observed by Tomy (1963).

Purewal and Dargon (1957) have shown that application of phosphorus had no effect on height of plants, leaf area and number of leaves whereas application of potash at the rate of 50 lbs $acre^{-1}$ increased plant height and leaf area but it had no effect on the number of leaves of colocasia.

According to Chidananda Pillai (1967), in colocasia, plant height and number of suckers were not significantly influenced by application of nitrogen, phosphorus and potash. The largest leaf area was recorded under the combination of 80 kg nitrogen and 65 kg potash ha^{-1}. Saiev (1978) found that leaf area per plant increased with increase in the rate of applied NP and NPK in potato. Hafizuddin and Haque (1979) observed that length of vine was not affected by N and K treatments in sweet potato.

In turmeric, an increasing trend in the number of tillers as well as leaf production with increasing fertilization upto 40:40:80 kg NPK ha^{-1} in the shade was observed. However NPK 30:30:60 kg ha^{-1} recorded the maximum height in the shade and NPK 20:20:40 kg ha^{-1} in the open (Anon., 1983). Pushpakumari (1989) reported that leaf number and plant height/vine length of lesser yam, tannia and elephant foot yam were not significantly influenced by the fertillizer levels but for greater yam there was significant increase in the plant height with increase in fertilizer levels.

Growth analysis:

Leaf area index was found to be increased by N application in sweet potato (Bourke, 1985). In tannia, fertilizer treatments did not show any significant influence on the LAI at any of the growth stages whereas in greater yam, LAI was found to be significantly influenced by different fertilizer levels at 190 days after planting and maximum LAI was observed for the highest fertilizer dose ie., 80:60:80 kg NPK ha^{-1} (Pushpakumari, 1989). She also reported that net assimilation rate did not vary significantly due to fertilizer levels in crops like lesser yam, greater yam, elephant foot yam and tannia grown as intercrops in coconut graden.

In sweet potato, N application increased CGR (Bourke, 1985). In tannia there was no significant difference in CGR among the fertilizer treatments but in greater yam the effect was significant and CGR was found to be the lowest for the highest fertilizer dose (80: 60:80 kg NPK ha^{-1})., CGR ranged from 1.80 to 2.89 g m^{-2}

day^{-1} and from 0.65 to 1.14 g m^{-2} during the 1st and 2nd years respectively. (Pushpakumari, 1989).

Dry matter production:

Nambiar *et al.* (1976) reported no significant effect on the weight of vine in sweet potato due to increased fertilizer application. Geetha (1983) opined that N at the rate of 60 kg ha^{-1} and K at the rate of 120 kg ha^{-1} were sufficient to produce the highest dry matter yield in coleus. In sweet potato, N application increased total plant dry weight of all plant components and K application was found to increase total plant dry weight (Bourke, 1985). In an experiment for comparing the fertilizer levels viz., 60:60:90 , 80:80:120 and 100:100:150 kg NPK ha^{-1}, no significant difference due to fertilizer levels on the length of vine, LAI and total dry matter production was observed (Sasidharan, 1985). In a study with potato variety Kufri Jyothi, the dry matter production increased significantly due to the application of different levels of N, P and K (Rajanna *et al.*, 1987). Total dry weight at harvest stage did not vary significantly due to fertilizer levels in crops like lesser yam, tannia and elephant foot yam but in greater yam dry matter production was found to be the highest at the highest fertilizer dose ie., 80:60:80 kg NPK ha^{-1} (Pushpakumari, 1989).

Yield and yield attributes:

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

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

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

In ginger, Samad (1953) reported no significant response to fertilizer application in Malabar though there was an increase in yield with 100 kg N ha^{-1}. Thomas (1965) obtained no significant response with 4 levels of N(0,50,100 and 150 kg ha^{-1}) and 3 levels of P_2O_5 (0,45 and 90 kg ha^{-1}) whereas Lokanath and Dash (1964) observed significant increase in yield with the application of 60 kg N, 40 kg P_2O_5 and 60 kg K_2O ha^{-1}. Kannan and Nair (1965) recommended 36 kg N, 36 kg P_2O_5 and 72 kg K_2O ha^{-1} for optimum yield of ginger. Application of N and P each at 57 and 114 kg ha^{-1} increased the total yield by 18-32 per cent and 13-19 per cent respectively in ginger (Aiyadurai, 1966). Nair (1969) and Paulose (1970) recommended 60:60:150 kg NPK ha^{-1} for economic yield of ginger. In an experiment to study the effect of 3 levels each of N (50, 75 and 100 kg ha^{-1}), P_2O_5 (50, 75 and 100 kg ha^{-1}) and K_2O (100,150 and 200 kg ha^{-1}) on the yield of ginger variety Rio-de-Janeiro, it was observed that the application of N above

50 kg ha^{-1} reduced the yield of ginger significantly. P and K had no significant effect on the yield at the levels studied (Muralidharan, 1973). The yield of ginger doubled with the application of 30 kg N ha^{-1}. Yield also increased slightly with that of potassium but not with phosphorus (Aclan and Quisumbing, 1976).

In turmeric, the higher levels of fertilization resulted in increased yields of raw turmeric from 24 to 30 t ha^{-1} and decreased the curing percentage from 25 to 24 per cent (Ramakrishna Reddy and Rama Rao, 1978). According to Lee et al. (1981) in ginger, fertilizer nitrogen significantly increased the number of third order shoots and fourth order rhizome branches and the total yields of shoots and rhizomes and a N dose of 200-300 kg ha^{-1} gave maximum yield.

Bourke (1985) reported that in sweet potato, N application increased tuber yield and mean tuber weight and K application increased tuber yield, number of tubers per plant and mean tuber weight. Trials with potato cv. Kufri Bahar using 75 or 150 kg N and 0-120 kg K_2o ha^{-1} showed that 150 kg N and 120 kg K_2o ha^{-1} resulted in larger tubers, higher bulking rates and finally higher tuber yield. (Satyanarayana and Arora, 1985). In a study conducted on potatoes, in west Bengal, yield was found to be increasing with increasing NPK rates and were highest with 225 kg ha^{-1} each of N, P_2O_5 and K_2O (Roy and Tripathi, 1986).

Greater yam responded linearly to fertilizer levels recording maximum yield at the highest fertilizer dose given ie., 80:60:80 kg NPK ha^{-1} when grown as an intercrop in coconut garden whereas in lesser yam maximum yield was at medium fertilizer level and in elephant foot yam at lowest level (Pushpakumari, 1989). Mahabaleshwar et al. (1990) reported that in tapioca highest yield was obtained with N_{120} P_{60} K_{180} kg ha^{-1} beyond which vegetative growth was promoted. It was also observed that the dry matter of the tubers were low at higher rate of fertilizers and suggested that this may be due to more retention of moisture in the soil and tubers due to higher nutrient contents in soil.

Samad et al. (1956) observed in rice, substantial increase in straw yield in heavily manured plots over moderately manured ones. In sweet potato, K application increased harvest index (Bourke, 1985). Greater yam and elephant foot yam recorded significantly lower top yields at lowest fertilizer level ie., at 40:30:40 and

40:30:50 kg NPK ha^{-1} respectively (Pushpakumari, 1989).

Quality of the produce:

Mandal *et al.* (1969) reported that crude protein content showed an increase upto 80 kg N and 40 kg K_2O ha^{-1} in *Dioscorea esculenta*. Geetha (1983) observed that the application of nitrogen and phosphorus at 90 kg ha^{-1} each enhanced the protein content and starch content in coleus. Prakasha 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) percentage essential oil content of coriander seeds was found to be increasing with the increase in N application from 0 to 60 kg ha^{-1}.

Aclan and Quisumbing (1976) reported that none of the three elements N, P and K influenced fibre content of ginger rhizomes. Carveho *et al.* (1983) observed no significant effect of fertilizers on crude protein and fibre contents of sweet potato. In lesser yam, crude fibre content was not influenced by different levels of fertilizers (Sasidharan, 1985).

Nutrient uptake:

Pena (1967) observed that application of N increased the N content of taro leaves, but decreased their P and K contents. At the same time application of P increased the P content but decreased the K content and application of K increased K content but decreased Ca and Mg contents. Sobulo (1972) estimated that a yam crop of 26 t ha^{-1} removed 133, 10 and 84 kg ha^{-1} of N, P and K respectively.

The total N in ginger shoots and rhizomes increased with increasing fertilizer N application (Lee et al., 1981). According to Lee and Asher (1981) leaf N concentrations and the yield of ginger shoots and rhizomes increased with the total amount of N applied upto the highest level studied ie., 336 kg N ha^{-1}. Forage N content increased with decreasing light intensity from 1.0 to 1.6 and from 1.2 to 1.9 per cent without and with N respectively. Phosphorus and potassium contents tended to be higher under shade and higher with applied N except of P (Eriksen and Whitney, 1981). The NPK concentration in plant tops and tubers of potato increased with increase in NPK and irrigation rates (Roy and Tripathi, 1986). Sharma and Grewal (1991) reported that N, P and K uptake by potato crop increased progressively with increase in their rate of application and the nutrient uptake was found closely linked with productivity.

Materials and Methods

MATERIALS AND METHODS

A field experiment was carried out to determine the nutrient requirements of ginger under varying levels of light intensities.

Experimental site:

The experiment was conducted at the Instructional Farm Vellayani, Thiruvananthapuram, located at 8^{o} 5′ North latitude, 77^{o} 1′ East longitude and at an altitude of 29 m above mean sea level.

The soil of the experimental location was red loam belonging to the Vellayani series and texturally classed as sandy clay loam. The physical and chemical characteristics of the soil are given in Table 1.

Table 1. Soil characteristics of experimental field.

A.	**Mechanical composition:**		
	Coarse sand	%	63.2
	Fine sand	%	13.5
	Silt	%	2.5
	Clay	%	20.4
B.	**Chemical properties:**		
	Available nitrogen	(Kg ha^{-1})	184.4
	Available P_2O_5	(Kg ha^{-1})	33.7
	Available K_2O	(Kg ha^{-1})	103.8
	p^H		5.2

Cropping history of the field;

The experimental field was under bulk cultivation of vegetables for the last three years.

Season:

The experiment was conducted during June - February 1992.

MATERIALS

Planting materials:

Ginger cultivar Rio-de-Janeiro was used for the experiment. Healthy and disease free rhizomes each weighing 15g were used for planting.

Fertilizers:

Fertilizers with the following grades were used for the experiment.

Urea	46 per cent Nitrogen
Superphosphate	16 per cent P_2O_5
Muriate of potash	60 per cent K_2O

Shade Material:

Unplaited dry coconut leaves were used for providing the required levels of shade.

METHODS

Layout of the experiment:

The experiment was laid out in strip plot design with five replications. The plot size was 5 x 1 m. The layout plan is given in Fig.1.

Table 2. Treatments.

A. **Shade levels:**

S_o - 0 per cent shade (open)

S_1 - 25 per cent shade (low)

S_2 - 50 per cent shade (medium)

S_3 - 75 per cent shade (high)

B. **Fertilizer levels:**

F_1 - 75 per cent of the recommended dose of NPK

F_2 - 100 per cent of the recommended dose of NPK

F_3 - 125 per cent of the recommended dose of NPK

F_4 - 150 per cent of the recommended dose of NPK

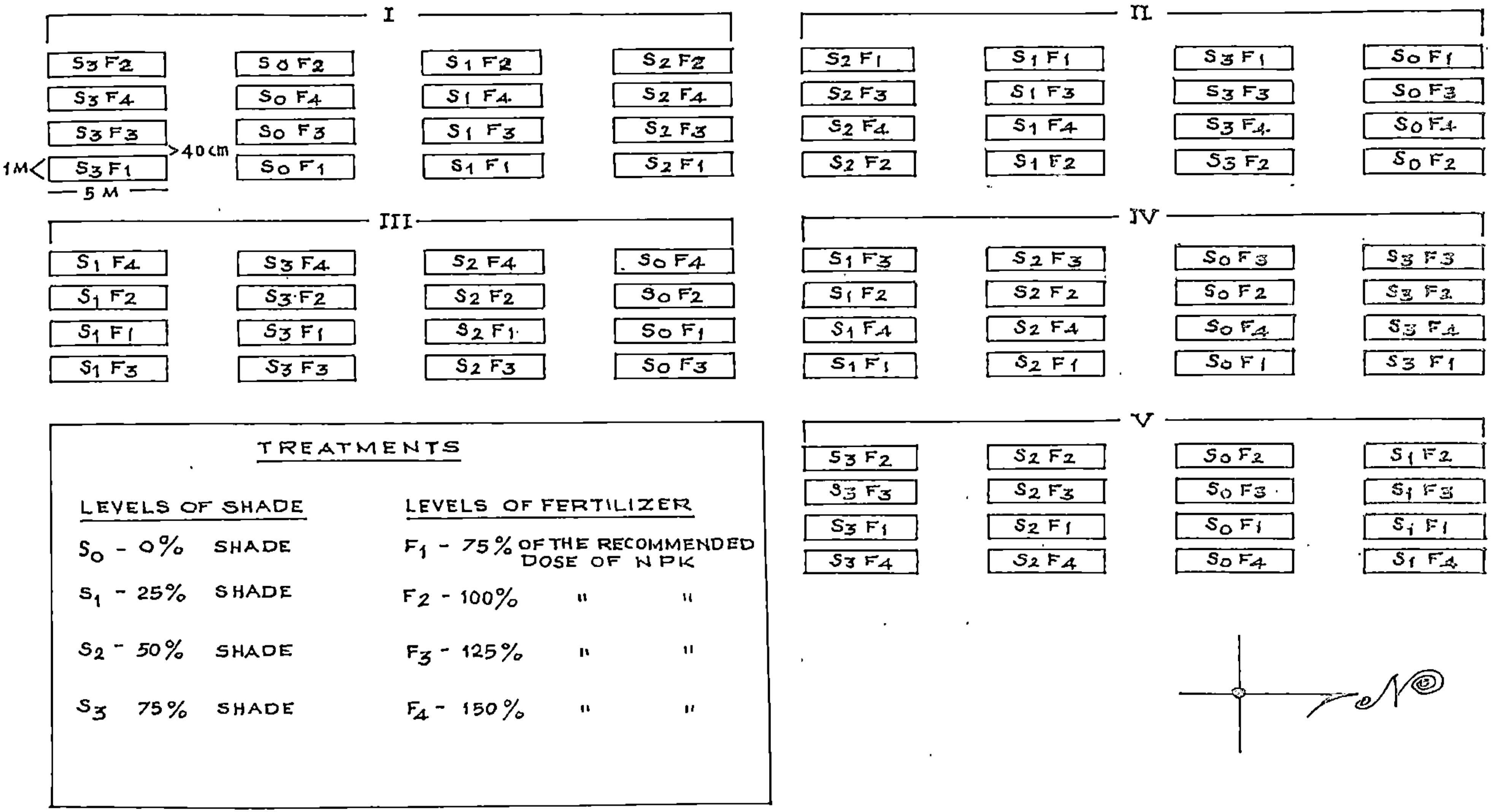
Treatment combinations - 16:

T_1 - S_0F_1	T_5 - S_1F_1	T_9 - S_2F_1	T_{13} - S_3F_1
T_2 - S_0F_2	T_6 - S_1F_2	T_{10} - S_2F_2	T_{14} - S_3F_2
T_3 - S_0F_3	T_7 - S_1F_3	T_{11} - S_2F_3	T_{15} - S_3F_3
T_4 - S_0F_4	T_8 - S_1F_4	T_{12} - S_2F_4	T_{16} - S_3F_4

Land preparation and planting:

Beds of size 5 x 1 m and 25 cm height were made on previously dug soils with 40 cm spacing between the beds. Drainage channels were provided. Farmyard manuare was applied to each bed at the rate of 30 t ha^{-1} by placing in small pits taken at a spacing of 25

FIG.1. LAY OUT PLAN - STRIP PLOT DESIGN.



x 25cm and seed rhizomes were planted in the pits at a depth of 4-5 cm. The pits were then covered with soil.

Shading:

Artificial shading to the required level as per the treatment was provided by placing dry coconut fronds on erected pandals and arranged in such a way as to provide shade intensities of 25, 50 and 75 per cent, respectively. LI-COR L1-188 B Quantum radiometer with a photometric sensor was used for adjusting the shade. Pandals of size 6m x 6m were erected separately for each shade level. Sufficient space (3m) was provided in between the pandals to avoid mutual shading. Each pandal was covered on all the sides with unplaited coconut leaves except for 1 m from the ground level to avoid direct entry of sun rays.

There were variations in light intensity upto a maximum level of about $\pm$ 5 per cent at different locations within a pandal. Frequent checks were made throughout the course of the experiment to maintain the shade intensities to the requisite level.

Fertilizer application:

The recommended fertilizer dose of 75:50:50 kg N, P_2O_5 and K_2O ha^{-1} as per package of practices (Anon., 1989) was followed.

Seventy five, 100, 125 and 150 per cent of this recommended dose ie., 56.25:37.50:37.50, 75:50:50, 93.75:62.50:62.50 and 112.50:75:75 Kg N,P_2O_5 and K_2 O ha^{-1} were given as fertilizer treatments Viz., F_1, F_2, F_3 and F_4 respectively. For all the treatments, full dose of P_2O_5 and half the dose of K_2O were given as basal dressing, half the dose of N two months after planting and remaining portions of N and K_2O four months after planting.

Mulching:

Mulching was done immediately after planting with green leaves at the rate of 15 t ha^{-1} and repeated with green leaves twice at the rate of 7.5 t ha^{-1} first two months and the second four months after planting.

After cultivation:

Hand weeding was done before each mulching and repeated weeding, according to weed growth during the 5th and 6th months after planting. Earthing up was also done during the first mulch.

Plant protection:

The crop was comparatively free from diseases and pests. However, incidence of leaf spot was noticed and it was kept under check by periodic spraying of Bordeaux mixture.

OBSERVATIONS:

Random sampling technique was adopted to select the sample plants for studying the various growth characters. Five plants were selected at random as observation plants for recording observations and the mean worked out. Observations on plant height, number of tillers per plant and number of leaves per plant were taken at 60,120 and 180 days after planting (DAP). Observations on dry matter production were taken at 90, 135 and 180 DAP. After 180 days no growth observation was taken since the above ground parts already started drying up in the treatment with no shade.

The observations recorded:

1. **Plant height:**

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

2. **Number of tillers per plant:**

The number of tillers was determined by counting the number of aerial shoots arising around a single plant.

3. **Number of leaves per plant:**

The number of fully opened leaves was taken.

4. **Leaf area index (LAI):**

Leaf area index was computed at 90, 135 and 180 days after planting. Five sample plants were randomly selected in each plot and the number of leaves was counted in each plant. The length and maximum width of leaves in the middle tiller of all the sample plants were measured separately and leaf area was computed based on the length breadth method.

The relationship between leaf area (Y) and the product of length and breadth (X) was estimated from a sample of 50 leaves. The relationship was found to be

$$Y = 0.6695\ x - 0.7607$$

This relationship was utilized for estimating the leaf area. Thereafter the LAI was computed using the following relationship.

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

5. **Rhizome spread:**

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

6. **Rhizome yield:**

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

7. **Top yield:**

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

8. **Utilization index:**

It is the ratio of the rhizome weight to the top weight. This was worked out from the dry weight of rhizomes and dry weight of top parts.

9. **Harvest index:**

Harvest index was calculated as follows.

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

Y econ and Y biol were dry weight of rhizome and total dry weight of plant, respectively.

10. **Recovery of dry ginger:**

Immediately after the harvest, the rhizomes were cleaned thoroughly and the skin was scraped off. They were chopped into small pieces for easy drying and dried in a cross flow air oven at 55 $\pm$ 2°C to a constant moisture content of 10 per cent. The weight of the dry ginger was recorded and expressed as percentage of the fresh weight.

GROWTH ANALYSIS:

1. **Net assimilation rate (NAR):**

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

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

W_2 = Total dry weight of plant g m^{-2} at time t_2

W_1 = Total dry weight of plant g m^{-2} at time t_1

$(t_2 - t_1)$ = Time interval in days

A_2 = LAI at time t_2

A_1 = LAI at time t_1

2. **Crop growth rate (CGR):**

It was worked out using formula of Watson (1958).

CGR = NAR X LAI, expressed as g m^{-2} day^{-1}.

3. **Dry matter production (DMP):**

Pseudostem and rhizomes of the uprooted plants were separated and dried to constant weight at 70°C to 80°C in hot air oven. The sum of dry weight of components gave the drymatter yield and it was expressed as g per plant.

4. **Bulking rate (BR):**

The rate of bulking in rhizome was worked out on the basis of increase in dry weight of rhizome (g) per plant per day.

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

W_2 = Dry weight of rhizome at time t_2

W_1 = Dry weight of rhizome at time t_1

CHEMICAL ANALYSIS:

1. **Chlorophyll content of leaves:**

Chlorophyll a, chlorophyll b and total chlorophyll content of leaves were estimated 150 days after planting by the spectrophotometric method as described by Starnes and Hadley (1965).

2. **Uptake of NPK:**

The samples collected for recording the dry weight were used for chemical analysis. The nitrogen content of haulm and rhizome was determined by modified microkjeldahl method, phosphorus content by the vanado molybdo phosphoric yellow colour method (Jackson, 1967) and potassium by atomic absorption spectrophotometric method as suggested by Perkin - Elmer Corporation (1982).

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

3. **Volatile oil:**

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

4. **Non volatile ether extract (NVEE):**

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

5. **Fibre content:**

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

6. **Soil Analysis:**

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

Available Nitrogen:

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

Available phosphorus:

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

Available potassium:

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

ECONOMIC EVALUATION:

1. **Net return:**

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

2. **Benefit cost ratio (Return per rupee invested):**

This was calculated by using the relationship

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

3. **Return per rupee invested on fertilizers:**

This was calculated by using the relationship

Return per rupees invested on fertilizers =

$$\frac{\text{Gross return} - \text{cost of cultivation except that incurred on fertilizers}}{\text{Cost of fertilizers}}$$

Results

RESULTS

The results of the field experimentation and chemical analysis are presented below:

Plant height:

The data on plant height as a result of varying degrees of shade and fertilizer levels are presented in Table 3.

Plant height went on increasing with increasing shade levels at all the three growth stages studied ie., 60,120 and 180 days after planting and differed significantly from each other. Plant height at zero per cent shade was the lowest. Effect of fertilizer on the plant height was also found to be significant at all the growth stages and an increasing trend was observed at all the growth stages., maximum height was recorded at F_4 level. Shade-fertilizer interaction was not significant at any of the growth stages.

Number of tillers per plant:

Table 4 presents data on mean tiller production per plant.

Tiller production in ginger was noticed to be affected by shade at later growth stages ie., at 120

Table 3. Effect of shade and fertilizer levels on the mean height of ginger plants (cm)

a. 60 DAP

Shade levels	Fertilizer levels				Mean sh.
	F_1	F_2	F_3	F_4	
S_0	27.21	27.86	30.36	30.52	28.99
S_1	30.69	33.19	35.05	35.02	33.49
S_2	35.85	37.50	40.41	39.36	38.27
S_3	41.00	40.98	40.90	43.41	41.57
Mean Fer.	33.69	34.88	36.68	37.07	
F test	Sh-s	Fer-s	Sh.Fer-NS		
CD (.05)	2.358	1.580			

b. 120 DAP

S_0	34.73	36.28	37.15	37.48	36.40
S_1	39.21	42.21	42.74	44.49	42.16
S_2	45.56	48.31	49.36	48.99	48.05
S_3	49.70	50.56	52.45	52.73	57.36
Mean Fer.	42.30	44.33	45.42	45.92	
F test	Sh-s	Fer-s	Sh.Fer-NS		
CD(0.05)	1.683	1.216			

C. 180 DAP

S_0	41.02	42.44	45.31	45.93	43.68
S_1	51.08	57.54	53.59	54.43	52.65
S_2	55.79	59.60	59.53	61.39	59.08
S_3	61.03	61.05	63.57	64.19	62.46
Mean Fer.	52.23	53.66	55.49	56.47	
F test	Sh-s	Fer-s	Sh.Fer-NS		
CD(0.05)	2.045	1.391			

Table 4. Effect of shade and fertilizer levels on the mean number of tillers per plant (ginger)

a. 60 DAP

Shade levels	Fertilizer levels				Mean sh.
	F_1	F_2	F_3	F_4	
S_0	2.75	3.05	3.50	3.35	3.16
S_1	3.35	3.55	3.70	3.85	3.61
S_2	3.50	3.30	3.45	3.65	3.48
S_3	3.15	3.10	3.40	3.50	3.29
Mean Fer.	3.19	3.25	3.51	3.60	
F test	sh-NS	Fer-NS	Sh.Fer-NS		

b. 120 DAP

S_0	5.20	4.98	5.95	5.90	5.51
S_1	5.45	6.33	6.83	6.40	6.25
S_2	5.18	5.15	5.10	5.10	5.13
S_3	4.78	4.73	4.90	5.00	4.85
Mean Fer.	5.15	5.29	5.69	5.6	
F test CD(0.05)	Sh-s 0.612	Fer-s 0.404	Sh.Fer-NS		

C. 180 DAP

S_0	12.08	12.03	15.58	15.8	13.87
S_1	16.20	16.43	17.78	19.2	17.40
S_2	11.40	11.65	12.30	12.75	12.03
S_3	9.45	8.70	9.55	8.53	9.06
Mean Fer.	12.28	12.00	13.80	14.07	
F test CD(0.05)	Sh-s 1.790	Fer-s 0.868	Sh.Fer-S 0.971		

and 180 DAP. Highest tiller number was recorded at 25 per cent shade and was found to differ significantly from all other shade levels at these two stages. The highest shade level (S_3) gave the lowest tiller number at 120 and 180 DAP. Tiller production under 50 per cent shade was found to be comparable with that under open conditions at both these stages, but significantly lower than that under 25 per cent shade.

Effect of shade and fertilizer treatments was found to be nonsignificant at 60 DAP. At 120 DAP, fertilizer level, F_3 recorded highest tiller number and was significantly superior to F_1 whereas at 180 DAP, F_4, showed maximum tiller production which was significantly superior to F_1 and F_2 but was on par with F_3. Significant interaction between shade and fertilizer levels was observed at 180 DAP. Maximum tiller production was observed under 25 per cent shade at the highest fertilizer level, F_4 which was significantly higher than all other shade levels. Under open conditions and 50 per cent shade, an increasing trend in tiller number was observed with increasing fertilizer levels whereas under 75 per cent shade, no general trend was noticed in this aspect. The data clearly shows that 25 per cent shade offers maximum favourable conditions for tiller production and the response to major nutrients in terms of tiller production is also notable at this shade level.

Number of leaves per plant:

The data presented in Table 5 indicate that there was significant variation in the number of leaves per plant with varying shade levels at all the three growth stages. Leaf number was found to be maximum under 25 per cent shade and was significantly superior to all other shade levels at 120 and 180 DAP. But at 60 DAP, leaf number was found to be minimum under open conditions and was significantly lower than other shade levels which were on par with each other. At 120 and 180 DAP, leaf number was found to be the lowest under heavy shade (75 per cent) and that under open condition and 50 per cent shade were comparable with each other.

At all stages, a general trend of increase in leaf number was observed with increase in fertilizer levels, F_4 recording the highest leaf number except at 120 DAP where F_3 recorded maximum leaf number. Interaction between shade and fertilizer was found to be significant at 120 and 180 DAP. At 120 DAP, fertilizer level, F_3 recorded the highest leaf number per plant under zero, 50 and 75 per cent shade and F_4, under 25 per cent shade. But at 180 DAP, F_4 produced

Table 5. Effect of shade and fertilizer levels on the mean number of leaves per plant (ginger)

a. 60 DAP

Shade levels	Fertilizer levels				Mean sh.
	F_1	F_2	F_3	F_4	
S_0	25.78	30.05	31.78	35.40	30.75
S_1	33.55	35.28	36.40	39.05	36.07
S_2	32.28	33.35	34.08	37.30	34.25
S_3	33.05	33.53	38.35	38.73	35.91
Mean Fer.	31.16	33.05	35.15	37.62	
F test	Sh-s	Fer-s	Sh.Fer-NS		
CD (0.05)	2.635	3.038			

b. 120 DAP

S_0	74.33	74.98	79.50	77.50	76.58
S_1	87.58	94.50	90.73	95.50	92.08
S_2	70.13	75.25	79.55	75.43	75.09
S_3	49.78	56.28	62.23	60.75	57.26
Mean Fer.	70.45	75.25	78.00	77.29	
F test	Sh-s	Fer-s	Sh.Fer-S		
CD(0.05)	4.065	4.502	3.771		

C. 180 DAP

S_0	156.93	163.80	192.58	200.55	178.46
S_1	215.05	262.60	263.88	292.88	258.60
S_2	162.13	171.68	178.30	182.18	173.57
S_3	86.38	96.00	111.20	97.75	97.83
Mean Fer.	155.12	173.52	186.47	193.34	
F test	Sh-s	Fer-s	Sh.Fer-S		
CD(0.05)	8.388	8.853	15.984		

maximum leaves per plant at all shade levels except under heavy shade where F_3 recorded maximum leaf production.

As in the case of tiller number, leaf number was also found to be maximum under low shade (25 per cent) and response to nutrients was also better under this shade level when increase in leaf number was considered.

Chlorophyll content:

Total chlorophyll and its fractions, chlorophyll 'a' and chlorophyll 'b' increased progressively with increasing levels of shade at 150 DAP (Table 6 and Fig. 2). The ratio of chlorophyll 'a' to 'b' was found to be unaffected by shade and fertilizer treatments. At all shade levels, fertilizer treatments showed a general trend of increase in total chlorophyll as well as chlorophyll 'a' and chlorophyll 'b'. No significant interaction was observed between shade and fertilizer treatments.

Leaf area index (LAI):

Table 7 depicts the leaf area index (LAI) as influenced by shade and fertilizer treatments.

Table 6. Effect of shade and fertilizer levels on the mean content of chlorophyll fractions of ginger leaves at 150 days after planting (mg g^{-1} fresh weight)

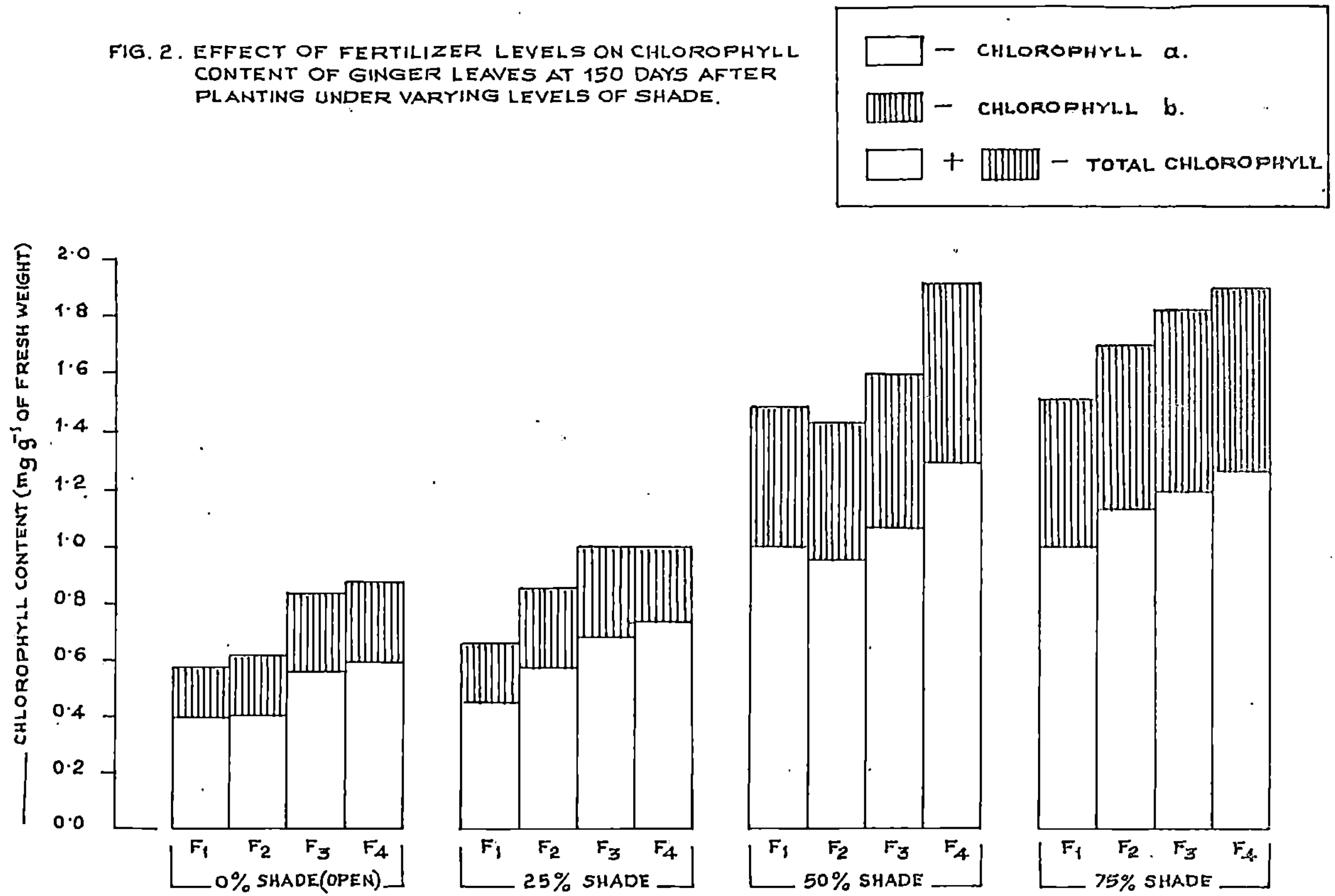
a. Chlorophyll 'a' and Chlorophyll 'b'

Shade levels	Fertilizer levels								Mean Sh.	
	F_1		F_2		F_3		F_4			
	Ch.a	Ch.b	Ch.a	Ch.b	Ch.a	Ch.b	Ch.a	Ch.b	Ch.a	Ch.b
S_0	0.393	0.180	0.408	0.205	0.560	0.283	0.588	0.278	0.487	0.236
S_1	0.445	0.213	0.575	0.278	0.678	0.330	0.735	0.350	0.608	0.293
S_2	1.008	0.480	0.955	0.480	1.068	0.535	1.293	0.638	1.081	0.533
S_3	1.008	0.515	1.135	0.565	1.198	0.630	1.273	0.630	1.153	0.585
Mean Fer.	0.713	0.347	0.768	0.382	0.876	0.444	0.972	0.474		
F test CD(0.05)			Sh-S 0.0503	Sh-S 0.0292	Fer-S 0.0430	Fer-S 0.0291	Sh.Fer-NS	Sh.Fer-NS		

b. Total chlorophyll and chlorophyll a/b

	(a+b)	a/b	(a+b)	a/b	(a+b)	a/b	(a+b)	a/b	(a+b)	a/b
S_0	0.573	2.205	0.613	2.010	0.843	1.993	0.865	2.113	0.723	2.080
S_1	0.658	2.078	0.853	2.090	1.008	2.055	1.085	2.110	0.901	2.083
S_2	1.488	2.100	1.435	2.003	1.603	2.008	1.930	2.028	1.614	2.034
S_3	1.523	1.978	1.700	2.003	1.828	1.900	1.903	2.015	1.738	1.974
Mean Fer.	1.060	2.090	1.150	2.026	1.320	1.989	1.446	2.066		
F test CD(0.05)			Sh-S 0.0766	Sh-NS -	Fe-S 0.0635	Fer-NS -	Sh.Fer-NS -	Sh-Fer-NS -		

FIG. 2. EFFECT OF FERTILIZER LEVELS ON CHLOROPHYLL CONTENT OF GINGER LEAVES AT 150 DAYS AFTER PLANTING UNDER VARYING LEVELS OF SHADE.



Effect of shade, fertilizer treatments and their interactions were found to be significant at all the three growth stages namely 90, 135 and 180 days after planting. Leaf area index was found to be the highest under 25 per cent shade at 135 DAP but it was on par with that under 50 per cent shade at 90 DAP and 180 DAP. However at all the growth stages, LAI was found to be significantly lower under open conditions compared to shade treatments.

In general, an increasing trend in LAI was observed with increasing fertilizer levels. At all growth stages, LAI at F_1 fertilizer level was found to be significantly lower compared to other fertilizer levels. At 90 and 180 DAP F_2, F_3 and F_4 treatments were found to be on par., but at 135 DAP, F_4 produced significant increase in LAI over F_2. Trends in LAI with increase in fertilizer levels were different in different shade levels. At full illumination, F_4, recorded maximum LAI at 90 and 180 DAP whereas at 135 DAP, F_3 recorded highest LAI. At all stages, F_4 gave maximum LAI under 25 per cent shade. Under 50 per cent shade, F_4 produced maximum LAI at 90 and 135 DAP and F_3, at 180 DAP. Under heavy shade, F_3 gave highest LAI at 90 and 135 DAP and at 180 DAP, F_2 recorded maximum LAI.

Table 7. Effect of shade and fertilizer levels on the mean leaf area index of ginger

a. 90 DAP

Shade levels	Fertilizer levels F_1	F_2	F_3	F_4	Mean sh.
S_0	2.373	2.528	2.855	2.598	2.588
S_1	2.878	3.008	2.965	3.635	3.121
S_2	3.008	3.158	2.853	3.190	3.052
S_3	2.535	2.865	2.970	2.515	2.721
Mean Fer.	2.698	2.890	2.911	2.985	
F test CD (0.05)	Sh-s 0.188	Fer-s 0.125	Sh.Fer-S 0.247		

b. 135 DAP

S_0	3.175	3.638	3.478	4.058	3.587
S_1	4.375	5.095	5.195	6.048	5.178
S_2	4.000	5.128	5.420	5.428	4.994
S_3	4.005	4.360	4.833	4.410	4.402
Mean Fer.	3.889	4.555	4.731	4.986	
F test CD(0.05)	Sh-s 0.106	Fer-s 0.298	Sh.Fer-S 0.280		

C. 180 DAP

S_0	5.775	6.903	8.135	7.625	7.109
S_1	11.158	11.660	13.078	14.935	12.708
S_2	11.400	13.080	19.795	13.493	13.192
S_3	8.205	12.240	10.385	10.775	10.401
Mean Fer.	9.134	10.971	11.598	11.707	
F test CD(0.05)	Sh-s 1.031	Fer-s 1.020	Sh.Fer-NS 1.450		

The analysis of data reveals that LAI and the capacity to respond to increased levels of major nutrients in terms of LAI were more in low to medium shade compared to open conditions and heavy shade.

Net assimilation rate (NAR):

The data on the net assimilation rate and the results of the statistical analysis of the same are shown in Table 8.

Net assimilation rate showed a decreasing trend with increase in shade. Under open condition, NAR was found to be significantly higher compared to all other shade levels at both growth phases (90-135 DAP and 135-180 DAP). Net assimilation rate under 25 and 50 per cent shade levels were found to be on par but showed a drastic decrease under heavy shade (75 per cent).

Effect of fertilizer was not significant in the early growth phase (90-135 DAP) but in the later phase, F_4 was found to be significantly superior to F_1. Shade-fertilizer interaction was also observed in this growth phase. A positive response to fertilizer treatments was noticed under zero, 25 and 50 per cent shade levels whereas under heavy shade NAR failed to show any regular trend.

Table 8. Effect of shade and fertilizer levels on net assimilation rate of ginger plants (g m^{-2} day^{-1})

a. Between 90 and 135 DAP

Shade levels	Fertilizer levels				Mean Sh.
	F_1	F_2	F_3	F_4	
S_0	1.078	1.049	1.089	1.092	1.077
S_1	1.056	0.933	0.936	0.861	0.946
S_2	0.824	0.774	0.919	0.900	0.854
S_3	0.682	0.657	0.698	0.674	0.678
Mean Fer.	0.910	0.853	0.911	0.882	

F Test	Sh.S	Fer-NS		Sh.Fer-NS
CD(0.05)	.0949			

b. Between 135 and 180 DAP

S_0	1.350	1.390	1.368	1.473	1.395
S_1	0.968	1.120	1.158	1.135	1.095
S_2	1.050	1.048	1.040	1.175	1.078
S_3	0.850	0.655	0.745	0.765	0.754
Mean-Fer.	1.055	1.053	1.078	1.137	

F Test	Sh.s	Fer-S	Sh.Fer-S
CD(0.05)	0.084	0.045	0.109

Crop growth rate (CGR):

Table 9 depicts the crop growth rate under varying levels of shade and fertilizer treatments.

At both the growth phases (90-135 DAP and 135-180 DAP), effect of shade as well as fertilizer levels was significant. Crop growth rate was found to be maximum under 25 per cent shade at both growth phases followed by that under 50 per cent shade and open conditions and was the lowest under 75 per cent shade. During the early growth phase (90-135 DAP), CGR at zero and 50 per cent shade was found to be on par and during the later growth phase ie., from 135 to 180 DAP, CGR at 25 and 50 per cent shade was found to be on par.

In the early growth phase, fertilizer levels F_2, F_3 and F_4 were found to be on par with each other but significantly superior to F_1 and in the later growth phase, there was significant increase in CGR with each increase in fertilizer dose and F_4 was observed to produce maximum CGR. At both growth phases shade-fertilizer interaction was found to be nonsignificant.

Table 9. Effect of shade and fertilizer levels on the crop growth rate of ginger (g m^{-2} day^{-1})

a. Between 90 and 135 DAP

Shade levels	Fertilizer levels				Mean Sh.
	F_1	F_2	F_3	F_4	
S_0	2.998	3.235	3.453	3.640	3.331
S_1	3.830	3.780	3.748	4.045	3.851
S_2	2.878	3.208	3.800	3.703	3.397
S_3	2.295	2.418	2.728	2.318	2.437
Mean Fer.	2.998	3.160	3.432	3.426	
F test CD (0.05)	Sh.s 0.392		Fer.S 0.329		Sh.Fer-NS

b. Between 135 and 180 DAP

S_0	6.013	7.075	8.000	8.613	7.425
S_1	7.518	9.358	10.915	11.915	9.858
S_2	8.045	9.580	10.498	11.108	9.808
S_3	5.268	5.388	5.678	5.833	5.541
Mean Fer.	6.711	7.850	8.704	9.367	
F test CD(0.05)	Sh-S 0.856		Fer-S 0.615		Sh.Fer-NS

Dry matter production (DMP):

Significant variation was noticed among shade levels with respect to the dry matter production. Dry matter production at 25 and 50 per cent shade were found to be on par with each other but significantly superior to zero and 75 per cent shade (Table 10 and Fig.3). There was a drastic reduction in DMP at 75 percent shade both at 135 and 180 DAP, the extent of decrease being 17.8 and 22.2 per cent respectively of that under open conditions.

At all growth stages, fertilizer levels showed an increasing trend in DMP with increasing fertilizer levels. Significant interaction between shade and fertilizer levels was noticed at 90 and 135 DAP. At these growth stages, from open conditions to 50 per cent shade, DMP was found to be increasing with increasing fertilizer level and recorded maximum value at F_4 level., but under heavy shade F_3 level produced the highest DMP. Thus dry matter production and the response to increased level of nutrients in terms of DMP were found to be better under low to medium (25 to 50 per cent) shade.

Table 10. Effect of shade and fertilizer levels on the mean dry matter production of ginger

a. 90 DAP

Shade levels	Fertilizer levels				Mean Sh.
	F_1	F_2	F_3	F_4	
S_0	6.705	7.643	8.448	10.123	8.229
S_1	6.733	8.735	9.165	10.138	8.693
S_2	8.215	8.668	8.258	8.770	8.478
S_3	7.398	7.228	8.143	7.813	7.695
Mean Fer.	7.263	8.068	8.503	9.211	
F test CD (0.05)	Sh-S 0.530		Fer-S 0.583		Sh.Fer-S 0.513

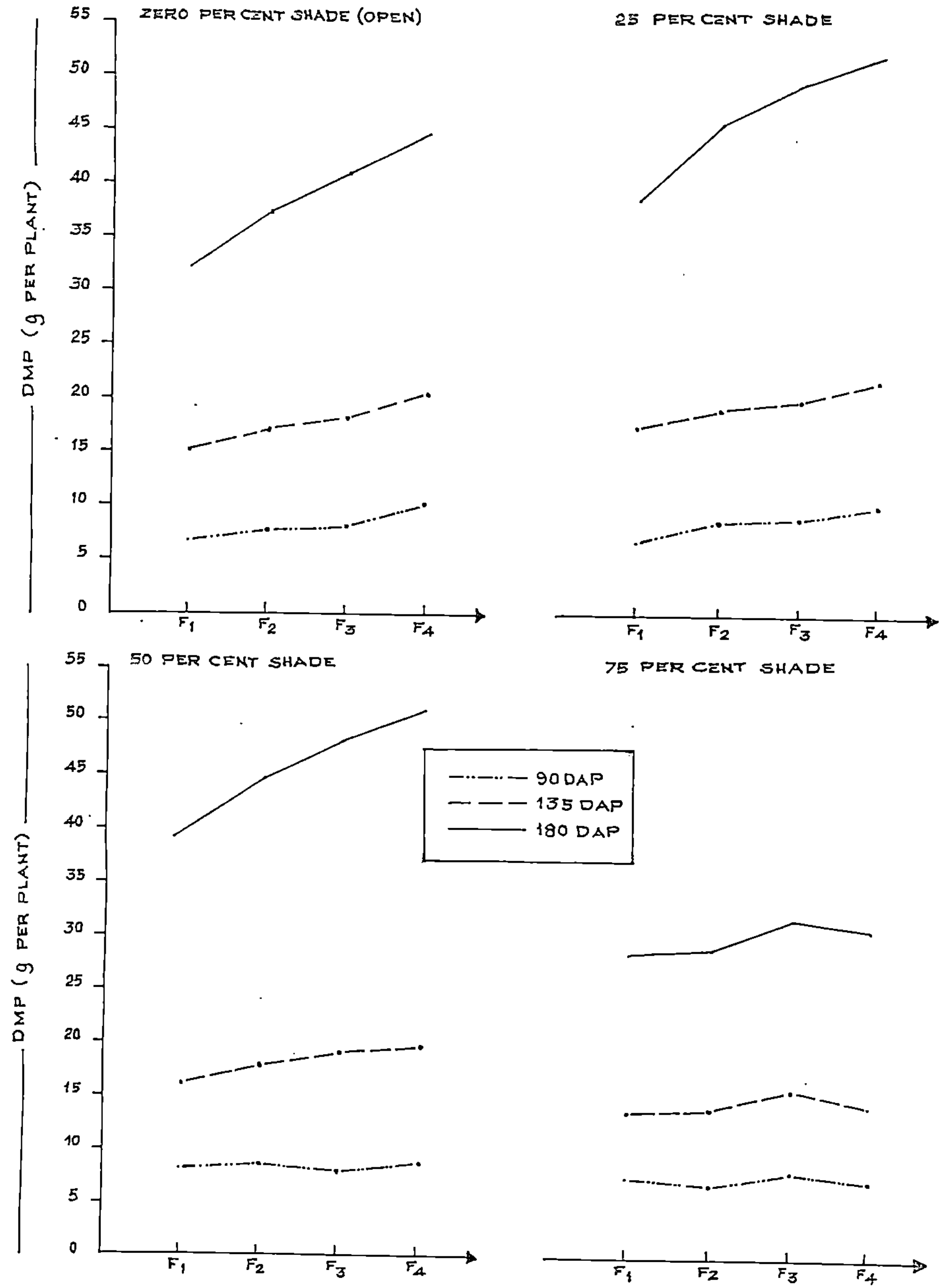
b. 135 DAP

S_0	14.988	16.740	18.150	20.363	17.560
S_1	17.500	19.375	19.863	21.875	19.653
S_2	16.313	17.688	18.963	19.525	18.122
S_3	62.500	13.913	15.813	14.338	14.441
Mean Fer.	15.625	16.929	18.197	19.025	
F Test CD(0.05)	Sh-S 0.794		Fer-S 0.834		Sh.Fer-S 1.296

c. 180 DAP

S_0	32.02	37.31	40.47	44.60	38.60
S_1	38.64	45.74	49.67	52.13	46.55
S_2	38.97	44.57	48.38	50.81	45.68
S_3	28.52	29.05	31.78	30.72	30.02
Mean Fer.	34.54	39.17	42.48	44.57	
F Test CD(0.05)	Sh-S 3.263		Fer-S 2.022		Sh.Fer-S 4.022

FIG. 3. EFFECT OF FERTILIZER LEVELS ON DRY MATTER PRODUCTION OF GINGER UNDER VARYING LEVELS OF SHADE.



Bulking rate:

The data on bulking rate are furnished in Table 11.

During both the growth phases bulking rate was found to be maximum under 25 per cent shade and was significantly superior to all other shade levels except in the second growth phase (135 to 180 DAP) where S_1, was found to be on par with S_2. Bulking rate was significantly lower under S_3 (75 per cent shade) at both growth phases.

Bulking rate showed a positive response to increasing levels of fertilizers and at both growth phases the effect of fertilizer treatments were found to be significant. During the growth phase from 135 to 180 DAP, significant interaction between shade and fertilizer levels was observed. Under zero and 50 per cent shade, fertilizer level F_2 showed significant increase in bulking rate over F_1, and was found to be on par with F_3 and F_4. But under 25 per cent shade, bulking rate showed significant increase with each increment in fertilizer dose. Under 75 per cent shade, fertilizer treatments did not show any significant effect on bulking rate. Thus low shade was found to provide optimum conditions for rhizome development.

Table 11. Effect of shade and fertilizer levels on bulking rate of ginger rhizomes (g day^{-1})

a. Between 90 and 135 DAP

Shade levels	Fertilizer levels				Mean Sh.
	F_1	F_2	F_3	F_4	
S_0	0.114	0.122	0.141	0.162	0.135
S_1	0.144	0.143	0.157	0.171	0.153
S_2	0.096	0.114	0.120	0.129	0.115
S_3	0.077	0.092	0.097	0.084	0.087
Mean Fer.	0.108	0.118	0.128	0.137	
F test CD (0.05)	Sh. 0.0132		Fer.S 0.0102		Sh.Fer-NS

b. Between 135 and 180 DAP

S_0	0.192	0.265	0.296	0.276	0.257
S_1	0.227	0.278	0.319	0.373	0.299
S_2	0.210	0.260	0.278	0.306	0.264
S_3	0.118	0.116	0.120	0.118	0.116
Mean Fer.	0.185	0.230	0.253	0.268	
F test CD(0.05)	Sh-S 0.0198		Fer-S 0.0318		Sh.Fer-S 0.0319

Rhizome spread:

Rhizome spread showed significant difference among shade levels (Table 12). Rhizome spread under 50 per cent shade was found to be significantly higher than that under zero and 25 per cent shade but was on par with that under heavy shade. Fertilizer treatments F_3 and F_4 did not show any significant difference in rhizome spread but were found to be statistically superior to F_1 and F_2 levels. No significant interaction was noticed between shade and fertilizer levels.

Green ginger yield:

The highest green ginger yield was recorded under 25 per cent shade followed by 50, zero and 75 per cent shade (Table 13). The percentage yields at 25, 50 and 75 per cent shade levels were 119.1, 109.7 and 82.9 per cent of the yield at full illumination. There were statistically significant differences among yields at different fertilizer levels. The fertilizer level, F_4, had the highest mean ginger yield and this was statistically superior to all other fertilizer levels. Fertilizer levels F_2 and F_3 were found to be on par but superior to F_1. Shade-fertilizer interaction was not significant.

Table 12. Effect of shade and fertilizer levels on rhizome spread of ginger (cm)

Shade levels	Fertilizer levels				Mean Sh.
	F_1	F_2	F_3	F_4	
S_0	15.42	15.34	16.00	15.38	15.53
S_1	15.25	15.90	16.11	16.18	15.88
S_2	16.31	16.42	17.15	17.27	16.78
S_3	16.17	15.88	16.60	16.95	16.40
Mean Fer.	15.812	15.886	16.461	16.44	
F test CD(0.05)	Sh-S 0.548		Fer-S 0.565		Sh.Fer-NS

Table 13. Effect of shade and fertilizer levels on green ginger yield (kg ha^{-1})

Shade levels	Fertilizer levels				Mean.Sh
	F_1	F_2	F_3	F_4	
S_0	12705	13747	14453	14780	13921
S_1	15165	15820	16731	18585	16575
S_2	14385	15102	15295	16294	15269
S_3	10457	11820	11900	11973	11538
Mean Fer.	13178	14122	14595	15408	
F Test CD(0.05)	Sh-S 1155		Fer-S 546		Sh.Fer-NS

Recovery of dry ginger:

The data on recovery of dry ginger is presented in Table 14.

Percentage dry ginger recovery failed to show any significant difference between treatments. Neither shade nor fertilizer levels significantly influenced dry ginger recovery and no interaction between shade and fertilizer levels was noticed.

Dry ginger yield:

The data on dry ginger yield as influenced by shade and fertilizer levels are presented in Table 14 and Fig.4.

Highly significant variation was noticed among shade levels with respect to total dry ginger yield on a hectare basis. The yield in 25,50 and 75 per cent shade expressed as percentage yield in the open were 114.0, 104.1 and 78.4 per cent respectively. The dry ginger yields at zero and 50 per cent shade was statistically on par whereas that at 75 per cent shade was significantly lower compared to other shade levels.

Among the fertilizer levels, F_4 recorded the highest yield and thére was significant increase in yield with each increment in fertilizer dose from F_1, to F_4.

Table 14. Effect of shade and fertilizer levels on dry ginger recovery and dry ginger yield.

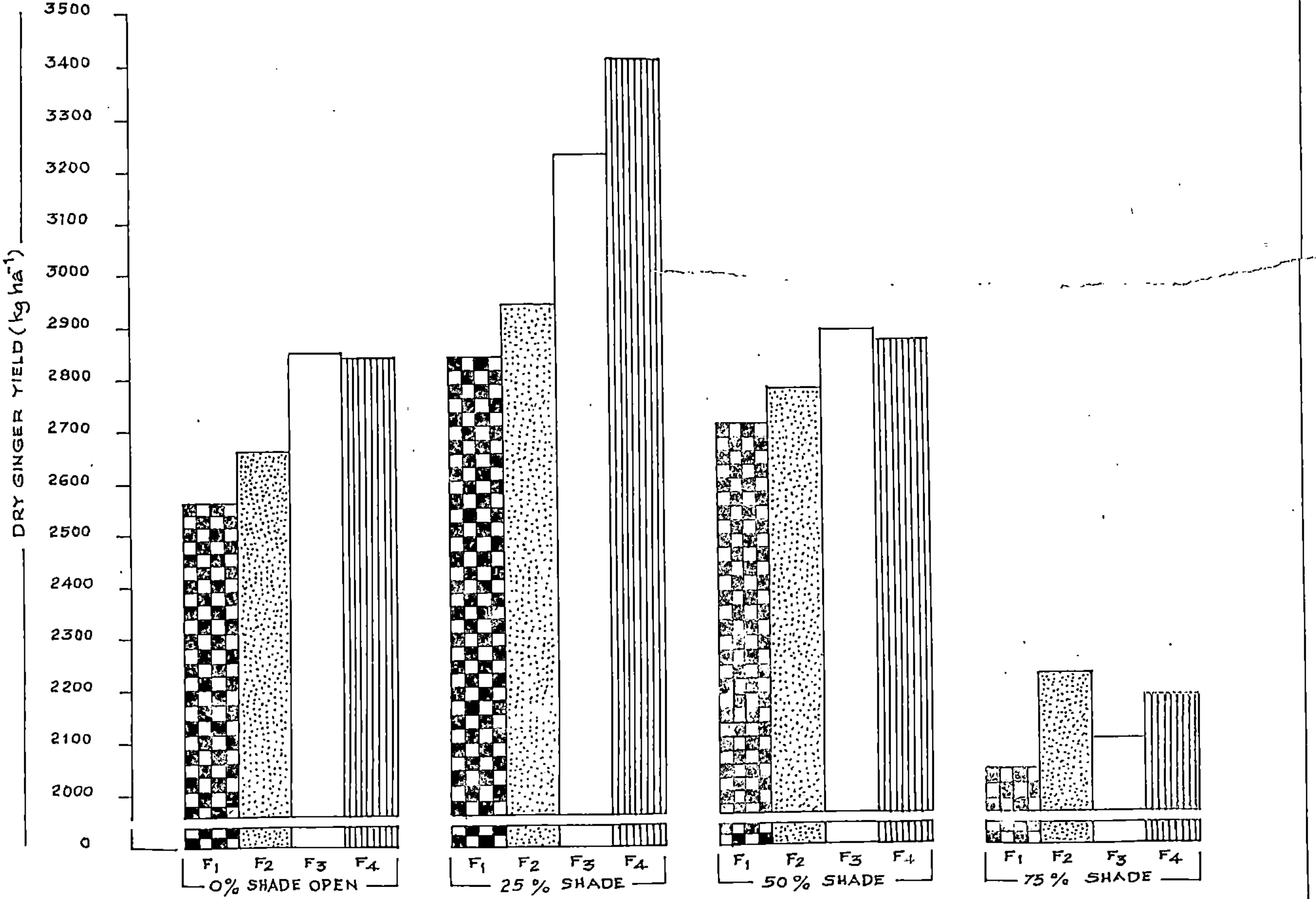
a. Dry ginger recovery (%)

Shade levels	F_1	F_2	F_3	F_4	Mean Sh.
S_0	20.19	19.38	19.40	19.23	19.55
S_1	18.75	18.65	19.35	18.35	18.78
S_2	18.93	18.43	18.90	18.25	18.63
S_3	19.55	18.85	18.13	18.25	18.70
Mean Fer.	19.35	18.83	18.94	18.32	
F test CD(0.05)	Sh-NS		Fer-NS		Sh.Fer-NS

b. Dry ginger yield (kg ha^{-1})

S_0	2561.50	2656.50	2850.75	2840.75	2727.40
S_1	2843.25	2945.00	3233.75	3415.25	3109.30
S_2	2715.00	2779.50	2894.50	2971.75	2840.20
S_3	2044.75	2223.75	2102.25	2184.50	2138.80
Mean Fer.	2541.10	2651.20	2770.30	2853.10	
F test CD(0.05)	Sh-S 240.53		Fer-S 67.94		Sh.Fer-S 134.63

FIG. 4. EFFECT OF SHADE AND FERTILIZER LEVELS ON DRY GINGER YIELD.



Significant interaction between shade and fertilizer levels was found. Under open conditions, F_3, recorded maximum yield which was significantly superior to F_1 and F_2 but was on par with F_4. The influence of fertilizer treatments on dry ginger yield under open condition was explained by the linear regression

$Y = 22.598 + 0.0416\,x$ with a coefficient of determination $(R^2) = 0.9455$

Where x = % of the recommended dose at which N, P_2O_5, and K_2O were applied.

Under 25 per cent shade, a significant increase in dry ginger yield with each increment in fertilizer dose was observed upto the highest fertilizer dose, F_4. The effect of fertilizer levels on the dry ginger yield under 25 per cent shade was explained by the linear regression equation

$Y = 22.068 + 0.08022\,x$ with a coefficient of determination $(R^2) = 0.9858$

Where X = % of the recommended dose at which N, P_2O_5, and K_2O were applied.

Under 50 per cent shade also, dry ginger yield showed a general trend of increase with increase in fertilizer dose. Under this shade level, yield as a function of fertilizer was fitted by the linear regression

$Y = 24.407 + 0.03555\ x$ with a coefficient of determination $(R^2) = 0.9973$

where x = % of the recommended dose at which N, P_2O_5, and K_2O were applied.

Fertilizer treatments F_2, F_3 and F_4 were found to be on par but significantly superior to F_1, under heavy shade. The influence of fertilizer treatments on dry ginger yield under 75 per cent shade was given by the regression equation

$Y = 19.797 + 0.01416\ x$ with a coefficient of determination $(R^2) = 0.5662$

where x = % of the recommended dose at which N, P_2O_5, and K_2O were applied.

In short, low shade (25 per cent) was found to have a beneficial effect on productivity of ginger and also found to improve the capacity of the plant to utilize higher doses of nutrients.

Top yield:

Top yield was the lowest in the open and was significantly low compared to all other shade levels (Table 15). With decrease in light intensity, there was a progressive increase in top yield upto 50 per cent shade. Top yields under 25 and 75 per cent shade was found to be on par.

Effect of fertilizer was significant at all levels and the top yield was found to be increasing with increase in fertilizer levels. Interaction between shade and fertilizer levels was also significant. At zero per cent shade, F_4 was observed to be on par with F_3 but significantly superior to F_1, and F_2. Under 25 and 50 per cent shade levels top yields were maximum at F_4 level and was significantly superior to all other fertilizer levels. Under heavy shade F_2, F_3, and F_4 were found to be on par but superior to F_1. Analysis of data shows that both shade and fertilizer treatments had a positive influence on top yield.

Utilization index (UI):

Significant variation was noticed in the utilization index under varying shade levels (Table 15). Utilization index was superior under open and found to be steadily decreasing with increase in shade though UI at S_2 and S_3 were on par. A decreasing trend in UI was observed with increasing fertilizer levels also., F_3 and F_4, recorded significantly lower UI when compared to F_1. Shade-fertilizer interaction was not significant. In general the data indicates that both shade and fertilizer had an unfavourable effect on UI.

Harvest index:

Table 15 provides data on harvest index.

Table 15. Effect of shade and fertilizer levels on top yield, utilization index and harvest index of ginger

a. Top yield Kg ha^{-1})

Shade levels	F_1	F_2	F_3	F_4	Mean Sh.
S_0	1007.50	1074.75	1127.75	1194.50	1101.13
S_1	1369.75	1438.75	1651.00	1801.75	1565.31
S_2	1877.00	2043.50	2162.00	2334.75	2104.31
S_3	1493.75	1672.25	1723.75	1685.75	1643.88
Mean Fer.	1437.00	1557.31	1666.13	1754.19	
F Test CD(0.05)	Sh-S 118.49		Fer-S 70.33		Sh.Fer-NS 114.93

b. Utilization index

S_0	2.55	2.48	2.53	2.39	2.48
S_1	2.08	1.98	1.96	1.89	1.98
S_2	1.44	1.36	1.34	1.27	1.36
S_3	1.37	1.33	1.25	1.29	1.31
Mean Fer.	1.86	1.79	1.77	1.71	
F test C.D(0.05)	Sh-S 0.0640		Fer-S 0.0882		Sh.Fer-NS

c. Harvest index

S_0	0.718	0.713	0.718	0.705	0.713
S_1	0.675	0.665	0.663	0.655	0.664
S_2	0.593	0.578	0.570	0.553	0.573
S_3	0.578	0.573	0.550	0.565	0.566
Mean Fer.	0.641	0.632	0.625	0.620	
F test CD(0.05)	Sh-S 0.009		Fer-S 0.013		Sh.Fer-NS

As in the case of utilization index, harvest index (HI) was also found to be the highest under open conditions and steadily decreasing with increase in shade intensity. However harvest index at S_2 and S_3, levels found to be on par HI at different fertilizer levels also showed a declining trend with increasing fertilizer levels, the values being 0.641, 0.632, 0.625 and 0.620 at F_1, F_2, F_3 and F_4 levels respectively. Harvest index at F_1 and F_2 and F_2, F_3 and F_3 and F_4, were found to be on par. As observed in the case of UI, the effects of shade and fertilizer levels on HI were also independent.

Volatile oil:

Volatile oil content was found to be the highest under 25 per cent shade followed by that under 50 per cent shade which was on par with that under 75 per cent shade. Volatile oil content under open condition was found to be significantly lower when compared to other shade levels. Effect of fertilizer treatments and shade-fertilizer interaction were found to be nonsignificant.

Non-volatile ether extract (NVEE):

Non volatile ether extract content under 25 and 50 per cent shade were found to be on par with each other and significantly superior to that under zero and

Table 16. Effect of shade and fertilizer levels on volatile oil, non volatile ether extract and fibre content of ginger rhizomes on dry weight basis

a. Volatile oil content (v/w)%

Shade levels	F_1	F_2	F_3	F_4	Mean-Sh
S_0	1.525	1.875	1.875	1.900	1.794
S_1	2.275	2.100	2.100	2.275	2.188
S_2	2.075	1.825	1.900	2.000	1.950
S_3	1.950	1.975	1.825	1.875	1.906
Mean Fer.	1.956	1.944	1.925	2.013	
F test CD(0.05)	Sh-S 0.200		Fer-NS		Sh.Fer-NS

b. NVEE content (%)

S_0	5.125	5.075	4.725	4.750	4.919
S_1	5.450	5.700	5.125	5.250	5.381
S_2	5.125	5.400	4.950	5.250	5.181
S_3	4.750	4.550	4.400	4.425	4.531
Mean Fer.	5.113	5.181	4.800	4.919	
F test CD(0.05)	Sh-S 0.426		Fer-NS		Sh.Fer-NS

c. Fibre content (%)

S_0	7.268	6.975	7.343	6.929	7.128
S_1	7.030	6.855	6.918	6.633	6.859
S_2	6.468	6.795	6.615	6.358	6.559
S_3	6.523	6.373	6.255	6.598	6.437
Mean Fer.	6.822	6.750	6.780	6.628	
F test CD(0.05)	Sh-S 0.233		Fer-NS		Sh.Fer-NS

75 per cent shade (Table 16). The NVEE contents at 25 and 50 per cent shade were 5.381 and 5.181 per cent respectively on dry weight basis. As observed in the case of volatile oil, effect of fertilizer treatments on NVEE and shade- fertilizer interaction were not significant.

Fibre content:

Fibre content was the highest in the open and was significantly high compared to all other shade levels. Fibre content showed a decreasing trend with increase in shade intensity though the fibre contents at 50 and 75 per cent shade were observed to be on par. Neither the effect of fertilizers on fibre content nor shade-fertilizer interaction was significant.

Uptake of nutrients:

Data presented in Table 17 reveals the influence of shade and fertilizer treatments on the uptake of major nutrients (Fig. 5).

The uptake of nitrogen increased from zero to 50 per cent shade and then showed a decrease under 75 per cent shade. The uptake of N at 25, 50 and 75 per cent shade levels were 131.1, 148.8 and 125.7 per cent respectively, of the uptake at zero per cent shade. N uptake under 25 per cent and 75 per cent shade were found to be on par. With each increase in fertilizer dose there was a significant increase in N uptake. Shade-fertilizer interaction were found to be significant. Under zero, 50 and 75 per cent shade, N uptake was found to be maximum at F_3 level which was on par with F_4 but significantly superior to F_1 and F_2. Under 25 per cent shade, F_4 showed maximum uptake and there was significant increase in uptake with increase in fertilizer dose.

The phosphorus uptake was found to be the highest under 50 per cent shade followed by 25 per cent shade. Phosphorus uptake under open conditions and 75 per cent shade were on par with each other but significantly lower when compared to that under 50 and 25 per cent shade. An increasing trend in P uptake was observed with increase in fertilizer levels. The effect of fertilizer on P uptake was found to be different under varying shade levels. Under zero, 25 and 50 per cent shade levels, P uptake was found to be maximum at F_4 level which was statistically significant over all other shade levels, but under 75 per cent shade, there was no regular trend shown in P uptake with increase in fertilizer levels.

Potassium uptake was found to follow a similar pattern as that of nitrogen, the uptake at 25,

Table 17. Effect of shade and fertilizer levels on the N,P and K uptake of ginger plants

a. N uptake (kg ha^{-1})

Shade levels	F_1	F_2	F_3	F_4	Mean Sh.
S_0	57.50	60.79	73.58	72.29	66.04
S_1	72.71	75.19	92.92	105.45	86.57
S_2	85.28	93.40	105.90	108.52	98.27
S_3	70.61	83.30	88.26	91.58	83.44
Mean Fer.	71.52	78.17	90.17	94.46	
F Test CD(0.05)	Sh.S 4.786		Fer-S 3.459		Sh.Fer-S 5.844

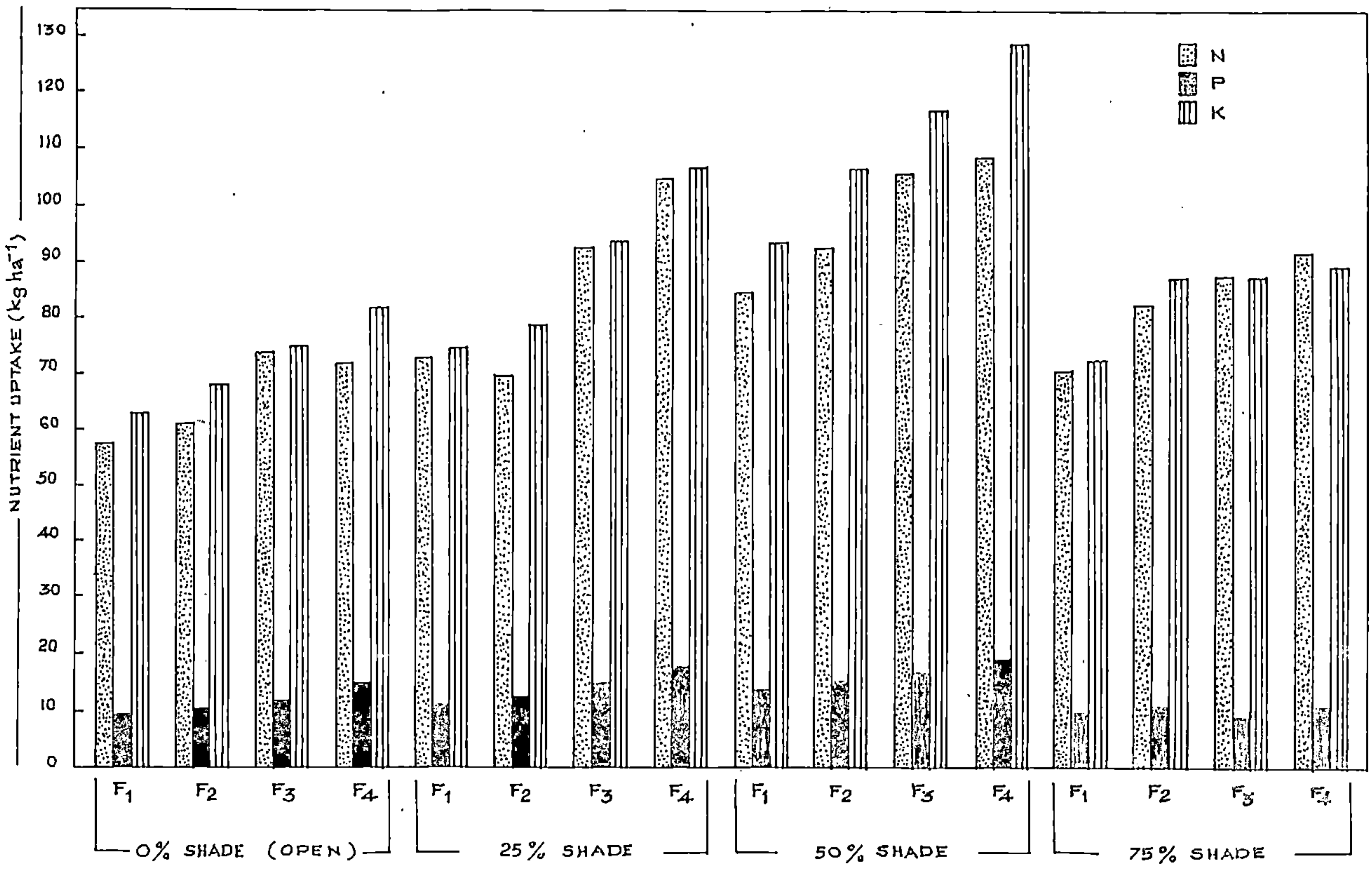
b. P uptake (kg ha^{-1})

S_0	9.390	10.41	11.89	14.64	11.58
S_1	11.41	12.51	14.65	18.14	14.19
S_2	13.91	15.52	17.32	19.49	16.56
S_3	10.29	10.85	9.65	11.20	10.50
Mean Fer.	11.25	12.33	13.38	15.87	
F test CD(0.05)	Sh-S 1.140		Fer-S 0.706		Sh.Fer-S 1.152

c. K uptake (kg ha^{-1})

S_0	62.81	68.03	75.12	81.93	71.97
S_1	74.57	78.80	93.41	107.06	88.46
S_2	93.77	106.94	117.62	128.92	111.81
S_3	73.17	88.11	83.40	89.78	83.62
Mean Fer.	76.08	85.47	92.39	101.92	
F Test CD(0.05)	Sh-S 8.028		Fer-S 3.724		Sh.Fer-S 5.931

FIG. 5. EFFECT OF SHADE AND FERTILIZER LEVELS ON NUTRIENT UPTAKE OF GINGER PLANTS.



50 and 75 per cent shade being 122.9, 155.4 and 116.2 per cent respectively, of the uptake at zero per cent shade. Potassium uptake was found to be increasing with increase in fertilizer levels. Under zero, 25 and 50 per cent shade levels, fertilizer levels produced a steady increase in K uptake upto F_4 level whereas under 75 per cent shade, no regular trend was observed in K uptake.

Soil NPK content:

Table 18 presents data on soil NPK content as influenced by shade and fertilizer treatments.

The soil nitrogen content was found to increase steadily with increasing fertilizer levels. Fertilizer levels F_1 and F_2 and F_3 and F_4 were found to be on par. Effect of shade and shade-fertilizer interaction were found to be nonsignificant. Soil phosphorus content was found to be influenced by both shade and fertilizer levels. Soil available phosphorus content was found to be the highest under 75 per cent shade followed by that under open condition. Soil available P content under 25 and 50 per cent shade were on par but significantly lower to that under open and 75 per cent shade. There was significant increase in soil available P content with increasing fertilizer levels. Soil potassium content also showed the same trend with increasing fertilizer levels and was found

Table 18 Effect of shade and fertilizer levels on the available N, available P_2O_5 and available K_2O contents in soil

a. Soil N content ($kgha^{-1}$)

Shade levels	F_1	F_2	F_3	F_4	Mean Sh.
S_0	213.43	217.24	241.83	246.16	229.66
S_1	221.05	222.34	243.01	251.30	234.42
S_2	212.77	226.84	235.46	257.58	233.16
S_3	221.90	238.42	260.89	262.69	245.97
Mean Fer.	217.29	226.21	245.30	254.43	
F test CD (0.05)	Sh-NS		Fer-S 12.75		Sh.Fer-NS

b. Soil P_2O_5 content ($kg\ ha^{-1}$)

S_0	38.09	44.11	46.50	54.29	45.75
S_1	35.13	39.12	42.62	49.01	41.47
S_2	36.49	37.09	41.48	48.23	40.82
S_3	41.52	47.56	50.05	54.72	48.46
Mean Fer.	37.81	41.97	45.16	51.56	
F test CD (0.05)	Sh-S 2.801		Fer-S 2.785		Sh.Fer-NS

c. Soil K_2O content ($kg\ ha^{-1}$)

S_0	111.18	130.03	145.81	162.36	137.34
S_1	102.46	122.69	130.06	129.33	121.14
S_2	105.55	115.90	116.77	148.80	121.75
S_3	133.21	131.90	139.57	144.32	137.25
Mean Fer.	113.10	125.13	133.05	146.20	
F test CD (0.05)	Sh-NS		Fer-S 10.593		Sh.Fer-NS

to be unaffected by shade levels. Shade-fertilizer interaction was also absent.

Economics:

The data on economics of fertilizer application to ginger under varying levels of shade are presented in Table 19.

Net return, benefit : cost ratio and return per rupee invested on fertilizers were found to be the highest under 25 per cent shade followed by 50 per cent shade. Under open, 25 and 50 per cent shade levels, return per rupee invested on fertilizers showed a steady decrease with increase in fertilizer dose whereas under heavy shade no regular trend was observed.

Under open conditions maximum profit (Rs.20849 ha^{-1}) was obtained for F_3 level of fertilizer application. Benefit : cost ratio was also maximum at F_3, level, but maximum return per rupee invested on fertilizers was obtained for the lowest level of fertilizer application (F_1). Under 25 and 50 per cent shade, F_4 level gave highest net return and benefit cost ratio. There was a steady increase in profit and benefit cost ratio and a decreasing trend in return per rupee invested on fertilizers with increase in

Table 19 Economics of fertilizer application to ginger under varying levels of shade

Treatments	Cost of cultivation Rs. ps.	Mean yield Kgha -1	Value of yield Rs. Ps.	Profit Rs. Ps.	Benefit : cost ratio	Return per rupee invested on fertilizers
Open condition						
F_1	41279.15	2561.5	56353.20	15073.85	1.365	18.07
F_2	41573.50	2656.5	58443.00	16869.50	1.406	15.33
F_3	41867.85	2850.8	62717.60	20849.75	1.498	15.17
F_4	42162.25	2840.8	62497.60	20335.35	1.482	12.51
25 per cent shade						
F_1	41279.15	2843.3	62552.6	21273.45	1.515	25.09
F_2	41573.50	2945.0	64790.0	23216.50	1.558	20.72
F_3	41867.85	3233.8	71143.6	29275.75	1.699	20.89
F_4	42162.25	3415.3	75136.6	32974.35	1.782	19.69
50 per cent shade						
F_1	41279.15	2715.0	59730.0	18450.85	1.447	21.89
F_2	41573.50	2779.5	61149.0	19575.50	1.471	17.62
F_3	41867.85	2894.5	63679.0	21811.15	1.521	15.82
F_4	42162.25	2471.8	65379.6	23217.35	1.551	14.15
75 per cent shade						
F_1	41279.15	2044.8	44985.6	3706.45	1.040	5.20
F_2	41573.50	2223.8	48923.6	7350.10	1.177	7.24
F_3	41867.85	2102.3	46250.6	4382.75	1.105	3.28
F_4	42162.25	2184.50	48059.0	5896.75	1.140	4.34

Cost of inputs
Seed ginger - Rs.9/kg FYM - Rs.260/tonne N-Rs.7.60/kg P_2O_5 - Rs.9.05/kg K_2O - Rs.310/Kg
Labour charge - Rs.53/head Price of dry ginger - Rs.22/kg.

fertilizer dose upto the highest dose given both under low and medium shade. However under 25 per cent shade, at F_4 level of fertilizer application, net return and benefit : cost ratio were Rs.32974 ha^{-1} and 1.782 whereas under 50 per cent shade values were only Rs.23217 ha^{-1} and 1.551 respectively. Under 75 per cent shade, F_2, registered the maximum profit and benefit : cost ratio.

Discussion

DISCUSSION

The economic produce or yield of a crop plant is mainly determined by light since the energy provided by photophosphorylation plays a pivotal role in the metabolicm reations of green plants, especially photosynthetic efficiency, photorespiration and translocation of photosynthates from source to sink. Crop plants differ markedly in their adaptation to light intensities. Shading of crop plants at various stages of growth and development is a cultural operation which influences plant growth, yield and quality of the produce. Now it is well known that the crop yield is the result of interaction among factors like heredity, environment and plant nutrition.

Studies conducted at different locations in Kerala and elsewhere revealed that ginger is a shade loving plant giving increased yield under low shade (25 per cent shade). The main yield components of the ginger plants viz., height of the plant, number of tillers, leaf number and area, and rhizome characters are found to be influenced by varying shade levels. In the present investigation, an attempt has been made to study the variation, if in the fertilizer use efficiency of ginger plants under varying shade regimes and so as to determine the fertilizer requirement of the crop at each shade level.

Based on the yield trends, the ability of the plant to utilize higher levels of nutrients under varying levels of shade has been worked out. Comparison is also made among fertilizer treatments at each shade level separately. Observations on growth parameters are taken to explain the yield trends at each shade level.

Plant height:

Plant height was found to be increasing with increase in shade intensity from zero to 75 per cent shade as evidenced by the data presented in Table 3. Similar results were reported in crops like tobacco (Panikar et al., 1963), maize (Moss and Stinson, 1961) and easterlily (Kohi and Nelson, 1963). Ginger plants grown under full sunlight were found to be shorter compared to shaded plants (Aclan and Quisumbing, 1976). According to Meyer and Anderson (1952) high irradiance may 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 enlargement. This may be the possible reason for reduced plant height under open condition.

Under all shade levels fertilizer treatments showed a positive influence on plant height and no interaction was observed between shade and fertilizer treatments. Purewal and Dargon (1957), Aclan and Quisumbing (1976) and Pushpakumari (1989) reported increase in plant height with increase in fertilizer levels in different crops.

Number of tillers per plant:

At later growth stages ie., 120 and 180 DAP, tiller production was found to be influenced by shading (Table 4). Tiller production at 25 per cent shade was found to be significantly higher compared to all other shade levels. In contrast to this observation, a reduction in tillering due to shade was reported in rice (Oshima and Murayama, 1960), wheat (Moursi et al., 1976), ginger and turmeric (Susan Varughese, 1989). However in the present experiment also, number of tillers was found to be significantly reduced under heavy shade. Reduced tillering under heavy shade may be due to the low R: FR ratio at the base of the plants caused by the shade. A limitation in energy supply resulting from the decreased proportion of incident radiation available per tiller may also be partly responsible for the decrease in tiller formation (Attridge, 1990).

Increased tillering with increase in fertilizer levels observed during the later growth phases in the present experiment was in accordance with the reports of Muralidharan et al. (1974) and Aclan and Quisumbing (1976) in the same crop. The response to fertilizer treatments was found to vary under varying light intensities at 180 DAP. The increase in tiller number observed up to the highest fertilizer level, under 25 per cent shade may be due to the better microclimate existing under low shade. But under heavy shade, reduced availability of photosynthates may be suppressing the growth and development of tillers.

Number of leaves per plant:

Leaf number was also found to be the highest under 25 per cent shade (Table 5) and leaf number under open condition was found to be significantly lower when compared to low to medium shade levels. Aclan and Quisumbing (1976) also observed a reduced number of leaves per plant, in ginger, grown under full sunlight.

Contrary to this, a decrease in number of leaves with increase in shade intensity from zero to 75 per cent was observed in ginger by Susan Varughese (1989). But under heavy shade, leaf number was found to be considerably reduced in this case also. Under heavy shade, low irradiance may lead to a retarded development of plant because of the resulting low rate of photosynthesis (Meyer and Anderson, 1952).

At all shade levels, leaf number was found to be increasing with increasing fertilizer dose. Similar results were reported in turmeric (Anon., 1983) and sweet potato (Bourke, 1985). Leaf number under 25 per cent shade was found to be significantly increasing with increase in fertilizer doses upto the highest fertilizer dose and this may be due to better soil moisture status and moderate light intensity available to the plant which favoured increased uptake of nutrients. At all other shade levels, above F_3 there was no further increase in leaf number.

Chlorophyll:

The increased chlorophyll content with increasing shade levels observed in this experiment (Table 6 and Fig.2) is in agreement with the finding of Shirley

(1929), Collard et al. (1977), Lalithabai (1981) and Ramanujam and Jose (1984) in different crops. In ginger and turmeric, Susan Varughese (1989) reported an increase in chlorophyll 'a' and chlorophyll 'b' with increase in shade intensity. This increase in chlorophyll content under shaded conditions is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency (Attridge, 1990). The increased chlorophyll content under 25 and 50 per cent shade might have contributed to the increased dry matter production under these shade levels whereas under heavy shade, very low light intensity might have limited the efficient utilization of increased chlorophyll content.

Under all shade levels, increasing levels of fertilizer produced a general trend of increase in chlorophyll content and its fractions. In wheat, Moursi et al. (1976) and in Ficus benjamina, Collard et al. (1977) reported similar effects of fertilizer treatments on chlorophyll content.

Leaf area index:

The tendency of the plants to increase the LAI under low to moderate shading as observed in the present investigation (Table 7) may perhaps be a plant adaptation to expose larger photosynthetic surface under limited illumination (Attridge, 1990). Ravisankar and Muthuswamy (1988) reported similar results in ginger. But according to Lalithabai (1981), LAI of ginger, turmeric and coleus were not influenced by different shade intensities. Under shaded conditions, reduced radiation may prevent scorching or wilting of leaves caused by marked increases in temperature within the leaf tissue from strong sunlight (Aasha, 1986) and thereby increase the leaf life under shade resulting in the retention of more number of leaves at any stage of the crop. But under heavy shade, LAI was found to be again decreasing and this is obviously due to decreased rate of leaf production under heavy shade which may be resulting from the lack of photosynthates.

As observed in the present experiment, an increase in LAI with increase in fertilizer levels was reported in sweet potato (Bourke, 1985) and greater yam (Pushpakumari, 1989). Leaf area index also showed the same trend as leaf number with increase in fertilizer level under each shade intensity since leaf number is the most important factor determining leaf area index.

Net assimilation rate:

Net assimilation rate was found to be higher under open conditions and low shade (Table 8). A positive correlation between NAR and irradiance was reported by Blackman and Wilson (1951), Newton (1963), and Coombe (1966). In sweet potato, Laura et al. (1986) observed lower NAR under shade. With increase in shade, NAR was found to be decreasing and this may be due to excessive leaf parasitism caused by increased LAI along with shade provided as treatments, thus reducing the photosynthetic efficiency. In soybean, low activity of ribulose 1,5 diphosphate carboxylase was reported at low light intensities (Bowes et al., 1972). Crockson et al. (1975) reported 38 per cent reduction in photosynthesis of bean leaves due to shading, mainly because of increase in stomatal and mesophyll resistance to diffusion of carbon dioxide. During the second phase of growth ie., from 135 to 180 DAP plants showed a differential response to fertilizer treatments under different shade levels. Net assimilation rate showed a positive response to fertilizer treatments under zero, 25 and 50 per cent shade levels. But under heavy shade no regular trend was observed and this may be due to the reduced photosynthetic activity under very low light intensity (Attridge, 1990).

Crop growth rate:

The higher crop growth rate observed under 25 per cent shade (Table 9) can be attributed to the increased LAI and moderate NAR exhibited by the plant under this shade level. Under open conditions, a fairly high rate of NAR and under 50 per cent shade, high LAI may contribute to a moderate rate of crop growth. But under heavy shade, CGR was found to be very low and might have resulted from low LAI and NAR maintained by the plant under this shade level. Reduced CGR under heavy shade is reported by many workers. Fukai et al. (1984) reported 50 per cent reduction in CGR in cassava when solar input was reduced upto 32 per cent. Reduced CGR under shaded situations were also reported in turmeric (Ramadasan and Satheesan, 1980), Cassava (Ramanujam et al., 1984) and in sweet potato (Roberts Nkrumah et al., 1986). Fertilizer treatments under all shade levels gave a regular trend of increase in CGR. Bourke (1985) reported similar effect on CGR. But in tannia, there was no significant difference in CGR among the fertilizer treatments (Pushpakumari, 1989). Interaction between shade and fertilizer treatments was absent. Ginger plants showed maximum CGR and increased response to nutrients in terms of CGR under 25 and 50 per cent shade. Hence it can not be considered as an obligate sun plant but as a shade loving plant.

Dry matter production :

Dry matter production was found to be high under low and medium shade levels (Table 10 and Fig. 3). The influence of the growth parameters like tiller number, leaf number, LAI and NAR have been reflected in DMP of the plant. Increased DMP in ginger under shaded condition was reported by Ravisankar and Muthuswamy (1986). Susan Varughese (1989) observed maximum DMP in ginger under 25 per cent shade. But under heavy shade (75 per cent), DMP was found to be significantly lower than that under open though the LAI was found to be higher than that under open condition. At this shade level, leaf parasitism would have substantially increased. Thus at intense shade level probably the parasitic effect would be maximum as the photosynthetically active radiation falling on the leaf surface was very less compared to that under open conditions and this effect might have probably reflected in NAR also, recording the lowest NAR under heavy shade.

Dry matter production showed a general trend of increase with increase in fertilizer dose under zero, 25 and 50 per cent shade and this can be attributed to the beneficial effect of fertilizer treatments on both LAI and NAR under these shade levels. Beneficial effect of fertilizer treatments on DMP was reported in sweet potato (Bourke, 1985), Potato (Rajanna et al., 1987) and greater yam (Pushpakumari, 1989). But under heavy shade fertilizer treatments failed to produce any regular trend in LAI or NAR which might have reflected in DMP also.

Yield and yield attributes:

Bulking rate:

The increased bulking rate observed under low shade may be due to increased NAR and efficient assimilate partitioning to rhizomes (Table 11). Under open and medium shade also, bulking rates were fairly high compared to heavy shade (75 per cent) and this may be due to better carbon dioxide assimilation existing under these light intensities. A delay in bulking and decreased rate of tuberization as observed under heavy shade in the present investigation were reported due to shading in crops like sweet potato (Togari, 1950, Zara et al., 1982, Martin, 1985 and Roberts Nkrumah et al. 1986) and cassava (Ramanujam et al., 1984).

An increasing trend in bulking rate with fertilizer levels was observed under all shade levels at 90 to 135 DAP and the possible reason for this effect may be the increased availability of nutrients at higher doses of fertilizers. Pushpakumari (1989) noticed significantly high bulking rate in greater yam at highest fertilizer dose of 80:60:80 kg NPK ha^{-1} whereas in lesser yam, no significant influence on bulking rate was observed. However at the early growth phase (90 to 135 DAP), no significant increase in bulking rate under heavy shade was observed with fertilizer treatment above F_2 level and in the later stage bulking rate was found to be totally unaffected by fertilizer treatment under heavy shade. This may be due to the inability of plant to utilize increased fertilizer doses under heavy shade. Thus low shade was found to provide most congenial conditions for rhizome development probably due to better soil conditions prevailing under low shade both in terms of soil temperature and moisture.

Rhizome spread:

Increased rhizome spread observed under medium to heavy shade (Table 12) may be due to the increased soil moisture status and reduced soil temperature existing under this shade levels. Under open conditions rhizome spread was found to be more compact probably due to higher soil temperature existing during day time. Fertilizer levels were found not to influence the length of tuber in lesser yam (Sasidharan,1985 and Pushpakumari, 1989). But an increasing trend in rhizome spread as observed in the present experiment was reported in greater yam, the plants receiving highest dose of fertilizer recorded maximum tuber length when grown as intercrop in coconut garden (Pushpakumari, 1989). Shade was not found to influence the effect of fertilizer treatments on rhizome spread.

Green ginger yield:

High green ginger yield obtained under low to medium (25 and 50 per cent) shade (Table 13) can be attributed to high LAI and moderate NAR observed under these shade levels. Under open conditions, yield was found to be comparatively low and this may be due to low LAI exhibited by the plants under open conditions throughout the growth period, which could have reduced the total photosynthates accumulated in the plant. At intense shade, the availability of light may become the decisive factor that limits the rhizome yield. Ravisankar and Muthuswamy (1988) reported higher green ginger yield when grown as an intercrop. Fertilizer treatments showed a positive influence on green ginger yield and interaction between shade and fertilizer was absent.

Dry ginger recovery:

Percentage dry ginger recovery was found to be not influenced by shade. This is not in agreement with the findings of Susan Varughese (1989) who reported an increase in percentage dry ginger recovery under shade. Though not significant, maximum dryage was noticed under open condition in the present experiment and this may be due to the higher soil temperature as a result of more intense and direct sunlight.

Dry ginger yield:

Highest dry ginger yield was produced under 25 per cent shade (Table 14 and Fig. 4). Increased yields under low shade was also reported in crops like tannia (Pushpakumari, 1989), ginger (Susan Varughese, 1989) and colocasia (Prameela, 1990). The yield increase under 25 per cent shade may be due to the combined effect of reduced soil temperature, increased soil moisture content and reduced leaf temperature by shading (Hanada, 1991). Contrary to this findings, a steady decrease in rhizome yield with increase in shade was reported in turmeric by Susan Varughese (1989). But Jayachandran et al. (1992) found that the yield of turmeric under 25 per cent shade was on par with that under open conditions. As observed in the present experiment, Roberts Nkrumah et al. (1986) reported very low yield in sweet potato under heavy shade.

A general trend of increase in yield with increase in fertilizer levels was noticed in the present experiment. Similar results were reported in crops like turmeric (Ramakrishna Reddy and Rama Rao, 1978), and greater yam (Pushpakumari, 1989). Differential response to increase in fertilizer levels was observed under varying shade levels. Highest dry ginger yield was produced at F_3 level of fertilizer application (93.75: 62.50:62.50 Kg NPK ha^{-1}) under open conditions and with further increase in fertilizer dose, no significant increase in yield was observed. It may be the poor soil moisture status and high soil temperature prevailing under direct sun which limited the capacity of plant to utilize higher doses of fertilizers. Under 25 and 50 per cent shade, highest yield was recorded at F_4 level (112.5:75:75 kg NPK ha^{-1}) and the increase in yield were 20.1 and 9.5 per cent respectively with the increase in fertilizer level from F_1 to F_4. This result clearly indicates that crop response to increased level of fertilizer dose is more under 25 per cent shade and this may be due to the existence of an optimum soil condition and light intensity for effecient utilization of available nutrients. Very high light intensity under open conditions, may cause stomatal closure preventing entry of carbon dioxide for assimilation as reported by Hardy (1958) or inactivation of enzyme due to increase in leaf temperature (Miginiac et al., 1990). Lack of response to fertilizer treatments under heavy shade (75 per cent) might have resulted from reduced rate of photosynthesis and poor partitioning. Duggor (1903) suggested that shading reduced the carbon dioxide assimilation and thereby the available constructive material for plants. Bowes et al. (1972) reported low activity of ribulose 1,5 diphosphate carboxylase at low intensities of light. Crockson et al. (1975) recorded 38 per cent reduction in photosynthesis of bean leaves due to shading mainly because of increase in stomatal and mesophyll resistance to diffusion of carbon dioxide.

Top yield:

The increase in top yield with the increase in shade from zero to 50 per cent, can be attributed to the promotion of vegetative growth under shade (Table 15). Reduced radiation would have prevented scorching or wilting of leaves caused by marked increases within the leaf tissue from strong sunlight, thus promoting vegetative growth. Enhanced top growth under shaded conditions was reported by workers like Hirota and Moritani (1980) and Ramanujam et al. (1964) in different crops. Under heavy shade, though the top yield was significantly lower than that under so per cent shade, it was significantly higher than that under open.

The general trend of increase in top yield observed with increase in fertilizer treatments is in agreement with the findings of Samad et al. (1956) who reported in rice, a substantial increase in straw yield with increased fertilizer application. Pushpakumari (1989) recorded significantly lower top yield at lowest fertilizer level ie., at 40:30:50 Kg NPK ha^{-1} in greater yam and elephant foot yam respectively. From zero to 50 per cent shade, increase in fertilizer dose was found to promote top growth whereas under heavy shade, above F_2 level, top growth was found not to be significantly increased and this effect may be due to the reduced rate of photosynthesis under very low light intensity which hinder the efficient uptake and utilization of nutrients.

Utilization index and harvest index:

Utilization index and harvest index were found to show a decreasing trend with increase in shade levels. Fertilizer levels also showed the same effect which might have resulted from increased top growth at higher fertilizer levels (Table 15). The efficiency of translocation of assimilates to economic part was found to be decreasing with increasing shade levels and fertilizer levels. Eventhen rhizome yield was found to be higher under 25 and 50 per cent shade because of considerably increased dry matter production under these shade levels as evidenced by the data given in Table 10. Under heavy shade both UI and HI did not show any further decrease compared to medium shade. But both top growth and rhizome yield were equally suppressed by further increase in shade. Thus at intense shade level along with reduced NAR, poor assimilate partitioning was also responsible for the reduced yield. However the assimilate partitioning under different levels of fertilizer treatments were observed to be not influenced by the existing shade intensity. The data clearly indicate that, though the dry matter production was high under low to medium shade, a major proportion of assimilate was utilized for top growth ie., proportionate assimilate partitioning to rhizome was lower than that under open. Sasidharan (1985) failed to observe any significant influence of fertilizer treatment on UI of leasser yam. But Ramanujam et al. (1984) opined that most of photosynthates of shade grown cassava plants were utilized for shoot growth at the expense of tuber growth.

Quality of the produce:

Non volatile ether extract content was found to be significantly high under 25 per cent shade whereas volatile oil content was significantly superior under 25 and 50 per cent shade. Ravisankar and Muthuswamy (1987) reported that ginger, under intercropped conditions, produced good quality rhizomes with high NVEE and volatile oil content. However, a progressive decrease in oleoresin content upto 50 per cent shade was reported in ginger by Susan Varughese (1989). According to Aclan and Quisumbing, (1976) fibre content of ginger rhizome was unaffected by light attenuation. But in the present experiment, fibre content was found to be the highest under open conditions and this may be due to the early attainment of maturity under open conditions. This result is in agreement with the findings of Natarajan *et al*. (1972) who reported an increasing trend in crude fibre content during maturity stages. Under all shade levels, effect of fertilizer treatments on NVEE, volatile oil and fibre contents was found to be non significant.

Uptake of nutrients:

NPK uptake was found to be maximum under 50 per cent shade followed by 25, 75 and zero per cent shade (Table 17 and Fig.5). Under open condition though plants showed a regular trend of increase in uptake with increase in fertilizer levels, this was not reflected in rhizome yield beyond F_3 level and this may be due to excessive shoot growth as indicated by high top yield and low utilization index at the highest fertilizer level. This clearly indicates that there is no necessity of increasing fertilizer dose beyond F_3 level ie., 125 per cent of the recommended dose of NPK under open conditions. Under 25 and 50 per cent shade, NPK uptake was found to be increasing with increase in fertilizer levels which was reflected in the increased dry matter production under these shade levels. Yield also showed the same trend as that of NPK uptake under these shade levels. This points out to the possibility of increasing the fertilizer dose under low and medium shade. But response to high doses of fertilizers was found to be more under 25 per cent shade ie., when fertilizer dose was increased from F_1 to F_4, yield increase was 20.1 per cent under 25 per cent shade whereas it was only 9.5 per cent under 50 per cent shade. The low response to nutrients under 50 per cent shade may be due to poor partitioning efficiency of assimilates under this shade level as indicated by the higher top yield and lower UI. However, under low shade, application of fertilizers at higher levels was found to be beneficial for increasing yield. Contrary to this, in turmeric, uptake of all the nutrients was found to decrease with shade except potassium (Susan Varughese, 1989). But in ginger, she reported an increasing trend in N and K uptake from zero to 25 per cent shade and then a decrease. Under heavy shade also, total NPK uptake was found to be higher than that under open conditions. Nitrogen showed an increasing trend with applied fertilizers, P and K uptake increased only upto F_2 level and dry ginger yield was also found to be maximum at F_2 level. This result suggests that there is no necessity of increasing fertilizer dose above F_2 level when ginger is grown under heavy shade. Hence, the present recommendation (KAU, 1989) is sufficient for the ginger crop when grown under heavily shaded situations.

Although N, P and K uptake under 75 per cent shade was higher than that under open, the yield was found to be decreased by 21.6 per cent when compared to open. From this, it could be concluded that the increased NPK uptake along with higher LAI can not ensure a high yield., but the photosynthetic efficiency and efficient partitioning are also equally important in determining the final yield of a crop.

Soil NPK content:

Soil NPK content showed a general trend of increase with increase in fertilizer dose under all shade levels. Such an increase in available nutrient status subsequent to their application was reported by Rajendran (1971).

Economics:

The gross and net return were maximum by growing ginger under low shade (Table 19). The shade in the decreasing order of benefit: cost ratio were 25, 50, zero and 75 per cent.

Among the fertilizer levels tried, F_3 gave maximum benefit: cost ratio under open conditions. This indicates that even under open condition increasing the fertilizer dose upto 125 per cent of the recommended dose (F_3) is beneficial. Under 25 and 50 per cent shade it is economical to apply higher doses of fertilizers ie., 150 per cent of the recommended dose. However fertilizer use efficiency is more under 25 per cent shade. The data clearly shows that when the crop is grown under heavily shaded situations, there is no necessity of increasing fertilizer dose above the recommended dose (F_2).

Summary

SUMMARY

An experiment was conducted at the College of Agriculture, Vellayani for studying the effects of different levels of fertilizers (75, 100, 125 and 150 per cent of the recommended dose of NPK) on the growth, yield and quality of ginger under varying shade levels adopting strip plot design with five replications. Nitrogen, phosphorus and potash were supplied in the form of urea, single super phosphate and muriate of potash respectively. The salient findings are summarised below.

The height of the plant was found to be significantly reduced under open conditions. There was significant increase in plant height with increase in shade intensity upto 75 per cent shade level. Under all shade levels there was an increasing trend in plant height with increase in fertilizer dose.

Low shade (25 per cent) was found to promote tiller production whereas heavy shade (75 per cent) inhibited tiller production.

At 180 days after planting, maximum tiller production was observed under 25 per cent shade at the highest fertilizer level. Under open condition and 50 per cent shade, an increasing trend in tiller number

was observed with increasing fertilizer levels whereas under 75 per cent shade no general trend was noticed.

Leaf number and response to nutients in terms of leaf number were maximum, under 25 per cent shade.

Total chlorophyll and its fractions, chlorophyll 'a' and chlorophyll 'b' were found to be increasing progressively with increasing levels of shade and fertilizers.

Leaf area index and the capacity to respond to increased levels of nutrients in terms of leaf area index were more in low to medium shade compared to open condition and heavy shade.

Net assimilation rate showed a decreasing trend with increase in shade and was found to be the lowest under heavy shade. A positive response to fertilizer treatments was noticed under open, 25 and 50 per cent shade levels whereas under heavy shade NAR failed to show any regular trend.

Crop growth rate was maximum under 25 per cent shade followed by that under 50 per cent shade and open condition and was lowest under 75 per cent shade. Under all shade levels, a general trend of increase in CGR with increase in fertilizer treatments was observed.

Dry matter production was observed to be higher under 25 and 50 per cent shade compared to open and 75 per cent shade. Under open condition DMP was found to be higher than that under heavy shade. The response to increased level of nutrients in terms of DMP was found to be higher under low to medium shade.

Bulking rate was maximum under 25 per cent shade and was found to be increasing with increase in fertilizer dose. During the growth phase from 135 to 180 days after planting, fertilizer treatments showed a positive influence on bulking rate except under heavy shade where fertilizer treatments failed to show any significant effect on bulking rate.

Rhizome spread was noticed to be the highest under 50 per cent shade followed by that under 75 per cent shade. Fertilizer treatments also significantly increased rhizome spread under all shade levels.

The highest green ginger yield was recorded under 25 per cent shade followed by 50 per cent shade and under these shade levels, significant increase in green ginger yield was recorded with each increment in fertilizer dose upto the highest fertilizer dose.

Dry ginger recovery was not significantly influenced by shade and fertilizer treatments.

Dry ginger yield was maximum under 25 per cent shade followed by 50 per cent shade and open condition and was lowest under heavy shade. Under open condition fertilizer dose, F_3 and under 25 and 50 per cent shade, F_4 recorded maximum yield. Under heavy shade, fertilizer dose above F_2, there was no significant increase in dry ginger yield.

Top yield was observed to be increasing with increase in shade intensity upto 50 per cent. Under open condition, fertilizer dose above F_3 and under heavy shade, above F_2, there was no significant increase in top yield. Fertilizer dose, F_4 recorded highest top yield under 25 and 50 per cent shade.

Utilization index and harvest index were found to be the highest under open condition compared to shaded conditions. The proportionate assimilate partitioning to economic part was observed to be decreasing with increase in shade and fertilizer levels.

Volatile oil content was found to be the highest under 25 per cent shade followed by that under 50 per cent shade. Effect of fertilizer treatments was found to be nonsignificant.

Fibre content was the highest in the open and showed a decreasing trend with increase in shade intensity. Neither the effect of fertilizer nor the shade-fertilizer interaction was significant.

The uptake of N, P and K showed an increasing trend with increase in shade upto 50 per cent and then showed a decrease. However nutrient uptake under 75 per cent shade was found to be higher than that under open conditions. Nitrogen uptake was observed to be increasing with fertilizer dose upto F_4 under 25 per cent shade whereas under zero, 50 and 75 per cent shade, only upto F_3 level. Phosphorus and potassium uptake were found to be increasing upto F_4 level under 25 and 50 per cent shade. No regular trend was observed under 75 per cent shade.

Soil N and K content were found to be unaffected by shade whereas P content was found to be highest under 75 per cent shade. Soil NPK content was found to be increased with increased fertilizer application.

The economics worked out for the fertilizer management practices under varying shade levels revealed that among the shade levels, 25 per cent shade gave the maximum net return, benefit cost ratio and return per rupee invested on fertilizer, followed by 50 per cent shade. Under open condition maximum profit was obtained for F_3 level fertilizer application and under 25 and 50 per cent shade F_4 level gave highest net return and benefit cost ratio. Under 75 per cent shade F_2 registered the maximum profit and benefit cost ratio.

References

REFERENCES

Aasha, K. 1986. Effect of varying light intensities on the growth and development of indoor foliage and flowering plants. M.Sc. Thesis. Kerala Agric. Univ., Thrissur.

Aclan, F. and Quisumbing, E.C. 1976. Fertilizer requirement, mulch and light attenuation on the yield and quality of ginger. Phil. Agr., 60; 180-191.

Aiyadurai, S.G. 1966. A review of research on spices and cashewnut in India. Indian Council of Agr. Res., Ernakulam. pp. 85-103.

* An, H.N. 1982. Light intensity effects on metabolism, growth and yield components of pea nuts. Diss. Abst. Int. B., 39 (7): 3083-3084.

Anonymous. 1983. Varietal cum manurial trial on turmeric. Ann. Rep. of 1981-82, Kerala Agric. Univ., Thrissur pp.106.

Anonymous. 1989. Ginger. In: Package of practices recommendations. Kerala Agric. Univ. Extension Division, Mannuthy, Thrissur. pp. 180-183.

Anonymous. 1990 a. The Hindu Survey of Indian Agriculture. Kasthuri and Sons Ltd. Madras pp.133.

Anonymous. 1990 b. Second Ann. Rep., 1989-'90 on ICAR adhoc scheme on shade studies on coconut based intercropping situations. Kerala Agric. Univ. Thrissur. p. 69.

Anonymous 1991. Farm Guide. Farm Information Bureau, Government of Kerala, Thiruvananthapuram. p. 133.

A O A C. 1975. Official Methods of Analysis. Association of Official Agricultural Chemists, Washington D.C. 12th Edn.

Attridge, T.H. 1990. Light and Plant Responses. Edward Arnold, A Division of Hodder and stoughtton Ltd. pp. 82-101.

Balram Jakhar. 1991. Small farmers must get right package. Indian Coconut J. 22 (8):2

* Blackman, G.E. and Wilson, G.L. 1951. I bid. 11. The constancy for different species of a logarithmic relationship between net assimilation rate and light intensity and its ecological significance. Ann. Bot. (N.S), 15:63-94.

Bourke, R.M. 1985. Influence of nitrogen and potassium fertilizer on growth of sweet potato (Ipomoea batatas) in Papua, New Guinea. Field crops Res., 12 (4):363-375.

Bowes, G., Ogren, W.L. and Hageman, R.H. 1972. Light saturation, photosynthesis rate, RuDp carboxylase activity and specific leaf weight in soybeans grown under different light intensities. Crop Sci., 12: 77-79.

Buttery, B.R. 1970. Effect of variation in leaf area index on growth of maize and soybeans Crop Sci., 10 (1): 9-13.

Caesar, K. 1980. Growth and development of Xanthosoma and Colocasia under different light and water supply conditions. Field Crops Res., 3 (3): 235-244.

Carveho, M.P.M. Ve., Vasconecllos, H. Deoi., Almeida, D.L. De., Lear, N.R. and Ramandas, V.L.N. 1983. Influence of phosphorus and potassium applied at two soil depths on the quality of sweet potato (lpomoea batatus Lam). Field Crops Abst., 37: 7.

Chase, A.R. and Poole, R.T. 1987. Effect of fertilizer, temperature and light level on growth of Syngonium podophyllum. White Butterfly. J. Am. Sòc. Hort. Sci., 112 (2): 296-300.

Chidananda Pillai, M.R. 1967. Studies on the effect of

N,P and K fertilization on the yield and quality of colocasia. (*Colocasia antiquorum*, Schott.) var. Thamarakkannan. M.Sc (Ag) thesis, Kerala Agric. Univ., Thrissur.

Collard, R.C., Joiner, J.N., Conover, C.A. and Mc Connell, D.B. 1977. Influence of shade and fertilizer on light compensation point of *Ficus benjamina* L. J. Am. Soc., Hort. Sci., 102 (4): 447-449.

* Coombe, D.E. 1966. The seasonal light climate and plant growth in a Cambridgeshire Wood. In Light as an Ecological Factor: Symp. Brit. Ecol. Soc., 6: 148-166.

Cooper, C.S. 1966. Response of birdsfoot trefoil and alfalfa to various levels of shade. Crop. Sci., 6: 63-66.

Crockson, R.K., Trcharne, K.J., Ludford, P. and Ozhun, T.L. 1975. Response of beans to shading. Crop Sci., 15: 412-416.

Duggor, B.M. 1903. The physiological effects of shading plants. J. Proc. Am. Hort. Soc., 1905. 15-17.

* Einert, A.E. and Box, C.O. 1967. Effect of light intensity on flower bud abortion and plant growth of Lilium longifolium. Proc. Am. Soc. Hort. Sci., 90: 427-432.

Eriksen, F.1. and Whitney, A.S. 1981. Effect of light intensity on growth of some tropical forage species. 1. Interaction of light intensity and nitrogen fertilization on six forage grasses. Agrom., J., 73 (3): 427-433.

Fukai, S., Alcoy, A.B., Llamela, A.B., and Patterson, R.D. 1984. Effect of solar radiation on growth of cassava (Manihot esculenta Crantz.) 1. Canopy development and dry matter growth. Field Crops Res., 9: 347-360.

Gastra, P. 1963. Climatic control of photosynthesis and respiration. In Environmental control of plant growth. Academic press. London: 113-140.

Geetha, K. 1983. Nutritional management in coleus (Coleus parviflorus Benth). M.Sc. (Ag) thesis. Kerala Agric. Univ., Thrissur.

Gopinathan, R. 1981. Effect of shade and moisture regimes on the growth of cocoa seedling. M.Sc. (Ag) thesis. Kerala Agric. Univ., Thrissur.

* Habfield, W. 1968. Leaf temperature, leaf pose and productivity of the tea bush. Nature, 219: 282-284.

* Hafizuddin, M. and Haque, M.A. 1979. Effect of nitrogen and potash at different levels on the yield of two local varieties of sweet potato. Bangladesh Hort., 7 (1/2) 18-23.

Hanada, T. 1991. The effect of mulching and row covers on vegetable production. Extension Bull. No. 332. Fd. Tech. Center, Taiwan.

* Hardy, F. 1958. The light relation of cacao. Cocoa Mannual. Inter. Amer. Inst. Agric. Sci., Turrialba. Costa Rica. 85-91.

* Hilton, T.R. 1983. The influence of phytochrome photoequilibrium on gibberellin like substances and chlorophyll content of chloroplast of Hordeum vulgare L. New phytologist, 95 (4): 545-548.

* Hirota, H. and Moritani, S. 1980. Effects of fertilizer application and shading on seedling growth of some temperate grasses. Bull. Fac. Agric., Niigata Univ. No. 32: 125-133.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice Hall of India, Pvt. Ltd., New Delhi. pp 38-183.

Jackson, M.L. 1967. Soil Chemical Analysis. Prentice Hall of India, Pvt. Ltd, New Delhi. pp 498.

Janardhan, K.V. and Murthy, K.S 1980. Effect of low light during vegetative stage on photosynthesis and growth attributes in rice. Indian J. Plant physiol., 23 (2):156-162.

Jayachandran, B.K., Meera Bai, M., Abdul Salam, M., Mammen, M.K. and Kunjamma. P. Mathew. 1992. Influence of shade on growth and productivity of turmeric (Curcuma longa L.) Spice India, 5 (4): 2-3.

Juliano, J.B. and Ramos, C.M. 1940. A study on growth habit of rice plants. Philippine Agricst., 29: 43-51.

Kannan, K. and Nair, K.P.V. 1965. Zingiber officinale (Ginger) in Kerala. Madras Agric. J., 52: 168-74.

* Kasele, I.N., Hahn, S.K., and Oputa, C.O. 1986. Effect of shade, nitrogen and potassium on cassava. Potash rev. Subject 27, 118th suite.

* Khol, H.C. and Nelson, R.L. 1963. Day length and light intensity as independent factors in determining height of easter lilies. Proc. Am. Soc. Hort. Sci., 83: 808-810.

* Kulasegaram, S. and Kathiravet Pillai, A. 1980. Effect of levels of shade on growth of young tea (Camellia sinensis L.) Tea Quarterly, 49 (3/4): 112-124.

Lalithabai, E.K. 1981. Shade response of common rainfed intercrops of coconut. M.Sc. (Ag) thesis. Kerala Agric. Univ., Thrissur.

Lalithabai, E.K. and Nair, R.V. 1982. Shade response of some common rainfed intercrops. Proc. Fifth Ann. Symp. Plantation Crops. Indian Society for Plantation Crops pp.394-401.

Laura, B., Roberts-Nkrumah, L.B., Ferguson, T.V. and Wilson, L. 1986. Response of four sweet potato cultivars to levels of shade: 2. Tuberization. Top. Agric. 63 (4): 265.

Lee, M.T and Asher, C.J 1981. Nitrogen nutrition of ginger Effect of sources, rates and times of nitrogen application. Plant and Soil., 62 (1): 2334.

Lee, M.T., Asher, C.J. and Whiley, A.W. 1981. Nitrogen nutrition of ginger (Zingiber officinale) 1. Effects of nitrogen supply on growth and development. Field Crops Res., 4: 55-68.

Lokanath, M. and Dash, N.K. 1964. Determination of optimum spacing, fertilization and method of planting ginger (Zingiber officinale Roscoe). Indian J. Agron., 9: 281-285.

* Loue, A. 1979. Fertilization and mineral nutrition of the potato. Potato Rev., 11 (9): 7.

Mahabaleshwar Hegde, Kumar, D.P. and Khan, M.M. 1990. Response of tapioca to different levels of nitrogen and potash. South Indian Hort., 38 (4): 193-195.

* Maliphant, G.K. 1959. Manurial and cultural experiments on cacao. VII. River Estate, Trinidad. Shade, sapcing, times and rates of fertilizer application experiment. Regional Res. Centre, ICTA, Trinidad. Rep. cacao Res., (1957-58) pp. 83-86.

Mandal, R.C., Singh, K.D. and Maini, S.B. 1969. Influence of nitrogen and potash on tuber yield and quality of Dioscorea esculenta. Ann. Rep., CTCRI. pp. 40-41.

Martin, F.W. 1985. Difference among sweet potatoes in response to shading. Trop Agric., 62 : 161-165.

Meyer, B.S. and Anderson, D.B. 1952. Plant physiology, D.Van Nostrand Company, INC pp. 624-627.

* Miginiac-Maslow, M., Decottignier, P., Jacquot, J.P and Gadal, P. 1990. Regulation of corn leaf NADP malate dehydrogenase light activation by the photosynthetic electron flow. Effect of photoinhibition studied in a reconstituted system. Biochimica et Biophysica, 1017 (3): 273-279.

* Minoru,T. and Hori, Y. 1969. Studies on photosynthesis of vegetative crops. 1. Photosynthesis of growing plant vegetables in relation to light intensity. Bull. Series A (Hiratsuka) No. 8. Hort. Res. Sta. Min. Agric and Forestry, Japan. pp. 139-140.

Monteith, J.L. 1969. Light interception and radiactive exchange in crop stands. In: Physiological Aspects of Crop yield. Eastin, J.O., Haskins, F.A., Sullivan, C.Y. and Van Bavel, C.H.M. (eds). Wisconsin pp. 89-110.

Monteith, J.L. 1978. Reassessment of maximum growth rate of C_3 and C_4 crops. Experimental Agriculture, 14: 1-5.

Moss, D.N and Stinson, H.T. 1961. Differential response of corn hybrids to shade. Crop Sci., 1: 416-418.

* Moursi, M.A., El-Gawad, A.A.A., El-Din, N.A.N., Ashour, N.1. and Yakout, G.M. 1976. Net assimilation rate and efficiency of solar energy conversion of wheat plants as affected by nitrogen fertilizer. and shading. Egyptian J. Agron., 1 (2): 163-169.

* Moursi, M.A., El-Gawad, A.A.A., El-Din, N.A.N., Ashour, N.1., Yakout, G.M. 1976. Effect of shading and nitrogen fertilizer on photosynthetic pigments and nitrogen contents of wheat blades. Egyptian J. Agron., 1 (2):171-178.

* Moursi, M.A., El. Gawad, A.A.A., Ashour, N.1., El-Din, N.A.N. and Yakout, G.W. 1976. Response of wheat yield to shading and nitrogen fertilizer. Egyptian J. Agron., 1 (2): 179-186.

Muralidharan, A. 1973. Effect of graded doses of NPK on the yield of ginger (Zingiber officinale R.) var. Rio-de-Janeiro. Madras Agric. J., 60 (8): 664-666.

Muralidharan, A., Varma, A.S. and Nair, E.V.G. 1974. Effect of nitrogen, phosphorus and potash on growth and yield of ginger (Zingiber officinale Roscoe). Indian J. Agron., 19: 102-104.

* Myhr, K. and Saebo, S. 1989. The effects of shade on growth, development and chemical composition in some grass species. Forsk. Fors. Landbr., 20: 297-315.

Nair, P.C.S. 1969. Ginger cultivation in Kerala. Arecanut and Spices, 1 (11) : 22-24.

Nambiar, I.P.S., Sadanandan, N. and Kunju, M.U. 1976. Effect of graded doses of nitrogen on growth and yield of sweet potato H-42 in red loam soils. Agric. Res. J. Kerala, 14(2): 118-120.

Natarajan, C.P., Padma Bai, R., Krishnamurthy, M.N., Raghavan, B., Sankaracharya, N.B., Kuppuswamy.S., Govindarajan, V.S. and Lewis, Y.S. 1972. Chemical composition of ginger varieties and dehydration studies on ginger. J. Fd. Sci. Technol., 9(3): 220-224.

* Nelson, C.D. 1964. The production and translocation of photosynthate ^{14}C in conifers. In: The formation of wood in forest trees. Zimmermann, M.H.(ed). Academic, New York pp. 243-257.

Newton, P. 1963. Studies on the expansion of the leaf surface 11. The influence of light intensity and photoperiod. J. Exp. Bot., 14: 458-482.

Oshima, M. and Murayama, N. 1960. Studies on the nitrogen nutrition of rice. Effect of shading on plants grown with different amounts of nitrogen. Bull. nat. Inst. Agric. Sci., 810: 1-36.

Panikar, S.N., Sajnani, B.T. and Walunjkar, W.G. 1969. Comparative performances of two varieties of cigar-wrapper tobacco, grown at varying nitrogen and spacing levels, under shade and in the open. Indian J. Agric. Sci., 39: 333-340.

Paulose, T.T. 1970. Development of ginger in India. Indian Spices, 7 (2):2-4.

* Pena, R.S. Dela. 1967. Effects of different levels of N,P and K fertilization on the growth and yield of upland and lowland taro. Diss. Abst., 28(5): 1758.

Perkin - Elmer Corporation. 1982. Analytical Methods for Atomic Absorption Spectrophotometry. AY-5 pp. 1-3 Perkin-Elmer Corporation, Norwalk, Connecticut, USA.

Prakasha Rao, Munnu Singh, Narayana, M.R. Ganesh Rao, R.S and Rajeshwar Rao, B.R. 1983. Fertilizer studies in Coriander (Coriandrum sativum L.) J. Agric. Sci., 100: 251-53.

Prameela, P. 1990. Screening different morphotypes of colocasia (Colocasia esculenta) for shade tolerance. M.Sc. (Ag) thesis. Kerala Agric. Univ. Thrissur.

Purewal, S.S. and Dargon, K.S. 1957. The effect of various fertilizers in relation to spacing on development and yield of Colocasia esculenta. Indian J. Agron., 1 : 4.

Pushpakumari, R. 1989. Fertilizer management of minor tuber crops in coconut based cropping system. Ph.D. thesis. Kerala Agric. Univ., Thrissur.

Rahman Md. O., Babu, S.H.R and Rao, S.N. 1990. Effect of graded levels of nitrogen on growth and yield of seed and essential oil of coriander. Indian Cocoa Arecanut and Spices J., 13 (4):130-132.

Rajanna, K.M., Shivashankar, T.S. and Krishnappa, K.S. 1987. Dry matter accumulation and uptake of nutrients in potato as affected by different levels of N, P and K. South Indian Hort., 36 (6): 421-428.

Rajendran, N., Kumar, B.M. and Nair, P.G. 1971. Effect of major nutrients on the yield and nutrient uptake of tuber crops. Ann. Rep., CTCRI. Thiruvananthapuram.

Ramadasan, A. and Satheesan, K.V. 1980. Ann. Rep., CPCRI, Kasaragode, Kerala pp. 813.

Ramakrishna Reddy, V. and Rama Rao, M. 1978. Effect of N, P and K fertilization on curing percentage and curcumin content of Turmeric (Curcuma longa L.). J. Hort., 35 (2) : 143-144.

* Ramanujam, T. and Jose, J.S. 1984. Influence of light intensity on chlorophyll distribution and anatomical characters of cassava leaves. Turrialba, 34 (4): 467-471.

* Ramanujam, T., Nair, G.M. and Indira, P. 1984. Growth and development of cassava (Manihot esculenta Crantz) genotypes under shade in a coconut garden. Turrialba, 34: 267-274.

Ravisankar, C. and Muthuswamy, S. 1986. Dry matter production and recovery of dry ginger in relation to light intensity. Indian Cocoa Arecanut and Spices J., 10 (1): 4-6.

* Ravisankar, C. and Muthuswamy, S. 1987. Study on the quality of (ginger Zingiber officinale Roscoe) grown in different light intensities. South Indian Hort., 35 (3):226-231.

* Ravisankar, C. and Muthuswamy, S. 1988. Influence of light and temperature on leaf area index, chlorophyll content and yield of ginger. J. Maharashtra Agric. Univ., 13 (2): 216-217.

Roberts-Nkrumah, L.B., Wilson, L.A. and Ferguson, T.V., 1986. Response of four sweet potato cultivars to levels of shade. Tuberisation. Trop. Agric., 63(4):265-265.

* Robinson, J.T. Hamilton, D.F. 1980. Effects of irradiance on nutrient uptake, growth and cold hardiness of Viburnum opulus L. Nanum. Scientia Horticulturae, 13(4): 391-397.

Ross, S. 1976. First aid for house plants Mc. Graw Hill Book Company, New Delhi.

Roy, R.K. and Tripathi, R.S. 1986. Effect of irrigation and fertilizer application on the growth, nutrient concentration and yield of autumn potato. Ann. Agric. Res., 7 (1): 114-123.

* Saiev, C. 1978. The use of chemical fertilizers on the irrigated potato crop on the succava plateau, Cerectari. Agronomics in Moldova, 3: 61-65.

Samad, A. 1953. Ginger cultivation in Malabar. Indian Fmg., 3(3): 22-5.

Samad, A., Chandramohan, J. and Vijayan, P.K. 1956. Certain agronomic practices contributing to the higher yields in rice. Madras Agric. J., 39: 600-607.

Sasidharan Nair, R.C. 1985. Effect of seed size and fertility levels on the yield and quality of Dioscorea esculenta (Lour). Burk. M.Sc. (Ag) thesis. Kerala Agric. Univ., Thrissur.

Satyanarayana, V. and Arora, P.N. 1985. Effect of nitrogen and potassium on yield and yield attributes of potato (var. Kufri Bahar). Indian J. Agron., 30 (3): 292-295.

Sharma, U.C. and Grewal, J.S. 1991. Response of potato to N P K fertilization and their interactional effects. J. Indian Potato Assoc., 18(1-2): 43-47.

Shirley, H.L. 1929. The influence of light intensity and light quality on growth of plants. Am. J. Bot.,16: 354-390.

Sobulo, R.A. 1972. Studies on white yam (Dioscorea rotundata) 11 Changes in the nutrient content with age. Exp. Agr., 8: 107-115.

Sreekumari, M.T., Abraham, K. and Ramanujam. T. 1988. The performance of cassava under shade. J. Root Crops, 14 (1): 43-52.

Starnes, W.J. and Hadley, H.H. 1965. Chlorophyll content of various strains of soybeans. Crop Sci., 5 : 9-11.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soil. Curr. Sci., 25: 259-260.

Susan Varughese. 1989. Screening of varieties of ginger and turmeric for shade tolerance. M.Sc.(Ag) thesis. Kerala Agric. Univ., Thrissur.

* Tao, H.Z and Zhang, C.H. 1986. Studies on photosynthetic characteristics of shaded tea plants. Plant Physiology Communications, 6: 42-96.

Thomas, K.M. 1965. Influence of N and P_2O_5 on the yield of ginger. Madras Agric J., 52: 512-515.

*Thomas, M.B. and Teoh, S.L. 1983. Culture of container grown Ficus macrophylla 11. Influence of shading and N fertilization. Royal New Zealand Institute of Horticulture. Ann. J., 11: 77-82.

* Togari, Y. 1950. A study in tuberous root formation in sweet potatoes. Bull. Agric. Ext. Stu. Tokyo, 1-96.

Tomy, P.J. 1963. Varietal response to fertilizer application in rice. M.Sc. thesis, Univ. Kerala.

* Virzo, De S.A. and Alfani, A. 1980. Adaptability of Mentha piperita L. to irradiance. Growth, specific leaf area and levels of chlorophyll, protein and mineral nutrients as affected by shading. Biologia Plantarum. 22(2): 117-123.

* Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. Ann. Bot., 23: 431-439.

Wahua, T.A.T. and Miller, D.A. 1978. Effects of shading on the N_2 fixation, yield and plant composition of field grown soybean. Agron. J., 70(3): 387-392.

Whiley, A.W. 1980. Growth and fibre development ginger (Zingiber officinale Rosc.) in south-east Queensland Aust. J. Exp. Agric. Anim. Husb., 20: 608-612.

Wilson, L.A. 1964. The use of rooted leaves and graft plants for the study of carbohydrate metabolism in sweet potato. Proc. Int. Symp. Trop. Root Crops. pp. 246-257.

* Wormer, H.O. 1934. Res. Bull. Univ. Nebr. Agricultural Experiment station. 75: 1-32.

Zara, D.L., Cueves, S.E. and Carlos I.J. Jr. 1982. Performance of sweet potato grown under coconuts. In: Sweet potato. Villareal, R.L. and Griggs, T.D. (Eds). AVRDC, Taiwan pp. 233-242.

* Original not seen.

NUTRIENT REQUIREMENT OF GINGER (*Zingiber officinale* R.)

UNDER SHADE

By

ANCY JOSEPH

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Horticulture
COLLEGE OF AGRICULTURE
Vellayani, Thiruvananthapuram

1992

ABSTRACT

An investigation was carried out to determine the fertilizer requirement of ginger under varying shade intensities at the College of Agriculture, Vellayani during the year 1991-92. The experiment using ginger cv. Rio-de-Janeiro was laid out in strip plot design with four shade levels (S_0, S_1, S_2 and S_3) and four fertilizer levels (F_1, F_2, F_3 and F_4) and was replicated five times. The shade levels were zero (open), 25, 50 and 75 per cent and the fertilizer levels were 75, 100, 125 and 150 per cent of the recommended dose (75:-50:50 N, P_2O_5 and K_2O Kg ha^{-1}) as per the package of practices recommendations of KAU.

Under open conditions, plant height was found to be the lowest. Leaf number, leaf area index, chlorophyll content, crop growth rate, dry matter production, bulking rate and green ginger yield were found to be lower under open condition when compared to 25 and 50 per cent shade levels. However dry ginger yield under open condition was found to be comparable with that under 50 per cent shade and this might have resulted from high net assimilation rate and better partitioning under open condition as indicated by high utilization index and harvest index. Fertilizer treatments showed a positive influence on vegetative

growth, chlorophyll content, rhizome yield and NPK uptake. Under open conditions, significant increase in dry ginger yield was obtained only upto F_3 and maximum profit was also obtained for F_3. Quality of the produce was found to be unaffected by fertilizer treatments.

Growth and yield of ginger were found to be the highest under 25 per cent shade. Response to fertilizer treatments in terms of growth characters and yield were found to be the highest under this shade level. Significant increase in green and dry ginger yield was obtained with each increment in fertilizer dose upto the highest level, F_4. Quality of ginger was also superior under low shade and was unaffected by fertilizer treatments.

Under 50 per cent shade, vegetative growth and dry ginger yield were higher than that under open conditions but lower than that under 25 per cent shade. Though the leaf area index and dry matter production were comparable with that under 25 per cent shade, poor partitioning as indicated by lower utilization index and harvest index might have contributed to the lower yield. Under this shade level, as fertilizer dose increased from F_1 to F_4, significant increase in yield was obtained. But the increment was only 9.5 per cent as against 20.1 per cent obtained under 25 per cent shade.

Under 75 per cent shade vegetative growth and rhizome yield were found to be highly reduced compared to open, 25 and 50 per cent shade. Response to fertilizer treatments was also poor. There was no significant increase in yield with application of fertilizers above F_2 level.

The study clearly indicates the necessity of increasing the fertilizer dose to 150 percentage of the recommended dose when ginger is grown under 25 and 50 per cent shade.