EVALUATION OF GINGER CULTIVARS FOR SHADE TOLERANCE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled 'Evaluation of ginger cultivars for shade tolerance is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
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CERTIFICATE

Certified that this thesis entitled 'Evaluation of ginger cultivars for shade tolerance' is a record of research work done independently by Ms.Beena Elizabeth George under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Ms.Beena Elizabeth George, a candidate for the degree of Master of Science in Agriculture agree that the thesis entitled 'Evaluation of ginger cultivars for shade tolerance' may be submitted by Ms. Beena Elizabeth George, in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Solar radiation exercises qualitative as well as inducive effects on plant growth and development. Biomass production, a significant determinant of final yield is strongly correlated with the interception of radiation by foliage. Plants differ widely in their adaptation to light intensities. Some crops achieve optimum growth and development in low light intensities, while some others are well adapted to shade.

With the Indian population ever on the increase, the availability of cultivated and cultivable land is getting constrained posing a severe threat to the already deplorable food position. Increasing production per unit area per unit time will be an answer to this problem. Adoption of multiple cropping system in the available land is a viable proposition in this context, especially in Kerala, where the majority of farm holding is as low as 0.02 to 1 ha. This factor along with the compatibility of certain crops with low light intensities has envisaged the practice of intercropping or mixed cropping particularly in coconut plantations.

In Kerala, about 8 lakh ha of land is under coconut. Sole cropping of coconut does not give the farmers adequate income and employment potential, while multiple cropping system will ensure maximum biomass and returns per unit area of land, time and inputs generating products to meet the diverse needs of the farm families.

Coconut palm (<u>Cocos nucifera</u>. L) popularly known as the 'Tree of Heavens' (Kalpa Vriksha) is an integral part of every homestead in Kerala. It is a multipurpose tree with unique growth habits, and belongs to the monocotyledonous family, Palmae.

Solar energy is a crucial factor in determining the final yield of the intercrops in coconut garden. Basic resources such as solar radiation and space are under utilized in coconut gardens. Its peculiar growth habits permit diverse perennial or annual crops in the interspaces, especially in the early and later phases of its life cycle. The light intensity available under coconut plantations varies with age, variety and spacing.

Ginger, <u>Zingiber officinale</u> Rosc. belonging to the family, Zingiberaceae is an important annual spice crop of India, particularly, Kerala, highly valued for its aroma and pungency. Ginger with its multitude of uses is highly esteemed in the national and international markets. It occupies a lion's share in India's foreign exchange earnings and plays a dominant role in Kerala's agricultural economy. Besides, being an export earner, it provides reasonable returns to the farmer also.

Studies on crop performances at graded shade levels of a few common intercrops of coconut plantations were taken up at the College of Horticulture, Vellanikkara, Thrissur during 1981 to 1983, based on which ginger was classified as shade loving. Only one variety each of these crops was included in the study. Differential response of genotypes to different levels of light intensities necessitated the screening of varieties suited to shade. Consequently, Varughese (1989) selected six shade tolerant varieties from the thirteen varieties, tested.

Ginger cultivars vary widely in their tolerance to different shade levels. Eventhough there are a number of shade tolerant ginger cultivars, their relative suitability for raising as an intercrop in coconut gardens has not been evaluated. As the response of genotypes to shade varies widely under artificial and natural conditions, separate trials were taken up under controlled conditions at different shade levels and as intercrop in coconut gardens with the following objectives.

1) To assess the growth and yield of ginger cultivars under different levels of shade.
2) To study changes in the quality of ginger as affected by shading.
3) To work out prediction models for yield of ginger cultivars at different levels of shade.

Review of Literature

2. REVIEW OF LITERATURE

Solar radiation is the primary energy source for crop production. Plant productivity in a community is governed by its ability to absorb and utilize photosynthetically active radiation, for various metabolic activities and its efficiency in partioning the assimilates into sink, effectively, which is greatly influenced by the environmental conditions under which it grows, though it depends on the genetic make up of the plant, to a lesser extent. Thus, the growth, yield and quality of the produce in many crops is greatly influenced by shade at various stages of growth and development. Studies have been conducted in many crops with reference to the effect of shade on various aspects such as vegetative characters, photosynthetic efficiency, dry matter accumulation, flowering and fruiting. However, published data on the effect of shade on growth, development, yield and quality of ginger are meagre. Hence an attempt is made to review the works on shade irrespective of the crops. Further, the present study was undertaken both under artificial (controlled light intensities) and natural shade (in coconut plantations). Literature regarding the performance of crops under the above situations are reviewed, separately.

2.1 Response to light intensity

2.1.1 Under controlled light intensities

Hardy (1958) reported that the most favourable light intensity for cocoa seedlings was about 25 per cent of full sunlight. Exposure to intense light was detrimental to photosynthesis (Singh, 1967). Bai and Nair (1982) observed that the growth and yield of turmeric were highest at 50 per cent of full illumination. Hinsley (1986) reported a significant reduction in growth, when shade intensity was increased from 51-76 per cent in fraser fir (Abies fraseri Poir.). Zelenskii (1987) opined that sufficiently high level of light intensity appeared necessary for the successful performance of spring wheat as determined from photochemical activity of isolated chloroplasts. According to Lee (1987) flower bud initiation and differentiation were accelerated by high light intensity. The leaf area of field bind weed (Convolvulus arvensis) decreased as light level decreased, but that of Russian knap weed (Centurea repens) increased as light intensity decreased (Armando et al., 1988). Most of the colocasia morphotypes, out of the eleven morphotypes tried, recorded the highest yield at 25 per cent shade (Prameela, 1990). Pillai (1990) observed high vegetative growth and yield for Clocimum under shaded conditions.

The performance of ginger under varying intensities of light has been reported by many workers. Minoru and Hori (1969) reported that Zingiber mioga required a saturating light intensity of 20 klx. Nair (1969) opined that for better performance, ginger preferred low light intensities. Ginger grown under full sunlight was shorter and had fewer leaves per tiller, but the yield was however comparable with those obtained from plants grown under 25 and 50 per cent shade intensities, which clearly pointed out that the best performance of ginger was when grown under slight shade, but not when the shade intensity exceeded 50 per cent. This was confirmed by Aclan and Quinsumbing (1976), Bai (1981) and Bai and Nair (1982). Varughese (1989) reported highest yield of ginger at 25 per cent shade.

The above results clearly indicate the ability of ginger to thrive well under shade and pin point its suitability to intercropping situations in coconut plantations.

2.1.2 Under natural shade - Ginger as an intercrop in coconut garden

The feasibility of growing ginger as an intercrop in coconut garden was reported earlier by Nair et al (1974) and Sannamarappa et al. (1984). According to Ravisankar and Muthuswamy (1987) ginger was highly suited for intercropping in areca plantations which resulted in increased yields and an improvement in the quality of the produce.

2.2 Genotypic response to light intensity

The differential response of varieties to shade has been studied in several crops, including tuber crops. Furuya et al., (1984) observed the differential response to light in timothy cultivars (Phleum partense). The effect of mild and heavy shade on 18 shade tolerant sweet potato cultivars revealed significant difference in shade response (Martin, 1985). Caiger (1986) observed significantly higher yields in three Colocasia esculenta cultivars in full sun as against that in 50 per cent shade. The response to varying light intensities was similar in seven species of amaranthus tried (Simbolon and Sutarno, 1986). A study on the effect of partial shading on the yield of 25 rice varieties revealed that IET 3257, IET 4697 and IET 5633 recorded highest grain yields under normal sunlight (Jadhav, 1987). Vijayalakshmi et al. (1987) observed better performance of variety Ponni at 25 per cent of normal light. Sreekumari et al. (1988) identified seven cassava genotypes as shade tolerant with respect to tuber yield. Differential response of varieties to shade was observed in crops like ginger and turmeric (Varughese, 1989) and in colocasia (Prameela, 1990).

2.3 Growth and growth attributes

2.3.1 Plant height

Positive influence of shade on plant height has been reported in several crops. Allen (1975) found that soyabean grown under 70 per cent shade grow much taller than those in the open. Gopinathan (1981) reported an increase in plant height in cocoa upto a shade level of 55 per cent and thereafter a decrease with increase in shade intensities. According to Bai and Nair (1982), plant height in coleus, sweet potato, ginger and turmeric increased with increasing intensities of shade. The positive effect of shade on plant height in ginger and turmeric was further confirmed by Varughese (1989). She reported an increase in plant height upto 50 per cent shade beyond which it decreased. Several other workers also reported a similar trend in crops like tomato (Kamarudhin, 1983), winged bean (Sorenson, 1984), cassava (Ramanujam et al., 1984 and Sreekumari et al., 1988), sweet red pepper (Rylski and Spigelman, 1986) and broad bean (Xia, 1987). Jadhav (1987) observed an increase in plant height by about 37.4 per cent in rice due to partial shading. This was in confirmation with the finding of Singh et al. (1988). Favourable effect of shade on plant height was also reported in potato (De Magante and Zaag, 1988), Ixora (Nalawadi et al. 1988), passion fruit (Menzel and Simpson, 1989), colocasia (Premeela, 1990) and clocimum (Pillai, 1990).

On the contrary, negative influence of shade on plant height was reported in crops like bird's foot trefoil and alfalfa (Cooper, 1966) and red gram (George, 1982). George (1982) and Bai and Nair (1982) observed that plant height was unaffected by shading in cowpea, black gram and colocasia.

Thus it is seen that, though there are a few exceptions, in general, plant height is found to increase with increase in shade intensities.

2.3.2 Tillering

Beinhart (1963) reported increased branching at higher light intensities in white clover. Similar result was observed in crops like sweet potato, coleus (Bai, 1981), ginger and turmeric (Bai, 1981 and Varughese, 1989). Nalawadi et al. (1988) observed more number of branches in the open as against that in partial shade in Ixora.

Pillai (1990) recorded more number of branches in the open in clocimum. A shade response study in colocasias revealed no significant difference between shade levels with respect to the number of tillers (Prameela, 1990).

Ishimine et al. (1985) reported a decrease in tiller number with increase in light intensities in Vase grass (Paspalum urvillei Steud.). Venkataraman and Govindappa (1987) observed an increase in the number of primary shoots, in case of coffee seedlings grown under shade compared to those exposed to full day light.

From the above it is clear that solar radiation has a decisive role in the tillering pattern of the plant.

2.3.3 Dry matter production

Lesser dry matter production at higher shade levels was reported in plants such as cowpea (Dolan, 1972), beans (Crookston et al., 1975), rice (Rai and Murthy, 1977; Venkitaswaralu and Sreenivasan, 1978; Vijayalakshmi et al., 1987), Colocasia esculenta (Caesar, 1980), soybean (Benjamin et al., 1981).

On the contrary, increases in the dry matter production at higher shade levels were reported in Xanthosoma sagittifolium (Caesar, 1980), cocoa (Gopinathan, 1981), cotton (Singh, 1986), coffee (Venkataraman and Govindappa, 1987), Samantha roses (Cocker and Hannan, 1988) and passion fruit (Menzel and Simpson, 1988). Radha (1979) observed no significant reduction in dry matter accumulation with increase in shade levels upto 75 per cent in pineapple.

According to Bai (1981) the dry matter production in ginger followed a quadratic pattern with an optimum shade of 20.11 per cent. Ravisankar and Muthuswamy (1986) also observed increased dry matter production at reduced light intensity in ginger. This was further confirmed by Varughese (1989) who recorded the highest dry matter accumulation at 25 per cent shade in ginger. Prameela (1990) also noticed the same trend in colocasia.

Ravisankar and Muthuswamy (1988) also reported more dry matter accumulation at all growth stages in ginger raised as an intercrop in arecanut gardens when compared with that grown in the open.

The above findings clearly reveal that low light intensity has a favourable effect on dry matter accumulation in ginger.

2.3.4 Growth analysis

Positive influence of shade on various growth ratios have been reported. Cooper and Qualls (1967) reported an increase in the specific leaf area with increase in shade levels in bird's foot trefoil and alfalfa. Low LAI was observed at high light intensities in cotton (Bhatt and Ramanujam, 1975). NAR increased with increase in shade in ginger (Bai, 1981). In cassava, Fukai et al. (1984) reported an increase in SLA as against a decrease in LAI with higher shade levels. Sorenson (1984) observed higher leaf area ratio in winged bean (Psophocarpus tetragonolobus L.) at shaded conditions. CGR and NAR during both shading periods (before and after heading) decreased with light intensity following sigmoid curves in wheat (Wang and Nakaseko, 1986). George and Nair (1987) observed that in cowpea, leaf weight ratio increased substantially with shading. In cowpea, a positive correlation of shade with LAR, RGR and SLA was also noticed (Jadhav, 1987). Reduced light intensity increased SLA and LAI in Satsuma mandarin oranges (Ono and Iwagaki, 1987). Venkataraman and Govindappa (1987) observed an increase in NAR with increasing levels of shade in coffee seedlings. According to

Vijayalakshmi *et al*. (1988), rice variety, Ponni had greater genotypic stability to maintain higher harvest index under low light intensity. Muller (1988) reported best growth rate in citrus at 40 per cent shading. An increase in net Co_2 assimilation with increasing shade levels was noticed in mango (Schaffer and Gaye, 1989).

In contrast to the above findings a negative correlation of various growth ratios with increasing intensities of shade was also reported. In cocoa, Hardy (1958) though observed a significant decrease in NAR with increase in shade, it was seen compensated by greater leaf area development. NAR of wheat decreased with increasing shade intensities (Mousri *et al*., 1976). According to Pandey *et al*. (1980), the NAR and AGR of chickpea decreased with a decrease in light intensity. Ramadasan and Satheesan (1980) recorded highest LAI, CGR and NAR in three turmeric cultivars grown in the open. A reduction in HI with increasing intensities of shade was reported in ginger (Bai, 1981). Vijayalakshmi *et al*. (1987) also observed a reduction in HI under shaded condition in rice. An inverse effect of shade on CGR, LAI and NAR was reported in field pea (Jadhav, 1987). Decrease in leaf area with a decrease in light intensity was noticed in field bind weed (Armando *et al*., 1988) and in passion fruit (Menzel and Simpson, 1989).

Pandey *et al.* (1980) observed that LWR and RGR were unaffected by different levels of shade in chickpea. In cocoa, NAR was not significantly influenced by shade levels (Gopinathan, 1981). Varughese (1989) observed no significant difference between shade levels with respect to HI in ginger. Prameela (1990) recorded highest HI at 25 per cent shade level in colocasia and with further increase in shade levels, the HI decreased, significantly.

Ravisankar and Muthuswamy (1988) reported a significant negative correlation of various growth ratios with light intensity, in ginger, raised in arecanut gardens. LAI, NAR and CGR were higher in crop grown in low light intensities.

The above reports clearly indicate the favourable influence of shade levels on growth ratios.

2.4 Chlorophyll content

Seybold and Egle (1937) reported an increase in chlorophyll 'b' content under low light intensities. According to Gardner *et al.* (1952) concentration of chlorophyll per unit area or weight of leaves increased with decreasing light intensities, until the intensity was too low for the plants to survive. An increase in chlorophyll content in the shaded leaves was reported in crops like cocoa (Evans and Murray, 1953 Guers, 1971), pineapple (Radha, 1979), colocasia (Bai, 1981; Prameela, 1990), ginger and turmeric (Bai, 1981; Varughese, 1989), peach (Kappel and Flore, 1983; Nii and Kurowia, 1988), bean (Sorenson, 1984), tobacco (Anderson et al., 1985), cotton (Bhat and Ramanujam, 1975), rice (Singh et al., 1988), [illegible], mango (Schaffer and Gaye, 1989), groundnut (George and Nair, 1990).

Inverse relationship of shade and chlorophyll content has also been reported. Shade reduced the chlorophyll content in peanut (Rao and Mitra, 1988) and maize (Bhutani et al., 1989).

In ginger, chlorophyll a to b ratio was not found to be markdely affected by shading (Varughese, 1989) where as in colocasia chlorophyll a to b ratio was found to decrease with shading (Prameela, 1990).

Ravisankar and Muthuswamy (1988) reported higher content of total chlorophyll and its components in ginger grown in two year old and six year old arecanut plantations compared to those grown in pure stand in the open.

Thus, in general, chlorophyll content in leaves was found to increase with increase in shade intensities.

2.5 Physiological activities

It has been known for a long time that plants which occupy shaded habitats are incapable of high photosynthetic rate, but they perform efficiently at low light intensities. Since, synthesis, translocation, partitioning and accumulation of photosynthetic products within the plant are controlled genetically and influenced by the environment, the yields are likely to be increased by genetic manipulation, by identifying plants having both greater sink capacity and growth duration (Monteith, 1977).

Adaptation to low light intensity includes greater leaf area per leaf weight ratio (Blackman, 1956), reduced shoot : root ratio (Brouwer, 1966) and reduced rates of dark respiration (Kumura, 1968).

Positive influence of shade on photosynthesis and dry matter accumulation has been reported in ginger and turmeric (Bai and Nair, 1982).

Thus, it can be seen that shade tolerant crops can orient various physiological activities in such a way that it does not ultimately affect the yield and in shade loving crops, physiological processes resume its optimum activity at low light intensities.

2.6 Yield

Productivity of a plant depends upon its capacity to efficiently harvest the solar energy for various metabolic activities and also its efficiency in partitioning the assimilates into harvestable sink.

Negative correlation of shade with yield was reported in many crops like maize (Early *et al.*, 1966), sorghum (Pepper and Prine, 1972), rice (Rai and murthy, 1977; Vijayalakshmi *et al.*, 1987), soybean (Wahua and Miller, 1978), cotton (Pandey *et al.*, 1980), turmeric (Ramadasan and Satheesan, 1980), pulses (George, 1982), cowpea (Krishnankutty, 1983) and cassava (Ramanujam *et al.*, 1984; Okoli and Wilson, 1986).

Positive influence of shade on yield was also reported in many crops. Chinese cabbage, lettuce and spinach recorded highest fresh weight at 35 per cent shade beyond which the performance was poor than those in the full sunlight (Moon and Pyo, 1981). Highest yield was recorded in ginger and turmeric at 25 and 50 per cent shade levels, respectively (Bai and Nair, 1982). This was further confirmed by Varughese (1989), who also obtained highest yield in ginger at 25 per cent shade. The average fruit yield for tomato, cucumber, bean, capsicum, melon and okra grown under shade tended to be higher than that in the open but this tendency declined with increase in shade intensity (El. Aidy, 1984).

Shading during early stages of growth had no effect on tuber formation, while shading at tuber initiation stage reduced the rate of tuber formation (Gracy and Holmer, 1970). Shading at maturity did not reduce the yield, though yield was affected by shading, during flowering, pegging and filling in groundnut (Rao and Mittra, 1988).

The above findings indicate the positive influence of shade on the yield of shade tolerant crops like ginger.

2.7 Content and uptake of nutrients

Content and uptake of nutrients in crops, were always found to be correlated with light intensity. Kraybill (1922) observed higher content of N in shaded apple trees. Potassium content of some grass species when grown under 80-90 per cent shade was nearly double than that in those grown in the open (Myhr and Saebo, 1969; Rodriguez et al. (1973). Santo and Algani (1976) reported high contents of N and K in mint (Mentha piperitta). Bai (1981) observed an increase in the contents of N, P and K in coleus, colocasia, sweet potato, ginger and turmeric with increase in shade. N content in leaves increased as shade increased in mango (Schaffer and Gaye, 1989). Nitrogen content increased upto 25 per cent shade and then showed a declining trend with further increase in shade levels, while that of P and K were higher under 75 per cent shade in clocimum (Pillai, 1990). Highest contents of N, P and K were recorded at 25 per cent shade in colocasia (Prameela, 1990).

On the contrary, an inverse relationship of nutrient content and uptake with shade was reported in several crops. Gopinathan (1981) observed highest content of N, P and K in the leaves of cocoa grown in the open. Similar trend was reported by Pillai (1990) in clocimum.

In cocoa, the uptake of N, P and K was more under shade, compared to that in the open (Gopinathan, 1981). Uptake of N and K in ginger increased from 0-25 per cent shade level and then declined while P uptake decreased with shade. But the potassium uptake was highest at 50 per cent shade in turmeric (Varughese, 1989). In colocasia, highest uptake of N, P and K were recorded at 25 per cent shade (Prameela, 1990).

The above cited literature clearly reveals that in shade tolerant crops like ginger, content and uptake of nutrients, such as N, P and K tended to be more at lower shade levels.

2.8 Quality of the produce

Light regimes of a plant determine the productivity and quality of its produce (Tikhomirov et al., 1976).

Shade exerts is positive influence on the quality of the produce in many crops. Partial shade during fruit development improved the quality of pineapple (Nayar et al., 1979). The total soluble solids increased as the shade intensity increased in pineapple (Aravindakshan and Radha, 1980). Fong et al. (1980) observed improvement in the quality of green tea at 75 per cent shade for 2-3 weeks.

Shade improved the quality of products of Camellia sinensis var. assamica, Coffea arabica, Cinchona ledgeriana and Rauvolfia yunnanensis (Feng, 1982). In sweet red pepper highest yield of high quality fruits was obtained at 12 to 26 per cent shade (Rylski and Spigelman, 1986). Fruit quality and shelf life period of tomato were enhanced by shading (Holstein and Glas, 1989). Shade increased the production of organic substance and improved the berry quality in grapes by increasing the acid content (Iannini, 1989).

In contrast to the above findings, a negative correlation of shade and quality of the produce was also reported. Maize grown at lower light intensities recorded a decrease in total protein and oil content (Early et al., 1960) and sugar content (Knipmeyer et al., 1962). Sugar content in pineapple decreased as the shade increased (Aravindakshan and Radha, 1980).

Protein yield of pulses, viz., groundnut, cowpea, red gram and blackgram were high in the open compared to that under shade (George, 1981). Oil content in clocimum grown under shade was low compared to that in the open (Balyan et al., 1982; Pillai, 1990). Curcumin content in turmeric rhizome showed a progressive decrease with increase in shade (Varughese, 1989). Both oil yield and oil content in clocimum were high in the open compared to that under shade (Pillai, 1990). In colocasia, oxalic acid and starch content were higher in the open compared to that under shade (Prameela, 1990).

In some crops, certain quality aspects were not affected by shade. Protein content of pulse crops viz., groundnut, cowpea, blackgram and red gram was not affected by variations in light intensity (George, 1982). Rao and Mittra (1988) observed no significant effect of shade on the seed oil content of pea nut.

Effect of shade on the quality of ginger was also reported by many workers. Indian commercial varieties of ginger usually contain 0.5 to 2.5 per cent essential oil and 4 to 6 per cent oleoresin (Mathew et al., 1973; Natarajan and Lewis, 1980; Sankarikutty et al., 1982). Nybe et al. (1980) observed significant variation in oleoresin content in 25 ginger cultivars, the highest value of 10.5 per cent in Rio-de-jeneiro, followed by Maran. Sreekumar et al. (1980) recorded wide variation in oleoresin content in 30 ginger cultivars ranging from 3.0 in Poona to 10.8 per cent in Rio-de-jeneiro. The essential oil content in ginger was positively correlated with oleoresin content which inturn was correlated with gingerol (Rathnambal et al., 1987). They also reported a variation in oleoresin content ranging from 5.30 to 8.59 per cent. According to Varughese (1989), ginger varieties grown in the open yielded best quality rhizomes.

In a study conducted at Tamil Nadu Agricultural University, Coimbatore, the quality of ginger improved when grown under arecanut tree canopy (Ravisankar and Muthuswamy, 1987).

The literature cited above unveils that crops and varieties exhibited differential response to shade. Growth, yield and quality of the produce in crops are greatly influenced by shade, either bearing a positive or negative relation and that shade tolerant crops like ginger was always found to be favoured by low light intensities.

Materials and Methods

3. MATERIALS AND METHODS

Two separate field experiments were conducted under natural and artificial shade, with the prime objective of evaluating the ginger cultivars for shade tolerance.

The trials were carried out at the College of Horticulture, Vellanikkara, Thrissur, Kerala, India situated at 10° 32' N latitude and 76° 10' E longitude and at an altitude of 22.25 m above mean sea level.

3.1 Trial under controlled light intensities

3.1.1 Cropping history of the field

The area was under a shade trial with ginger and turmeric during the year before last year and a similar experiment was oonducted with colocasia during the previous year.

3.1 Soil

The soil at the experimental site was deep well drained sandy clay loam. The data on physical and chemical properties of the soil are given in Table 1.

3.1.3 Season and climate

The experiment was conducted during the period May 1990 to January 1991. Ginger cultivars were planted on 17th and 18th May, 1990. The crop wwas harvested after 250 days of planting.

The meteorological data for the period from May 1990 to February 1991 are presented in Appendix-1.

Table 1. Physico - chemical properties of the soil

1. Physical properties:

a) Mechanical composition (Hydrometer method, Bouyoucos, 1952)

Sand	-	77.5 per cent
Silt	-	5.0 per cent
Clay	-	17.5 per cent

b) Texture - Sandy clay loam

2. Chemical properties:

Constituents	Content	Rating	Method used for estimation
Total nitrogen	0.2 per cent	High	Microkjeldahl (Jackson, 1958)
Available phosphorus (Bray - 1 extract)	19 ppm	High	Chloro stannous reduced molybdo phosphonic blue colour method (Jackson, 1958)
Available potassium (Neutral normal ammonium acetate)	93.75 ppm	Medium	Flame photometry (Jackson, 1958)
pH (1:2 soil : water)	5.4	Strongly acidic	pH meter method (Jackson, 1958)

The crop received a total of 2451.8 mm rainfall during the period from 17th May to January 19th, 1991 and the relative humidity ranged from 69 to 95 per cent. Except for the heavy rains during the month of July and August, which had provided a favourable condition for the incidence of soft rot disease, the weather conditions on the whole, were conducive for normal growth of ginger.

3.1.4 Provision of shade

Pandals of size 27 x 11 m were erected on wooden poles to provide artificial shade to the desired level using unplaited coconut leaves. In order to minimise mutual shading of the shade levels, sufficient space (2.5 m) was provided between the main plot treatments. All sides of the pandal were also covered with unplaited coconut leaves leaving a clearance of one metre from ground level, in order to avoid entry of slant rays, and to allow wind movement. LI-COR integrating quantum radiometer with line quantum sensor was used for adjusting the shade intensity approximately to the required level. Frequent checks were made throughout the course of the trial to maintain the shade intensities to the desired level.

3.1.5 Planting material and planting

Six cultivars of ginger were used for the experiment. Healthy rhizomes free from pest and disease were selected. As a prophylactic measure against the incidence of pests and diseases these rhizomes were soaked for 30 minutes in a solution containing a mixture of Dithane M.45 (0.3 per cent) and Ekalux (0.2 per cent) and the treated rhizomes were spread on the floor in shade, to drain the water.

Rhizome bits of 15 g weight each having one or two viable healthy buds were planted in small pits taken on raised beds of width 1 m at spacing of 25 x 25 cm to a depth of 4-5 cm. Sufficient space was provided between beds of different cultivars. Mulching was done immediately after planting.

3.1.6 Manures and fertilizers

The crop received recommended cultural and manurial practices as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1989). Nitrogen, phosphorus and potassium were applied in the form of urea (46 per cent) super phosphate (16 per cent) and muriate of potash (60 per cent), respectively.

3.1.7 After cultivation

Mulching was done using green leaves for soil moisture retention and weed control. Weeding and earthing up were done one month and two months after planting.

3.1.8 Plant protection

Incidence of soft rot was very severe during the crop growth period, and fungicides viz. Dithane M.45 (0.3 per cent), Emisan (0.075 per cent), Bordeaux mixture (1 per cent) and cheshunt compound (0.3 per cent) were used for soil drenching at periodic intervals to combat the disease. During the later stages a combined infection of soft rot and bacterial wilt and shoot borer incidence were observed. To control the shoot borer Ekalux (0.2 per cent) was sprayed followed by soil application of phorate after 1 month.

3.1.9 Lay out of the experiment (Fig. 1)

Design - Split plot

Number of replications - 4

Plot size

a) Main plot 22.50 m^2 b) Subplot 3.75 x 1 m^2

Details of treatments

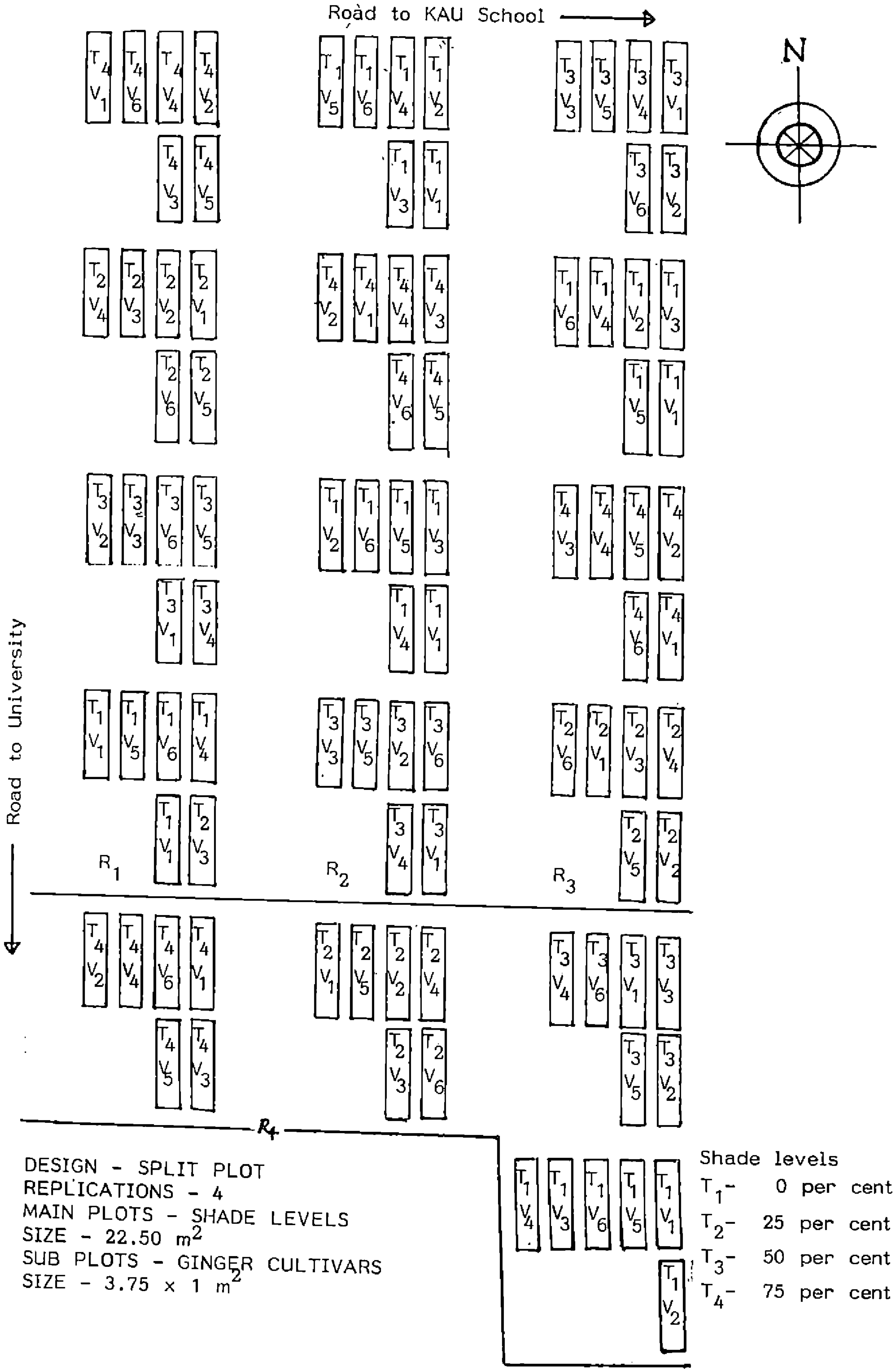
a) Main plot treatments

Notation	Shade levels
T_1	- 0 per cent shade
T_2	- 25 per cent shade
T_3	- 50 per cent shade
T_4	- 75 per cent shade

b) Subplot treatments

Notation	Cultivars (6)
V_1	- Maran
V_2	- Kuruppampadi
V_3	- Himachal
V_4	- Rio-de-jeneiro
V_5	- Nedumangad
V_6	- Amballore local

Fig. 1. Lay out plan of the experimental field
(Artificial shade)


Road to KAU School
N
Road to University
R1
R2
R3
R4
DESIGN - SPLIT PLOT
REPLICATIONS - 4
MAIN PLOTS - SHADE LEVELS
SIZE - 22.50 m2
SUB PLOTS - GINGER CULTIVARS
SIZE - 3.75 x 1 m2
Shade levels
T1 - 0 per cent
T2 - 25 per cent
T3 - 50 per cent
T4 - 75 per cent

3.2 Field trial under coconut gardens

3.2.1 Cropping history of the field

The trial was carried out in a coconut plantation about 12 years old. The interspaces of coconut palms were previously occupied by leguminous green manure crops.

3.2.2. Soil

The soil of the experimental area was deep, well drained sandy clay loam

Table 2. The physico-chemical characteristics of the soil

1. Mechanical composition (Hydrometer method, Bouyoucos, 1962)

Sand	- 52.3 per cent
Silt	- 22.5 per cent
Clay	- 25.2 per cent
Texture	- Sandy clay loam

2. Chemical composition

Constituent	Content	Rating	Method used for estimation
Total nitrogen	0.126 per cent	Medium	Microkjeldahl method (Jackson, 1958)
Available phosphorus (Bray 1 extract)	7.4 ppm	Low	Chlorostannous reduced molybdo phosphoric blue colour method (Jackson, 1958)
Available potassium (Neutral normal ammonium acetate extract)	159.8 ppm	Medium	Flame photometry (Jackson, 1958)
pH (1:2.5, Soil:water)	5.3	Strongly acidic	pH meter method (Jackson, 1958)

3.2.3 Season and climate

The experiment was conducted during the period June 1990 to February 1991. Ginger cultivars were planted on 7th and 8th June, 1990 and harvested 248 and 249 days after planting. The meteorological data for the period from June 1990 to February 1991 are presented in Appendix-1.

3.2.4 Planting material

Five ginger cultivars were used for planting. Except the cultivar, Rio-de-jeneiro, all the cultivars tried under artificial shade were raised here also.

3.2.5 Manures and fertilizers

Same practice was followed as that under artificial shade.

3.2.6 After cultivation

Practices followed were the same as those under artificial shade.

3.2.7 Plant protection

The crop suffered severe incidence of soft rot bacterial wilt and shoot borer attack as in the case of crop raised under artificial shade. Same chemicals as those in artificial shade were applied here.

3.2.8 Lay out and design (Fig. 2)

Design	- RBD
Number of replications	- 4
Treatments	Cultivars (5)

Notation

V_1	-	Maran
V_2	-	Kuruppampadi
V_3	-	Himachal
V_5	-	Nedumangad
V_6	-	Amballore local

Each of the ginger cultivar was planted around a coconut palm leaving a basin area of 12.56 m^2. Net area around one palm planted with ginger was 29.75 m^2. The cultivar Rio-de-jeneiro (V_4) was not raised here due to the shortage of planting material which on the other hand was included in the artificial shade trial.

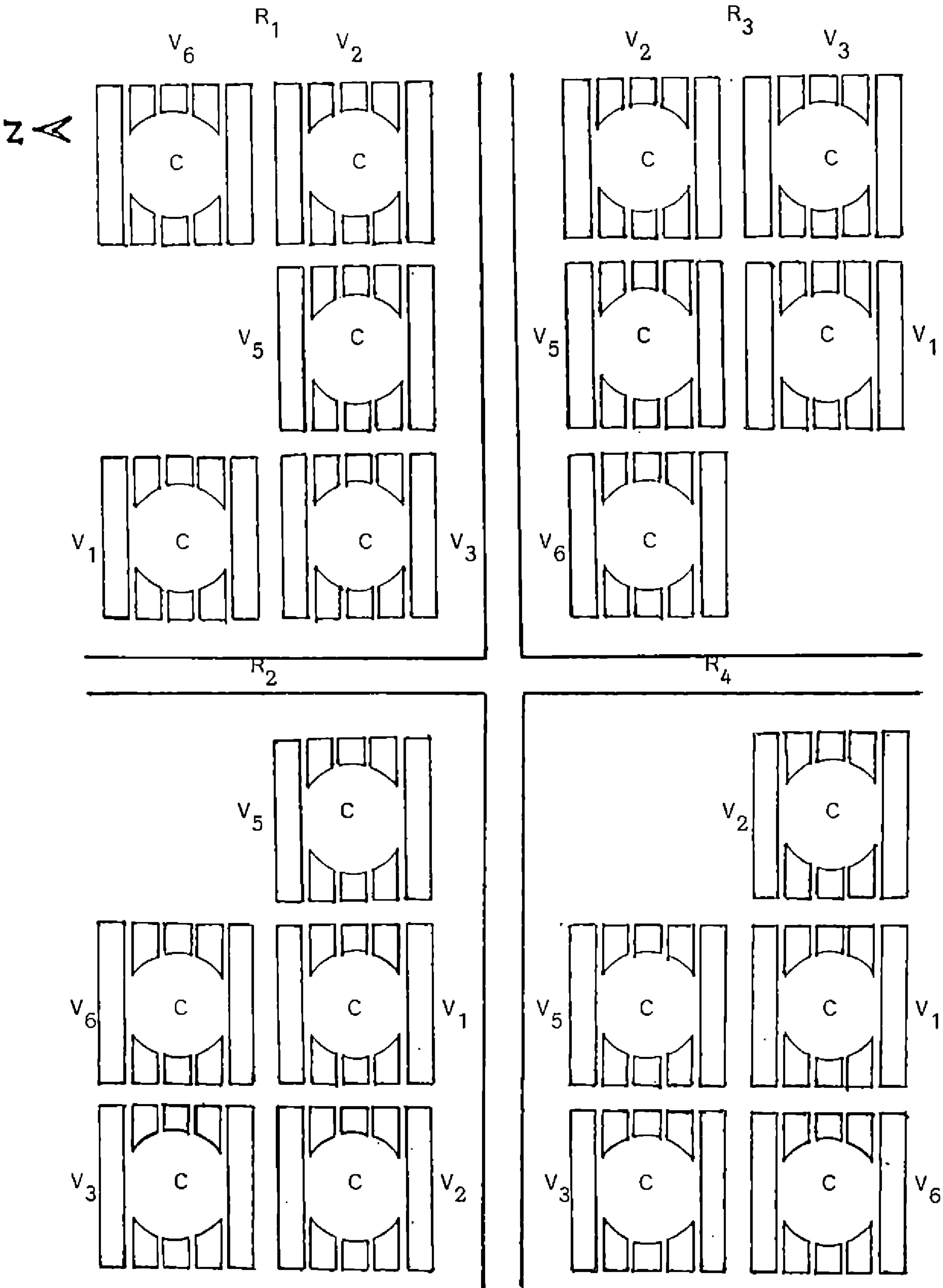
3.2.9 Shade

The light infiltration under coconut canopy was measured using LI-COR integrating quantum radiometer with line quantum sensor. The average of the hourly intervals was taken as the mean light infiltration percentage.

3.3 Observations

Observations followed the same pattern in both the trials.

Fig. 2. Lay out plant of the experimental field
(Natural shade)



DESIGN - RBD
TREATMENTS - CULTIVARS (5)
REPLICATIONS (4)
PLOT SIZE - 29.75 m^2
C - Coconut

V_1 - Maran
V_2 - Kuruppampadi
V_3 - Himachal
V_5 - Nedumangad
V_6 - Amballore local

Sampling technique

In order to select the sample plants for studying the various growth characters, random sampling technique was adopted. For recording the different biometric observations at bimonthly intervals, five plants were selected at random as observation plants. Pre-harvest observations were started 60 days after planting and were continued upto 180 days after planting.

The following observations were recorded

A. Biometric observations

1. Plant height

The height of the selected plants were measured from the base of the main pseudostem to the tip of the topmost leaf and the average worked out.

2. Number of tillers per plant

The number of tillers was determined by counting the number of aerial shoots arising around a single plant and the average of the five sample plants was worked out for each subplot.

3. Net assimilation rate (NAR)

This growth ratio refers to the change in dry weight of the plant per unit leaf area per unit time. This observation was recorded at 60 DAP and 120 DAP, using the formula suggested by Williams (1946) and expressed as g m^{-2} day^{-1}.

4. Chlorophyll content of leaves

Chlorophyll a, chlorophyll b, total chlorophyll content and chlorophyll a to b ratio of leaves of sample plants of each treatment were estimated at 150 DAP by spectrophotometry (Starnes and Hadley, 1965). Second terminal leaf of five plants from each treatment selected at random constituted the sample.

5. Rhizome yield

Yield of rhizomes was recorded from the sample plants and the rest of the plants, separately. The sum of these worked out and expressed as t ha^{-1} of fresh produce.

6. Haulm yield

The yield of top (vegetative part) in five observation plants was recorded and expressed as t ha^{-1} of dry weight.

7. Harvest index (HI)

Harvest index in crop plants is a measure of assimilate partitioning of photosynthates from biological yield to economic sink. Harvest index was calculated as follows. Harvest index $= \frac{Y\ econ}{Y\ biol}$ where Y econ and Y biol were dry weight of rhizome and total dry weight of plant respectively.

8. Percentage dryage

Percentage dryage was calculated from fresh weight and loss in weight on drying. It is the ratio of dry weight and fresh weight of rhizome expressed as a percentage.

9. Total dry weight

Pseudostem and rhizomes of the uprooted plants were separated and dried to constant weight at 70°C to 80°C in hot air oven. From the dry weight of component parts for five plants, average dry weight per plant for these parts was worked out. The sum of the dry weight of component parts gave total dry matter yield. It was expressed as g plant^{-1}.

B. Chemical studies

1. Content of fertilizer nutrients

For chemical analysis, samples of plant components, collected for recording the dry weight were used. The nitrogen content of rhizome and haulm were determined by Microkjeldahl's digestion and distillation method. Phosphorus content was determined colorimetrically by Vanadomolybdo phosphoric yellow colour method (Jackson, 1958) and the potassium content in the plant components was determined using flame photometer (Jackson, 1958).

2. Uptake of fertilizer nutrients

The total uptake values of nitrogen, phosphorus and potassium by the plant were calculated from the nutrient content and dry weight and expressed as kg ha^{-1}.

3. Quality analysis

Ginger samples collected for quality analysis were chopped and sundried for 7 days. The dried samples were mechanically ground to pass through a 60 mesh sieve. Grinding was done on the same day of analysis.

1. Oleoresin content in ginger rhizome

Cold percolation method using 100 per cent acetone as solvent (ISI, 1974) was adopted for estimating the oleroresin content in ginger rhizomes. Details of the procedure are given below.

Ten g of the ground sample was transferred to a Soxhlet apparatus the outlet of which was plugged with cotton. The sample was bound in a filter paper and placed in the extractor. Twenty five ml of 100 per cent acetone was added and allowed to stand for 16 h. The drippings were collected in a previously weighed extraction flask. After the entire solvent was drained, an additional quantity of the solvent was added to the sample in the extractor, such that solvent was just over the sample. The extraction was carried out till the last siphoned material was colourless. Six to eight siphonings, were needed in a period of 2-2½ hours. The solvent from the extract was removed by distillation under controlled temperature. The residue obtained was dried at 80°C and weighed and expressed as percentage.

2. Oil content in ginger rhizome

Clevenger appratus is used for the estimation of oil content in ginger rhizomes. Details of the procedure are given below.

Ten g of the ground sample was transferred to an extraction flask. The sample was distilled using water for extraction of oil. A condensor was attached to the extraction flask, through a trap. The sample was distilled for 2-2½ hours. The separated oil was then read from the graduated neck of the trap.

C. Disease incidence

Incidence of soft rot, bacterial wilt and phyllosticta leaf spot was observed in the artificial shade trial. Cultivars grown under natural shade suffered from soft rot and bacterial wilt but was totally free from phyllosticta leaf spot. The cultivars were scored for their disease susceptibility as totally affected and unaffected.

D. Statistical analysis

The experimental data were subjected to analysis of variance for split plot design and RBD following the method of Panse and Sukhatme (1978) in the case of trial No.1 and 2 respectively. Appropriate prediction models were also worked out for all these cultivars.

Results

RESULTS

Observations on various plant characters were taken to evaluate the performance of ginger cultivars with respect to growth, yield and quality both under artificial and natural shade to make a relative comparison between them. Also, the yield of ginger cultivars at different shade intensities were predicted and suitable prediction model for each cultivar was developed to test their fitness to field situation, particularly in coconut plantations. The results of these trials are presented in this chapter.

A. Under controlled light intensities

Biometric observations

1. Plant height (Tables 3, 4, 5, Appendix 2)

Plant height increased with increase in shade intensities at all stages, except 60 DAP. Highest plant height was observed at 75 per cent shade at all the three stages, where it was significantly superior to 0, 25 and 50 per cent shade at 60 DAP and was comparable with 50 per cent shade at the other two stages. However, at both 120 and 180 DAP, the lowest plant height was recorded in the open.

Cultivars exhibited significant difference at all stages. Both at 60 DAP and 120 DAP, Kuruppampadi registered the highest value. At 60 DAP, Kuruppampadi was significantly superior to other cultivars, while at 120 DAP it was comparable with Amballore

Table 3. Effect of shade on plant height, number of tillers and NAR of ginger cultivars

Treatment	Plant height			Number of tillers			NAR g m^{-2} day^{-1}	
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP
Levels of shade (%)								
T_1 (0)	41.93	48.15	51.19	2.51	10.89	14.29	4.12	1.88
T_2 (25)	39.70	55.80	69.65	2.07	10.58	15.59	2.76	2.05
T_3 (50)	36.28	57.30	81.53	2.51	12.17	14.02	2.52	2.58
T_4 (75)	47.53	60.14	82.65	1.82	9.16	12.28	3.06	2.26
SEm±	2.47	1.45	3.95	0.43	0.90	0.75	0.44	0.19
CD (0.05)	5.59	3.29	8.93	NS	NS	NS	0.99	0.43
Cultivar								
T_1 (Maran)	42.95	51.51	69.04	2.22	10.33	12.62	2.29	2.59
V_2 (Kuruppampadi)	47.04	61.00	72.93	1.48	8.96	12.25	3.22	3.33
V_3 (Himachal)	43.30	53.47	68.95	3.05	11.80	11.75	3.65	2.46
V_4 (Rio-de-jeneiro)	37.13	55.09	70.53	3.34	15.02	20.42	2.98	1.70
V_5 (Nedumangad)	37.28	54.42	74.75	1.50	9.12	12.40	3.35	2.21
V_6 (Amballore local)	40.46	56.61	71.33	1.78	8.98	13.32	3.20	0.85
SEm±	1.45	2.63	2.06	0.21	0.99	1.19	0.38	0.31
CD (0.05)	2.90	5.27	4.13	0.43	1.97	2.38	0.76	0.62

	Main plot	Subplot
Plant height 60 DAP	T_4 T_1 T_2 T_3	V_2 V_3 V_1 V_6 V_5 V_4
Plant height 120 DAP	T_4 T_3 T_2 T_1	V_2 V_6 V_4 V_5 V_3 V_1
Plant height 180 DAP	T_4 T_3 T_2 T_1	V_5 V_2 V_6 V_4 V_1 V_3
Number of tillers 60 DAP		V_4 V_3 V_1 V_6 V_5 V_2
Number of tillers 120 DAP		V_4 V_3 V_1 V_5 V_6 V_2
Number of tillers 180 DAP		V_4 V_6 V_1 V_5 V_2 V_3
NAR 60 DAP	T_1 T_4 T_2 T_3	V_3 V_5 V_2 V_6 V_4 V_1
NAR 120 DAP	T_3 T_4 T_2 T_1	V_2 V_1 V_3 V_5 V_4 V_6

Table 4. Interaction effect of shade levels and ginger cultivars on plant height at 60 DAP

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	46.90	37.38	35.18	52.36	42.95
V_2 (Kuruppampadi)	45.35	42.65	44.55	55.61	47.04
V_3 (Himachal)	49.38	43.63	34.60	45.60	43.30
V_4 (Rio-de-jeneiro)	35.85	39.41	27.10	46.18	37.13
V_5 (Nedumangad)	39.90	36.13	32.13	40.98	37.28
V_6 (Amballore local)	34.21	39.03	44.13	44.48	40.46
Mean	41.93	39.70	36.28	47.53	

S.E. of difference between 2 subplot means at the same level of main plot = 2.90

CD for the above at 5 per cent level = 5.81

S.E. of difference between 2 main plot means at the same level of subplot = 3.63

CD for the above at 5 per cent level = 7.69

0	V_3	V_1	V_2	V_5	V_4	V_6
25	V_3	V_2	V_4	V_6	V_1	V_5
50	V_2	V_6	V_1	V_3	V_5	V_4
75	V_2	V_1	V_4	V_3	V_6	V_5

Table 5. Interaction effect of shade levels and ginger cultivars on plant height at 180 DAP

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	52.18	61.94	80.80	81.25	69.04
V_2 (Kuruppampadi)	56.95	70.75	85.70	78.33	72.93
V_3 (Himachal)	51.61	72.67	74.53	77.00	68.95
V_4 (Rio-de-jeneiro)	51.13	61.93	83.05	86.00	70.53
V_5 (Nedumangad)	50.00	78.34	81.58	89.10	74.75
V_6 (Amballore local)	45.25	72.30	83.55	84.20	71.33
Mean	51.19	69.65	81.53	82.65	

S.E. of difference between 2 subplot means at the same level of main plot = 4.13

CD for the above at 5 per cent level = 8.25

S.E. of different between 2 main plot means at the same level of subplot = 5.46

CD for the above at 5 per cent level = 11.66

0 — V_2 V_1 V_3 V_4 V_5 V_6

25 — V_5 V_3 V_6 V_2 V_1 V_4

50 — V_2 V_6 V_4 V_5 V_1 V_3

75 — V_5 V_4 V_6 V_1 V_2 V_3

local. Though Nedumangad gave the highest plant height at 180 DAP, it was comparable with Kuruppampadi and Amballore local.

Cultivar x shade interaction was significant at 60 DAP and 180 DAP only. Himachal recorded the highest plant height which was comparable with Kuruppampadi in the open and at 25 per cent shade. But Kuruppampadi gave the highest value at 50 and 75 per cent shade. Plant height exhibited an increasing trend with shade levels except for Kuruppampadi at 180 DAP, where the plant height increased upto 50 per cent shade and then declined. Highest plant height was observed in Kuruppampadi in the open and at 50 per cent shade, which was comparable with all cultivars except Amballore local and Himachal, respectively. Nedumangad recorded the highest plant height at 25 and 75 per cent shade. At 25 per cent shade, Nedumangad was comparable with all cultivars other than Maran and Rio-de-jeneiro, whereas at 75 per cent shade, Nedumangad was superior to Kuruppampadi and Himachal.

Number of tillers (Tables 3, 6, Appendix 2)

There was no significant difference between shade levels with respect to number of tillers, at any of the stages.

Cultivars differed significantly in tiller number. Rio-de-jeneiro recorded the highest tiller number at all stages, and was comparable with Himachal at 60 DAP.

Table 6. Interaction effect of shade levels and ginger cultivars on the number of tillers at 180 DAP

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	11.83	11.20	14.58	12.87	12.62
V_2 (Kuruppampadi)	10.78	19.40	10.23	8.60	12.25
V_3 (Himachal)	15.45	10.48	11.05	10.02	11.75
V_4 (Rio-de-jeneiro)	25.05	16.55	10.02	15.75	20.42
V_5 (Nedumangad)	8.32	15.92	10.13	15.23	12.40
V_6 (Amballore local)	14.34	14.00	13.78	11.18	13.32
Mean	14.29	14.59	14.02	12.28	

S.E. of difference between 2 subplot means at the same level of main plot = 2.38

CD for the above at 5 per cent level = 4.76

S.E. of difference between 2 main plot means at the same level of sub plot = 2.30

CD for the above at 5 per cent level = 4.67

0 V_4 V_3 V_6 V_1 V_2 V_5

25 V_2 V_4 V_5 V_6 V_1 V_3

50 V_4 V_1 V_6 V_3 V_2 V_5

75 V_4 V_5 V_1 V_6 V_3 V_2

Cultivar and shade revealed significant interaction only at 180 DAP. Rio-de-jeneiro was superior to other cultivars in the open and at 50 per cent shade, while at 25 and 75 per cènt shade, it was comparable with Nedumangad. Kuruppampadi gave the highest tiller number at 25 per cent shade and the lowest at 75 per cent.

Net assimilation rate (NAR) (Tables, 3, 7, 8, Appendix 3, Fig. 3)

NAR registered significant difference between shade levels at both 60 and 120 DAP. Highest and lowest value for NAR were observed in the open, at 60 and 120 DAP respectively. Open condition was significantly superior to other shade intensities at 60 DAP. But at 120 DAP, 50 per cent shade recorded the highest NAR which was comparable with 75 per cent shade.

Cultivars exhibited significant difference at both 60 and 120 DAP. Himachal recorded the highest NAR at 60 DAP which was comparable with all other cultivars except Maran. But at 120 DAP, though Kuruppampadi was found to be significantly superior to other cultivars, Himachal also fared well.

Significant interaction between shade levels and cultivars was observed at both 60 and 120 DAP. Kuruppampadi recorded the highest NAR in the open at 60 DAP which was comparable to Himachal. AT 25 per cent shade also, it was comparable with Amballore local which gave the highest NAR. At 50 per cent shade, no significant difference was observed between cultivars. Rio-de-jeneiro was found to be superior to all the cultivars at 75 per

Table 7. Interaction effect of shade levels and ginger cultivars on net assimilation rate at 60 DAP

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	3.69	2.26	1.92	1.29	2.29
V_2 (Kuruppampadi)	6.36	2.06	2.91	1.55	3.22
V_3 (Himachal)	5.23	2.85	3.02	3.52	3.65
V_4 (Rio-de-jeneiro)	2.36	2.01	1.89	5.65	2.98
V_5 (Nedumangad)	4.30	3.28	3.19	2.61	3.35
V_6 (Amballore local)	2.78	4.08	2.19	3.74	3.20
Mean	4.12	2.76	2.52	3.06	

S.E. of difference between 2 subplot means at the same level of main plot = 0.76

CD for the above at 5 per cent level = 1.52

S.E. of difference between 2 main plot means at the same level of subplot = 0.82

CD for the above at 5 per cent level = 1.70

0 V_2 V_3 V_5 V_1 V_6 V_4

25 V_6 V_5 V_3 V_1 V_2 V_4

50 V_5 V_3 V_2 V_6 V_1 V_4

75 V_4 V_6 V_3 V_5 V_2 V_1

Table 8. Interaction effect of shade levels and ginger cultivars on net assimilation rate at 120 DAP

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	4.76	2.62	0.81	2.15	2.59
V_2 (Kuruppampadi)	1.99	2.46	4.94	3.91	3.33
V_3 (Himachal)	2.69	2.71	1.51	2.91	2.46
V_4 (Rio-de-jeneiro)	1.09	2.35	2.46	0.91	1.70
V_5 (Nedumangad)	1.68	1.36	3.95	1.86	2.21
V_6 (Amballore local)	0.97	0.81	1.77	1.81	0.85
Mean	1.88	2.05	2.58	2.26	

S.E. of difference between 2 subplot means at the same level of main plot = 0.62

CD for the above at 5 per cent level = 1.24

S.E. of difference between 2 main plot means at the same level of subplot = 0.60

CD for the above at 5 per cent level = 1.21

0	V_1	V_3	V_2	V_5	V_4	V_6
25	V_3	V_1	V_2	V_4	V_5	V_6
50	V_2	V_5	V_4	V_6	V_3	V_1
75	V_2	V_3	V_1	V_5	V_6	V_4

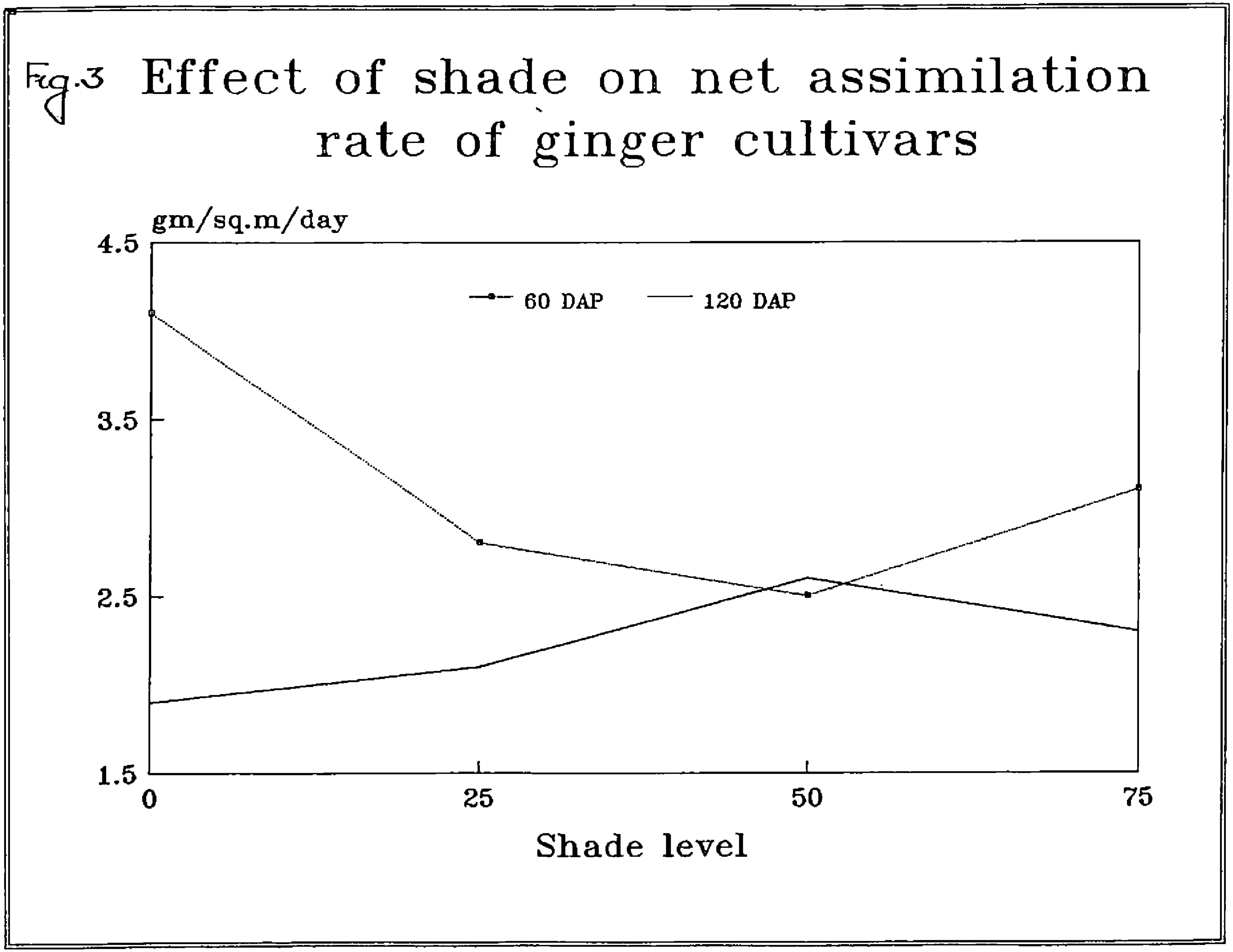


Fig.3 Effect of shade on net assimilation rate of ginger cultivars
gm/sq.m/day
4.5
3.5
2.5
1.5
60 DAP
120 DAP
0
25
50
75
Shade level

cent shade. At 120 DAP, Maran registered the highest NAR in the open. AT 25 per cent shade highest NAR was observed in Himachal which was comparable with all cultivars except Nedumangad and Amballore local. At 50 and 75 per cent shade, Kuruppampadi gave the highest value which was comparable with Nedumangad and Himachal respectively.

Chlorophyll content (Table 9)

Total chlorophyll and its fractions increased progressively with increasing levels of shade at 150 DAP, but the ratio of chlorophyll a to b tended to increase with increase in shade from 25 to 75 per cent shade intensity with the highest ratio in the open.

Rio-de-jeneiro recorded the highest content of total chlorophyll, closely followed by Himachal. Kuruppampadi gave the lowest value. The range in total chlorophyll content was from 1.15 to 1.52 mg g^{-1} fresh weight in different cultivars.

Rhizome yield (Tables 10, 11, 13, Appendix 3, Fig. 4, 6)

Shade levels exhibited significant difference in rhizome yield on fresh weight as well as dry weight basis. Plants in the open were significantly inferior to those under shade in terms of rhizome yield. Yields at 25, 50 and 75 per cent shade were 202, 201 and 188 per cent compared to that in the open. Twenty five, 50 and 75 per cent shade intensities were comparable though 25

Table 9. Effect of shade on contents of chlorophyll fractions of ginger cultivars at 150 DAP

Treatment	Chlorophyll 'a' mg gm^{-1} fresh weight	Chlorophyll 'b' mg gm^{-1} fresh weight	Chlorophyll (a+b) mg gm^{-1} fresh weight	Chlorophyll mg gm^{-1} fresh weight
Levels of shade (%)				
T_1 (0)	0.40	0.19	0.61	1.98
T_2 (25)	0.79	0.53	1.33	1.47
T_3 (50)	0.86	0.55	1.42	1.54
T_4 (75)	0.93	0.56	1.43	1.66
Cultivar				
V_1 (Maran)	0.74	0.44	1.18	1.68
V_2 (Kuruppampadi)	0.71	0.45	1.15	1.55
V_3 (Himachal)	0.78	0.60	1.39	1.30
V_4 (Rio-de-jeneiro)	0.96	0.54	1.52	1.73
V_5 (Nedumangad)	0.77	0.55	1.33	1.38
V_6 (Amballore local)	0.67	0.51	1.17	1.32

Table 10. Effect of shade on rhizome yield, haulm yield, harvest index, total dry weight and percentage dryage of ginger cultivars

Treatment	Rhizome yield (fresh weight basis) t ha^{-1}	Rhizome yield (dry weight basis) t ha^{-1}	Haulm yield t ha^{-1}	Harvest index	Total dry weight gm $plant^{-1}$	Percentage dryage
Levels of shade (%)						
T_1 (0)	8.84	1.51	1.35	0.50	17.89	16.50
T_2 (25)	17.87	2.99	1.59	0.64	28.67	16.73
T_3 (50)	17.74	3.04	1.97	0.61	31.58	16.95
T_4 (75)	16.60	2.82	1.80	0.61	29.41	17.27
SEm±	1.77	0.31	0.81	0.03	2.32	0.05
CD (0.05)	5.50	0.70	0.42	0.07	5.24	0.12
Cultivar						
V_1 (Maran)	14.65	2.64	1.56	0.63	26.62	18.00
V_2 (Kuruppampadi)	17.16	3.01	1.32	0.68	27.05	17.50
V_3 (Himachal)	21.56	4.00	1.63	0.71	35.16	18.48
V_4 (Rio-de-jeneiro)	11.35	1.39	1.99	0.40	21.12	12.20
V_5 (Nedumangad)	15.32	2.37	1.71	0.55	25.45	15.40
V_6 (Amballore local)	11.53	2.14	1.88	0.54	25.92	19.60
SEm±	1.04	0.18	0.19	0.03	1.43	0.05
CD (0.05)	2.08	0.35	0.39	0.07	2.85	0.10

	Main plot	Subplot
Rhizome yield (Fresh weight basis)	$\overline{T_2\ T_3\ T_4}\ T_1$	$V_3\ V_2\ V_5\ V_1\ V_6\ V_4$
Rhizome yield (Dry weight basis)	$\overline{T_3\ T_2\ T_4}\ T_1$	$V_3\ V_2\ V_1\ V_5\ V_6\ V_4$
Haulm yield	$\overline{T_3\ T_4\ T_2}\ T_1$	$V_4\ V_6\ V_5\ V_3\ V_1\ V_2$
Harvest index	$\overline{T_2\ T_3\ T_4}\ T_1$	$V_3\ V_2\ V_1\ V_5\ V_6\ V_4$
Total dry weight	$\overline{T_3\ T_4\ T_2}\ T_1$	$V_3\ V_2\ V_1\ V_6\ V_5\ V_4$
Percentage dryage	$\overline{T_4\ T_3\ T_2}\ T_1$	$V_6\ V_3\ V_1\ V_2\ V_5\ V_4$

Fig 4 *Effect of shade on rhizome yield of ginger cultivars*

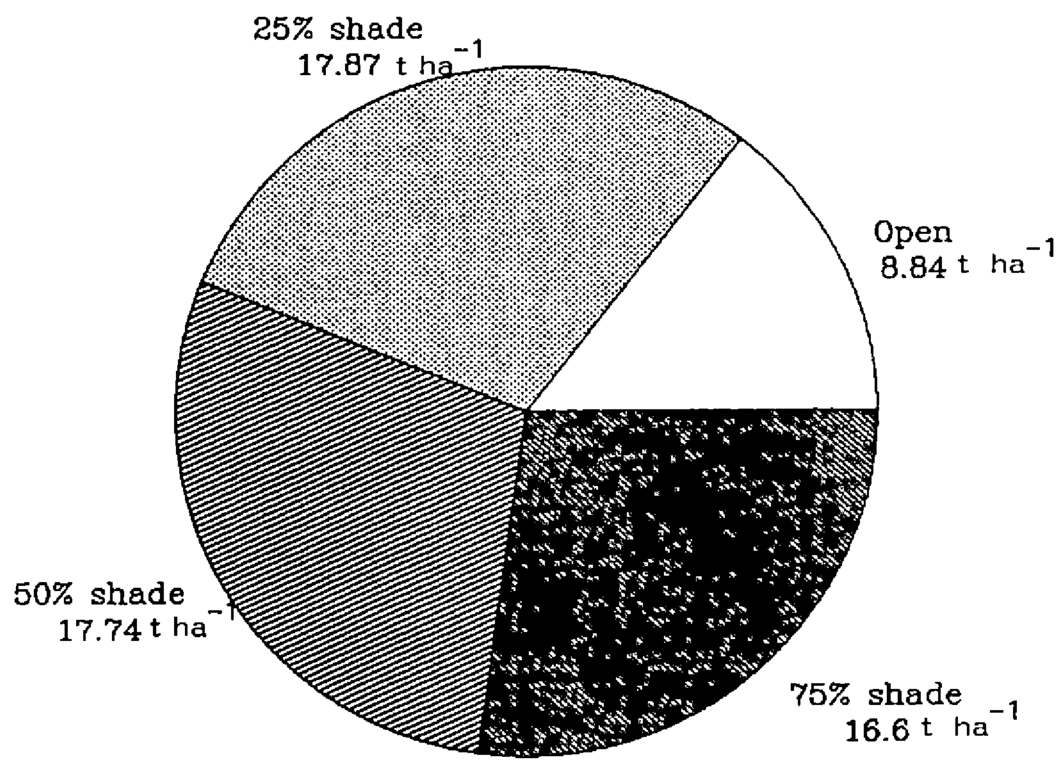


Table 11. Interaction effect of shade levels and ginger cultivars on rhizome yield (fresh weight basis)

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	6.72	18.62	19.01	14.26	14.65
V_2 (Kuruppampadi)	15.53	14.88	19.18	19.01	17.16
V_3 (Himáchal)	14.57	22.91	22.13	26.62	21.56
V_4 (Rio-de-jeneiro)	4.98	13.40	13.50	13.50	11.35
V_5 (Nedumangad)	4.09	25.06	18.08	14.06	15.32
V_6 (Amballore local)	7.14	12.34	14.56	12.07	11.53
Mean	8.84	17.87	17.74	16.60	

S.E. of difference between 2 subplot means at the same level of main plot = 2.08

CD for the above at 5 per cent level = 4.16

S.E. of difference between 2 main plot means at the same level of sub plot = 2.59

CD for the above at 5 per cent level = 5.50

0	V_2	V_3	V_6	V_1	V_4	V_5
25	V_5	V_3	V_1	V_2	V_4	V_6
50	V_3	V_2	V_1	V_5	V_6	V_4
75	V_3	V_2	V_1	V_5	V_4	V_6

and 50 per cent shade recorded the highest values on fresh and dry weight basis, respectively.

Significant difference was observed in the case of cultivars as well. Himachal gave the highest rhizome yield of 21.56 t ha^{-1} and 4 t ha^{-1} on fresh and dry weight basis, respectively, whereas Rio-de-jeneiro gave the lowest rhizome yield of 11.35 t ha^{-1} and 1.39 t ha^{-1} on fresh and dry weight basis, respectively.

Interaction between shade levels and cultivars was also significant. When analysed on fresh weight basis, it was seen that, though Kuruppampadi and Nedumangad recorded the highest rhizome yield in the open and at 25 per cent shade, they were comparable with Himachal, the highest yielder at 50 and 75 per cent shade. On dry weight basis though Kuruppampadi recorded the highest value in the open, it was comparable with Himachal which gave the highest rhizome yield at all other shade levels. Further, at 75 per cent shade Himachal was found superior to all other cultivars both on fresh and dry weight basis. In general, the performance of Amballore local was poor in terms of rhizome yield in all shade levels except in the open on fresh weight basis, whereas on dry weight basis, Rio-de-jeneiro recorded the lowest value at 0, 25, 50 and 75 per cent shade.

Prediction model (Table 12, Fig. 5)

The rhizome yield at different shade intensities were plotted to observe the varied shadal effects for the different cultivars.

Table 12. Prediction models for ginger cultivars

Cultivars	Prediction model	R^2
V_1 (Maran)	$\log y = a+b(\log x)+c(\log x)^2 + d(\log x)^3$ $= 0.825052 - 0.046084x + 0.60282x^2 - 0.25253x^3$	0.834**
V_2 (Kuruppampadi)	$\log y = a+b(\log x)+c(\log x)^2+d(\log x)^3$ $= 1.160018 - 0.50712x + 0.4492x^2 - 0.073811x^3$	0.220
V_3 (Himachal)	$\log y = a+b(\log x)+c(\log x)^2+d(\log x)^3$ $= 1.162496 + 0.46180x - 0.37722x^2 + 0.10545x^3$	0.833**
V_4 (Rio-de-Janeiro)	$\log y = a+b(\log x)+c(\log x)^2+d(\log x)^3$ $= 0.612199 + 0.45009x + 0.046080x^2 - 0.080884x^3$	0.574**
V_5 (Nedumangad)	$\log y = a+b(\log x)+c(\log x)^2+(\log x)^3$ $= 0.609913 + 1.0190x - 0.072622x^2 - 0.17318x^3$	0.966**
V_6 (Amballore local)	$\log y = a+bx+cx^2$ $= 7.0465 + 0.29916x - 0.00308x^2$	0.605**

where y = yield
x = shade (%)

** - Significant at 1 per cent level

Table 13. Interaction effect of shade levels and ginger cultivation on rhizome yield (dry weight basis)

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	1.19	3.33	3.42	2.61	2.64
V_2 (Kuruppampadi)	2.66	2.58	3.38	3.43	3.01
V_3 (Himachal)	2.62	4.19	4.11	5.06	4.00
V_4 (Rio-de-jeneiro)	0.59	1.63	1.66	1.69	1.39
V_5 (Nedumangad)	0.62	3.84	2.80	2.21	2.37
V_6 (Amballore local)	1.37	2.41	2.87	1.92	2.14
Mean	1.51	2.99	3.04	2.82	

S.E. of difference between 2 subplot means at the same level of main plot = 0.35

CD for the above at 5 per cent level = 0.71

S.E. of difference between 2 main plot means at the same level of subplot = 0.45

CD for the above at 5 per cent level = 0.96

0 V_2 V_3 V_6 V_1 V_5 V_4

25 V_3 V_5 V_1 V_2 V_6 V_4

50 V_3 V_1 V_2 V_6 V_5 V_4

75 V_3 V_2 V_1 V_5 V_6 V_4

Fig. 5' Rhizome yield of ginger cultivars as influenced by shade levels

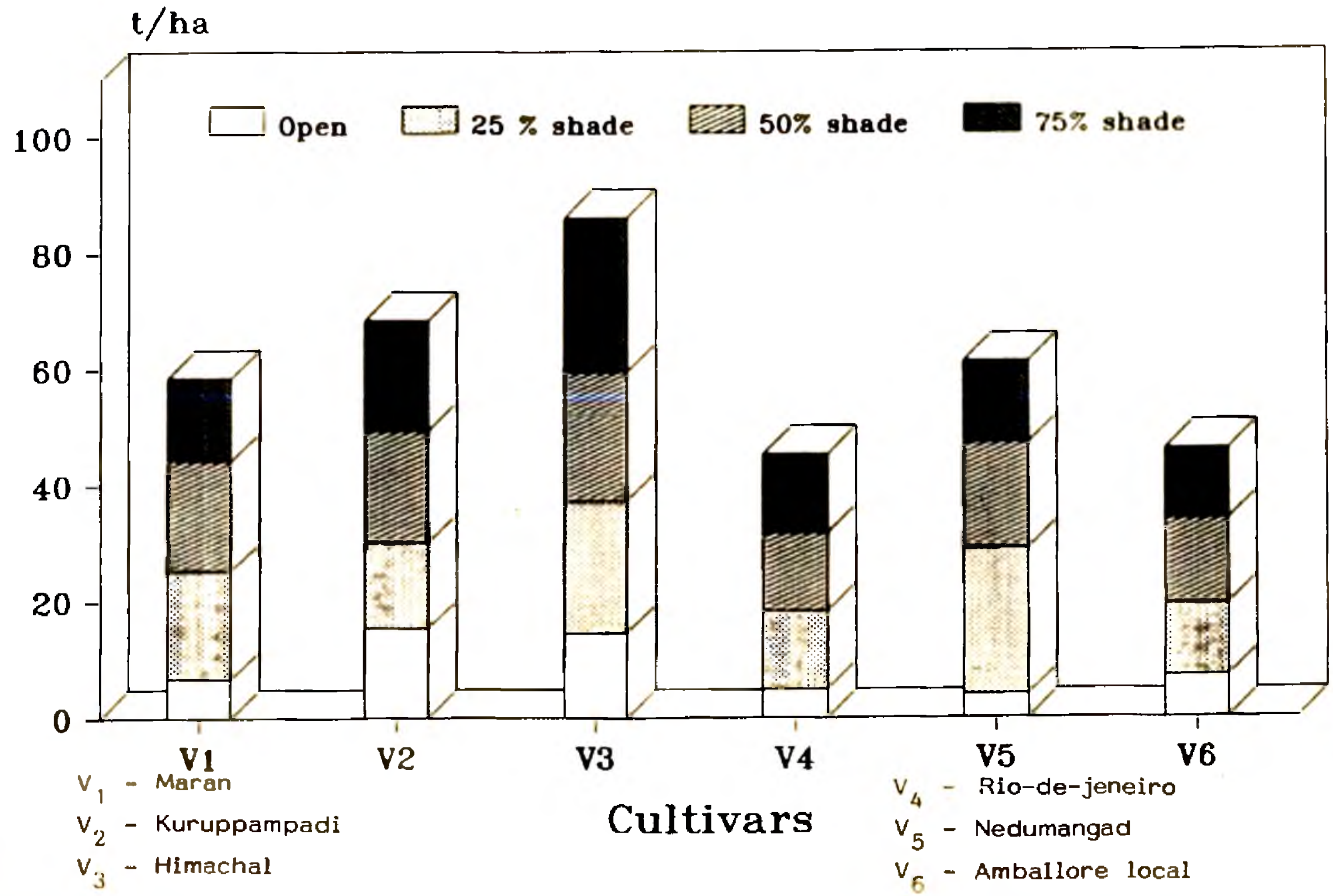
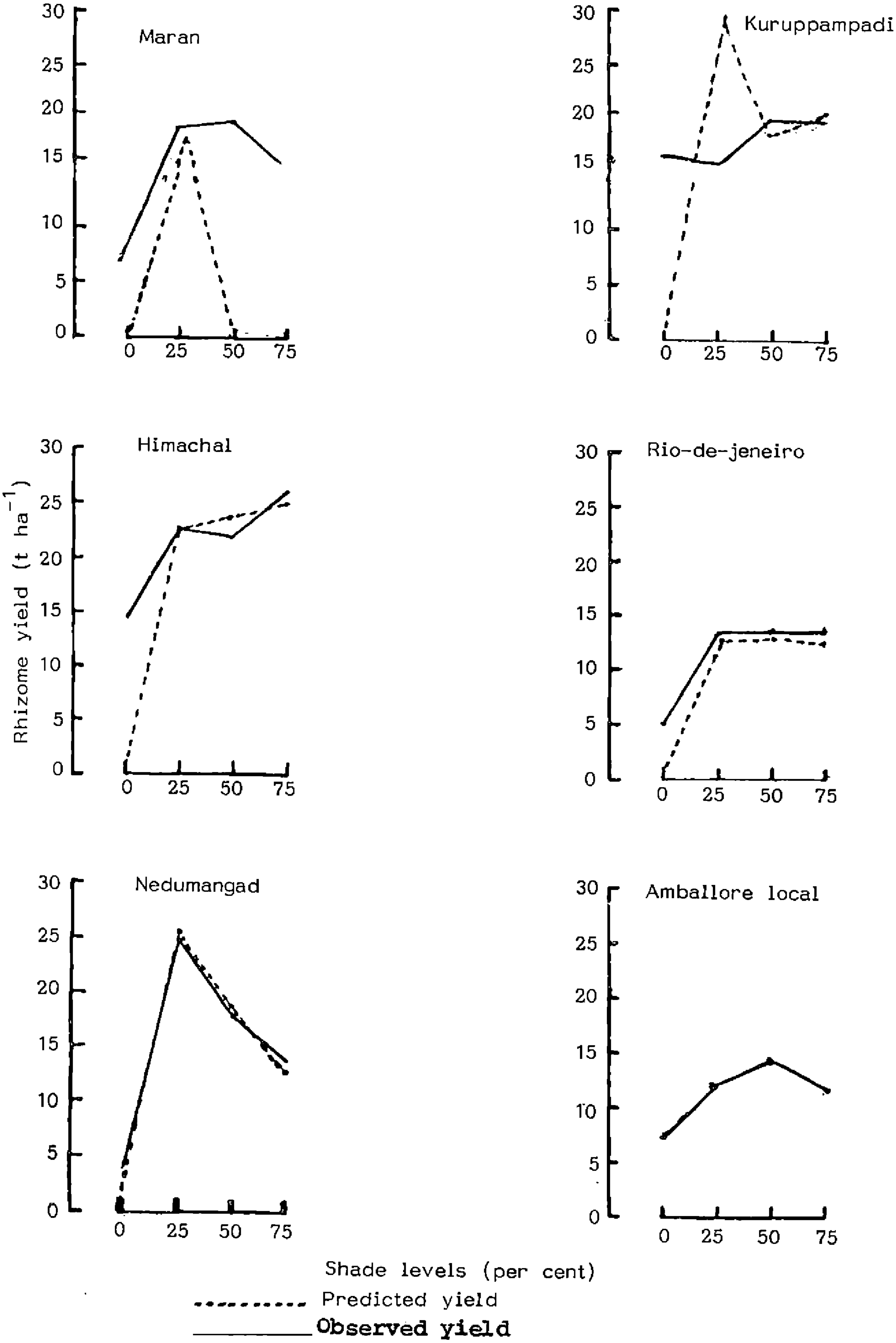


Fig. 6. Prediction models for ginger cultivars



The graphs did not show a uniform response. But the logarithms of yield as well as shade levels showed a cubic nature of response for all the cultivars, except Amballore local. Hence the model $\log y = a+b(\log x)+c(\log x)+d(\log x)^3$ was fitted to the data in case of all the cultivars other than Amballore local for which the yield prediction could be well effected using the model $y = a+bx+cx^2$.

The logarithmic model fitted well for Himachal which gave the highest yield at 50 and 75 per cent shade (Fig. 6). Kuruppampadi which also gave good yields had a close fit for the model. For Nedumangad, the fitted predictor model showed high degree closeness to the original data. Though no data was available for comparison under natural situation for Rio-de-jeneiro, the model had a good fit to the data. For Maran, the model did not give a good fit at the higher levels of shade, while at lower levels, the same could be used with fairly high degree of confidence for prediction.

Haulm yield (Tables 10, 14, Appendix 3)

There was significant difference between shade levels with respect to haulm yield. Haulm yield was highest (1.97 t ha^{-1}) at 50 per cent shade, which was comparable with 75 and 25 per cent shade, and was superior to that in the open.

Cultivars also differed significantly in terms of haulm yield. Rio-de-jeneiro recorded the highest haulm yield of 1.99 t ha^{-1} while Kuruppampadi gave the lowest value of 1.32 t ha^{-1}.

Table 14. Interaction effect of shade levels and ginger cultivars on haulm yield

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	0.84	1.32	2.82	1.24	1.56
V_2 (Kuruppampadi)	1.35	1.22	1.49	1.21	1.32
V_3 (Himachal)	1.85	0.92	1.35	2.39	1.63
V_4 (Rio-de-jeneiro)	1.74	1.48	2.34	2.40	1.99
V_5 (Nedumangad)	1.02	2.77	1.33	1.70	1.71
V_6 (Amballore local)	1.31	1.84	2.49	1.88	1.88
Mean	1.35	1.59	1.97	1.80	

S.E. of difference between 2 subplot means at the same level of main plot = 0.39

CD for the above at 5 per cent level = 0.78

S.E. of difference between 2 main plot means at the same level of subplot = 0.40

CD for the above at 5 per cent level = 0.82

0	V_3	V_4	V_2	V_6	V_5	V_1
25	V_5	V_6	V_4	V_1	V_2	V_3
50	V_1	V_6	V_4	V_2	V_3	V_5
75	V_4	V_3	V_6	V_5	V_1	V_2

Shade x cultivar interaction was also significant. Himachal recorded the highest value in the open which was comparable with Rio-de-jeneiro, Kuruppampadi and Amballore local. At 25 per cent shade, Himachal registered the lowest haulm yield whereas at 50 per cent shade, it was comparable with Nedumangad which gave the lowest value. Maran recorded the highest haulm yield which was comparable with Amballore local and Rio-de-jeneiro. Haulm yield at 75 per cent shade was highest in Rio-de-jeneiro which in turn was comparable with all cultivars except Maran and Kuruppampadi.

Harvest index (HI) (Tables 10, 15, Appendix 3)

Shade levels differed significantly with respect to harvest index. Highest HI was observed at 25 per cent shade which was comparable with that at 50 and 75 per cent shade, and was superior to that under direct sun.

Significant difference was observed between cultivars. Himachal gave the highest HI (0.71) which was comparable with Kuruppampadi, while Rio-de-jeneiro recorded the lowest value (0.40) which was lower than all other cultivars.

Interaction between shade levels and cultivars was also significant. Though Kuruppampadi recorded the highest value of HI in the open and at 75 per cent shade, it was comparable with Himachal which gave the highest value at 25 and 50 per cent

Table 15. Interaction effect of shade levels and ginger cultivars on harvest index

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	0.59	0.71	0.54	0.67	0.63
V_2 (Kuruppampadi)	0.65	0.66	0.69	0.74	0.68
V_3 (Himachal)	0.59	0.82	0.76	0.69	0.71
V_4 (Rio-de-jeneiro)	0.27	0.52	0.42	0.41	0.40
V_5 (Nedumangad)	0.38	0.48	0.69	0.56	0.55
V_6 (Amballore local)	0.50	0.56	0.54	0.57	0.54
Mean	0.50	0.65	0.61	0.61	

S.E. of difference between 2 subplot means at the same level of main plot = 0.07

CD for the above at 5 per cent level = 0.13

S.E. of difference between 2 main plot means at the same level of subplot = 0.07

CD for the above at 5 per cent level = 0.14

0	V_2	V_1	V_3	V_6	V_5	V_4
25	V_3	V_1	V_2	V_5	V_6	V_4
50	V_3	V_2	V_5	V_1	V_6	V_4
75	V_2	V_3	V_1	V_6	V_5	V_4

shade. Rio-de-jeneiro registered the lowest HI irrespective of the shade levels tried.

Percentage dryage (Table 10)

Percentage dryage also exhibited significant difference at various shade levels. Seventy five per cent shade level recorded the highest value which was higher than that at other shade levels. Percentage dryage increased with increase in shade.

Cultivars also showed significant difference in percentage dryage. Amballore local recorded the highest value (19.60 per cent) while, Rio-de-jeneiro, the lowest (12.20 per cent).

No significant interaction was noticed between shade levels and cultivars.

Total dry weight (Tables10, 16, Appendix 3)

There was significant difference between shade levels with respect to total dry weight. Highest value was recorded at 50 per cent shade which was comparable with that at 25 and 75 per cent shade. But the lowest value was observed in the open which was significantly inferior to that at other shade levels.

Cultivars also differed significantly. Himachal recorded the highest total dry weight and was significantly superior to other cultivars while Rio-de-jeneiro gave the lowest value, which was inferior to all other cultivars.

Table 16. Interaction effect of shade levels and ginger cultivars on total dry weight

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	12.71	29.12	40.12	24.05	26.62
V_2 (Kuruppampadi)	25.05	23.72	30.41	29.01	27.05
V_3 (Himachal)	27.99	31.94	34.15	46.57	35.16
V_4 (Rio-de-jeneiro)	14.55	19.39	24.96	25.57	21.12
V_5 (Nedumangad)	10.26	41.29	25.83	24.44	25.45
V_6 (Amballore local)	16.77	26.57	33.50	26.83	25.92
Mean	17.89	28.67	31.58	29.41	

S.E. of difference between 2 subplot means at the same level of main plot = 2.85

CD for the above at 5 per cent level = 5.71

S.E. of difference between 2 main plot means at the same level of subplot = 3.49

CD for the above at 5 per cent level = 7.38

0	V_3	V_2	V_6	V_4	V_1	V_5
25	V_5	V_3	V_1	V_6	V_2	V_4
50	V_1	V_3	V_6	V_2	V_5	V_4
75	V_3	V_2	V_6	V_4	V_5	V_1

Cultivar x shade interaction was significant. In the open, Himachal recorded the highest value which was comparable with Kuruppampadi and at 25 per cent shade, Nedumangad was found to be significantly superior to other cultivars. At 50 per cent shade, Maran gave the highest value closely followed by Himachal, which was superior to other cultivars at 75 per cent shade.

Chemical studies

Content of fertilizer nutrients (Tables 17, 18, 19, 20, 21, 22, Appendix 4)

Shade levels as well as cultivars showed significant difference with respect to N, P and K content in haulm. But in rhizomes, no significant difference was observed in the case of P content.

Highest N content in haulm and rhizome was observed in the open and at 25 per cent shade, respectively. Nitrogen content both in haulm as well as rhizome went on decreasing upto 50 per cent shade and recorded the lowest value at 50 per cent shade. Between cultivars, the variation in N content was from 1.49 per cent (Nedumangad) to 1.98 per cent (Amballore local) in haulm and 0.47 per cent (Himachal) to 0.53 per cent (Kuruppampadi) in rhizome.

Significant interaction between shade levels and cultivars was observed with respect to N content in haulm and rhizome. Maran and Kuruppampadi recorded the highest N content in haulm at 0 and 25 per cent shade, respectively. Nedumangad registered

Table 17. Effect of shade on contents of N, P and K of ginger cultivars at harvest

Treatment	Nitrogen % Haulm	Nitrogen % Rhizome	Phosphorus % Haulm	Phosphorus % Rhizome	Potassium % Haulm	Potassium % Rhizome
Levels of shade (%)						
T_1 (0)	1.91	1.61	0.49	0.50	1.54	2.70
T_2 (25)	1.72	1.62	0.51	0.52	1.37	2.79
T_3 (50)	1.49	1.27	0.49	0.51	1.80	2.69
T_4 (75)	1.88	1.43	0.52	0.51	1.70	2.78
SEm±	0.07	0.03	0.01	0.01	0.05	0.09
CD (0.05)	0.16	0.06	0.02	NS	0.11	NS
Cultivar						
V_1 (Maran)	1.86	1.48	0.51	0.51	1.69	2.63
V_2 (Kuruppampadi)	1.96	1.59	0.53	0.50	1.54	2.47
V_3 (Himachal)	1.69	1.57	0.47	0.51	1.50	2.61
V_4 (Rio-de-jeneiro)	1.51	1.19	0.51	0.51	1.58	3.59
V_5 (Nedumangad)	1.59	1.48	0.51	0.52	1.65	2.43
V_6 (Amballore local)	1.98	1.59	0.49	0.51	1.65	2.71
SEm±	0.08	0.04	0.01	0.01	0.05	0.08
CD (0.05)	0.15	0.07	0.02	NS	0.10	0.16

	Main plot				Subplot					
Nitrogen % (Haulm)	T_1	T_4	T_2	T_3	V_6	V_2	V_1	V_3	V_4	V_5
Nitrogen % (Rhizome)	T_2	T_1	T_4	T_3	V_2	V_6	V_3	V_1	V_5	V_4
Phosphorus % (Haulm)	T_4	T_2	T_1	T_3	V_2	V_1	V_4	V_5	V_6	V_3
Potassium % (Haulm)	T_3	T_4	T_1	T_2	V_1	V_5	V_6	V_4	V_2	V_3
Potassium % (Rhizome)	T_2	T_4	T_1	T_3	V_4	V_6	V_1	V_3	V_2	V_5

the highest N content in haulm at 50 per cent shade. But Amballore local gave the highest value at 75 per cent shade.

With regard to N content in rhizome, Amballore local recorded the highest value in the open, whereas at 25 and 50 per cent shade, Kuruppampadi and Maran recorded the highest values, respectively. However, at 75 per cent shade, Nedumangad gave the highest value. In general, haulm contained more N than rhizome.

Phosphorus content in haulm was highest at 75 per cent shade and the lowest at 0 and 50 per cent shade. Among cultivars, Kuruppampadi gave the highest value (0.53 per cent) and Himachal the lowest (0.47 per cent).

Shade x cultivar interaction was also significant with respect to P content in haulm. Maran recorded the highest P content in haulm, in the open, while, Rio-de-jeneiro gave the highest value at 25 and 75 per cent shade. But at 50 per cent shade, Kuruppampadi registered the highest value. On the whole, there was no much difference between the P content of haulm and rhizome.

Potassium content in haulm was highest at 50 per cent shade which was comparable with that at 75 per cent shade. There was no significant difference between shade levels with respect to K content in rhizome. Among the cultivars, the variation in the content of K was from 1.50 per cent (Himachal) to 1.69 per cent (Maran) in haulm and 2.47 per cent (Kuruppampadi) to 3.59 per cent (Rio-de-jeneiro) in rhizome.

There was significant interaction between shade levels and cultivars with respect to K content in haulm. Rio-de-jeneiro and Kuruppampadi recorded the highest values at 25 and 75 per cent shade, respectively, while Maran gave the highest value both in the open and 50 per cent shade.

Cultivar x shade interaction was significant with regard to K content in rhizome. However, Rio-de-jeneiro recorded the highest value, irrespective of the shade levels. Comparing rhizome and haulm, rhizomes were found to have more K content.

Uptake of nutrients (Tables 23, 24, 25, 26, Appendix 4, Fig.7)

There was significant difference between shade levels with regard to N uptake. Highest value of N uptake was observed at 75 per cent shade which was comparable to that at 25 per cent, while, the lowest value was recorded in the open.

Cultivars also differed significantly with respect to N uptake. Himachal (91.23 kg ha^{-1}) was significantly superior to other cultivars in this regard, while, Rio-de-jeneiro (58.23 kg ha^{-1}) was inferior to all.

Table 18. Interaction effect of shade levels and ginger cultivars on N content of haulm

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	2.52	1.08	1.76	2.10	1.86
V_2 (Kuruppampadi)	2.05	2.48	1.18	2.15	1.96
V_3 (Himachal)	1.48	2.01	1.27	2.01	1.69
V_4 (Rio-de-jeneiro)	2.01	0.99	1.08	1.96	1.51
V_5 (Nedumangad)	1.51	1.66	1.86	0.94	1.49
V_6 (Amballore local)	1.91	2.11	1.76	2.16	1.98
Mean	1.91	1.72	1.49	1.88	

S.E. of difference between 2 subplot means at the same level of main plot = 0.15

CD for the above at 5 per cent level = 0.31

S.E. of difference between 2 main plot means at the same level of subplot = 0.16

CD for the above at 5 per cent level = 0.32

0 V_1 V_2 V_4 V_6 V_5 V_3

25 V_2 V_6 V_3 V_5 V_1 V_4

50 V_5 V_1 V_6 V_3 V_2 V_4

75 V_6 V_2 V_1 V_3 V_4 V_5

Table 19. Interaction effect of shade levels and ginger cultivars on N content of rhizome

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	1.75	1.12	1.67	1.38	1.48
V_2 (Kuruppampadi)	1.66	2.55	0.96	1.18	1.59
V_3 (Himachal)	1.47	1.90	1.37	1.55	1.57
V_4 (Rio-de-jeneiro)	1.67	0.99	1.09	1.00	1.19
V_5 (Nedumangad)	1.31	1.71	1.13	1.76	1.48
V_6 (Amballore local)	1.77	1.47	1.38	1.73	1.59
Mean	1.61	1.62	1.27	1.43	

S.E. of difference between 2 subplot means at the same level of main plot = 0.07

CD for the above at 5 per cent level = 0.14

S.E. of difference between 2 main plot means at the same level of subplot = 0.07

CD for the above at 5 per cent level = 0.15

0	V_6	V_1	V_4	V_2	V_3	V_5
25	V_2	V_3	V_5	V_6	V_1	V_4
50	V_1	V_6	V_3	V_5	V_4	V_2
75	V_5	V_6	V_3	V_1	V_2	V_4

Table 20. Interaction effect of shade levels and ginger cultivars on P content of haulm

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	0.53	0.50	0.50	0.50	0.51
V_2 (Kuruppampadi)	0.50	0.50	0.60	0.50	0.53
V_3 (Himachal)	0.48	0.50	0.40	0.50	0.47
V_4 (Rio-de-jeneiro)	0.48	0.53	0.50	0.55	0.51
V_5 (Nedumangad)	0.48	0.50	0.50	0.55	0.51
V_6 (Amballore local)	0.50	0.53	0.45	0.50	0.49
Mean	0.40	0.51	0.49	0.52	

S.E. of difference between 2 subplot means at the same level of main plot = 0.02

CD for the above at 5 per cent level = 0.05

S.E. of difference between 2 main plot means at the same level of subplot = 0.02

CD for the above at 5 per cent level = 0.05

0	V_1	V_2	V_6	V_3	V_4	V_5
25	V_4	V_6	V_1	V_2	V_3	V_5
50	V_2	V_1	V_4	V_5	V_6	V_3
75	V_4	V_5	V_1	V_2	V_3	V_6

Table 21. Interaction effect of shade levels and ginger cultivars on K content of haulm

Cultivar	Shade level (per cent) 0	25	50	75	Mean
V_1 (Maran)	1.74	1.40	1.92	1.68	1.69
V_2 (Kuruppampadi)	1.41	1.19	1.76	1.80	1.54
V_3 (Himachal)	1.46	1.06	1.90	1.59	1.50
V_4 (Rio-de-jeneiro)	1.61	1.60	1.54	1.58	1.58
V_5 (Nedumangad)	1.36	1.59	1.90	1.76	1.65
V_6 (Amballore local)	1.63	1.39	1.81	1.78	1.65
Mean	1.54	1.37	1.80	1.70	

S.E. of difference between 2 subplot means at the same level of main plot = 0.10

CD for the above at 5 per cent level = 0.20

S.E. of difference between 2 main plot means at the same level of subplot = 0.10

CD for the above at 5 per cent level = 0.21

0   V_1 V_6 V_4 V_3 V_2 V_5

25   V_4 V_5 V_1 V_6 V_2 V_3

50   V_1 V_3 V_5 V_6 V_2 V_4

75   V_2 V_6 V_5 V_1 V_3 V_4

Table 22. Interaction effect of shade levels and ginger cultivars on K content of rhizome

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	2.46	2.07	3.20	2.80	2.63
V_2 (Kuruppampadi)	2.62	2.39	2.37	2.51	2.47
V_3 (Himachal)	2.82	2.32	2.53	2.77	2.61
V_4 (Rio-de-jeneiro)	2.87	4.09	3.50	3.91	3.59
V_5 (Nedumangad)	2.60	2.59	2.22	2.31	2.43
V_6 (Amballore local0	2.83	3.26	2.34	2.40	2.71
Mean	2.70	2.79	2.69	2.78	

S.E. of difference between 2 subplot means at the same level of main plot = 0.16

CD for the above at 5 per cent level = 0.33

S.E. of difference between 2 main plot means at the same level of subplot = 0.17

CD for the above at 5 per cent level = 0.36

0	V_4	V_6	V_3	V_2	V_5	V_1
25	V_4	V_6	V_5	V_2	V_3	V_1
50	V_4	V_1	V_3	V_2	V_6	V_5
75	V_4	V_1	V_3	V_2	V_6	V_5

Shade x cultivar interaction was also significant. Kuruppampadi registered the highest value in the open and Nedumangad, the lowest. At 25 per cent shade, highest value was observed in Nedumangad which was comparable with Himachal. On the other hand, Rio-de-jeneiro gave the lowest value both at 25 and 50 per cent shade. Maran and Himachal gave the highest values at 50 and 75 per cent shade, respectively.

Shade levels differed significantly with regard to P uptake. The lowest value was observed in the open which was inferior to other shade levels, which were comparable. Cultivars also showed significant difference in this aspect. Himachal recorded the highest P uptake (28.20 kg ha^{-1}) and Rio-de-jeneiro, the lowest (17.45 kg ha^{-1}).

Shade x cultivar interaction was also significant with respect to P uptake. Himachal recorded the highest value in the open as well as at 75 per cent shade, while, Nedumangad and Maran registered the highest values at 25 and 50 per cent shade, respectively.

With regard to K uptake, there was significant difference between shade levels. Potassium uptake increased upto 25 per cent shade and thereafter it showed a progressive decline. Highest value was recorded at 25 per cent shade and the lowest in the open. Cultivars also showed significant difference. Himachal recorded the highest value (152.88 kg ha^{-1}) and Amballore local (79.30 kg ha^{-1}) the lowest.

Table 23. Effect of shade on uptake of nutrients N, P and K, Oleoresin and oil content of ginger cultivars

Treatment	Uptake ($kg\ ha^{-1}$) N	P	K	Oleoresin (%)	Oil (%)
Level of shade (%)					
T_1 (0)	59.25	13.89	58.82	6.66	2.58
T_2 (25)	74.83	23.49	137.37	8.45	2.58
T_3 (50)	71.04	25.33	124.52	5.78	2.83
T_4 (75)	78.88	24.19	112.54	11.13	2.92
SEm±	2.97	1.74	3.98	-	-
CD (0.05)	6.72	3.94	9.01	-	-
Cultivar					
V_1 (Maran)	71.39	21.12	107.07	6.64	3.0
V_2 (Kuruppampadi)	72.70	21.76	125.74	7.25	3.0
V_3 (Himachal)	91.23	28.20	152.88	7.28	2.63
V_4 (Rio-de-jeneiro)	58.23	17.45	96.74	9.07	2.88
V_5 (Nedumangad)	65.20	21.13	88.14	8.38	2.50
V_6 (Amballore local)	67.25	20.70	79.30	9.07	2.38
SEm±	2.62	1.32	33.27	-	-
CD (0.05)	5.24	2.64	6.54	-	-

Uptake of N	T_4	T_2	T_3	T_1	V_3	V_2	V_1	V_6	V_5	V_4
Uptake of P	T_3	T_4	T_2	T_1	V_3	V_2	V_5	V_1	V_6	V_4
Uptake of K	T_2	T_3	T_4	T_1	V_3	V_3	V_1	V_4	V_5	V_6

Table 24. Interaction effect of shade levels and ginger cultivars on uptake of N

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	42.27	51.70	131.75	59.85	71.39
V_2 (Kuruppampadi)	86.66	96.15	49.84	58.16	72.70
V_3 (Himachal)	73.47	104.74	81.02	105.70	91.23
V_4 (Rio-de-jeneiro)	66.71	30.36	49.58	86.29	58.23
V_5 (Nedumangad)	29.46	109.38	55.61	66.34	65.20
V_6 (Amballore local)	56.97	56.62	58.46	96.94	67.25
Mean	59.25	74.83	71.04	78.88	

S.E. of difference between 2 subplot means at the same level of main plot = 5.24

CD for the above at 5 per cent level = 10.47

S.E. of difference between 2 main plot means at the same level of subplot = 5.63

CD for the above at 5 per cent level = 11.66

0	V_2	V_3	V_4	V_6	V_1	V_5
25	V_5	V_3	V_2	V_6	V_1	V_4
50	V_1	V_3	V_6	V_5	V_2	V_4
75	V_3	V_6	V_4	V_5	V_1	V_2

Table 25. Interaction effect of shade levels and ginger cultivars on uptake of P

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	10.36	23.29	31.00	19.82	21.12
V_2 (Kuruppampadi)	17.55	18.98	26.90	23.61	21.76
V_3 (Himachal)	21.93	25.55	28.06	37.26	28.20
V_4 (Rio-de-jeneiro)	11.45	16.41	19.97	21.97	17.45
V_5 (Nedumangad)	8.18	33.99	21.34	21.02	21.13
V_6 (Amballore local)	13.89	22.73	24.72	21.46	20.70
Mean	13.89	23.49	25.33	24.19	

S.E. of difference between 2 subplot means at the same level of main plot = 2.64

CD for the above at 5 per cent level = 5.28

S.E. of difference between 2 main plot means at the same level of subplot = 2.97

CD for the above at 5 per cent level = 6.21

0	V_3	V_2	V_6	V_4	V_1	V_5
25	V_5	V_3	V_1	V_6	V_2	V_4
50	V_1	V_3	V_2	V_6	V_5	V_4
75	V_3	V_2	V_4	V_6	V_5	V_1

Table 26. Interaction effect of shade levels and ginger cultivars on uptake of K

Cultivar	Shade level (per cent)				Mean
	0	25	50	75	
V_1 (Maran)	50.97	87.87	194.65	94.80	107.07
V_2 (Kuruppampadi)	83.26	196.04	127.94	95.71	125.74
V_3 (Himachal)	105.95	208.76	127.72	169.08	152.88
V_4 (Rio-de-jeneiro)	33.26	102.98	115.79	134.94	96.74
V_5 (Nedumangad)	28.33	139.11	84.24	100.90	88.14
V_6 (Amballore local)	51.15	89.45	96.76	79.84	79.30
Mean	58.82	137.37	124.52	112.54	

S.E. of difference between 2 subplot means at the same level of main plot = 6.54

CD for the above at 5 per cent level = 13.08

S.E. of difference between 2 main plot means at the same level of subplot = 7.18

CD for the above at 5 per cent level = 14.93

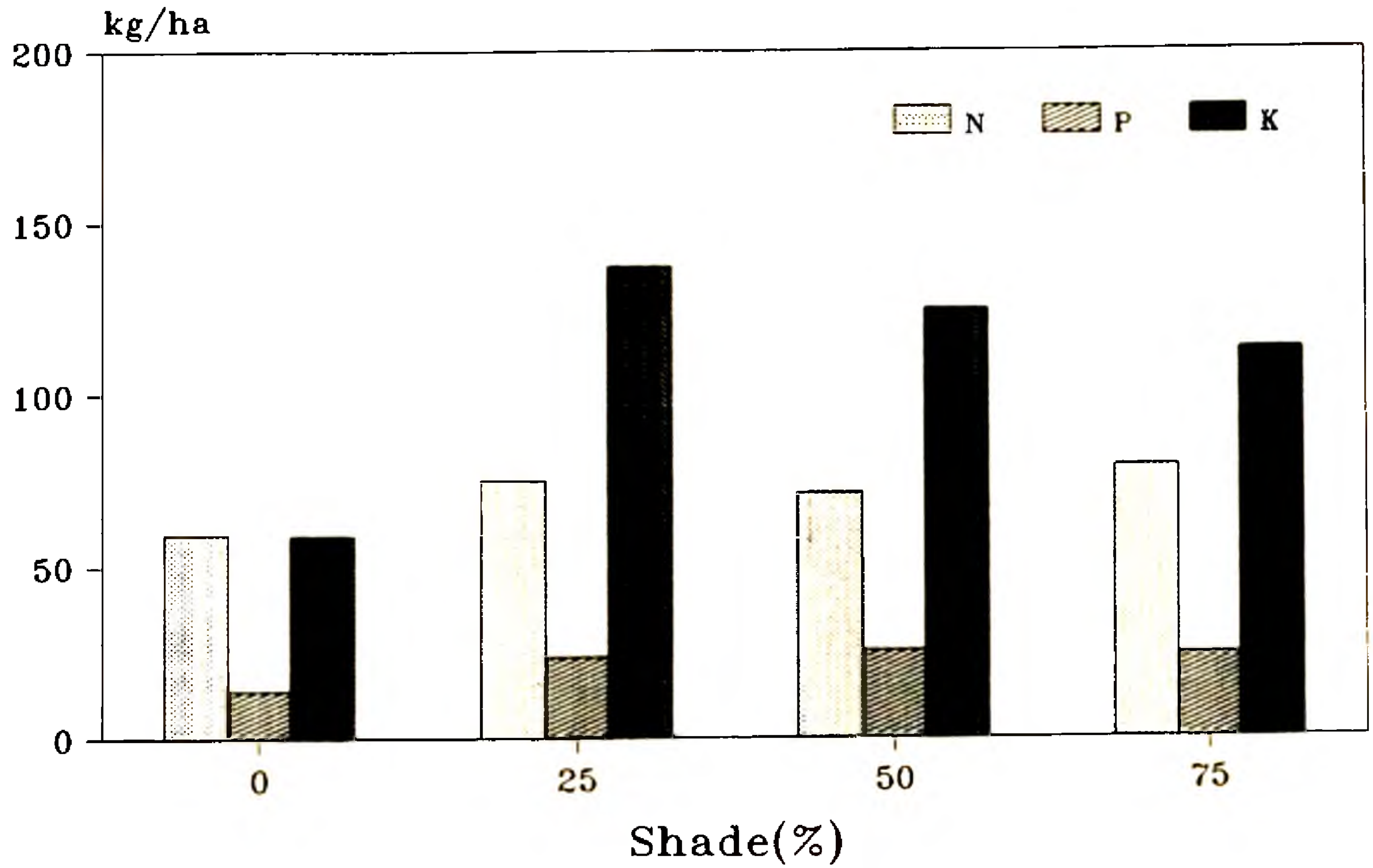
0 V_3 V_2 $\overline{V_6 \quad V_1}$ $\overline{V_4 \quad V_5}$

25 $\overline{V_3 \quad V_2}$ V_5 V_4 $\overline{V_6 \quad V_1}$

50 V_1 $\overline{V_2 \quad V_3 \quad V_4}$ $\overline{V_6 \quad V_5}$

75 V_3 V_4 $\overline{V_5 \quad V_2 \quad V_1}$ V_6

Fig.7 Effect of shade on N, P and K uptake of ginger cultivars



Significant interaction was noticed between shade levels and cultivars with respect to K uptake. Himachal registered the highest value in the open, 25 and 75 per cent shade, while, Maran gave the highest value at 50 per cent shade. In general, the uptake of N, P and K at 25, 50 and 75 per cent shade were 126, 120, 133 and 234, 212, 191 and 169, 182 and 174 per cent of that in the open.

Oleoresin content (Table 23)

An increase in oleoresin content was observed upto 25 per cent shade. Then, it exhibited a declining trend upto 50 per cent shade, after which it again increased and the highest value was recorded at 75 per cent shade (11.13 per cent). However, open condition registered the lowest value (6.66 per cent).

Among the cultivars, Rio-de-jeneiro gave the highest value (9.07 per cent) followed by Nedumangad (8.38 per cent) and Maran recorded the lowest value (6.64 per cent).

Oil content (Table 23)

In general, oil content was found to increase with increase in shade intensity. Open and 25 per cent shade recorded similar values. Highest value of 2.92 per cent was noticed at 75 per cent shade.

Among the cultivars, Maran and Kuruppampadi recorded the highest value of 3.0 per cent and Amballore local, the lowest value of 2.38 per cent.

Disease incidence

Incidence of soft rot disease was high under shade compared to that in the open. The incidence of bacterial wilt was observed in the later stages of plant growth irrespective of shade levels with the highest incidence in the open. Cultivars were scored for their disease susceptibility. Rio-de-jeneiro was found to be highly susceptible to soft rot. Other cultivars were also affected by soft rot due to their nearness to Rio-de-jeneiro. However, Amballore local was least affected by this disease.

Incidence of phyllosticta leaf spot was observed during initial stages of plant growth and was high in the open compared to that under shade. All cultivars were found to be equally susceptible to this disease.

B. Under natural shade

Plant height (Table 27, Appendix 5)

There was no significant difference between cultivars with respect to plant height at 60 DAP and 180 DAP. On the other hand, at 120 DAP cultivars differed significantly in plant height where Kuruppampadi recorded the highest plant height, while Maran recorded the lowest. Nedumangad and Amballore local were comparable with Kuruppampadi at 120 DAP.

Number of tillers (Table 27, Appendix 5)

At 60 DAP, the cultivars differed significantly with respect to the number of tillers, where Maran recorded the highest number of tillers and Kuruppampadi, the lowest. Himachal, Amballore local and Nedumangad were comparable with Maran. At 120 DAP and 180 DAP, cultivars showed no significant difference.

Net assimilation rate (NAR) (Table 27, Appendix 6)

Significant difference was observed between cultivars, both at 60 DAP and 120 DAP with respect to NAR. At 60 DAP, Kuruppampadi recorded the highest value, which was significantly superior to the rest. The lowest value was observed in Amballore local. At 120 DAP, Amballore local recorded the highest NAR and was superior to other cultivars and Kuruppampadi gave the lowest value which was comparable with Maran.

Chlorophyll content of leaves (Table 28)

At 150 DAP, the chlorophyll a and chlorophyll a to b ratio were highest in Himachal and lowest in Amballore local, whereas chlorophyll b and total chlorophyll content were highest in Nedumangad.

Table 27. Plant height, number of tillers and NAR of ginger cultivars under natural shade

Treatment	Plant height (cm)			Number of tillers			Net assimilation rate g m^{-2} day^{-1}	
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP
V_1	42.80	55.45	79.36	1.35	5.40	9.70	3.42	1.15
V_2	44.83	68.74	80.75	0.25	2.98	8.00	4.22	0.98
V_3	44.88	58.20	72.05	0.90	5.50	7.40	3.48	1.63
V_5	45.83	65.80	83.70	0.35	3.48	7.25	1.52	1.77
V_6	41.83	59.85	74.90	0.50	4.20	6.90	0.42	3.39
SEm±	4.89	3.49	4.35	0.30	1.03	1.09	0.58	0.09
CD (0.05)	NS	7.60	NS	0.65	NS	NS	0.13	0.20

Plant height 120 DAP V_2 V_5 V_6 V_3 V_1

Number of tillers 60 DAP V_1 V_3 V_6 V_5 V_2

NAR 60 DAP V_2 V_3 V_1 V_5 V_6

NAR 120 DAP V_6 V_5 V_3 V_1 V_2

Table 28. Contents of chlorophyll fractions of ginger cultivars at 150 DAP under natural shade

Treatment	Chlorophyll 'b' mg g^{-1} fresh weight	Chlorophyll 'b' mg g^{-1} fresh weight	Chlorophyll (a+b) mg g^{-1} fresh weight	Chlorophyll a/b
V_1 (Maran)	0.80	0.49	1.29	1.63
V_2 (Kuruppampadi)	0.71	0.45	1.16	1.57
V_3 (Himachal)	0.82	0.42	1.24	1.95
V_5 (Nedumangad)	0.78	0.56	1.34	1.39
V_6 (Amballore local)	0.66	0.50	1.16	1.32

Rhizome yield (Table 29, Appendix 6)

Though no significant difference was observed between cultivars, Amballore local recorded the highest rhizome yield, both on fresh weight and dry weight basis.

Haulm yield (Table 29, Appendix 6)

With regard to haulm yield the cultivars revealed the same trend as that of rhizome yield.

Harvest index (HI) (Table 29, Appendix 6)

Cultivars did not differ significantly with respect to HI. However, Amballore local gave the highest value for HI and Nedumangad, the lowest.

Pércentage dryage (Table 29, Appendix 6)

The cultivar differences were highly significant here, with Amballore local recording the highest value (19.80 per cent) and Nedumangad the lowest (15.60 per cent).

Total dry weight (Table 29, Appendix 6)

The cultivars showed no significant difference in total dry weight.

Table 29. Rhizome yield, haulm yield, harvest index, percentage dryage and total dry weight of ginger cultivars under natural shade

Treatment	Haulm yield t ha^{-1}	Rhizome yield t ha^{-1}	Harvest index	Percentage dryage	Total dry weight g $plant^{-1}$
V_1	3.42	3.42	0.36	18.10	10.88
V_2	1.11	3.84	0.39	17.70	11.18
V_3	1.05	3.47	0.36	18.78	10.63
V_5	1.36	3.51	0.29	15.60	11.89
V_6	0.97	5.20	0.52	19.80	12.53
SEm±	0.21	1.07	0.08	0.11	2.00
CD	NS	NS	NS	0.24	NS

Percentage dryage V_6 V_3 V_1 V_2 V_5

Chemical studies

Content of fertilizer nutrients (Table 30, Appendix 7)

Significant difference was observed between cultivars with respect to N content in both haulm and rhizome. Amballore local gave the highest value of N content in haulm while Himachal, in rhizome. The lowest value for N content both in haulm and rhizome was noticed in Nedumangad.

With respect to P content in both haulm and rhizome, cultivars showed no significant difference.

Cultivars differed significantly for K content in both haulm and rhizome. Himachal recorded the highest value for K content in haulm and Maran gave the highest value in rhizome. Amballore local and Nedumangad recorded the lowest value for K content in haulm and rhizome, respectively.

Uptake of nutrients (Table 30, Appendix 7; Fig 8)

Nitrogen uptake differed significantly with cultivars. Amballore local recorded the highest uptake of N and was superior to other cultivars and it was lowest in Nedumangad which was comparable with Maran.

With regard to P uptake there was no significant difference between cultivars.

Cultivars revealed significant difference with regard to K uptake. Though Maran recorded the highest value it was

Table 30. Uptake of nutrients N, P and K, Oleoresin content and oil content of ginger cultivars under natural shade

Treatment	Nitrogen %		Phosphorus %		Potassium %		Uptake (kg ha^{-1})			Oleoresin %	Oil %
	Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome	N	P	K		
V_1	1.27	1.96	0.48	0.53	1.36	3.24	16.16	8.64	40.86	7.0	3.0
V_2	1.47	1.37	0.53	0.51	1.57	2.48	28.73	9.23	26.80	7.2	3.0
V_3	1.31	2.45	0.50	1.68	2.58	22.91	8.50	30.87	6.0	2.5	
V_5	0.99	0.69	0.53	0.53	1.51	2.39	15.61	10.02	34.27	6.27	3.5
V_6	1.91	1.66	0.45	0.58	1.31	2.47	40.89	10.06	37.75	8.6	3.0
SEm±	0.16	0.05	0.04	0.04	0.09	0.08	2.80	1.41	3.23		
CD(0.05)	0.34	0.12	NS	NS	0.20	0.18	6.10	NS	7.03		

Uptake of N V_6 V_2 V_3 V_1 V_5

Uptake of K V_1 V_6 V_5 V_3 V_2

N content (%)

1) Haulm V_6 V_2 V_3 V_1 V_5

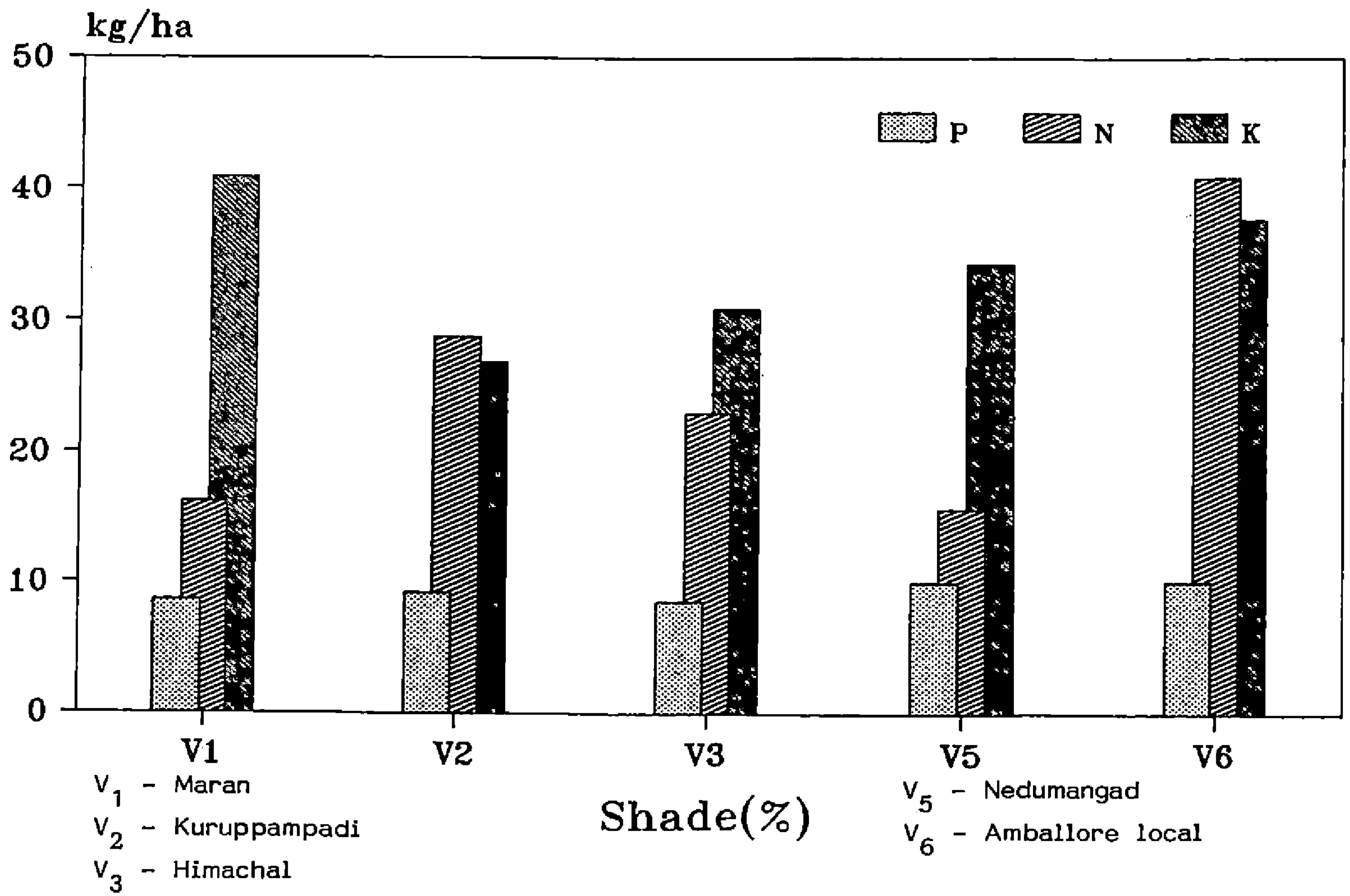
2) Rhizome V_3 V_1 V_6 V_2 V_5

K Content (%)

1) Haulm V_3 V_2 V_5 V_1 V_6

2) Rhizome V_1 V_3 V_2 V_6 V_5

Fig.8 Uptake of nutrients in N, P and K of ginger cultivars under natural shade



comparable with Amballore local while Kuruppampadi recorded the lowest value which was comparable with Himachal.

Oleoresin content (Table 30)

Amballore local recorded the highest value (8.6 per cent) for oleoresin content and Himachal recorded the lowest value (6.0 per cent).

Oil content (Table 30)

Highest value for oil content was observed in Nedumangad (3.5 per cent) and the lowest in Himachal, (2.5 per cent) whereas the oil content was same in the other cultivars.

Disease incidence

The crop suffered from soft rot and bacterial wilt. Cultivars were scored for their disease susceptibility. Amballore local was least affected while all other cultivars were found to be equally susceptible. However, in this trial, the crop was totally free from phyllosticta leaf spot.

Discussion

DISCUSSION

This chapter gives an overall assessment of the performance of ginger cultivars under controlled light intensities (artificial shade) and under coconut plantations (natural shade).

a. Artificial shade

Results indicated that in most of the cultivars, the rhizome yield increased upto 50 per cent shade level and then decreased. Plants in the open gave significantly lower yields. The yield at 25, 50 and 75 per cent shade levels expressed as percentage of that in the open were 202, 201 and 188 per cent on fresh weight basis and 198, 201 and 187 per cent on dry weight basis, respectively. On fresh weight basis, highest yield of 17.87 t ha^{-1} was obtained at 25 per cent shade which was comparable with that at 50 and 75 per cent shade. In the case of rhizome yield on dry weight basis, 50 per cent shade registered the highest value of 3.04 t ha^{-1} followed by 25 and 75 per cent shade all of which were comparable and were significantly higher than that in the open condition. As the yields at all the shade levels were higher than that in the open, ginger can be categorized as a shade loving crop.

Bai (1982) obtained highest yield of ginger at 25 per cent shade, wherein only one cultivar was tested. She observed a decline in yield with further increase in the shade intensity. Varughese

(1989) also observed the same trend in ginger But in the present study, all the shade intensities were comparable and superior to the open condition indicating that the cultivars tested were more suited to shaded condition than to open.

Better performance of the crop under 25, 50 and 75 per cent shade may be attributed to the higher rate of photosynthesis as indicated by the high dry matter accumulation, harvest index and higher content of total chlorophyll. Hardy (1958) attributed the better performance of the crops under shade to the presence of a threshold illumination intensity beyond which the stomata of shade loving plants tend to close. This might be one of the reasons for the better performance of ginger at all shaded situations compared to that under direct sun. The mechanism of shade affinity, thus has been related with stomatal behaviour. Assuming this as one of the factors responsible for the shade response of the crop, it may be inferred that stomatal closure had a dominant influence on the crop performance. Another favourable effect of shade on plants is believed to be the auxin enhancement probably acting synergistically with gibberellic acid (Leopald, 1964). Theoratically photo destruction of auxin is less in shaded stands. Shading tends to increase the auxin levels (Evans, 1973).

Further, Kochhar (1978) reported a direct inhibitory effect of strong light on photosynthesis, wherein photo oxidation of certain cell constituents takes place with the use of oxygen and the release of carbondioxide. This reduces the photosynthetic efficiency without inducing visible harm to the plants. This might be one of the reasons for the poor performance of ginger under direct sun. The light compensation point for photosynthesis was found to be higher for plants in the open condition (Okali and Owusu, 1975). The lower chlorophyll content of 0.61 mg g^{-1} fresh weight in the open as against 1.43 mg g^{-1} of fresh weight at 75 per cent shade appears to substantiate this. Better performance of ginger under slight shade than in the open was reported by Aclan and Quisumbing (1976), Bai (1981) and Varughese (1989).

On analysing the performance of different cultivars at the varying shade intensities, Himachal performed better both under shade and in the open. But it was found to be more suited to 75 per cent shade intensity, wherein it gave an average yield of 26.62 t ha^{-1} as against 14.57 t ha^{-1} in the open. Nedumangad performed better under 25 per cent shade while Himachal out yielded all the other cultivars at 50 and 75 per cent shade levels. Thus based on the rhizome yield the cultivars that can be grown under each of the shade levels are classified as follows.

0 per cent shade	-	Kuruppampadi, Himachal
25 per cent shade	-	Nedumangad, Himachal, Maran
50 per cent shade	-	Himachal, Kuruppampadi, Maran, Nedumangad, Amballore local
75 per cent shade	-	Himachal, Kuruppampadi

From the prediction model fitted it is quité evident that Himachal performs well under shade. But for Kuruppampadi the lack of fit of any prediction model or the comparative poor fit of logarithmic model indicates the erratic response of the cultivar to various shade intensities. Though Kuruppampadi performed best when compared to other cultivars under direct sun it gave better yields at 50 and 75 per cent shade. On the other hand Amballore local with a good fit for quadratic model indicates a clear trend of its better performance at the medium shade level of 50 per cent.

Dry matter accumulation followed the same trend as that of rhizome yield and the percentage values at 25, 50 and 75 per cent shade levels were 160, 176 and 164 per cent of the dry matter accumulation in the open.

Plant height exhibited an increasing trend with increase in shade intensities. This is in confirmation with the result reported by Bai and Nair (1982) in coleus, sweet potato, ginger and turmeric. Though the trend in plant height under various shade intensities does not follow exactly the same pattern as that of the rhizome yield, it was seen that plant height under shaded condition was higher than that in the open. The increase in plant height under shade may be due to better photosynthetic efficiency under low illumination.

There was no significant difference between shade levels with respect to the tiller number. Though the tiller number increased upto 25 per cent shade, it exhibited a progressive decrease with increase in shade intensities. This is contradictory to the report by Bai (1981) in ginger wherein only one cultivar was tested. Further the taller plants observed at higher shade intensities indicate the possible diversification of energy for increasing the plant height rather than to increase the tiller number. This confirms the finding of Prameela (1990) where she could observe no significant effect of shade levels on the tiller production in colocasia.

Net assimilation rate (120 DAP) went on increasing with shade upto 50 per cent and then showed a slight decline. However, the NAR at 50 and 75 per cent shade levels were comparable. High NAR at higher shade levels could be attributed to the increased rate of photosynthesis under shade. The light compensation point for photosynthesis was found to be higher for plants in the open condition than that under shade (Okali and Owusu, 1975). High value of NAR at initial stages may be due to the transfer of assimilates from relatively large sized seed rhizome to the developing plant and also the vertical leaf orientation during this period (Mithorpe, 1963). Low NAR values at later stage is attributed to the dense canopy of ginger stand, which has many horizontal leaves resulting in excessive mutual shading (Duncan, 1971) and increased rate of respiration (Whiley, 1980). In the present study, though the NAR values are high under shade than in the open, it does not follow the exact trend of yield, with shade. Chlorophyll content was higher under shaded condition. This is in confirmation with the reports in various crops like colocasia (Bai, 1981; Prameela, 1990), ginger and turmeric (Bai, 1981; Varughese, 1989), [illegible]. The lower chlorophyll content in sun leaves may be attributed to the decomposition of chlorophyll under intense light intensities (Kochhar, 1978).

Total dry weight increased upto 50 per cent shade and then decreased though the total dry weight values at higher shade levels were comparable. Total dry weight and NAR followed the same trend. An increase in the dry matter accumulation at higher shade levels was reported in Xanthosoma sagithifolium (Caesar, 1980).

Harvest index and rhizome yield were high in plants grown under shade indicating better translocation of photosynthetics to ginger rhizomes at low light intensity. The trends in HI, rhizome yield and total dry weight clearly reveal that at lower shade levels, there is better partioning of assimilates into harvestable sink. Both on fresh and dry weight basis, the rhizome yield under lower light intensities were comparable and significantly better than that in the open.

On close examination of the pattern of nutrient uptake by shade plants, uptake of all the fertilizer nutrients was much higher under shaded situations when compared to that in the open. The poor rhizome yield together with low nutrient uptake under direct sun indicates the scope of reducing the dose of fertilizer nutrients, such as N, P and K in the open. This is contadictory to the finding of Varughese (1989) where she suggested the scope of reducing the fertilizer dose of N at higher shade levels.

Though the oleoresin content did not show any clear trend, plants grown under 75 per cent shade recorded the highest oleoresin content of 11.1 per cent. This may be due to the unobstructed photosynthesis leading to the accumulation of secondary metabolites like resins, resin acids and unoxidised sugars, which constitute the major components of the acetone extracted oleoresin of ginger rhizome and also the retention of volatile oil moiety, which otherwise undergoes oxidation, degradation, isomerisation and polymerisation (Zachariah and Gopalan, 1987). Oil content was more in the shade plants compared to that in the open.

b. Natural shade

In coconut plantation, with a natural shade of about 50 per cent illumination, all the five cultivars tested were comparable with respect to rhizome yield. However, Amballore local out yielded the other cultivars with respect to harvest index, haulm yield, rhizome yield and total dry weight also, no significant difference was observed between cultivars. Values for NAR, HI and dry matter accumulation were highest in Amballore local. The same cultivar was found to be more suited under 50 per cent shade, when compared to its performance at other shade intensities under artificial shade conditions. The good fit of the cultivar to the quadratic prediction model also indicates its better suitability to the medium shade level of 50 per cent. However, it could not outyield Himachal at 50 per cent shade intensity under artificial condition (Table 11). This might be due to the genotypic variations. Himachal may be more responsive to fertilizer nutrients while Amballore local may be more efficient in utilizing native nutrients. The better N & P status under controlled light intensities might have contributed to higher yield in the case of Himachal at 50 per cent shade.

Under artificial conditions, Amballore local gave an average yield of 14.56 t ha^{-1} at 50 per cent shade as against 5.2 t ha^{-1} on fresh weight basis under natural shade. The drastic reduction in yield under natural shade may primarily be due to late planting of the crop. The crop was planted late in the season. Reduction in yield due to late planting in ginger was reported earlier by Aiyadurai (1966) in a study conducted at Ambalavayal. Another probable reason may be the low N and P status of the soil under natural shade compared to that under controlled light intensities. As the cultivar, Rio-de-jeneiro was not raised under natural shade, comparison of its performance under both situations could not be made. However, the performance of Rio-de-jeneiro was poor under artificial shade.

With respect to the content and uptake of fertilizer nutrients also, the cultivars exhibited differential response under both situations. However, similar pattern of response was observed in case of K content of rhizome, both under natural and artificial shade. It was found that values of oil and oleoresin content were high under natural shade than that under artificial shade, but it was just the reverse for chlorophyll content and its fractions. However, chlorophyll a/b ratio was high under natural shade.

The salient features of the above discussion may be summarised as follows:

1. As the overall performance of the crop was far better under shade than in the open, ginger may be considered as a shade loving crop. This makes it ideally suited for intercropping in coconut gardens.
2. Himachal is chosen as the cultivar suited to all situations with its better adaptability to intense shade level of 75 per cent.
3. Amballore local performed better under natural shade in coconut plantations at about 50 per cent shade.
4. The increased uptake of fertilizer nutrients with higher yields under shade indicates the possibility of enhancing the fertilizer dosage for ginger when grown under shade.
5. The chlorophyll, oleoresin and oil contents are higher in plants grown under medium to high shade level.
6. To obtain high yields with quality products, the crops should necessarily be grown under shade.

Summary

SUMMARY

Two field experiments were laid out, one under artificial shade and another under natural shade in coconut plantation at the College of Horticulture, Vellanikkara, Thrissur, Kerala, India during the year 1990-91. The trial under artificial shade was intended to evaluate the performance of ginger cultivars under different shade intensities and that under natural shade was to test the fitness of these cultivars, as intercrop in coconut garden. The results of the experiments are summarised below.

Shade levels as well as cultivars exhibited significant difference with respect to rhizome yield both on fresh and dry weight basis. Significant interaction was observed between shade levels and cultivars. Plants grown under shade performed better than those in the open in terms of rhizome yield. Though 25 per cent shade recorded the highest rhizome yield, it was comparable with that at 50 and 75 per cent shade. As the overall performance of the crop was better under shade than in the open, ginger may be classified as a shade loving crop.

Based on the rhizome yield, the cultivars that are the best under each of the shade levels are classified as follows:

0 per cent shade - Kuruppampadi, Himachal

25 per cent shade - Nedumangad, Himachal, Maran

50 per cent shade - Himachal, Kuruppampadi, Maran, Nedumangad and Amballore local

75 per cent shade - Himachal, Kuruppampadi

Among the cultivars, Himachal performed well under all situations.

The effect of shade on plant height, chlorophyll content, net assimilation rate and percentage dryage was positive. But no significant difference was observed between different shade levels with respect to tiller number.

Yield prediction could be well effected using the logarithmic model, $\log y = a+b(\log x)+c(\log x)^2+d(\log x)^3$, in all cultivars, except Amballore local, out of the various models tried. In the case of Amballore local, quadratic prediction model ($y = a+bx+cx^2$) was found to be more suited.

The values of harvest index and total dry weight at 25, 50 and 75 per cent shade level were comparable and were significantly higher than that under direct sun. Among the cultivars, Himachal registered the highest values for these parameters.

Uptake values of N, P and K were high under shade than in the open. Nitrogen contents in haulm and rhizome were highest in the open and 25 per cent shade, respectively. There was no significant difference between shade levels with respect to the content of P and K in the rhizome.

Plants grown under shade registered higher values for oil and oleoresin content compared to that grown in the open. Thus the quality of ginger rhizome was found to be improved when grown under shade.

In coconut plantation with a natural shade of about 50 per cent, all the five cultivars, viz., Maran, Kuruppampadi, Himachal, Nedumangad and Amballore local revealed no significant difference with respect to rhizome yield. However, Amballore local outyielded the other cultivars. No significant difference was observed between the cultivars with respect to haulm yield, harvest index and total dry weight also. However, with respect to net assimilation rate and percentage dryage there was significant difference between the cultivars with Amballore local recording the highest values.

With respect to the content and uptake of fertilizer nutrients, the cultivars exhibited differential response under both situations. However, similar pattern of response was observed in case of K content in rhizome both under natural and artificial shade. Values of oil and oleoresin content were high under natural shade than that under artificial shade. But the chlorophyll content and its fractions were more under artificial shade. In general, the performance of all the cultivars was poor under natural shade compared to that under artificial shade.

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* Originals not seen

Appendices

APPENDIX-I

Meteorological data for the crop period (18-5-1990 to 25-2-1991)

Month and date	Temperature °C		Soil temperature at 5 mm depth		Humidity %		Rain mm	Sun-shine hours	Evpn mm
	Max.	Min.	FN	AN	FN	AN			
1	2	3	4	5	6	7	8	9	10
14-5-90 to 20-5-90	31.7	24.1	26.5	34.2	91	73	86.5	5.6	3.4
21-5-90 to 27-5-90	28.6	23.6	25.5	31.6	95	81	190.7	1.2	2.3
28-5-90 to 3-6-90	29.5	23.5	25.9	31.6	93	82	129.3	2.7	3.0
4-6-90 to 10-6-90	29.9	23.1	25.8	33.3	93	75	72.4	2.5	3.1
11-6-90 to 17-6-90	29.1	23.1	24.9	30.8	95	80	215.3	2.9	2.2
18-6-90 to 24-6-90	29.7	23.3	25.7	31.5	94	80	87.5	3.5	2.6
25-6-90 to 1-7-90	30.6	23.6	26.0	32.5	93	73	98.7	6.0	3.5
2-7-90 to 8-7-90	27.7	22.1	24.7	30.5	94	85	265.6	1.3	2.3
9-7-90 to 15-7-90	28.6	22.4	25.3	31.0	94	85	190.1	1.6	2.5
16-7-90 to 22-7-90	27.6	22.4	25.0	29.8	95	87	198.1	1.5	2.2
23-7-90 to 29-7-90	29.3	22.5	25.8	28.7	93	71	78.0	4.2	3.1
30-7-90 to 5-8-90	28.9	23.0	25.2	31.3	95	78	114.0	2.7	2.8
6-8-90 to 12-8-90	28.0	22.5	25.0	29.3	95	80	91.7	1.2	2.2
13-8-90 to 19-8-90	28.5	23.3	25.2	30.3	94	77	121.6	2.7	3.0
20-8-90 to 26-8-90	29.7	23.1	26.0	32.3	94	72	28.3	4.3	3.0
27-8-90 to 2-9-90	30.6	23.6	26.3	34.2	92	65	14.7	7.4	3.7
3-9-90 to 9-9-90	30.0	23.1	26.3	32.3	94	74	60.9	3.9	3.1
10-9-90 to 16-9-90	34.5	24.0	27.1	35.2	91	64	0	7.7	3.9
17-9-90 to 23-9-90	31.0	23.4	27.2	34.2	90	65	6.9	6.6	3.8

Contd.

Appendix-I. Continued

1	2	3	4	5	6	7	8	9	10
24-9-90 to 30-9-90	31.1	23.1	26.5	35.2	89	69	16.6	6.5	3.5
1-10-90 to 7-10-90	30.6	22.5	25.4	33.3	93	70	26.9	6.3	3.6
8-10-90 to 14-10-90	32.4	23.7	26.9	39.5	92	63	14.4	8.8	4.1
15-10-90 to 21-10-90	33.5	23.2	26.5	39.0	88	62	22.3	7.3	4.1
22-10-90 to 28-10-90	31.8	23.3	26.0	33.4	92	78	133.9	5.5	3.0
29-10-90 to 4-11-90	29.1	22.4	24.9	30.4	95	76	184.2	3.1	2.1
5-11-90 to 11-11-90	31.2	21.1	24.6	33.9	89	62	0	7.8	3.5
12-11-90 to 18-11-90	31.1	22.8	25.4	34.6	92	65	0.6	5.3	2.9
19-11-90 to 25-11-90	33.1	23.2	25.9	38.0	84	54	0	7.6	3.7
26-11-90 to 20-12-90	31.8	23.4	24.7	35.1	75	52	0.8	5.8	5.0
3-12-90 to 9-12-90	31.9	24.8	25.2	36.0	71	48	1.8	7.4	5.9
10-12-90 to 16-12-90	31.9	22.3	24.3	37.7	70	43	0	8.3	6.3
17-12-90 to 23-12-90	32.7	22.0	24.8	37.9	76	46	0	7.7	4.4
24-12-90 to 30-12-90	32.5	23.7	25.4	38.9	79	44	0	8.2	7.0
1-1-91 to 7-1-91	33.1	22.1	24.8	26.3	83	50	–	7.8	4.5
8-1-91 to 14-1-91	33.4	21.8	24.5	26.2	75	44	–	9.3	5.5
15-1-91 to 21-1-91	33.4	23.6	25.4	27.0	72	44	–	8.4	6.9
22-1-91 to 28-1-91	34.2	22.1	24.6	26.7	66	28	–	9.8	8.4
29-1-91 to 4-2-91	34.5	21.4	25.2	27.3	76	39	–	9.2	6.7
5-2-91 to 11-2-91	35.2	21.4	24.9	27.4	66	23	–	10.2	8.0
12-2-91 to 18-2-91	36.4	21.0	24.9	27.4	77	22	–	10.5	8.4
19-2-91 to 25-2-91	36.5	22.0	25.9	28.2	73	27	–	10.6	7.4

APPENDIX-2

Analysis of variance for plant height and number of tillers of ginger cultivars under artificial shade

Source	DF	Mean squares					
		Plant height			Number of tillers		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Replication	3	163.76	789.98	403.86	1.86	20.19	30.10
Main plot	3	536.01**	629.95**	5125.92*	2.80	36.69	25.94
Error (a)	9	73.37	25.31	186.98	2.18	9.62	6.83
Subplot	5	236.30**	168.75**	82.48*	10.34**	91.23**	173.06**
Interaction	15	85.83**	94.93	96.30**	0.39	7.74	53.00**
Error (b)	60	16.87	55.51	34.06	0.37	7.79	11.35

* Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX-3

Analysis of variance for net assimilation rate, percentage dryage, haulm yield, rhizome yield, harvest index and total dry weight of ginger cultivars under artificial shade

Source	DF	Mean squares							
		Net assimilation rate 60 DAP	Net assimilation rate 120 DAP	Percentage dryage	Haulm yield	Rhizome fresh weight basis	Yield dry weight basis	Harvest index	Total dry weight
Replication	3	0.72	0.50	0.08	0.02	44.84	1.72	0.01	54.87
Main plot	3	11.98**	2.17*	2.56**	1.70*	447.84**	12.72**	0.10**	899.89**
Error (a)	9	2.31	0.42	0.04	0.41	37.55	1.16	0.01	64.35
Subplot	5	3.42*	11.33**	114.15**	0.91*	233.34**	12.29**	0.20**	335.58**
Interaction	15	6.72**	6.50**	0.03	1.41**	44.72**	1.30**	0.02*	174.98**
Error (b)	60	1.15	0.77	0.02	0.30	8.63	0.25	0.01	16.30

* Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX-4

Analysis of variance for content and uptake of nutrients N, P and K of ginger cultivars under artificial shade

Source	DF	Mean squares								
		N content		P content		K content		N	P	K
		Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome	uptake	uptake	uptake
Replication	3	0.02	0.00	0.00	0.00	0.01	0.05	172.13	28.48	49.83
Main plot	3	0.92*	0.68**	0.00*	0.00	0.87**	0.07	1717.18**	668.47**	28594.29**
Error (a)	9	0.06	0.01	0.00	0.00	0.03	0.09	105.82	36.36	190.18
Subplot	5	0.78**	0.38**	0.01**	0.00	0.08**	2.96**	1994.11**	198.34**	11755.15**
Interaction	15	0.86*	0.56**	0.01**	0.00	0.10**	0.64**	3260.38**	97.69**	4589.07**
Error (b)	60	0.05	0.01	0.00	0.00	0.02	0.05	54.83	13.94	85.60

* Significant at 5 per cent level
**Significant at 1 per cent level

APPENDIX-5

Analysis of variance for plant height and number of tillers of ginger cultivars under natural shade

Source	DF	Mean squares					
		Plant height			Number of tillers		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Replication	3	107.11	21.41	71.46	0.071	1.55	8.27
Treatment	4	10.94	121.03*	86.80	0.823*	5.10	4.91
Error	12	47.76	24.33	37.78	0.183	2.14	2.38
Total	19	49.38	44.23	53.41	0.300	2.67	3.84

* Significant at 5 per cent level

APPENDIX-6

Analysis of variance for net assimilation rate, percentage dryage, haulm yield, rhizome yield, harvest index and total dry weight of ginger cultivars under natural shade

Source	DF	Mean squares							
		Net assimilation rate 60 DAS	Net assimilation rate 120 DAS	Percentage dryage	Haulm yield	Rhizome fresh weight basis	Yield dry weight basis	Harvest index	Total dry weight
Replication	3	0.002	0.013	0.017	0.038	0.313	0.008	0.004	2.21
Treatment	4	10.02**	3.65**	9.70**	0.082	2.25	0.139	0.031	2.43
Error	12	0.007	0.016	0.025	0.085	2.29	0.927	0.011	7.98
Total	19	3.84	0.78	2.06	0.077	1.97	1.51	0.014	5.90

** Significant at 1 per cent level

APPENDIX-7

Analysis of variance for content and uptake of nutrients N, P and K of ginger cultivars under natural shade

Source	DF	Mean squares								
		N content		P content		K content		N uptake	P uptake	K uptake
		Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome			
Replication	3	0.081	0.005	0.006	0.001	0.038	0.022	30.69	1.97	7.93
Treatment	4	0.459**	1.73**	0.003	0.004	0.092**	0.483**	437.07**	2.18	122.77**
Error	12	0.049	0.006	0.003	0.003	0.017	0.013	15.66	3.99	20.83
Total	19	0.140	0.369	0.004	0.003	0.036	0.11	106.76	3.29	40.26

* Significant at 5 per cent level

** Significant at 1 per cent level

EVALUATION OF GINGER CULTIVARS FOR SHADE TOLERANCE

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

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ABSTRACT

A study entitled 'Screening of ginger cultivars for shade tolerance' was conducted during May 1990 to February 1991 at the College of Horticulture, Vellanikkara, Thrissur, Kerala, India. Two separate trials were carried out, one under artificial shade and the other under natural shade in coconut gardens. The trial under artificial shade was intended to assess the performance of ginger cultivars under different levels of shade, while that under natural shade was taken up to test the fitness of these cultivars under intercropped situation in coconut garden.

Trial under artificial shade was laid out in split plot design with four shade levels (0, 25, 50 and 75 per cent shade) as main plot treatments and six cultivars (Maran, Kuruppampadi, Himachal, Rio-de-jeneiro, Nudumangad and Amballore local) as subplot treatments with four replications. The trial under natural shade was laid out in randomised block design with five cultivars (Maran, Kuruppampadi, Himachal, Nedumangad and Amballore local) and four replications. For providing shade under artificial shade trial, pandals were erected on wooden frames and covered with unplaited coconut fronds to provide required levels of shade. LI-90 A Quantum sensor and LI-191 SA Line Quantum sensor were used for adjusting the shade intensities to the desired levels.

As the overall performance of the crop was better under shade than in the open, ginger may be classified as a shade loving

crop. Rhizome yields at 25, 50 and 75 per cent shade levels were comparable and significantly higher than that under direct sun with 25 per cent shade recording the highest value. Yield parameters such as harvest index and total dry weight were also highest at 25 per cent shade. Significant interaction was noticed between shade levels and ginger cultivars on rhizome yield. Himachal was found to be adapated to all situations. Quality of ginger rhizomes was found to be improved when grown under shade. Nutrient uptake was also higher under shaded situation. Based on the rhizome yield the cultivars adapted to each of the shade levels are as follows.

0 per cent shade	- Kuruppampadi, Himachal
25 per cent shade	- Nedumangad, Himachal, Maran, Kuruppampadi
50 per cent shade	- Himachal, Kuruppampadi, Maran, Nedumangad and Amballore local
75 per cent shade	- Himachal, Kuruppampadi

The logarithmic model, $\log y = a+b(\log x)+c(\log x)^2+d(\log x)^3$ was found to be a good fit for all the cultivars except Amballore local, for which the yield prediction could be well effected using the quadratic model ($y = a+bx+cx^2$).

All the cultivars tested under natural shade, revealed no significant difference with respect to rhizome yield and most of the growth and yield attributes. Among the cultivars, Amballore local fared comparitively better under natural shade, where the percentage illumination was about 50 per cent. However, the performance of all the cultivars was poor in terms of rhizome yield under natural shade in coconut garden.

Plates

Plate 1. General view of the experimental field with the frame constructed for providing shade

Plate 2. General view of the experimental field after providing shade

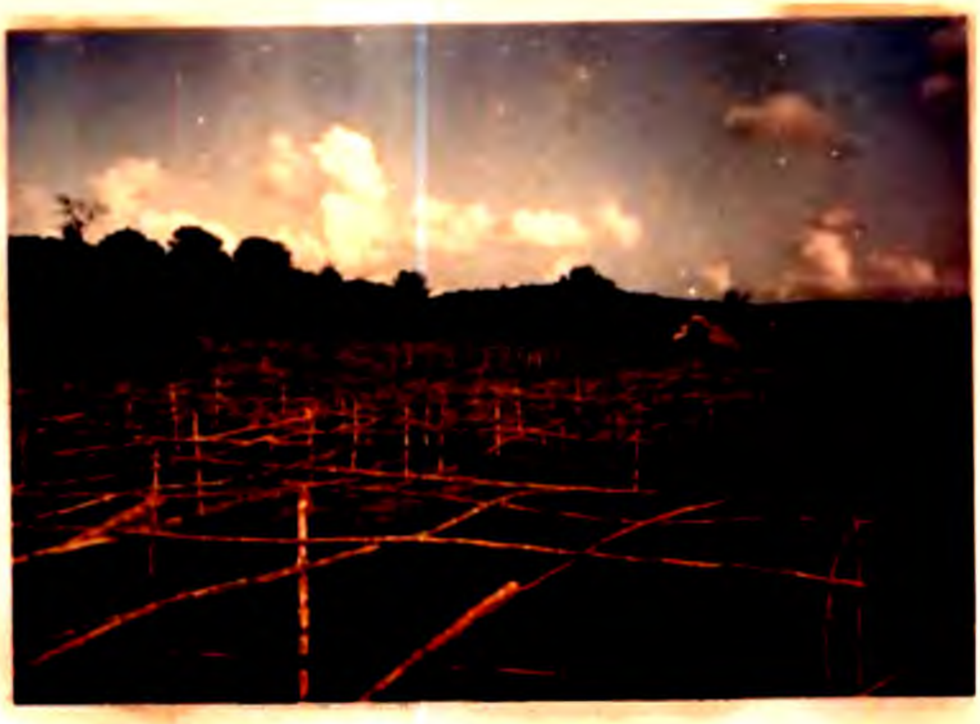
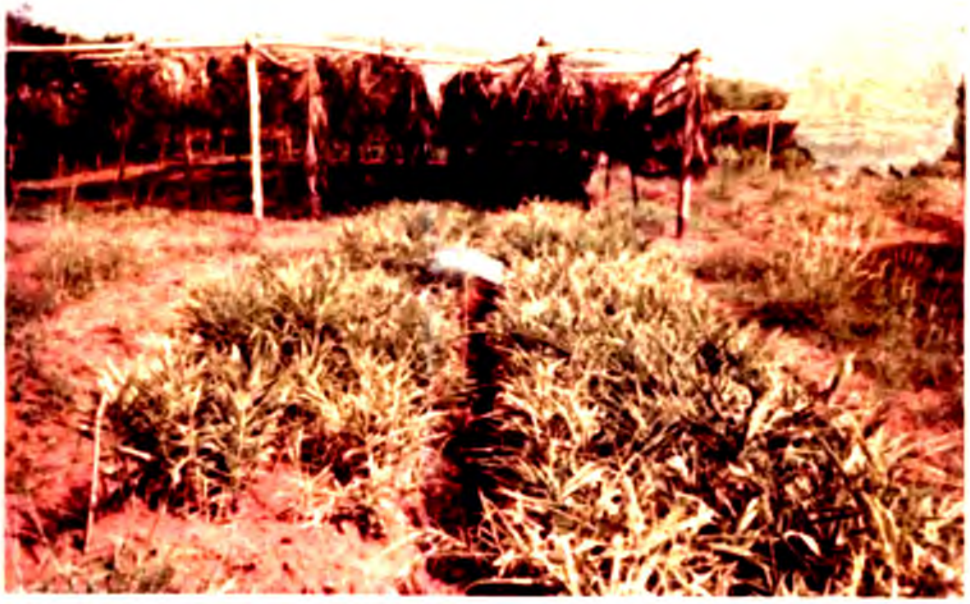


Plate 3. Ginger cultivars at 0 per cent shade

Plate 4. Ginger cultivars at 25 per cent shade

Plate 3. Ginger cultivars at 0 per cent shade

Plate 4. Ginger cultivars at 25 per cent shade



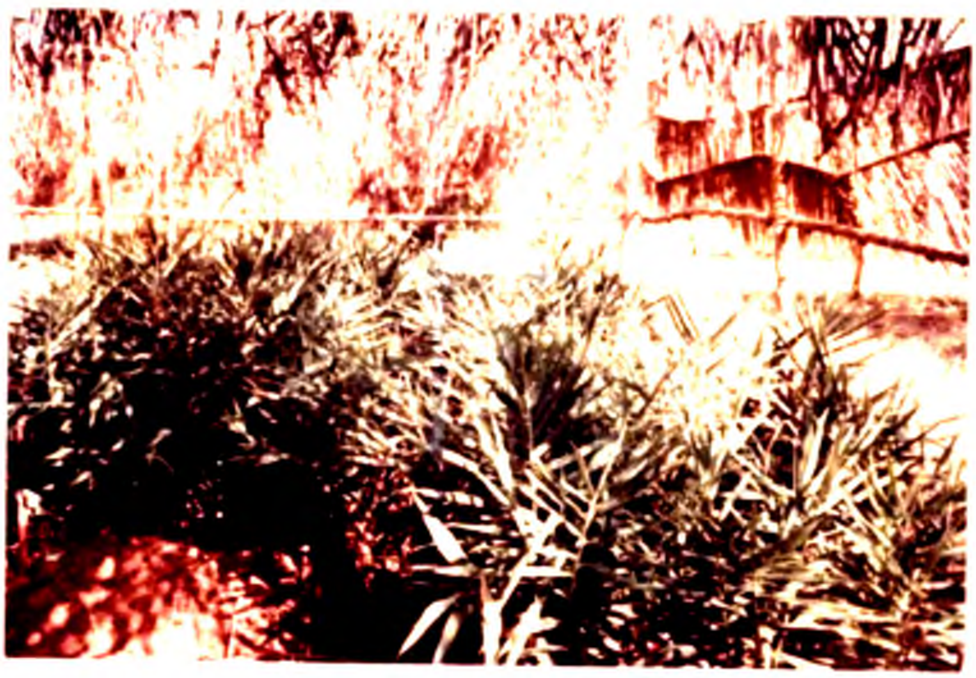


Plate 5. Ginger cultivars at 50 per cent shade

Plate 6. Ginger cultivars at 75 per cent shade