SCREENING OF VARIETIES OF GINGER AND TURMERIC FOR SHADE TOLERANCE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled 'Screening of varieties of ginger and turmeric for shade tolerance' is a bonafide recod 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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Certified that this thesis entitled 'Screening of varieties of ginger and turmeric for shade tolerance' is a record of research work done independently by Miss. Susan Varughese under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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To my parents

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Introduction

INTRODUCTION

Solar radiation is one of the primary factors governing the ultimate yield of any crop. In intercropped situations involving a main-crop like coconut if water and nutrients are available in amounts adequate enough to ensure lack of competition for these two factors, light becomes the sole limiting factor for intercrop growth and productivity.

The practice of intercropping or mixed cropping in coconut garden has been in vogue since early times and is a common practice in Kerala where there is an intense pressure on land. This system of farming not only increases the productivity per unit area and per unit time but also enhances agricultural labour requirement. Added to this, is the fact that land at present is becoming a shrinking resource for agricultural use owing to competing non-agricultural demands.

Ginger and turmeric are two among the recommended crops for intercropping in coconut gardens and are included in the crop cafetaria for multiple cropping. These two are also valued as important spice crops of the world. From ages past, India is in the unique position of being the largest producer and exporter of ginger accounting for nearly half of the total world trade.

Studies on crop performances at graded shade levels of a few common intercrops of the coconut belt were taken up at the College of Horticulture, Vellanikkara , Trichur, during 1981 to 1983. Based on the yield trend, ginger and turmeric were classed as shade loving. Only one variety each of these crops was included in those studies. Differential response of genotypes to the different levels of light penetration is to be considered a definite possibility and hence the scope for selecting varieties with abilities to perform better under shade. The present study was taken up with the primary objective of selecting varieties/genotypes of these two crops for different shade situations. Study of the changes in quality of economic produce induced by shading was also another important objective of this study.

Review of Literature

2. REVIEW OF LITERATURE

Light determines the rate of growth of any crop at any stage of development. Crop plants differ markedly in their adaptation to light intensities. Shading of crop plants at various stages of growth and development is an important factor which affects the plant growth, yield and quality of the produce. The influence of shade on various aspects such as vegetative characters, photosynthesis, drymatter accumulation, flowering and fruiting has been studied in many crops of commercial importance. However, published data on the growth, development, yield and quality of ginger and turmeric are scanty. Hence literature available on the subject, irrespective of the crops is briefly reviewed.

2.1 Light Requirement

Singh (1967) observed that exposure to intense light is detrimental to photosynthesis. According to Minoru and Hori (1969) *Zingiber mioga* Rosc. in particular required a saturating light intensity of 20 klx. Nair (1969) reported that ginger preferred light shade for better performance. Aclan and Quisumbing (1976) reported from their study of light attenuation on the yield and quality of ginger that plants grown under full sunlight were shorter and had fewer leaves per tiller. The yields, however were just as high as those obtained from plants grown under 25 and 50 per cent shade intensities. This indicated that ginger performed best when grown under slight shade but not in excess of 50 per cent. This supported the observation of Bai and Nair (1982) that ginger could efficiently grow under low light intensities. They also found that growth and yield of turmeric were highest at 50 per cent of full illumination. Relatively lower than full light intensity in combination with lower soil and air temperature and high relative humidity were more condusive for the successful cultivation of ginger (Ravisankar and Muthuswamy, 1987).

Based on the above results it can be noted that ginger and turmeric can be grown in shade as intercrops . To support this view, several early workers recommended ginger as an intercrop in mango orchard (Randhawa and Nandapuri, 1970), grapevine (Ranga reddy and Sathyanarayana, 1972), pigeon pea and castor (Purseglove, 1975) and chilli, okra, maize and tomato (Singh et al., 1981).

2.2 Growth and Growth Attributes

2.2.1 Plant height

Cooper (1966) in his attempt to find out the response of birdsfoot trefoil and alfalfa to various levels of shade (51, 76 and 92 per cent shade) found that plant height decreased proportionately with increasing levels of shade. Contradictory to this, several other workers reported an increase in plant height with increasing levels of shade in crops like maize (Moss and Stinson, 1961), easterlily (Kohl and Nelson, 1963), *Lilium longiflorum* (Einert and Box, 1967), crownvetch (Langille and Mckee, 1970) and alfalfa (Wolf and Blaser, 1972). While experimenting with tuber and rhizomatous crops, Bai and Nair (1982) observed positive influence of shading on stem length in ginger, coleus and sweet potato whereas height of colocasia was not affected by shading. In groundnut, George (1982) reported an increase in plant height due to shading while the effect was opposite in redgram. In her experiment, plant height of cowpea and blackgram was unaffected by shading. Positive influence of shading was also noticed in tomato (Kamaruddin, 1983), winged bean (Sorenson, 1984), Cassava (Ramanujam et al., 1984 and Sreekumari et al., 1988), sweet red pepper (Rylski and Spigelman, 1986), broadbean (Xia, 1987) and rice (Singh et al., 1988).

2.2.2. Leaf development

Birdsfoot trefoil had a lower proportion of leaves to stem when grown under low light intensity (Rhykerd et al., 1959). Under conditions of moderate shading, leaf area per plant of red clover was found to increase while leaf area in alfalfa remained constant and that of birdsfoot trefoil decreased (Mckee, 1962). A marked reduction in the rate of leaf development and leaf area was noticed in two drybean *(Phaseolus vulgaris.* L)cultivars grown in controlled environment chambers under standard light (390μE $m^{-2}s^{-1}$ approx. 22,000 lx at 400 700 nm) and shaded light (55 μE $m^{-2}s^{-1}$ approx 3,200 lx, at 400-700 nm) intensities (Crookston et al., 1975). *Vicia faba* plants subjected to 50 and 20 per cent shade exhibited 30 per cent reduction in the number of leaves per plant (Xia, 1987).

2.2.3 Drymatter production

Langille and Mckee (1970) subjected three varieties of crown vetch (*Coronilla varialı)* to six levels of shading (31 to 100 per cent) to evaluate the response of these varieties to reduced light under field conditions. Compared to unshaded top growth treated as 100 per cent, plants shaded to 30 per cent full day light yielded 40 per cent as much drymatter. Compared to root growth in the open treated as 100 per cent, plants shaded at equivalent of 31 per cent of full day light yielded only 22 per cent as much. Shading rice, resulted in 25 per cent reduction in total dry weight at harvest (Rai and Murthy, 1977). Venkateswaralu and Srinivasan (1978) also observed a decrease in total drymatter content in rice. *Xanthosoma saggittifolium* was reported to produce the highest drymatter yield under shade and *Colocasia esculenta* under full sunlight (Ceaser, 1980). Soybean plants grown under 70 per cent shade did not show any reduction in drymatter (Erikson and Whitney, 1984).

Although several crops showed reduction in total drymatter content, ginger crop grown at reduced light recorded the highest drymatter (Ravisankar and Muthuswamy, 1986, 1987). Singh (1986) studied the response of four cotton genotypes to reduced light intensity. Drymatter of all the genotypes increased with 35 percent reduction in light intensity. Peanut plants grown under higher irradiance accumulated three times more drymatter than plants under low irradiance. (Farnham et al., 1986). Vijayalakshmi et al. 1987) noticed a drastic reduction in drymatter accumulation in some rice varieties due to shading.

2.2.4 Growth analysis

Ramadasan and Satheesan (1980) recorded highest leaf area index, crop growth rate and net assimilation rate with three turmeric cultivars grown in open conditions compared to the same under shade. The net assimilation rate and absolute growth rate of chickpea were found to decrease with a decrease in sunlight from 100 per cent to 15 per cent while the leaf weight ratio, relative growth rate and relative leaf growth rate remained unaffected (Pandey et al., 1980). Sorenson (1984) observed an increase in leaf area ratio in winged bean (*Psophocarpus tetragonolobus*. L) by imposing shade. An increase in shoot : root ratio was also reported in three varieties of crownvetch(*Coronilla variali*) under low light intensity (31 per cent to 100 per cent full day light) (Langille and Mckee,1970). Low radiation (78 per cent and 32 per cent of full solar radiation) led to production of leaves with high specific leaf area in cassava while leaf area index under full sun increased (Fukai et al., 1984). Reduction in solar input upto 32 per cent reduced crop growth rate to about half that of control. Arabica coffee seedlings in full sunlight had the lowest rate of growth and development and showed symptoms of sunscorch (Santos and Napoles, 1985).

2.3 Chlorophyll Content

Shade plants generally have a higher chlorophyll content than the sunplants (Cooper and Qualls, 1967, Bjorkman, 1968). Chlorophyll a/b ratio is an important parameter in light intensity studies. It is constant in all varieties of a species under a particular set of environmental conditions. But this may vary considerably depending upon the light intensities to which leaves have been exposed (Tugnawat, 1977). While comparing the effect of reduced light intensities (35, 50 and 70 per cent of normal sunlight) on two rice cultivars Vijaya, a shade tolerant one and IR-8, a shade susceptible one, the shade tolerant cultivar had higher chlorophyll content (Nayak et al., 1978). Bai (1981) reported an increase in chlorophyll content with increasing shade levels (25, 50 and 75 per cent shade) in crops like ginger and turmeric. Grant and Ryug (1984) reported from their studies on influence of within canopy shading on chlorophyll content that leaves of kiwifruit grown under shade had significantly lower chlorophyll a:b ratio. Reduction in chlorophyll content of exposed leaves upto 44 per cent was noted by Vijayakumar et al. (1985) in black pepper as compared to the shaded leaves. Lamina from tobacco grown under intense shade had higher levels of chlorophyll a and chlorophyll b than those from plants grown without shade (Anderson et al, 1985).

With increasing leaf maturity chlorophyll a was found to reduce but chlorophyll b increased resulting in the increased total chlorophyll content (Chittiraichelvan et al., 1987). They also observed that with increase in leaf senescence, chlorophyll b showed a drastic reduction but chlorophyll a increased marginally with a net result of reduced total chlorophyll content. An increase in chlorophyll content with decrease in light intensity was also reported in crops like winged bean (Sorenson, 1984), rice (Singh et al., 1988) and potato (Singh, 1988).

Although several workers reported an increase in chlorophyll content with increase in intensity of shading Pandey et al. (1980) in chickpea and Grant and Ryug (1984) in leaves of kiwifruit observed the same concentration at varying shade.

2.4 Physiological Activities

Effect of shade on physiological processes like photosynthesis, respiration, nitrogen fixation and enzyme activities had been studied in many agriculturally important crops. Adaptation to low light intensity includes greater leaf area per leaf weight ratio (Blackman, 1956), lowered shoot:root ratio (Brouwer, 1966) and reduced rates of dark respiration (Kumura, 1968).

A comparative study on light and shade on leaflets of a common flowering plant *Vicia americana* revealed striking differences in leaflet form, size, thickness and internal structure. The marked thinness of shaded leaflets was supposed to be due to the failure of the mesophyll cells to enlarge (Cormack, 1955). Nitrogen metabolism of the corn plant was found to be adversly affected by low light intensity (Knipmeyer et al., 1962). Cooper (1966) noticed differences in the partition of drymatter under different intensities of shade. The shade plants generally had a much lower carboxy dismutase activity than the sunplants (Bjorkman, 1968). In soybean the low activity of ribulose 1, 5 diphosphate carboxylase had been reported at low intensities of light (30, 50 and 70 per cent light) by Bowes et al. (1972). It was also observed that under reduced light nitrate reductase activity of tea leaf was significantly increased compared to those grown under full sunlight (Barua et al., 1984). Considerable differences between varieties in their photosynthetic rate per unit leaf area had been found in many crop plants. In the experiment of Willey and Holliday (1971 a, 1971 b) shading greatly reduced yield in wheat indicating source limitation. Photosynthesis and drymatter accumulation had been reported to be adversely affected by shade in many species of plants. But in the case of ginger and turmeric positive influence of shade had been reported (Bai and Nair, 1982). Krishnankutty (1983) observed differences in the translocation of assimilates in brinjal grown under varying intensities of light (25, 50 and 75 per cent light).

Shading reduced the rate of photosynthesis in crops such as alfalfa (Wolf and Blaser, 1972), beans (Crookston et al., 1975), grapes (Vasundara, 1981 and Mathai, 1987), pigeonpea (Luthra et al., 1985), cotton (Singh, 1986) and groundnut (Senaguptha and Jadhav, 1988).

Farnham et al., (1986) studied the effect of light level on dinitrogen fixation and carbohydrate distribution in Virginia peanuts. Plants grown under higher irradiance fixed three times more nitrogen and had greater reproductive potential than plants under low irradiance Carbohydrate content in root, stem and leaf tissue was maximum in sunplants than in shadeplants.

Investigations on cuticular resistance to transpiration as affected by different densities of shade namely 75, 50 and 25 per cent of full sunlight in two tea clones revealed that there was a progressive increase in the cuticular resistance with increasing densities of shade (Harikrishnan and Sharma, 1980). Handique and Manivel (1987) also recorded lower stomatal resistance in tea under full sun compared to leaves under shade.

2.5 Yield

Shade is one of the many factors which limits the productivity in crop plants. The differential response to shade is a response to a changed light condition. Therefore differences in photosynthetic mechanism could conceivably account for the differences in yield. Shading during the period of storage sometimes reduced yield substantially, sometimes only slightly (Evans, 1973).

In an early study, maize plants subjected to shade during the entire growing period (10, 40, 70 and 100 per cent light) recorded reduced yield compared to those grown under full sun (Earley et al., 1966). With *Solanum* potato, Gracy and Holmer (1970) found that shading at the beginning of tuber initiation reduced the rate of tuber formation and growth while shading during the early stages had no effect on the number of tubers though it reduced the final yield. Pepper and Prine (1972) reported a severe reduction in yield in sorghum due to shading. Venkateswaralu and Srinivasan (1978) from their studies on shading effect (40 to 50 per cent of normal light) with Sona and RP-4-14 irrigated rice revealed that varietal reponses differed for panicle number and grain yield. In another study conducted with late duration indica rice varieties, the mean grain yield and harvest index were reduced by 68 per cent and 60 per cent, respectively (Rai and Murthy, 1977). They were of the opinion that the reduction in yield was mainly because of low distribution of drymatter to sink. Vijayalakshmi et al. (1987) also recorded reduced grain yield in rice varieties. In soybean the per cent grain yields under 20, 47, 63, 80 and 93 per cent shade were 90, 75, 48, 18 and 2 per cent of unshaded plants, respectively (Wahua and Miller, 1978). Number of pods and yield in cotton were drastically reduced when the plants were shaded during the reproductive phase though the number of grains per pod and 100 grain weight remained unaffected (Pandey et al., 1980). Production of fruit was strongly affected in black night shade *(Solanum nigrum L.)* a leaf and fruit vegetable in West Java, whereas the production of edible leaf was not affected by 35 to 60 per cent shade and only moderately affected by 75 to 85 per cent shade (Fortuin and Omta, 1980).

Xanthosoma saggittifolium and *Colocasia esculenta* var.*antiquorum* were tested in a pot trial for shade tolerance (Caeser, 1980). *Xanthosoma* produced only the corm under shade and the growth of cormels was negligible. Colocasia had highest yield with full light.

Ramadasan and Satheesan (1980) reported that yield of turmeric rhizome was significantly higher in the open than under shade. Reduction in yield due to intercropping with pigeonpea, maize or green gram was also reported by Singh and Randhawa (1988). Contradictory to this Bai and Nair (1982) recorded highest yield of turmeric with plants grown under 50 per cent shade.

With Chinese cabbage, lettuce and spinach the highest fresh weights were with crops grown in 35 per cent shade. Crops grown in 70 per cent shade were poorer than crops in full sunlight (Moon and Pyo, 1981). George (1982) observed a drastic reduction in yield of pulse crops due to shading. Barua and Sarma (1982) reported increased yields of tea bushes grown under shade. The average fruit yields of tomatoes, cucumbers, bean, capsicum, melons and okras grown under shade tended to be higher than those in the open but such tendency was reduced with the increase in the amount of shade (El. Aidy, 1984). According to Erikson and Whitney (1984) response of soybean to shade was intermediate with no reduction in grain yield at 70 per cent sun.

Effect of solar radiation on the growth and yield of cassava was studied by many and it was found that cassava will respond to reduced light with a significant loss in tuber yield (Ramanujam, et al., 1984 and Okoli and Wilson, 1986). Reduction in solar input upto 78 per cent was found to result in 86 per cent reduction in tuber yield in this crop (Fukai et al., 1984). Ravisankar and Muthuswamy (1986, 1987) from the Tamil Nadu Agricultural University recorded the highest yield of ginger with a low light intensity of 15.3 klx. Earlier, Bai and Nair (1982) also recorded highest yield of ginger with 25 per cent shade. Shading resulted in 32 per cent lower yield in 'Vona' winter wheat due mostly to lower spike density (Mc Master et al., 1987). Sreekumari et al. (1988) identified seven cassava genotypes as shade tolerant in respect of tuber yield. Among the different rice varieties tried at Coimbatore, the variety Ponni performed better even in 25 per cent of normal light (Vijayalakshmi et al., 1987).

2.6 Quality of the Produce

Light regimes of a plant determine the productivity and quality of its produce (Tikhomirov et al., 1976). The quality of the final product depends on a number of factors most important among them being the cultivar. Here again very little is known about the effect of shade on other important crops are reviewed.

Corn plants grown at lower light intensities recorded a decrease in protein and sugar content (Knipmeyer, 1962). In easterlily, Kohl and Nelson (1963) observed deterioration in plant quality under low light intensity. Shading was found advantageous in tomato as it reduced the proportion of non-uniformly coloured fruits (Cooper et al., 1964). Comparing between sunadapted and shadeadapted species of higher plants, Bjorkman (1968) observed comparatively lower content of soluble protein in shade plants. Hopping (1977) tried to find out the changes in berry quality of palomino grapevine grown under artificial shade (26 per cent of full sun). No change in berry quality was observed because of shading. Partial shade during the stage of fruit development was found to improve the quality of pineapple (Nayar et al., 1979). In another study conducted on the same crop, total soluble solids showed an increase from 15.3 per cent at 0 per cent shade to 16.05 per cent at 75 per cent shade. The acidity of the fruit juice increased and sugar content decreased as the intensity of shade increased (Aravindakshan and Radha, 1980). Shading to 75 per cent for two to three weeks was found to improve the quality of green tea (Fong et al., 1980). The results of some shading experiments showed that growing *Camellia sinensis* var. *assamica*, *Coffea arabica*, *Cinchona ledgeriana* and *Rauvolfia yunnanensis* under the shade improved the quality of their respective products and made better use of available sunlight (Feng , 1982). Tobacco leaves from increased shade had more red colouration, less yellow colouration, less brightness and more total colour change than those from plants grown without shade (Anderson et al, 1985). It was also stated that shading during growth contributed to development of offcolour in air cured tobacco leaves. In sweet red pepper, highest yield of high quality fruits was obtained with 12 to 26 per cent shade (Rylski and Spigelman, 1986).

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 and Sankarikutty et al., 1982). Nybe et al. (1980) observed significant variation in oleoresin content in 25 ginger cultivars the maximum of 10.5 per cent being in Rio-de-jeneiro followed by Maran (10.0 per cent). Sreekumar et al.(1980) noticed wide variation in oleoresin content in 30 ginger cultivars the range being 3.0 (Poona) to 10.8 per cent in Rio-de-jeneiro. The ginger crop grown in shade provided quality rhizomes (Ravisankar and Muthuswamy, 1987). They also reported that volatile oil and non volatile acetone extract showed a slow increase with increasing shade, that starch and protein content increased and that crude fibre content was unaffected by shading. Philip (1983) suggested highly significant variation among the turmeric types in curcumin content. Rathnambal (1986) observed the variation in curcumin content as 2.3 per cent in cultivar Hahim to 10.9 per cent in cultivar Edapalayam. The essential oil content in ginger is positively correlated with oleoresin content but is negatively correlated with starch, in turn oleoresin content is correlated with gingerol (Rathnambal et al., 1987). In their study, oleoresin content showed variation from 5.30 to 8.59 per cent. Singh and Randhawa (1988) reported that the oil and curcumin content in turmeric were not affected by intercropping.

The above literature review clearly indicates that considerable differences exist between crops and varieties in their response to shade. One of the most pronounced effects of reduced light intensity was on plant height. The effect was positive in crops like maize, alfalfa, coleus, ginger, groundnut, sweet potato, tomato, turmeric and cassava, while it was negative in redgram and neutral in colocasia. All reported results indicated an increase in leaf area index, crop growth rate and net assimilation rate with an increase in light intensity. Another noticeable trend was an increase in chlorophyll content with increase in shading. Effect of shade on quality aspects was found to be highly variable. A deterioration in the quality of the produce was observed in crops like corn, easterlily and tobacco while it improved the quality of the produce in crops like coffee, cinchona, pineapple, sweet red pepper, tomato and tea. Another conclusion that can be drawn from the review is that shading reduced yield considerably in cereals and pulses. It had also been indicated that crops like ginger, cucumber, pineapple, spinach, tea, lettuce, tomato and melons can be grown safely under shade. These are however only the general conclusions from most of the reported experiments and deviations in shade response had also been recorded in the same crop in some cases, presumably as a result of variations in the level of shade provided for the experimental set up which was not reported in most of the cases.

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was conducted with a view to screen out varieties of ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* L.) for shade tolerance during the year 1988-89.

The experiment was carried out at the College of Horticulture, Vellanikkara, Trichur, 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 Cropping History of the Field

The area was left fallow during the previous one or two years and was under annual crops prior to it.

3.2 Soil

The soil of 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.

3.3 Season and Climate

The experiment was conducted during the period May 1988 to February 1989. Ginger varieties were planted on 29th June and turmeric varieties on 2nd July, 1988. Ginger varieties were harvested 197, 201, 204 and 208 days after planting and turmeric varieties were harvested 217, 220, 224 and 228 days after planting from 0, 25, 50 and 75 per cent shade, respectively.

The meteorological data for the crop periods from June 1988 to February 1989 are presented in Appendix 1.

Table 1 Physical and chemical properties of the Soil

1. Mechanical composition

Sand		77.5 per cent	
Silt	-	5.0 per cent	(Hydrometer Method)
Clay	-	17.5 Per cent	(Bocyoucos, 1962)

2. Chemical properties

Constituent	Content		Rating	Method used for estimation
Total nitrogen	0.2	per cent	High	Microkjeldhal (Jackson, 1958)
Available Phosphorus (Bray-I) extract)	19	ppm	High	Chlorostannous reduced molybdo phosphoric blue colour method (Jackson, 1958)
Available potassium (Neutral normal ammonium acetate extract)	93.75	ppm	Medium	Flame photometry (Jackson, 1958)
pH (1:2.5 soil:water ratio)	5.4			pH meter(Jackson,1958)

The crops received a total of 1952.8 mm of rainfall which was evenly distributed during the actively growing period. There was almost no rainfall after December. The relative humidity ranged from 38.0 to 93.0 per cent. In general the weather conditions as a whole were condusive for the normal growth of ginger and turmeric.

3.4 Materials

3.4.1 Shading

Unplaited coconut leaves were used for providing shade to the desired level.

3.4.2 Seeds

Thirteen varieties of ginger and twelve varieties of turmeric were used for the experiment. Healthy rhizomes free from pest and disease were selected. These rhizomes were soaked for 30 min in 0.3 per cent Captafol solution and spread under shade to drain the water. In the case of ginger, 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 1m at a spacing of 25 cm x 25 cm. Finger rhizomes of turmeric each weighing 20 to 25 g were planted in small pits taken at a spacing of 15 cm x 30 cm on raised beds of 90 cm width. Sufficient space (30 cm) was provided between varieties in both the cases. Plot size in ginger was 1 x 1 m^2 and in turmeric, 0.9 x 0.6 m^2.

3.4.3 Fertilisers

Both the crops received the respective cultural and manurial practices as per the package of practices recommendations of the Kerala Agricultural University (1986). Nitrogen, phosphorus and potassium were supplied through urea, superphosphate and muriate of potash, respectively.

3.4.4 Plant protection measures

As a precaution against soft rot disease of ginger, soil drenching with Dithane M 45 was done 60 days after planting. The crop was then sprayed with Dimecron (0.05 per cent) and Cuman (0.3 per cent) against shoot borer attack and leafspot disease, respectively, when these were noticed.

3.5 Methods

3.5.1 Lay out of the experiment

The experiment was laid out in a split plot design with four replications. The lay out plan of the experiment is given in Fig 1. Shade levels were assigned to mainplots and varieties to subplots.

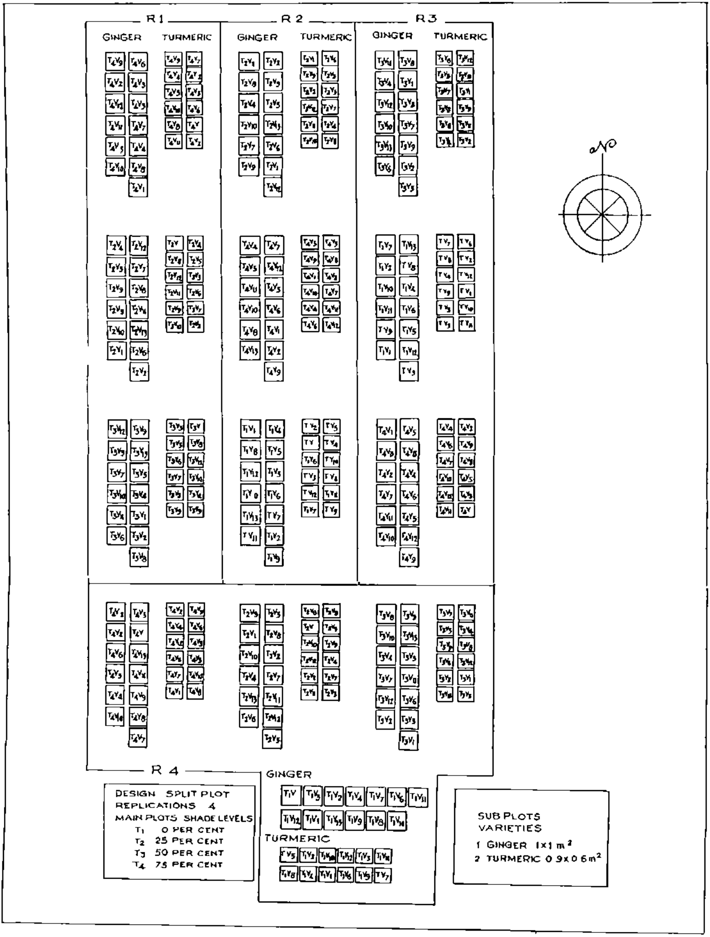
3.5.2 Details of treatments

3.5.2.1 Ginger

Mainplot treatments consisted of four levels of shade as indicated below.

T_1	-	0 per cent shade (open)
T_2	-	25 per cent shade
T_3	-	50 per cent shade
T_4	-	75 per cent shade

Fig 1 Layout plan of the experimental field


R 1
R 2
R 3
R 4
GINGER
TURMERIC
DESIGN SPLIT PLOT
REPLICATIONS 4
MAIN PLOTS SHADE LEVELS
T1 0 PER CENT
T2 25 PER CENT
T3 50 PER CENT
T4 75 PER CENT
SUB PLOTS
VARIETIES
1 GINGER 1x1 m²
2 TURMERIC 0 9x0 6 m²

Subplot treatments consisted of 13 varieties of ginger as given below.

V_1	-	Jorhat
V_2	-	Nadiya
V_3	-	Jamaica
V_4	-	Pottangi Selection 667
V_5	-	Rio-de-jeneiro
V_6	-	Pottangi Selection 17
V_7	-	Kuruppampadi
V_8	-	Jugijan
V_9	-	Valluvanad
V_{10}	-	PGS 35
V_{11}	-	Amballoor Local
V_{12}	-	PGS 10
V_{13}	-	Nedumangad

3.5.2.2 Turmeric

Mainplot treatments were same as that of ginger. Subplot treatments included 12 varieties of turmeric as listed below.

V_1	-	Myduckur
V_2	-	Armoor
V_3	-	PCT 2
V_4	-	PTS 9
V_5	-	Ethamatala
V_6	-	PCT 8
V_7	-	PTS 10
V_8	-	PTS 24
V_9	-	PCT 5
V_{10}	-	CO 1
V_{11}	-	B S R 1
V_{12}	-	P T S 38

3.5.3 Provision of shade

Pandals of size 27 m x 11 m were erected on wooden poles to provide artifical shade to the desired level. Unplaited coconut leaves were used for providing shade. Sufficient space (2.5 m) was provided between the treatments so that mutual shading of shade levels was minimised. All sides were also covered with unplaited coconut leaves except for 1 m from the ground level to avoid the direct entry of slant rays. Raised beds were taken leaving a boarder area of 1 m within the shade levels to avoid the boarder effect. An Aplab luxmeter was used for adjusting the shade intensities approximately to the required levels. There were variations upto a maximum level of about 10 per cent at different locations within a *Pandal*. Frequent checks were made throughout the course of the experiment to maintain the shade intensities to the desired level.

3.5.4 Observations

Sampling technique

Random sampling technique was adopted to select the sample plants for studying the various growth characters. Five plants were selected at random as observation plants for recording the different biometric observations at bimonthly intervals. These observation plants were harvested separately for recording observations of this stage and the rest of the plants of each plot were harvested together. Preharvest observations started exactly 60 days after planting and were continued upto 180 days of planting. At 180th day, no growth observation was taken for ginger at 0 per cent shade (open) since the drying up of the above ground parts had already started.

The observations recorded were the following.

A. Biometric observations

1. Plant height

The height of the selected plants in both the crops was 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 clump

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 worked out for both the crops.

3. Number of leaves per clump

The number of leaves per clump was determined by counting the number of leaves of all the tillers of the five sample clumps of both the crops and average worked out.

4. Chlorophyll content of leaves

Chlorophyll a, chlorophyll b and total chlorophyll content of leaves of both the crops were estimated periodically by spectrophotometric method as described by Starnes and Hadley (1965). Second terminal leaves of both the crops drawn at random from a few plants constituted the samples.

5. 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 dry weight of components gave the total drymatter yield and it was expressed as g plant $^{-1}$.

6. Rhizome yield

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

7. Haulm yield

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

8. Dry weight percentage of rhizome

Dry weight percentage was calculated from fresh weight and loss in weight on drying.

9. Harvest index

Harvest index was calculated as follows.

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

Y_{econ} and Y_{biol} were dry weight of rhizome and total dry weight of plant, respectively.

B. Chemical studies

1. Content of fertiliser nutrients

Samples of plant components collected for recording the dry weight were used for chemical analysis. The nitrogen and phosphorus contents of rhizome and haulm were determined colorimetrically using Nesslers reagent (AOAC, 1960) and by vanadomolybdo phosphoric yellow colour method (Jackson, 1958), respectively. The potassium content was determined flame photometrically (Jackson, 1958).

2. Uptake of fertiliser nutrients

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

3. Quality analysis

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

1. Oleoresin content in ginger rhizome

Oleoresin content in ginger rhizomes was estimated by cold percolation method using 100 per cent acetone as solvent (ISI, 1974). Details of the procedure are given below.

Ten g of the ground sample was transferred to a specially designed column, the outlet of which was plugged with cotton. Twenty five ml of 100 per cent acetone was added and allowed to stand for 16 h. The drippings through the cotton plug were collected in a pre weighed beaker. After the entire solvent was drained an additional quantity of 25 ml was added to the top of the extracted spice in the same glass column. After washing the spice with solvent, the solvent extracts were pooled up and oleoresin was obtained by removing the solvent by evaporation and expressed as percentage.

2. Curcumin content in turmeric rhizome

Rhizome samples collected for quality analysis were cured and sundried. The dried samples were then ground to pass through a 60 mesh sieve. Curcumin content was estimated by the method suggested by (ASTA, 1968).

C. Disease incidence

Severe incidence of bacterial wilt of ginger was noticed in the 0 per cent shade (open) treatment. The varieties were scored for their disease susceptibility as totally affected and unaffected.

D. Statistical analysis

The experimental data were subjected to analysis of variance following the method of Panse and Sukhatme (1978). In the case of ginger, where some of the varieties were lost in the open, respective data were analysed in two ways, one by deleting the mainplot in which the data were missing and second by deleting the missing varieties from all the replications. One of the missing varieties in the open (V_9)was found to be the best in all shade levels and hence to have a comparison of this variety with other varieties in the open, yield data were also analysed by deleting one replication. Accounting for the differences in moisture content, yield data were analysed on dry weight basis also.

Results

4. RESULTS

During the course of this investigation, observations on various plant characters were recorded to assess the performance of ginger and turmeric varieties and also to assess the effect of shade on growth, yield and quality of these varieties. The results of the experiment are presented in this chapter.

Ginger

Since some of the varieties were lost in the open (0 per cent shade) due to severe disease incidence, data were analysed in two ways. One excluding the mainplot (open) in which there was damage and the other *excluding the missing subplots (varieties) from all* the replications. Both are presented in the table. No growth observation had been recorded at 180th day in the open as there was total drying of shoots by that time.

4.1 Biometric Observations

4.1.1 Plant height (Table 2, Appendix 2)

Plant height went on increasing with increasing levels of shade from the low level of 0 per cent shade to the highest level of 75 per cent at 60 days after planting only, after which plants grown at 25 per cent shade had the highest plant height. Though the plant height was found to be the highest at 25 per cent shade, it was statistically on par with those at 50 and 75 per cent at these two stages. At all growth stages plants at 0 per cent shade differed significantly from other treatments and recorded the lowest plant height.

Among the varieties V_{13} (Nedumangad) significantly differed from other varieties and recorded the highest plant height at 120 and 180 days. Plant height values of V_{10} (PGS 35) and V_{12} (PGS 10) were significantly lower than those of all other varieties. The difference between two varieties was not statistically significant.

Variety x shade interaction was not significant at any stage.

With advancing age, plant height showed an increase though a marginal decrease was noticed at 180th day at all shade levels and in most of the varieties. The results showed a similar trend when analysed in both ways, with respect to shade levels as well as varieties.

4.1.2 Number of tillers (Tables 2, 3 and 4, Appendix 2)

Number of tillers decreased progressively with increasing levels of shade at all growth stages. Shade level T_1 (open) recorded the highest number of tillers, with significant difference from the rest of the treatments. Compared to open, decrease in tillering at T_2 level of shading was only 23 to 24 per cent. T_4 gave the lowest number of tillers at all stages and the decrease in tillering was 38 per cent and 47 per cent at 60 and 120 days, respectively.

Among the varieties, V_6 (Pottangi Selection 17) recorded highest tiller number upto 120th day. Rest of the treatments that had shown statistical equality with the highest tillering variety were V_{10}, V_{12}, V_9, V_8 and V_3.

Significant interaction between variety and shade levels was observed at 60 days and 180 days. At 60 days V_{10} recorded the highest number of tillers (6.1) in the open. Varieties V_8, V_{12} and V_2 maintained highest tiller number at 25,50 and 75 per cent shade, respectively. At 180 days, varieties V_{10}, V_{12} and V_6 had the highest tiller number at 25,50 and 75 per cent, respectively.

Table 2 Effect of shade on plant height and number of tillers of ginger varieties

Treatments	Plant height (cm) 60 DAP	Plant height (cm) 120 DAP (1)	Plant height (cm) 120 DAP (2)	Plant height (cm) 180 DAP	Number of tillers 60 DAP	Number of tillers 120 DAP (1)	Number of tillers 120 DAP (2)	Number of tillers 180 DAP
Levels of shade %								
T_1 0	48 3	66 2			4.7	14 0		
T_2 25	58 5	82 5	82 3	81 6	3 6	10 6	10 6	11 0
T_3 50	58 6	79 7	79 7	79.1	3.2	8 6	8 4	10 0
T_4 75	62 6	79 0	78 8	77 2	2.9	7 3	7 3	8 0
SEm$\pm$	1 37	1 44	1 76	1 24	0 21	0 51	0.54	0 28
CD (0 05)	4 39	4 60	NS	NS	0.68	1 65	1 9	0.98
Varieties								
V_1 Jorhat	62 0	73 2	75 8	71 7	3 1	9 2	8 4	7 7
V_2 Nadiya	58 4	73 7	76 3	73 9	3 6	9 6	9 0	8 6
V_3 Jamaica	65 4	77 4	80 2	77 4	3 7	10 4	9 8	9 8
V_4 Pottangi Selectlon 6o7	62 6	62 0	85 9	82 9	3 1	9 0	7 7	7 9
V_5 Rio de jeneiro	52 5		79 0	81.9	3.2		7 7	8 9
V_6 Pottangi Selection 17	60 4	82 6	87 6	85 9	4 2	12 3	10 8	12 5
V_7 Kuruppampadi	60 6	60 6	84 3	79 8	3 2	9 2	7 9	7 5
V_8 Jugijan	55 9	79 1	83 5	83 5	3 9	9 8	7 8	9 5
V_9 Valluvanad	65 0	77 9	80 1	78 2	3 9	11 5	10 1	10 0
V_{10} PGS 35	39 2	63.0	66 7	73 7	4 0	11 2	8 9	13 4
V_{11} Amballoor 1 ocal	54 2	77 4	81 5	79 4	3 2	8 6	7 4	7 4
V_{12} PGS 10	41 9	65 6	68 8	72 9	4 0	10 9	9 8	13 2
V_{13} Nedumangad	62 8	89 4	94 0	89 8	3 6	10 0	8 7	9 4
SEm$\pm$	1 42	1 50	1 9	1.9	0 20	0.52	0 45	0 54
CD (0 05)	3 94	4 14	5 3	5 3	0 54	1 45	1 27	1 52

(1) Data analysed by deleting one subplot (V_5)

(2) Data analysed by deleting one mainplot (T_1)

	Mainplot	Subplot
Plant height 60 DAP	$T_4\ T_3\ T_2\ T_1$	$V_3\ V_9\ V_{13}\ V_4\ V_1\ V_7\ V_6\ V_2\ V_8\ V_{11}\ V_5\ V_{12}\ V_{10}$
Plant height 120 DAP	(1) $T_2\ T_3\ T_4\ T_1$	(1) $V_{13}\ V_6\ V_4\ V_7\ V_8\ V_9\ V_{11}\ V_3\ V_2\ V_1\ V_{12}\ V_{10}$
	(2) $T_2\ T_3\ T_4$	(2) $V_{13}\ V_6\ V_4\ V_7\ V_8\ V_{11}\ V_3\ V_9\ V_5\ V_2\ V_1\ V_{12}\ V_{10}$
Plant height 180 DAP	$T_2\ T_3\ T_4$	$V_{13}\ V_6\ V_8\ V_4\ V_5\ V_7\ V_{11}\ V_9\ V_3\ V_2\ V_{10}\ V_{12}\ V_1$
Number of tillers 60 DAP	$T_1\ T_2\ T_3\ T_4$	$V_6\ V_{10}\ V_{12}\ V_8\ V_9\ V_3\ V_2\ V_{13}\ V_7\ V_{11}\ V_5\ V_1\ V_4$
Number of tillers 120 DAP	(1) $T_1\ T_2\ T_3\ T_4$	(1) $V_6\ V_9\ V_{10}\ V_{12}\ V_3\ V_{13}\ V_8\ V_2\ V_1\ V_7\ V_4\ V_{11}$
	(2) $T_1\ T_2\ T_3\ T_4$	(2) $V_6\ V_9\ V_{12}\ V_3\ V_2\ V_{10}\ V_{13}\ V_1\ V_7\ V_8\ V_4\ V_5\ V_{11}$
Number of tillers 180 DAP	$T_2\ T_3\ T_4$	$V_{10}\ V_{12}\ V_6\ V_9\ V_3\ V_8\ V_{13}\ V_5\ V_2\ V_4\ V_1\ V_7\ V_{11}$

Table 3 Interaction effects of shade levels and ginger varieties on number of tillers at 60 days after planting

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_1	Jorhat	3.4	3.4	3.3	2.4	3.1
V_2	Nadiya	3.9	3.8	3.1	3.8	3.6
V_3	Jamaica	4.0	3.9	3.5	3.6	3.7
V_4	Pottangi Selection 667	4.3	2.9	2.8	2.6	3.1
V_5	Rio-de-jeneiro	3.8	3.3	2.9	2.7	3.2
V_6	Pottangi Selection 17	5.3	4.3	3.8	3.6	4.2
V_7	Kuruppampadi	4.4	3.0	3.0	2.7	3.2
V_8	Jugijan	5.7	4.5	2.8	2.8	3.9
V_9	Valluvanad	5.5	3.9	3.3	3.1	3.9
V_{10}	PGS 35	6.1	4.3	3.4	2.4	4.0
V_{11}	Amballoor Local	4.8	3.2	2.4	2.5	3.2
V_{12}	PGS 10	5.3	3.7	3.7	3.3	4.0
V_{13}	Nedumangad	4.8	3.4	3.5	2.8	3.6
Mean		4.7	3.6	3.2	2.9	

Table 4 Interaction effects of shade levels and ginger varieties on number of tillers at 180 days after planting

Varieties		Shade levels (per cent)			Mean
		25	50	75	
V_1	Jorhat	8.75	8.65	5.83	7.7
V_2	Nadiya	9.19	8.80	7.88	8.6
V_3	Jamaica	11.08	10.00	8.40	9.8
V_4	Pottangi Selection 667	8.93	7.85	6.80	7.9
V_5	Rio-de-jeneiro	11.13	8.90	6.75	8.9
V_6	Pottangi Selection 17	13.38	13.15	11.11	12.5
V_7	Kuruppampadi	7.23	7.94	7.20	7.5
V_8	Jugijan	11.80	8.74	8.06	9.5
V_9	Valluvanad	10.75	10.55	8.80	10.0
V_{10}	PGS 35	18.18	13.80	8.31	13.4
V_{11}	Amballoor Local	8.04	7.15	7.03	7.4
V_{12}	PGS 10	15.49	13.90	10.20	13.2
V_{13}	Nedumangad	8.89	11.16	8.08	9.4
Mean		11.00	10.00	8.00	

With advancing age, number of tillers increased at all shade levels and in most of the varieties. The results analysed in both ways followed the same trend.

4.1.3 Number of leaves (Table 5, Appendix 3)

Highly significant variation was noticed between treatments with respect to number of leaves. A decrease in number of leaves was observed at all stages, by increasing the intensity of shading from 0 to 75 per cent. Treatments T_1 and T_2 significantly differed from the rest and recorded the highest number of leaves at all stages. The decrease in number of leaves at 25 per cent shade was only to the extent of 16 per cent and 19 per cent at 60 and 120 days, respectively. Another important observation was that the extent of decrease was more at later stages, these being 16, 23 and 25 per cent at 60 days while these were 19, 36 and 47 per cent at 120 days at 25, 50 and 75 per cent shade, respectively.

Among the varieties, V_9 and V_6 differed significantly from the other varieties with maximum number of leaves at 60th and 120th days. At 180th day the pattern was different and the varieties V_{12}, V_{10} and V_6 were found to have the highest leaf number, these three varieties being statistically at par. Data analysed in both ways followed the same trend.

4.1.4 Drymatter production (Table 5, Appendix 3)

Drymatter production also followed the same trend of rhizome yield and haulm yield, with increase in shading. Plants grown at 25 per cent shade recorded the highest drymatter yield. Data analysed in both ways followed the same trend.

Among the varieties V_{13}, V_3 and V_7 were found to be the highest drymatter yielders when analysed after deleting a few subplots while

Table 5 Effect of shade on number of leaves and drymatter production of ginger varieties

Treatments		No of leaves				Drymatter production g plant^{-1}	
		60 DAP	120DAP (1)	120DAP (2)	180DAP	(1)	(2)
Levels of shade %							
T_1	0	29 5	142 5			35 1	
T_2	25	24 7	115 1	114 4	81 0	40 5	42 8
T_3	50	22 7	90 0	88 8	74 2	30 3	33 0
T_4	75	22 1	74 8	74 0	62 4	22 2	22 9
SEm+		1 45	5 8	6 56	4 9	0 92	0 96
CD (0 05)		4 66	18 5!	22 71	NS	2 93	3 31
V_1	Jorhat	23 6	96 8	87 9	48 1	-	33 1
V_2	Nadiya	24 8	100 9	93 7	60 2	31 9	30 8
V_3	Jamaica	28 3	108 3	100 0	68 6	35 0	33 9
V_4	Pottangi Selection 667	23 0	95 6	83 3	49 3	31 3	30 1
V_5	Rio de Jeneiro	20 2		81 8	79 5		34 6
V_6	Pottangi Selection 17	30 0	130 9	20 4	103 6		41 9
V_7	Kuruppampadi	23 2	95 4	82 9	54 7	34 9	33 4
V_8	Jugijan	25 5	105 7	86 2	71 8	29 8	28 4
V_9	Valluvanad	30 3	121 5	.07.0	70 3		39 2
V_{10}	PGS 35	22 8	103 6	85 0	106 4	27 6	27 2
V_{11}	Amballoor Local	22 5	91 4	80 0	45 6	28 7	28 6
V_{12}	PGS 10	22 3	103 9	92 8	115 6	30 0	28 9
V_{13}	Nedumangad	25 7	113	100 5	69 4	39	37 8
SEm+		1 30	4 99	4 78	6 63	2 00	2 63
CD (0 05)		3 60	13 83	13 40	18 60	5 58	7 40

(1) Data analysed by deleting subplots (V_1 V_5, V_6, V_9)

(2) Data analysed by deleting one mainplot (T_1)

		Mainplot	Subplot
Number of leaves 60 DAP		T_1 T_2 T_3 T_4	V_9 V_6 V_3 V_{13} V_8 V_2 V_1 V_7 V_4 V_{10} V_{11} V_{12} V_5
Number of leaves 120 DAP	1)	T_1 T_2 T_3 T_4	V_6 V_9 V_{13} V_3 V_8 V_{12} V_{10} V_2 V_1 V_4 V_7 V_{11}
	2)	T_2 T_3 T_4	V_6 V_9 V_{13} V_3 V_2 V_{12} V_1 V_8 V_{10} V_4 V_7 V_5 V_{11}
Number of leaves 180 DAP		T_2 T_3 T_4	V_{12} V_{10} V_6 V_5 V_8 V_9 V_{13} V_3 V_2 V_7 V_4 V_1 V_{11}
Drymatter production	1)	T_2 T_1 T_3 T_4	V_{13} V_3 V_7 V_2 V_4 V_{12} V_8 V_{11} V_{10}
	2)	T_2 T_3 T_4	V_6 V_9 V_{13} V_5 V_3 V_7 V_1 V_2 V_4 V_{12} V_{11} V_8 V_{10}

these were replaced by V_6 and V_9 when analysed after deleting one mainplot.

No significant interaction was noticed between shade levels and varieties.

4.1.5 Chlorophyll content (Table 6)

Total chlorophyll and its fractions, chlorophyll a and chlorophyll b increased progressively with increasing levels of shade, at both the stages studied. Chlorophyll a to chlorophyll b ratio was not found to be markedly affected by shading.

At 100 days, variety V_2 (Nadiya) recorded the highest total chlorophyll content whereas the variety V_5 (Rio-de-jeneiro) recorded the highest value at 150 days. The range in total chlorophyll content of varieties at these stages were from 1.39 to 1.81 and 1.07 to 1.54 mg g^{-1} fresh weight, respectively.

With advancing age chlorophyll a and chlorophyll b decreased though the ratio between the two increased.

4.1.6 Rhizome yield (Tables 7, 8, 9 and 10, Fig 2 and 3, Appendix 4)

With increase in shading rhizome yield increased upto the light shade of 25 per cent and then decreased. Though T_2 (25 per cent shade) recorded the highest yield, it was found to be statistically on par with T_1 (0 per cent shade). Rhizome yields at 25, 50 and 75 per cent shade were 115, 68 and 48 per cent of that at 0 per cent on a fresh weight basis, when analysed by deleting a few subplots. The corresponding figures obtained, when analysed by deleting one replication and one subplot (V_5) were 108, 68 and 42 per cent. Data

Table 6 Effect of shade on contents of chlorophyll fractions of ginger varieties

Treatments		Chlorophyll a mg g-1 fresh weight		Chlorophyll b mg g-1 fresh weight		Chlorophyll (a+b) mg g 1 fresh weight		Chlorophyll a/b	
		100 DAP	150 DAP	100 DAP	150 DAP	100 DAP	150 DAP	100 DAP	150 DAP
Levels of shade(per cent)									
T_1	0	0.58	0.42	0.44	0.21	1.03	0.63	1.31	2.00
T_2	25	0.83	0.80	0.64	0.54	1.48	1.34	1.29	1.48
T_3	50	0.98	0.87	0.81	0.56	1.80	1.43	1.20	1.55
T_4	75	1.12	0.93	0.84	0.56	1.96	1.43	1.33	1.66
Varieties									
V_1	Jorhat	0.95	0.67	0.71	0.40	1.66	1.07	1.33	1.67
V_2	Nadiya	0.92	0.80	0.89	0.49	1.81	1.29	1.03	1.63
V_3	Jamaica	0.94	0.82	0.78	0.42	1.72	1.24	1.20	1.95
V_4	Pottangi Selection 667	0.81	0.69	0.76	0.43	1.51	1.12	1.06	1.60
V_5	Rio-de-jeneiro	0.91	0.98	0.65	0.56	1.57	1.54	1.40	1.75
V_6	Pottangi Selection 17	0.87	0.81	0.70	0.42	1.57	1.23	1.24	1.92
V_7	Kuruppampadi	0.89	0.71	0.65	0.45	1.54	1.16	1.36	1.57
V_8	Jugijan	0.81	0.73	0.69	0.41	1.51	1.14	1.17	1.78
V_9	Valluvanad	0.94	0.71	0.68	0.38	1.62	1.09	1.38	1.86
V_{10}	PGS 35	0.78	0.74	0.60	0.44	1.39	1.18	1.30	1.68
V_{11}	Amballoor Local	0.90	0.66	0.62	0.50	1.52	1.16	1.45	1.32
V_{12}	PGS 10	0.85	0.80	0.61	0.59	1.46	1.39	1.39	1.35
V_{13}	Nedumangad	0.87	0.78	0.63	0.56	1.50	1.34	1.38	1.39

analysed in three ways followed a similar trend in the case of shade levels, whereas the pattern was different among varieties.

Among the varieties, V_3 (Jamaica) recorded the highest yield (15.5 t ha^{-1}) when analysed by excluding the missing varieties (Analysis 1) while V_9 (Valluvanad) recorded the highest value (15.9 t ha^{-1}) when analysed by excluding one mainplot T_1 (Analysis 2). The same variety V_9 recorded the highest yield when analysed by deleting one replication and one subplot (Analysis 3). It is, however to be noted that the loss of V_9 (Valluvanad) in the open in a replication appeared to arise from its nearness to a highly susceptible variety V_5.

Results analysed in three ways showed significant interaction between shade levels and varieties. Variety V_3 (Jamaica) recorded the highest yield at all shade levels (Analysis 1). Rest of the varieties that had shown statistical equality with the highest yielding one at 25 per cent were V_4, V_8, V_2 and V_7 while only varieties V_2 and V_7 were found to be on par with this at 50 and 75 per cent.

Variety V_9 (Valluvanad) gave the highest yield at all shade levels when analysed by deleting one mainplot T_1. The other varieties that had shown statistical equality with this at 25 per cent shade were V_3, V_1 and V_4. Varieties V_3 and V_1 continued to be on par with this at 50 and 75 per cent also. As had been indicated earlier in the case of V_9, variety V_1 was also lost due to disease only from one of the four replications and this appeared to be due to its nearness to V_5.

Variety V_3 continued to be the best in the open when analysed by excluding one replication (R_1) and one subplot (V_5). Variety V_1 gave the highest yield at 50 per cent while V_9 recorded the highest yield at 25 and 75 per cent. The lowest yielding varieties at all shade levels were V_{12} and V_{10}.

Table 7 Effect of shade on rhizome yield of ginger varieties

Treatments		Fresh weight basis (t ha^{-1})			Dry weight basis (t ha^{-1})		
		(1)	(2)	(3)	(1)	(2)	(3)
Levels of shade(per cent)							
T_1	0	11.7	-	14.1	1.6		1.7
T_2	25	13.6	14.6	15.3	2.1	2.1	2.2
T_3	50	8.0	9.0	9.6	1.3	1.4	1.5
T_4	75	5.5	6.2	6.0	1.0	1.0	1.0
SEm+		0.66	0.64	0.52	0.12	0.09	0.13
CD (0.05)		2.1	2.21	1.80	0.39	0.31	0.45
V_1	Jorhat		13.1	14.6		2.2	2.1
V_2	Nadiya	12.5	11.7	12.6	1.9	2.0	1.9
V_3	Jamaica	15.5	13.8	16.1	2.1	2.1	2.2
V_4	Pottangi Selection 667	10.9	10.8	11.5	1.6	1.7	1.7
V_5	Rio-de jeneiro		8.6			1.0	
V_6	Pottangi Selection 17		10.0	10.5		1.2	1.1
V_7	Kuruppampadi	13.1	12.0	13.9	2.2	2.1	2.2
V_8	Jugijan	10.3	9.9	11.6	1.3	1.1	1.2
V_9	Valluvanad		15.9	17.4		2.5	2.6
V_{10}	PGS 35	2.8	2.9	3.1	0.6	0.6	0.7
V_{11}	Amballoor Local	7.2	6.9	7.6	1.4	1.4	1.3
V_{12}	PGS 10	4.0	4.0	4.4	0.5	0.5	0.6
V_{13}	Nedumangad	10.8	9.1	11.4	1.6	1.4	1.7
SEm+		0.63	0.68	0.75	0.12	0.12	0.13
CD (0.05)		1.77	1.90	2.12	0.34	0.34	0.37

(1) Data analysed by deleting subplots (V_1, V_5, V_6 and V_9)
(2) Data analysed by deleting one mainplot (T_1)
(3) Data analysed by deleting one replication (R_1) and one subplot (V_5)

		Mainplot	Subplot
Fresh weight basis	1)	$T_2\ T_1\ T_3\ T_4$	$V_3\ V_7\ V_2\ V_4\ V_{13}\ V_8\ V_{11}\ V_{12}\ V_{10}$
	2)	$T_2\ T_3\ T_4$	$V_9\ V_3\ V_1\ V_7\ V_2\ V_4\ V_6\ V_8\ V_{13}\ V_5\ V_{11}\ V_{12}\ V_{10}$
	3)	$T_2\ T_1\ T_3\ T_4$	$V_9\ V_3\ V_1\ V_7\ V_2\ V_{13}\ V_8\ V_4\ V_6\ V_{11}\ V_{12}\ V_{10}$
Dry weight basis	1)	$T_2\ T_1\ T_3\ T_4$	$V_7\ V_3\ V_2\ V_4\ V_{13}\ V_{11}\ V_8\ V_{10}\ V_{12}$
	2)	$T_2\ T_3\ T_4$	$V_9\ V_1\ V_3\ V_7\ V_2\ V_4\ V_{13}\ V_{11}\ V_6\ V_8\ V_5\ V_{10}\ V_{12}$
	3)	$T_2\ T_1\ T_3\ T_4$	$V_9\ V_3\ V_7\ V_1\ V_2\ V_{13}\ V_4\ V_{11}\ V_8\ V_6\ V_{10}\ V_{12}$

Table 8 Interaction effects of shade levels and ginger varieties on rhizome yield, t ha^{-1} (Analysis 1)

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_2	Nadiya	14.8	16.4	10.6	8.1	12.5
V_3	Jamaica	20.6	19.3	13.2	9.0	15.5
V_4	Pottangi Selection 667	11.4	18.4	8.2	5.7	10.9
V_7	Kuruppampadi	16.5	16.1	10.5	9.3	13.1
V_8	Jugijan	11.3	16.5	9.4	3.8	10.3
V_{10}	PGS 35	2.6	5.0	2.9	0.95	2.8
V_{11}	Amballoor Local	8.1	10.4	6.1	4.3	7.2
V_{12}	PGS 10	4.5	6.0	3.0	2.8	4.1
V_{13}	Nedumanagad	16.1	13.9	7.6	5.8	10.8
Mean		11.7	13.6	8.0	5.5	

SEm$\pm$ 1.78

CD (0.05) 3.54

0 V_3 V_7 V_{13} V_2 V_4 V_8 V_{11} V_{12} V_{10}

25 V_3 V_4 V_8 V_2 V_7 V_{13} V_{11} V_{12} V_{10}

50 V_3 V_2 V_7 V_8 V_4 V_{13} V_{11} V_{12} V_{10}

75 V_3 V_7 V_2 V_4 V_{13} V_8 V_{11} V_{12} V_{10}

Table 9 Interaction effects of shade levels and ginger varieties on rhizome yield, t ha^{-1} (Analysis 2)

Varieties		Shade levels (per cent)			Mean
		25	50	75	
V_1	Jorhat	18.2	13.6	7.4	13.1
V_2	Nadiya	16.4	10.6	8.1	11.7
V_3	Jamaica	19.3	13.2	9.0	13.8
V_4	Pottangi Selection 667	18.4	8.2	5.7	10.8
V_5	Rio-de-jeneiro	13.0	8.0	4.9	8.6
V_6	Pottangi Selection 17	14.9	9.3	6.0	10.0
V_7	Kuruppampadi	16.1	10.5	9.3	12.0
V_8	Jugijan	16.5	9.4	3.8	9.9
V_9	Valluvanad	21.3	14.4	12.1	15.9
V_{10}	PGS 35	5.0	2.9	0.95	2.9
V_{11}	Amballoor Local	10.4	6.1	4.3	6.9
V_{12}	PGS 10	6.0	3.0	2.8	4.0
V_{13}	Nedumangad	13.9	7.6	5.8	9.1
Mean		14.6	9.0	6.2	

SEm± 1.7

CD (0.05) 3.3

25 V_9 V_3 V_1 V_4 V_2 V_8 V_7 V_6 V_{13} V_5 V_{11} V_{12} V_{10}

50 V_9 V_1 V_3 V_2 V_7 V_8 V_6 V_4 V_5 V_{13} V_{11} V_{12} V_{10}

75 V_9 V_3 V_1 V_2 V_7 V_4 V_6 V_8 V_{13} V_5 V_{11} V_{12} V_{10}

Table 10 Interaction effects of shade levels and ginger varieties on rhizome yield, t ha^{-1} (Analysis 3)

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_1	Jorhat	18.5	18.0	14.9	7.2	14.6
V_2	Nadiya	15.2	17.0	11.8	6.6	12.6
V_3	Jamaica	22.8	19.0	13.6	8.9	16.1
V_4	Pottangi Selection 667	11.8	19.9	8.5	6.0	11.5
V_5	Rio-de-jenelro	-		-	-	-
V_6	Pottangi Selection 17	12.9	14.4	9.5	5.2	10.5
V_7	Kuruppampadi	19.3	16.5	10.4	9.4	13.9
V_8	Jugijan	13.7	17.3	10.6	4.6	11.6
V_9	Valluvanad	21.7	23.2	14.3	10.6	17.4
V_{10}	PGS 35	2.9	5.2	3.1	1.2	3.1
V_{11}	Amballoor Local	7.9	10.7	7.3	4.5	7.6
V_{12}	PGS 10	4.6	7.4	3.6	2.2	4.4
V_{13}	Nedumangad	17.4	14.6	7.6	5.9	11.4
Mean		14.1	15.3	9.6	6.0	

SEm $\pm$ 2.13

CD (0.05) 4.24

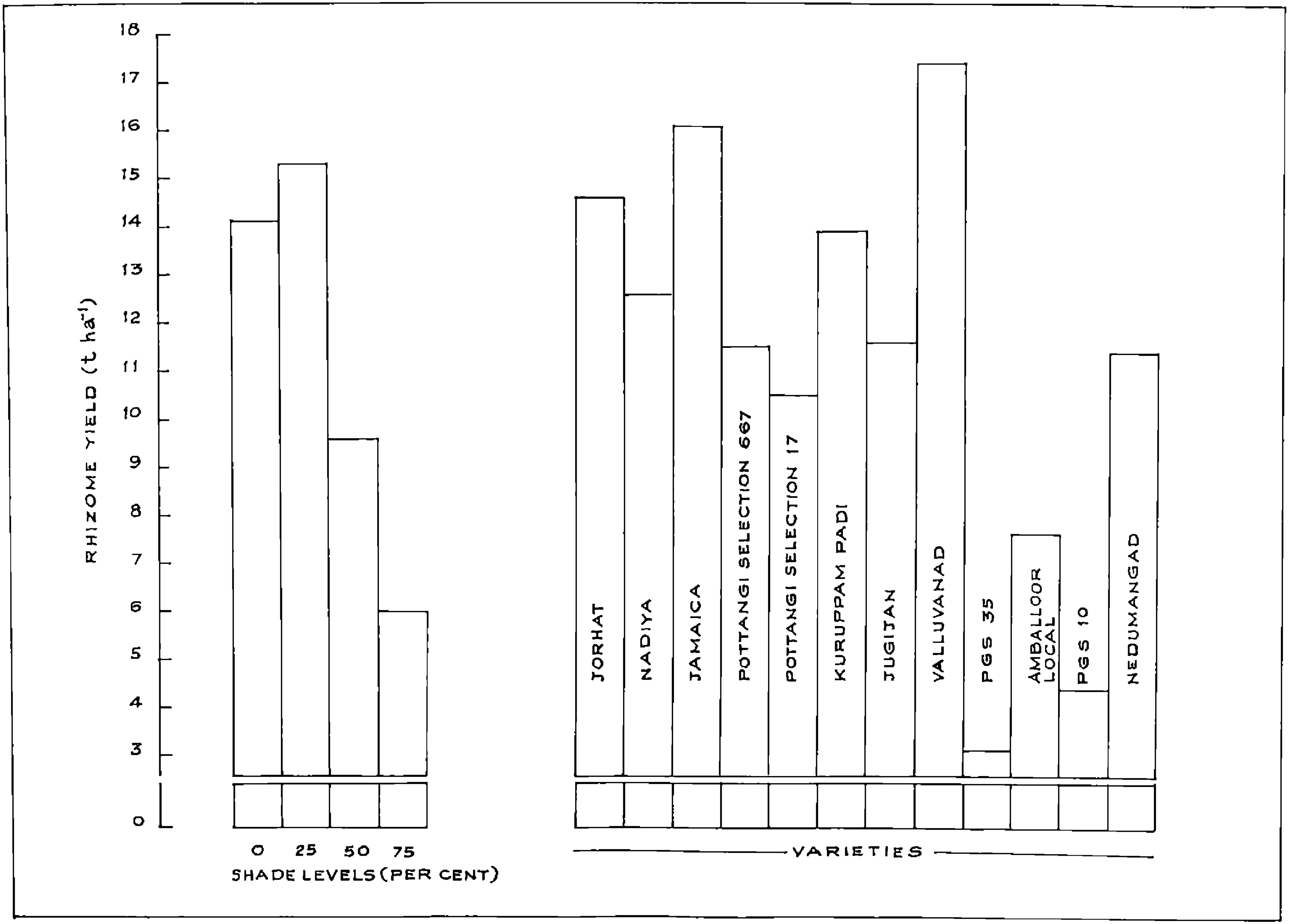
0 V_3 V_9 V_7 V_1 V_{13} V_2 V_8 V_6 V_4 V_{11} V_{12} V_{10}

25 V_9 V_4 V_3 V_1 V_8 V_2 V_7 V_{13} V_6 V_{11} V_{12} V_{10}

50 V_1 V_9 V_3 V_2 V_8 V_7 V_6 V_4 V_{13} V_{11} V_{12} V_{10}

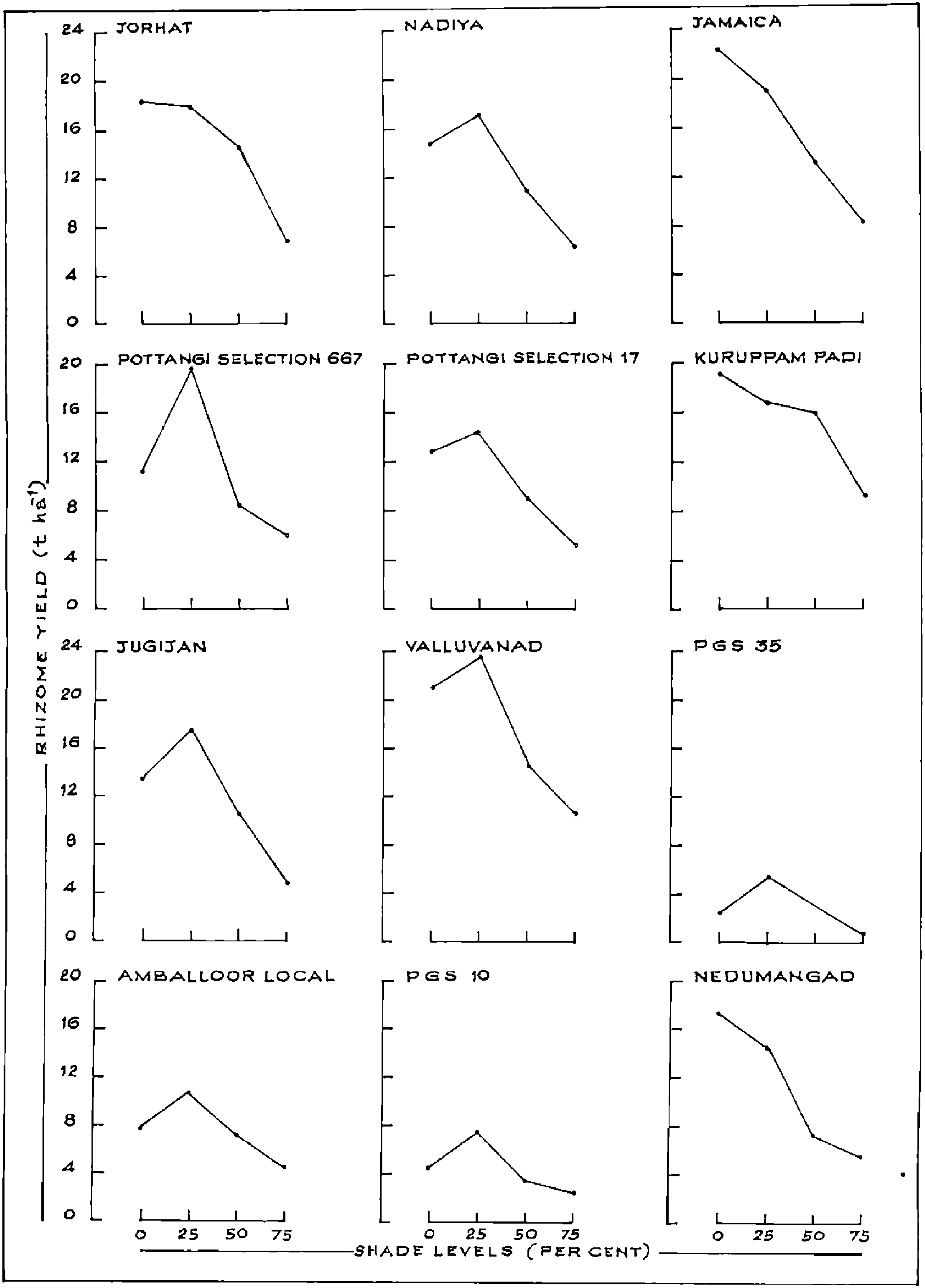
75 V_9 V_7 V_3 V_1 V_2 V_4 V_{13} V_6 V_8 V_{11} V_{12} V_{10}

Fig 2 Effect of shade on rhizome yield of ginger varieties (Analysis 3)



RHIZOME YIELD (t ha⁻¹)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
0
JORHAT
NADIYA
JAMAICA
POTTANGI SELECTION 667
POTTANGI SELECTION 17
KURUPPAM PADI
JUGIJAN
VALLUVANAD
PGS 35
AMBALLOOR LOCAL
PGS 10
NEDUMANGAD
0
25
50
75
SHADE LEVELS (PER CENT)
VARIETIES

Fig 3 Interaction effects of shade levels and ginger varieties on rhizome yield (Analysis 3)


RHIZOME YIELD (t ha⁻¹)
JORHAT
NADIYA
JAMAICA
POTTANGI SELECTION 667
POTTANGI SELECTION 17
KURUPPAM PADI
JUGIJAN
VALLUVANAD
PGS 35
AMBALLOOR LOCAL
PGS 10
NEDUMANGAD
0 4 8 12 16 20 24
0 25 50 75
SHADE LEVELS (PER CENT)

Since the moisture content of the rhizome appeared to increase with increasing shade, the data were analysed on dry weight basis also. Here also with increasing shade intensities, rhizome yield increased upto the light shade of 25 per cent and then decreased. The treatment T_2 had shown statistically significant superiority over other treatments, while T_1 and T_3 were found to be on par. Rhizome yields at 25, 50 and 75 per cent shade were 131, 81 and 62 per cent of that at 0 per cent, when analysed by deleting a few subplots. The corresponding figures obtained when analysed by deleting one replication and one subplot were 129, 88 and 58.

Data analysed in three ways followed almost the same trend in the case of shade levels while the pattern was different among varieties.

Among the varieties V_7 (Kuruppampadi) recorded the highest yield (2.2 t ha^{-1}) (Analysis 1). Varieties V_3 and V_2 were also found to be statistically on par with this variety. In the analysis (2) varieties V_9 and V_1 were found superior to others and the differences between these two varieties were statistically non significant. In analysis (3) also V_9 continued to be the best.

Lowest yielding varieties V_{10} and V_{12} recorded the lowest yield here also.

No significant interaction was noticed between shade levels and varieties.

4.1.7 Haulm yield (Table 11, Appendix 5)

Plants grown at 25 per cent shade gave the highest haulm yield and was on par with that at open.

Among the varieties V_{13} and V_{10} recorded the highest haulm yield when analysed by excluding the missing varieties, while V_6, gave the highest value when analysed by deleting one mainplot (T_1). Results analysed in two ways showed same trend.

4.1.8 Harvest index (Tables 11, 12 and 13, Appendix 5)

Plants at 25 per cent shade recorded the highest value and was statistically on par with that at 50 and 75 per cent. The pattern was almost same when analysed in two ways.

Among the varieties V_2, V_7 and V_3 registered the highest harvest index when analysed by deleting the missing varieties.

These varieties continue to record the highest value when analysed in the other way also along with V_1, V_9 and V_{11}.

Significant interaction was noticed between shade levels, and varieties.

Variety V_7 recorded the highest harvest index at 25 and 75 per cent shade, which was replaced by variety V_1 when analysed in the other way.

4.1.9 Percentage dryage (Table 11, Appendix 5)

With increase in shading there was a progressive increase in percentage dryage. The shade level T_4 recorded the highest value when analysed in both ways.

Among the varieties V_{11}, V_7, V_2 and V_1 were found to maintain higher percentage.

Table 11 Effect of shade on haulm yield, harvest index and percentage dryage of ginger Varieties

Treatments		Haulm yield t ha^{-1}		Harvest index		Percentage dryage	
		(1)	(2)	(1)	(2)	(1)	(2)
Levels of shade(per cent)							
T_1	0	3 7		0 33		11 7	-
T_2	25	3 9	4 2	0 39	0 39	14 6	14 3
T_3	50	3 1	3 3	0 36	0 37	15 3	15 0
T_4	75	2 2	2 3	0 36	0.37	16 9	16 3
SEm±		0 12	0 12	0 01	0 009	0 40	0 45
CD (0 05)		0 40	0 43	0 03	NS	1 29	NS
Varieties							
V_1	Jorhat		2 5	-	0 50	-	16 9
V_2	Nadiya	2 6	2.4	0 49	0.50	16 5	18 0
V_3	Jamaica	3 1	2 9	0 45	0 48	14 3	15 4
V_4	Pottangi Selection 667	3 0	2 8	0 40	0 40	16 2	
V_5	Rio de jeneiro		4 0		0 28		12 2
V_6	Pottangi Selection 17		5 0		0 25	-	12 1
V_7	Kuruppampadi	3 0	2 8	0 48	0 50	16 9	18 1
V_8	Jugijan	3 4	3 1	0 29	0 31	12 0	12 8
V_9	Valluvanad		3 3		0 47	-	16 0
V_{10}	PGS 35	3 7	3 6	0 18	0 18	9 9	10 6
V_{11}	Amaballoor Local	2 6	2 4	0 43	0 47	18 9	20.4
V_{12}	PGS 10	3 6	3 4	0 25	0 25	12 5	13 1
V_{13}	Nedumangad	4 2	4 2	0 32	0 30	15 2	15 6
SEm±		0 21	0 27	0 02	0 01	0 59	0.67
CD (0 05)		0 60	0 76	0 04	0 045	1 62	1 88

(1) Data analysed by deleting subplots (V_1, V_5, V_6 and V_9)

(2) Data analysed by deleting one mainplot (T_1)

		Mainplot	Subplot
Haulm yield	1)	T_2 T_1 T_3 T_4	V_{13} V_{10} V_{12} V_8 V_3 V_4 V_7 V_{11} V_2
	2)	T_2 T_3 T_4	V_6 V_{13} V_5 V_{10} V_{12} V_9 V_8 V_3 V_7 V_4 V_1 V_2 V_{11}
Harvest index	1)	T_2 T_3 T_4 T_1	V_2 V_7 V_3 V_{11} V_4 V_{13} V_8 V_{12} V_{10}
	2)	T_2 T_3 T_4	V_2 V_1 V_7 V_3 V_{11} V_9 V_4 V_8 V_{13} V_5 V_6 V_{12} V_{10}
Percentage dryage	1)	T_4 T_3 T_2 T_1	V_{11} V_7 V_2 V_4 V_{13} V_3 V_{12} V_8 V_{10}
	2)	T_4 T_3 T_2	V_{11} V_7 V_2 V_1 V_4 V_9 V_{13} V_3 V_{12} V_8 V_5 V_6 V_{10}

Table 12 Interaction effect of shade levels and ginger varieties on harvest index (Analysis 1)

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_2	Nadiya	0.45	0.51	0.48	0.50	0.49
V_3	Jamaica	0.37	0.47	0.52	0.45	0.45
V_4	Pottangi Selection 667	0.40	0.44	0.42	0.34	0.40
V_7	Kuruppampadi	0.41	0.54	0.44	0.53	0.48
V_8	Jugijan	0.23	0.29	0.36	0.28	0.29
V_{10}	PGS 35	0.15	0.20	0.15	0.22	0.18
V_{11}	Amballoor Local	0.29	0.50	0.47	0.45	0.43
V_{12}	PGS 10	0.24	0.29	0.19	0.29	0.25
V_{13}	Nedumangad	0.39	0.33	0.27	0.28	0.32
Mean		0.33	0.39	0.37	0.37	

Table 13 Interaction effects of shade levels and ginger varieties on harvest index (Analysis 2)

Varieties		Shade levels (per cent) 25	50	75	Mean
V_1	Jorhat	0.44	0.57	0.51	0.51
V_2	Nadiya	0.51	0.48	0.50	0.50
V_3	Jamaica	0.47	0.52	0.45	0.48
V_4	Pottangi Selection 667	0.44	0.42	0.34	0.40
V_5	Rio-de-jeneiro	0.30	0.24	0.31	0.28
V_6	Pottangi Selection17	0.24	0.26	0 25	0.25
V_7	Kuruppampadi	0.54	0.44	0.53	0.50
V_8	Jugijan	0.29	0.36	0.28	0.31
V_9	Valluvanad	0.48	0.48	0.46	0.47
V_{10}	PGS 35	0.20	0.15	0.22	0.19
V_{11}	Amballoor Local	0.50	0.47	0.45	0.47
V_{12}	PGS 10	0.29	0.19	0.29	0.25
V_{13}	Nedumangad	0.33	0.27	0.28	0.30
Mean		0.38	0.37	0.37	

No Significant interaction was noticed between shade levels and varieties.

4.2 Chemical Studies

4.2.1 Content of fertiliser nutrients (Table 14)

Nitrogen content of rhizome showed an increasing trend with increasing levels of shade with maximum content at 25 per cent shade level. Though the nitrogen content tended to decrease at 50 and 75 per cent shade, the contents at these shade levels were higher than that of control (open).

Variety with maximum nitrogen content in the rhizome was V_9 (Valluvanad) followed by V_3 (Jamaica) and V_{10} (PGS 35). The range in content of nitrogen between varieties was from 0.65 (Amballor Local) to 1.53 (Valluvanad). Nitrogen content of the haulm, prgressively decreased with increase in shade intensities from 0 to 75 per cent. The range in content of this nutrient in haulm in the different varieties was from 0.68 (PGS 35) to 1.4 (Pottangi Selection 17).

Phosphorus content of the rhizome decreased steadily with increasing shade levels. The content in the haulm, on the contrary, was found to increase to the level of 25 per cent shading, then decreased sharply at 50 per cent and there after remained steady upto the intense level of 75 per cent. Between varieties the variation in mean content of phosphorus was from 0.15 (Nedumangad) to 0.27 (Rio-de-jeneiro) in haulm and 0.30 (Amballoor Local) to 0.42 (Nadiya) in rhizome.

Not much difference was noticed in the potassium content of rhizome at varying intensities of shade. However, the content in haulm was found to increase with shade levels and the highest value

Table 14 Effect of shade on contents of N, P and K of ginger varieties at harvest

Treatment		Nitrogen %		Phosphorous %		Potassium %	
		Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome
Levels of shade (per cent)							
T_1	0	1.40	1.00	0.22	0.48	5.06	4.18
T_2	25	1.02	1.37	0.24	0.36	6.20	3.80
T_3	50	0.79	1.27	0.19	0.28	6.14	4.16
T_4	75	0.60	1.09	0.19	0.25	7.10	4.19
Varieties							
V_1	Jorhat	1.03	0.74	0.18	0.31	6.70	3.90
V_2	Nadiya	1.08	1.15	0.19	0.42	6.50	4.20
V_3	Jamaica	0.88	1.51	0.21	0.34	5.80	4.05
V_4	Pottangi Selection 667	1.10	1.08	0.19	0.31	5.80	3.25
V_5	Rid-de-jeneiro	1.30	1.10	0.27	0.37	6.02	5.07
V_6	Pottangi Selection 17	1.40	1.13	0.21	0.36	6.30	4.65
V_7	Kuruppampadi	1.02	1.18	0.22	0.32	6.50	3.70
V_8	Jugijan	0.84	1.36	0.18	0.37	5.90	5.10
V_9	Valluvanad	0.88	1.53	0.20	0.31	6.50	4.20
V_{10}	PGS 35	0.68	1.51	0.26	0.33	6.60	4.20
V_{11}	Amballoor Local	0.85	0.65	0.24	0.30	5.50	3.45
V_{12}	PGS 10	0.95	1.23	0.20	0.34	5.30	3.95
V_{13}	Nedumangad	0.76	1.20	0.15	0.41	5.90	3.47

was recorded at 75 per cent shade. Among the varieties potassium content of the rhizome ranged from 3.25 per cent (Pottangi Selection 667) to 5.1 per cent (Jugijan) whereas the range was from 5.3 (PGS 10) to 6.7 per cent (Jorhat) in the haulm.

4.2.2 Uptake of nutrients (Table 15)

The uptake of nitrogen increased from 0 per cent shade to 25 per cent and then showed a progressive and drastic decrease. Expressed as percentage of that in the open the uptake at 25, 50 and 75 per cent shade levels were 109, 75 and 51, respectively. The trend was almost same in the case of potassium also, the percentage uptake values at 25, 50 and 75 per cent shade levels being 118, 95 and 65, respectively. However, the uptake of phosphorus decreased with increasing shade intensities from 0 to 75 per cent. The uptake of this nutrient at 75 per cent shade was only 26 per cent of that at full illumination. The corresponding figures for 25 and 50 per cent shade levels were 74 and 46, respectively.

Varietal differences were noticed in the uptake of these nutrients. Variety, V_6 gave the maximum uptake of phosphorus and potassium. This variety recorded high value in the case of nitrogen also, but only next to V_9.

4.2.3 Oleoresin content (Table 15)

In general, ginger grown without shade yielded a higher oleoresin followed by 25 per cent shade imposition. There was a progressive decrease in the oleoresin content upto 50 per cent level of shade, afterwhich a marginal increase was noticed. The extent of decrease in oleoresin content at 50 per cent shade was about 25 per cent as compared to the open and the decreases were 9 and 19 per cent only at 25 and 75 per cent shade.

Table 15 Effect of shade on uptake of nutrients N, P and K and Oleoresin content in ginger varieties

Treatment		Uptake (kg ha^{-1})			Oleoresin (%)
		N	P	K	
Levels of shade (per cent)					
T_1	0	90.80	25.30	277.50	8.82
T_2	25	99.10	18.70	329.7	7.95
T_3	50	68.80	11.7	264.1	6.49
T_4	75	46.60	6.7	183.0	7.06
Varieties					
V_1	Jorhat	64.42	10.50	236.7	5.82
V_2	Nadiya	60.43	16.20	261.0	5.62
V_3	Jamaica	84.38	15.4	278.2	5.88
V_4	Pottangi Selection 667	72.53	13.10	236.4	7.26
V_5	Rio-de-jeneiro	82.15	14.70	250.8	9.23
V_6	Pottangi Selection 17	105.50	20.40	372.8	8.76
V_7	Kuruppampadi	79.0	18.20	291.1	6.38
V_8	Jugijan	65.8	13.10	236.8	9.36
V_9	Valluvanad	111.8	17.10	308.9	5.96
V_{10}	PGS 35	58.8	16.0	278.3	11.92
V_{11}	Amballoor Local	50.3	12.30	173.2	5.94
V_{12}	PGS 10	72.2	18.50	256.3	9.69
V_{13}	Nedumangad	84.8	17.50	246.1	7.48

4.3 Disease incidence

Varieties were scored for their disease susceptibility to bacterial wilt. The variety which was found highly susceptible was V_5 (Rio-de-jeneiro) and this variety was lost in open, from two of the four replications. The other varieties which were affected by this incidence were V_1, V_6 and V_9. These three varieties appeared to have acquired the disease because of their nearness to the susceptible variety, V_5. It is however to be noted that rest of the varieties in the open and all the varieties in the other three shade levels were totally free from this disease.

Turmeric

4.4 Biometric Observations

4.4.1 Plant height (Tables 16, 17 and 18, Appendix 6)

With increasing shade intensities, plant height increased upto the medium shade of 50 per cent and then progressively decreased. T_1 (open) gave the shortest plants and the difference was significant at all stages. At the initial stage of 60 days, the differences were not statistically significant between shade levels T_2, T_3 and T_4. At the next two stages, however the intense shade level of 75 per cent recorded significantly lower mean height values than the low and medium shade levels. The differences between the low and medium shade levels were not significant at any of the stages.

Differences were noticed among varieties in plant height, the overall range being 65.2 to 77, 88.3 to 116.8 and 81.8 to 118.1 cm at the three stages of observation. Varieties V_{11} and V_{10} had the maximum height at the later stages, though some other varieties recorded higher height values in the initial period. Variety V_6 (PCT 8) had shown lower values at all stages.

Variety x shade interaction was significant at 120 and 180 days. Variety V_{11} (B S R I) recorded maximum height at 25 and 50 per cent shade whereas varieties V_9 and V_1 gave maximum at 0 and 75 per cent shade, respectively 120 days after planting. At 180 days also V_{11} recorded maximum height at 25 and 50 per cent shade. At 75 per cent shade, V_{10} recorded the maximum height.

As expected, plant height showed an increase with advancing age at all shade levels and in most of the varieties, though a marginal

Table 16 Effect of shade on plant height and number of tillers of turmeric varieties

Treatments		Plant height (cm)			Number of tillers		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Levels of shade (per cent)							
T_1	0	60 4	93.8	91.7	1 6	3.8	3 3
T_2	25	74 2	117.0	113 9	1.2	1 7	1.7
T_3	50	74 5	116.6	115.0	1 3	1 6	1 5
T_4	75	71.2	98.0	95.0	1.2	1 3	1.4
SEm$\pm$		2 78	2.68	3.00	0.08	0 12	0 12
CD (0.05)		8.89	8.56	9 63	0 26	0 40	0 39
Varieties							
V_1	Myduckur	76.4	109.7	106.2	1.3	1.7	1.6
V_2	Armoor	72 1	97.6	93 5	1 2	1 9	1.9
V_3	PCT 2	71.7	106.9	104.6	1 5	2.4	2.4
V_4	PTS 9	65.2	105.3	106 9	1.3	1.9	1.9
V_5	Ethamatala	67 8	108 0	107.3	1 5	2.6	2 3
V_6	PCT 8	65.7	88.3	81 8	1 5	1.9	1.6
V_7	PTS 10	66.9	107.2	107 7	1.2	2 4	2.3
V_8	PTS 24	68.9	110 3	108.4	1.2	2 1	2.1
V_9	PCT 5	77.0	101.4	94.0	1.4	1.9	1.6
V_{10}	CO1	71.8	115.2	112.8	1.3	2 2	2.2
V_{11}	B S R 1	71.2	116.8	118 1	1.2	2 1	2.1
V_{12}	PTS 38	66 5	109 6	105.5	1 1	2 1	1.8
SEm$\pm$		2.16	2 55	2.59	0 09	0 14	0.15
CD (0.05)		6.00	7.08	7.19	0.27	0.39	0 42

	Mainplot	Subplot
Plant height 60 DAP	T_3 T_2 T_4 T_1	V_9 V_1 V_2 V_{10} V_3 V_{11} V_8 V_5 V_7 V_{12} V_6 V_4
Plant height 120 DAP	T_2 T_3 T_4 T_1	V_{11} V_{10} V_8 V_1 V_{12} V_5 V_7 V_3 V_4 V_9 V_2 V_6
Plant height 180 DAP	T_3 T_2 T_4 T_1	V_{11} V_{10} V_8 V_7 V_5 V_4 V_1 V_{12} V_3 V_9 V_2 V_6
Number of tillers 60 DAP	T_1 T_3 T_4 T_2	V_3 V_6 V_5 V_9 V_1 V_4 V_{10} V_2 V_7 V_8 V_{11} V_{12}
Number of tillers 120 DAP	T_1 T_2 T_3 T_4	V_5 V_3 V_7 V_{10} V_{11} V_{12} V_8 V_2 V_4 V_6 V_9 V_1
Number of tillers 180 DAP	T_2 T_3 T_4 T_1	V_3 V_5 V_7 V_{10} V_8 V_{11} V_2 V_4 V_{12} V_1 V_6 V_9

Table 17 Interaction effects of shade levels and turmeric varieties on plant height at 120 days after planting

Varities		Shade levels (%)				Mean
		0 (cm)	25 (cm)	50 (cm)	75 (cm)	
V_1	Myduckur	90.5	110.8	127.3	110.3	109.7
V_2	Armoor	89.7	107.3	104.7	88.6	97.6
V_3	PCT 2	92.5	120.0	107.0	108.2	106.9
V_4	PTS 9	98.3	120.0	118.2	84.8	105.3
V_5	Ethamatala	85.6	124.7	119.7	102.1	108.0
V_6	PCT 8	92.2	101.6	81.1	78.2	88.3
V_7	PTS 10	94.2	108.8	126.0	100.0	107.2
V_8	PTS 24	89.0	127.8	120.4	103.9	110.3
V_9	PCT 5	101.1	112.3	104.8	87.5	101.4
V_{10}	CO 1	100.1	122.7	127.8	110.1	115.2
V_{11}	B S R I	99.1	128.8	136.3	102.8	116.8
V_{12}	PTS 38	93.7	119.9	125.3	99.5	109.6
Mean		93.8	117.0	116.6	98.0	

Table 18 Interaction effects of shade levels and turmeric varieties on plant height at 180 days after planting

Varieties		Shade levels (%)				Mean
		0 (cm)	25 (cm)	50 (cm)	75 (cm)	
V_1	Myduckur	88.0	106.8	125.0	105.0	106.2
V_2	Armoor	89.4	100.4	100.5	83.80	93.5
V_3	PCT 2	91.4	115.8	106.0	105.20	104.6
V_4	PTS 9	96.9	122.7	121.9	86.2	107.0
V_5	Ethamatala	88.1	123.8	118.3	98.8	107.3
V_6	PCT 8	85.3	94.7	76.7	70.6	81.8
V_7	PTS 10	94.5	109.3	126.4	100.9	107.7
V_8	PTS 24	85.7	125.2	119.0	103.8	108.4
V_9	PCT 5	97.5	98.7	98.40	81.2	94.0
V_{10}	CO 1	96.6	122.0	125.1	107.4	112.8
V_{11}	B S R 1	99.5	132.3	136.7	103.9	118.1
V_{12}	PTS 38	88.1	115.6	125.7	92.6	105.5
Mean		91.7	113.9	115.0	95.0	

decrease was noticed at 180th day.

4.4.2 Number of tillers (Tables 16 and 19, Appendix 6)

The general trend was a decrease in the number of tillers with an increase in shade. The differences were significant at all the stages with the number of tillers being significantly higher in the open. The differences between remaining three levels, however, were not statistically significant.

Percentage tillering at 25 per cent shade was 75, 45 and 52 at 60, 120 and 180 days, respectively. The corresponding figures at 50 and 75 per cent shade were 82, 63 and 46 and 75, 35 and 63 per cent, respectively, of full illumination.

Significant differences were noticed among the varieties in tiller number. Varieties V_3 and V_5 recorded maximum tiller number at all stages studied from 60 to 180 days.

Variety x shade interaction was significant at 120 days. Varieties V_7, V_3 and V_8 recorded maximum tiller number at 0, 25 and 50 per cent shade, respectively. At 75 per cent shade, varieties V_2 and V_6, gave the maximum number.

With advancing age tiller number was found to increase at all shade levels and in most of the varieties upto 120th day, after which it remained almost same at 25, 50 and 75 per cent shade. But the plants grown in the open showed a drastic decrease in tiller number at 180 days.

4.4.3 Number of leaves (Table 20, Appendix 7)

Significant effect of shade on number of leaves was noticed at 120 days only, when the treatment T_1 significantly differed from

Table 19 Interaction effects of shade levels and turmeric varieties on number of tillers at 120 days after planting

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_1	Myduckur	3.3	1.2	1.1	1.1	1.7
V_2	Armoor	3.1	1.5	1.3	1.7	1.9
V_3	PCT 2	3.9	2.5	1.8	1.4	2.4
V_4	PTS 9	2.9	1.6	1.6	1.5	1.9
V_5	Ethamatala	4.9	2.4	1.7	1.3	2.6
V_6	PCT 8	2.8	1.4	1.8	1.7	1.9
V_7	PTS 10	5.5	1.6	1.4	1.3	2.4
V_8	PTS 24	3.6	1.5	1.9	1.4	2.1
V_9	PCT 5	3.2	1.7	1.5	1.4	1.9
V_{10}	Co 1	4.4	1.6	1.6	1.1	2.2
V_{11}	B S R 1	4.1	1.5	1.8	1.1	2.1
V_{12}	PTS 38	4.0	1.7	1.5	1.2	2.1
Mean		3.8	1.7	1.6	1.3	

the rest with maximum number of leaves. At 60 and 180 days, no significant difference was noticed between treatments though the trend was one of superiority of T_1 (open) and of a steady decrease in leaf number with increasing shade.

Between varieties, the differences were significant and V_5 and V_3 recorded maximum number of leaves at 60 and 120 days. At 180 days, the pattern was different and higher mean values were recorded by V_{11} and V_8.

With advancing age, number of leaves increased upto 120 days and then decreased, the extent of decrease being maximum at 0 per cent shade.

No significant interaction was noticed between shade levels and varieties at any of the stages.

4.4.4 Drymatter production (Table 20, Appendix 7)

With increase in shading, a progressive decrease was noticed in drymatter production. The lowest drymatter was seen in 75 per cent shade. Drymatter production at 25, 50 and 75 per cent shade were 75, 63 and 46 per cent of the dry weight in the open, respectively.

Among the varieties, the minimum drymatter accumulation was noticed in V_2 as against the higher value registered in V_9. The range was from 26.4 to 38.2 g plant^{-1}.

4.4.5 Chlorophyll content (Table 21)

Total chlorophyll content and its components chlorophyll a and chlorophyll b increased steadily with increasing levels of shade at all stages.

Table 20 Effect of shade on number of leaves and drymatter production of turmeric varieties

Treatments		Number of leaves 60 DAP	Number of leaves 120 DAP	Number of leaves 180 DAP	Drymatter production g plant^{-1}
Levels of shade (per cent)					
T_1	0	8 9	16 5	3.1	45.9
T_2	25	7 5	10 6	3 4	34.3
T_3	50	7 7	11.0	2 8	28.8
T_4	75	7.0	9.6	2.7	20.8
SEm$\pm$		0 54	0.71	0.31	1.84
CD (0 05)		NS	2 29	NS	2.24
Varieties					
V_1	Myduckur	8.0	10 3	2.0	27.6
V_2	Armoor	6 8	9 2	3 1	26.4
V_3	PCT 2	8.6	13.3	3.6	35 4
V_4	PTS 9	7.9	11 7	2 8	32.6
V_5	Ethamatala	9 3	15.2	3.4	35.0
V_6	PCT 8	8.6	10 9	0.2	27 6
V_7	PTS 10	7 4	12.2	3 5	32.0
V_8	PTS 24	7.2	12 1	4.2	34 9
V_9	PCT 5	8.2	11 1	1.6	38.2
V_{10}	CO1	6.9	13 0	3 7	32.1
V_{11}	B S R 1	7 3	12.6	4.4	37.1
V_{12}	PTS 38	7.1	11.4	3.6	30.6
SEm$\pm$		0.41	0.58	0.37	2 24
CD (0 05)		1 13	1 63	1.04	6.23

	Mainplot	Subplot
Number of leaves 60 DAP	T_1 T_3 T_2 T_4	V_5 V_3 V_6 V_9 V_1 V_4 V_7 V_{11} V_8 V_{12} V_{10} V_2
Number of leaves 120 DAP	T_1 T_3 T_2 T_4	V_5 V_3 V_{10} V_{11} V_7 V_8 V_4 V_{12} V_9 V_6 V_1 V_2
Number of leaves 180 DAP	T_2 T_1 T_3 T_4	V_{11} V_8 V_{10} V_3 V_{12} V_7 V_5 V_2 V_4 V_1 V_9 V_6

Table 21 Effect of shade on contents of chlorophyll fractions of turmeric varieties

Treatments		Chlorophyll a mg g^{-1} fresh weight		Chlorophyll b mg g^{-1} fresh weight		Chlorophyll a+b mg g^{-1} fresh weight		Chlorophyll a/b	
		100 DAP	150 DAP	100 DAP	150 DAP	100 DAP	150 DAP	100 DAP	150 DAP
Levels of shade (%)									
T_1	0	0.48	0.38	0.35	0.26	0.83	0.64	1.37	1.46
T_2	25	0.99	0.71	0.67	0.45	1.66	1.17	1.47	1.57
T_3	50	1.03	0.87	0.74	0.54	1.77	1.42	1.39	1.61
T_4	75	1.13	1.12	0.76	0.60	1.89	1.72	1.48	1.86
Varieties									
V_1	Myduckur	0.82	0.74	0.60	0.50	1.42	1.24	1.39	1.49
V_2	Armoor	0.85	0.77	0.61	0.52	1.46	1.29	1.36	1.44
V_3	PCT 2	0.88	0.90	0.60	0.50	1.48	1.40	1.48	1.82
V_4	PTS 9	0.98	0.82	0.70	0.49	1.68	1.31	1.45	1.59
V_5	Ethamatala	0.96	0.74	0.67	0.36	1.64	1.10	1.47	1.97
V_6	PCT 8	0.88	0.92	0.61	0.63	1.49	1.55	1.43	1.42
V_7	PTS 10	0.84	0.83	0.57	0.46	1.41	1.29	1.49	1.83
V_8	PTS 24	1.04	0.81	0.75	0.40	1.79	1.21	1.40	2.01
V_9	PCT 5	0.85	0.83	0.61	0.43	1.46	1.26	1.38	1.90
V_{10}	CO 1	0 91	0.64	0.65	0.48	1.56	1.12	1.45	1.54
V_{11}	B S R 1	0.93	0.54	0.54	0.35	1.17	0.90	1.73	1.53
V_{12}	PTS 38	0.91	0.73	0.65	0.42	1.56	1.15	1.36	1.68

Variety V_8 recorded the highest total chlorophyll content and its fractions at 100 days, where as at 150 days V_6 had the highest content of both the fractions and hence the highest chlorophyll content.

Over the stages, marked differences appeared in values with a fall in both the chlorophyll components at 150 days. Chlorophyll b was found to decrease more than chlorphyll a with age, hence chlorophyll a to b ratio tended to increase.

4.4.6 Rhizome yield (Tables 22, 23 and 24, Fig 4 and 5, Appendix 8)

With increase in shading, there was a progressive decrease in rhizome yield and the difference was highly significant. The yield at 75 per cent shade was only 30 per cent of that at full illumination. The corresponding figures at 25 and 50 per cent shade were 74 and 55 on fresh weight basis. Data analysed on dry weight basis also followed the same trend, the percentages of yields at the increasing shade levels being 78, 63 and 36, respectively.

Among the varieties V_9 (PCT 5) recorded the highest yield (15.9 t ha^{-1}). The other varieties that had shown statistical equality with this were V_{11}, V_{10}, V_3, V_5 and V_4. On a dry weight basis also V_9 gave the highest value (3.5 t ha^{-1}) followed by V_3, V_6 and V_5 and these three varieties were found to be statistically on par.

Results analysed in both fresh and dry weight basis showed significant interaction between varieties and shade levels, shading reduced yield in all varieties but one variety V_8 recorded the highest yield at 25 per cent shade, when analysed on a fresh weight basis. Variety V_9 (PCT 5) gave the highest yield at 0 per cent shade while the highest yielding varieties at 25, 50 and 75 per cent were V_8, V_{11} and V_1.

Variety V_9 recorded the highest yield at all shade levels when analysed on dry weight basis except at 50 per cent when V_1 gave the highest value. It was remarkable to note that with increasing shade levels, more and more varieties came to statistical parity with the highest yielding one.

Though the data are not sufficient for drawing final conclusions on the selection of varieties for the different shade levels, variety V_9 may be taken to be the best for the open based on the available data. This variety appeared good for two shade situations (25 and 75 per cent) also on dry weight basis.

4.4.7 Haulm yield (Table 22, Appendix 8)

The trend of haulm yield variation was same as that of rhizome. The maximum shading recorded the lowest yield.

Among the varieties V_{11} (B S R I) recorded the highest haulm yield as against the lowest yield registered in V_6.

4.4.8 Harvest index (Table 22, Appendix 8)

Harvest index failed to show any statistically significant difference between shade levels.

Among the varieties, havrvest index ranged from 0.30 (B S R I) to 0.56 (PCT 5).

4.4.9 Percentage dryage (Table 22, Appendix 8)

Shading increased the percentage dryage. Treatment T_4 differed significantly from the rest and recorded the highest value. The percentage dryage at this level of shading was 24 per cent higher than that at 0 per cent.

Table 22 Effect of shade on rhizome yield, haulm yield harvest index and percentage dryage of turmeric varieties

Tratments		Rhizome yield Fresh weight basis t ha-1	Rhizome yield Dry weight basis t ha 1	Haulm Yield (t ha 1)	Harvest index	Percentage Dryage
Levels of shade (per cent)						
T_1	0	19 3	3.3	5 9	0 40	16 9
T_2	25	14 2	2.6	4.4	0 41	18 5
T_3	50	10 7	2 1	3 9	0.38	19 0
T_4	75	5 8	1 2	2 8	0 39	21.0
SEm+		0 88	0 12	0 21	0 01	0 54
CD (0 05)		2 82	0 41	0 68	NS	1 73
Varieties						
V_1	Myduckur	12 2	2 2	4 0	0 34	17 1
V_2	Armoor	9 0	1 6	3 9	0 32	18 8
V_3	PCT 2	13 4	2 8	4 0	0 46	21 1
V_4	PTS	13 0	2 2	4 2	0 42	17 4
V_5	Ethamatala	13 1	2 6	4 1	0 44	20 4
V_6	PCT 8	11 5	2 7	2 7	0 54	24.4
V_7	PTS 10	11 3	1 9	4 5	0.37	17.9
V_8	PTS 24	12 7	2 0	5 0	0 35	16 7
V_9	PCT 5	15 9	3 5	3 6	0.56	23 2
V_{10}	CO 1	13 4	2 1	4 8	0 33	16 2
V_{11}	B S R 1	13 5	2 1	5 7	0 30	16 5
V_{12}	PTS 38	10.7	1 7	4 2	0 36	16 6
SEm+		1 11	0 20	0 29	0 01	0 68
CD (0 05)		3 08	0 55	0 82	0 05	1 89

		Mainplot	Subplot
1)	Rhizome yield		
	1) Fresh weight basis	T_1 T_2 T_3 T_4	V_9 V_{11} V_{10} V_3 V_5 V_4 V_8 V_1 V_6 V_7 V_{12} V_2
	2) Dry weight basis	T_1 T_2 T_3 T_4	V_9 V_3 V_6 V_5 V_4 V_1 V_{10} V_{11} V_8 V_7 V_{12} V_2
2)	Haulm yield	T_1 T_2 T_3 T_4	V_{11} V_8 V_{10} V_7 V_4 V_{12} V_5 V_3 V_1 V_2 V_9 V_6
3)	Harvest index	T_1 T_2 T_3 T_4	V_9 V_6 V_3 V_5 V_4 V_7 V_{12} V_8 V_1 V_{10} V_2 V_{11}
4)	Percentage dryage	T_4 T_3 T_2 T_1	V_6 V_9 V_3 V_5 V_2 V_7 V_4 V_1 V_8 V_{12} V_{11} V_{10}

Table 23 Interaction effects of shade levels and turmeric varieties on rhizome yield on fresh weight basis (t ha^{-1})

Varieties		Shade levels (per cent)				Mean
		0	25	50	75	
V_1	Myduckur	17 8	11 1	12 8	7 2	12 2
V_2	Armoor	12 7	12 0	7 6	3 8	9 0
V_3	PCT 2	20 4	18 0	8 0	7 2	13 4
V_4	PTS 9	18 2	15 3	13 0	5.3	13 0
V_5	Ethamatala	22 6	13 0	10 7	6 2	13 1
V_6	PCT 8	21.0	12 8	7 0	4.9	11.5
V_7	PTS 10	16.8	11 5	12 8	4.0	11.3
V_8	PTS 24	14 9	19 1	9 7	7 1	12.7
V_9	PCT 5	31.8	16 2	8 7	6 8	15 9
V_{10}	CO 1	20 2	16 1	11 5	6 0	13 4
V_{11}	B S R 1	18.4	15 6	13 4	6 8	13 5
V_{12}	PTS 38	16 4	9.0	13 0	4 2	10 7
		19 3	14 2	10 7	5.8	

SEm± 3.14

CD (0 05) 6.16

0 V_9 V_5 V_6 V_3 V_{10} V_{11} V_4 V_1 V_7 V_{12} V_8 V_2

25 V_8 V_3 V_9 V_{10} V_{11} V_4 V_5 V_6 V_2 V_7 V_1 V_{12}

50 V_{11} V_4 V_{12} V_7 V_1 V_{10} V_5 V_8 V_9 V_3 V_2 V_6

75 V_1 V_3 V_8 V_9 V_{11} V_5 V_{10} V_4 V_6 V_{12} V_7 V_2

Table 24 Interaction effects of shade levels and turmeric varieties on rhizome yield on dry weight basis (t ha 1)

Varieties		Shade levels(per cent) 0	25	50	75	Mean
V_1	Myduckur	2 12	2.00	3 54	1 26	2 24
V_2	Armoor	2 85	2 11	1 53	8 80	1 63
V_3	PCT 2	4 45	3 47	1 60	1 65	2 80
V_4	PTS 9	2 85	2 84	2 02	0 97	2 17
V_5	Ethamalala	4 34	2 51	2 24	1 33	2 60
V_6	PCT 8	4 53	3 05	1 71	1 32	2 66
V_7	PTS 10	2 48	1.94	2 27	0 82	1 88
V_8	PTS 24	2 36	2 83	1 70	1 22	2 03
V_9	PCT 5	6 52	3 64	2 02	1 93	3 53
V_{10}	CO 1	2 98	2 33	1.92	1 10	2.09
V_{11}	B S R 1	2 16	2 62	2 27	1.26	2 08
V_{12}	PTS 38	2.59	1.45	2 0	0 74	1 70
Mean		3.28	2 56	2 07	1 20	
SEm±	0.56					
CD (0.05)	1 10					

0 V_9 V_6 V_3 V_5 V_{10} V_4 V_{12} V_7 V_8 V_{11} V_1 V_2

25 V_9 V_3 V_6 V_4 V_8 V_{11} V_5 V_{10} V_2 V_1 V_7 V_{12}

50 V_1 V_7 V_{11} V_5 V_9 V_4 V_{12} V_{10} V_6 V_8 V_3 V_2

75 V_9 V_3 V_5 V_6 V_1 V_{11} V_8 V_{10} V_4 V_7 V_2 V_{12}

Fig 4 Effect of shade on rhizome yield of turmeric varieties

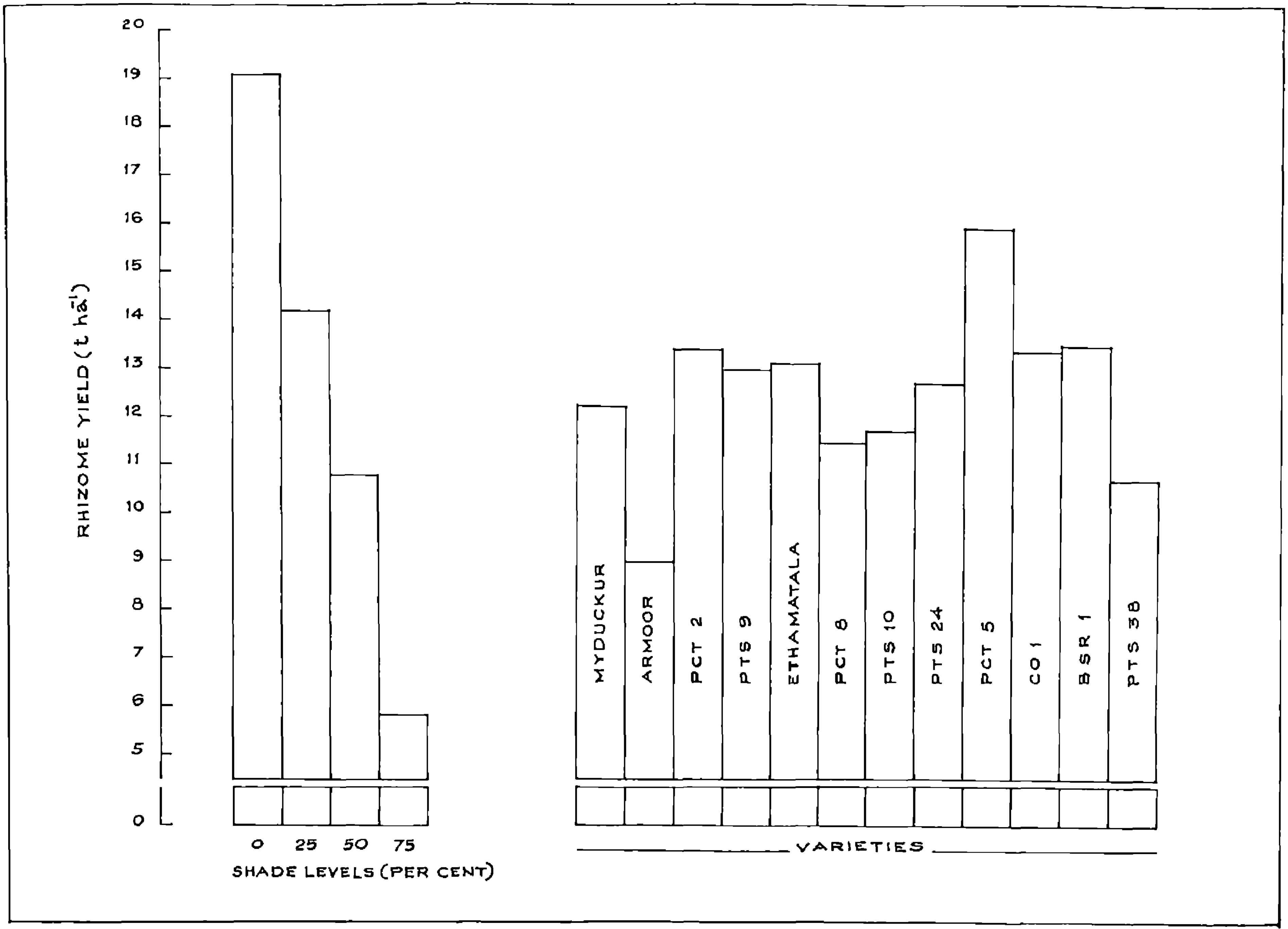
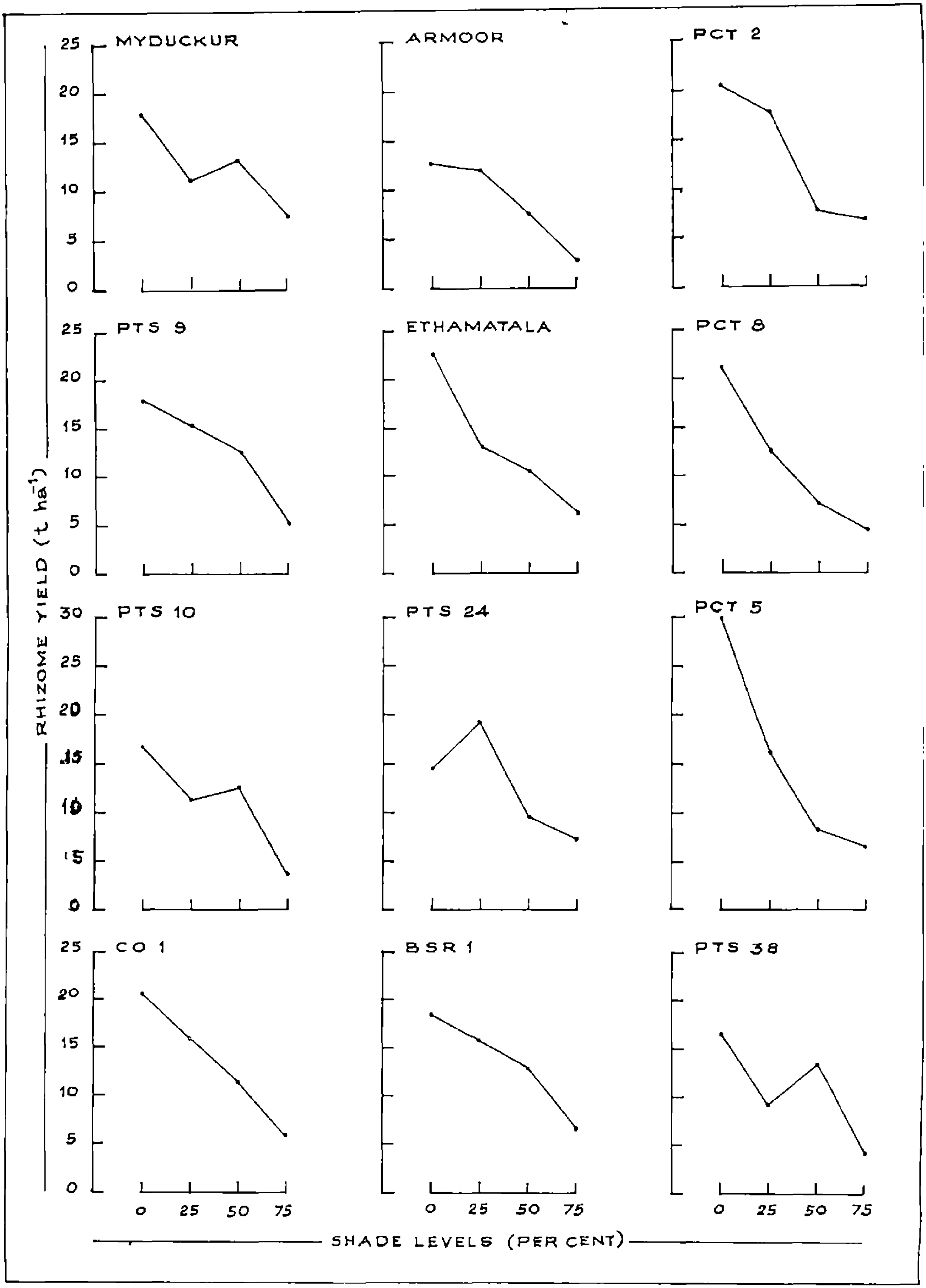

RHIZOME YIELD (t ha⁻¹)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
0
MYDUCKUR
ARMOOR
PCT 2
PTS 9
ETHAMATALA
PCT 8
PTS 10
PTS 24
PCT 5
CO 1
BSR 1
PTS 38
0
25
50
75
SHADE LEVELS (PER CENT)
VARIETIES

Fig 5 Interaction effects of shade levels and turmeric varieties on rhizome yield


MYDUCKUR
ARMOOR
PCT 2
PTS 9
ETHAMATALA
PCT 8
PTS 10
PTS 24
PCT 5
CO 1
BSR 1
PTS 38
RHIZOME YIELD (t ha-1)
0
25
50
75
SHADE LEVELS (PER CENT)

Varietal differences were also noticed. Varieties V_6 V_9 recorded the highest percentage dryage and these significantly differed from the rest of the varieties.

4.5 Chemical Studies

4.5.1 Content of fertiliser nutrients (Table 25)

Nitrogen content of the rhizome and haulm increased with shade intensities. Comparing between rhizome and haulm, rhizomes were found to have more nitrogen content.

Varieties V_4 and V_5 recorded maximum rhizome nitrogen content while V_2 followed by V_4 recorded the maximum content in haulm.

Not much differerencewas noticed between treatments of shade with respect to phosphorus content. However, an increasing trend was noticed in the case of haulm and a reverse trend in rhizome.

Variety V_6 recorded maximum content of phosphorus in rhizome, while V_1 had the maximum in haulm.

Potassium content of the haulm went on increasing with increasing shade upto the intense level of 75 per cent while plants grown at 50 per cent shade had the highest potassium content in rhizome. In general, haulm contained more potassium than rhizome.

Differences were noticed among varieties in their content of this nutrient. Variety V_2 had the maximum content in rhizome whereas V_{12} recorded the highest content in haulm.

Table 25 Effect of shade on contents of nutrients N, P and K of turmeric varieties

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium(%)	
		Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome
Levels of Shade(%)							
T_1	0	0.47	0.90	0.11	0.36	2.90	3.09
T_2	25	0.60	0.90	0.11	0.31	3.92	2.71
T_3	50	0.61	1.11	0.12	0.33	5.09	3.5
T_4	75	0.60	1.17	0.15	0.33	5.92	3.15
Varieties							
V_1	Myduckur	0.57	1.18	0.15	0.34	3.75	3.4
V_2	Armoor	0.72	0.95	0.13	0.32	4.00	3.7
V_3	PCT 2	0.52	1.02	0.13	0.37	4.87	2.7
V_4	PTS 9	0.64	1.27	0.12	0.34	3.40	3.4
V_5	Ethamatala	0.52	1.27	0.12	0.36	5.45	3.4
V_6	PCT 8	0.49	1.16	0.10	0.43	2.65	3.2
V_7	PTS 10	0.58	0.93	0.13	0.34	5.65	3.5
V_8	PTS 24	0.55	0.77	0.13	0.34	3.15	3.2
V_9	PCT 5	0.53	0.98	0.08	0.33	3.82	2.6
V_{10}	CO 1	0.63	0.93	0.13	0.32	5.27	3.3
V_{11}	B S R 1	0.55	0.81	0.13	0.27	5.62	2.2
V_{12}	PTS 38	0.57	1.00	0.12	0.30	5.90	3.2

4.5.2 Uptake of nutrients (Table 26)

Uptake of all the nutrients was found to decrease with shade except potassium where uptake was maximum at 50 per cent shade.

Varietal differences were also noticed in the uptake of nutrients. Variety V_5 (Ethamatala) recorded maximum uptake of phosphorus and potassium but nitrogen uptake was maximum in the variety V_4 (PTS 9) followed by V_5 (Ethamatala).

4.5.3 Curcumin content (Table 26)

As the shade was increased from 0 to 75 per cent, the curcumin content decreased from 5.9 to 3.9. The percentage decrease in curcumin content was only 5.2 at 25 per cent shade which increased to 29 and 24 at 50 and 75 per cent, respectively.

The curcumin content of varieties ranged from 2.3 (PCT 8) to 6.0 (PTS 24).

Table 26 Effect of shade on uptake of nutrients N, P and K and curcumin content of turmeric varieties

Treatments		Nitrogen kg ha^{-1}	Phosphorus kg ha^{-1}	Potassium kg ha^{-1}	Curcumin (%)
Levels of shade (Per cent)					
T_1	0	81.26	19.86	245.8	5.9
T_2	25	72.98	12.50	249.1	5.6
T_3	50	67.86	12.40	259.8	4.2
T_4	75	65.52	10.15	210.8	3.9
Varieties					
V_1	Myduckur	66.7	12.3	215.8	4.05
V_2	Armoor	63.2	11.3	262.5	5.61
V_3	PCT 2	81.4	14.2	238.9	5.06
V_4	PTS 9	93.7	9.1	178.3	5.2
V_5	Ethamatala	87.9	23.2	364.2	5.0
V_6	PCT 8	69.5	17.6	180.2	2.3
V_7	PTS 10	64.0	10.9	267.0	5.9
V_8	PTS 24	58.3	13.7	220.4	6.0
V_9	PCT 5	75.6	17.6	195.1	2.9
V_{10}	CO 1	62.3	11.6	269.6	5.6
V_{11}	B S R 1	63.3	12.5	288.5	5.5
V_{12}	PTS 38	60.0	10.9	262.2	5.5

Discussion

5. DISCUSSION

The present investigation was designed to find out how far the different shade levels alter the performance of ginger and turmeric varieties as compared to full open light. An overall assessment of the behaviour of these varieties in open as well as under varying intensities of shade has been made to gain information on these.

Ginger

Results indicated that in most of the varieties shading increased the rhizome yield upto the light shade of 25 per cent and then decreased. The maximum shading (75 per cent) recorded the lowest yield in all the varieties. The yields at 25, 50 and 75 per cent shade levels expressed as percentages of that in the open were 115, 68 and 48 (Analysis 1) and 108, 68 and 42 (Analysis 3) on fresh weight basis and 131, 81 and 62 (Analysis 1) and 129, 88 and 58 (Analysis 3) on dry weight basis, respectively. As yields tend to be higher at a certain level of shade than in the open, ginger varieties tested appear to fall generally in the category of shade loving plants. Similar results were earlier reported by Bai and Nair (1982). Such a better performance under 25 per cent shade may be explained due to the higher rate of photosynthesis, as indicated by the highest dry matter production coupled with the highest harvest index recorded at this level of shading. Better performance of this crop under shade than in the open has been reported earlier by Aclan and Quisumbing (1976). In crops like tomatoes (El. Aidy, 1984), coffee (Santos and Napoles, 1985), pineapple (Nayar et al., 1979) and tea (Barua and Sarma, 1982) also such trend has been reported. The explanation given by Hardy (1958) for the better performance of crops under shade than in the open is that there is often a threshold illumination intensity beyond which the stomata of shade loving plants tend to close. The same can be one of the reasons for the better performance of ginger under shade. However, reports on such a stomatal behaviour of ginger were not available from literature. Assuming that this was the factor responsible for the shade response of this crop, it may be deduced that the stomatal closure had the dominant influence upto the light shade of 25 per cent, beyond which availability of light for photosynthesis, probably, became the decisive limiting factor.

Since yield is a function of harvest index and drymatter accumulation the trends in these two parameters have been analysed to understand their respective contribution to yield. Drymatter accumulation by plants followed strictly the same trend as that of rhizome yield and the percentage values at 25, 50 and 75 per cent shade levels were 115, 86 and 63, respectively. These data on drymatter accumulation show that shading did not result in any appreciable decrease in the rate of photosynthesis upto 25 per cent shade. Not only that there was no decrease in photosynthesis, shading also tended to increase the drymatter accumulation by plants. This is in conformity with the findings of Ravisankar and Muthuswamy (1986). As regards havest index, significantly higher values were noticed at 25 per cent shade followed by 50 and 75 per cent though the differences among these three treatments were not statistically significant. Hence it appears that translocation of carbohydrates to economic part was increased by shading. This may be an exception as the commonly reported observation is one of substantial decrease in havest index in most crops (Ramanajum et al., 1984 on cassava, Senaguptha and Jahav, 1988 on groundnut, Singh, 1988 on potato and Rai and Murthy, 1977 on rice). Eventhough the higher harvest index values were noted at 50 and 75 per cent, the influence of this was not reflected on rhizome yield, presumably because of lower rate of photosynthesis at intense shade as indicated by lower drymatter accumulation.

An increase in the ratio of leaf area to leaf weight with shading has been reported (Cooper and Qualls, 1967). This may represent an adaptive mechanism, since for each unit weight of drymatter partioned into leaves a greater amount of area is exposed to available light. Though details on such aspects are not collected in the present study, this can also be one of the reasons for the better growth and yield of this crop under shade.

As compared to drymatter accumulation and yield, growth characters like plant height,number of leaves and number of tillers followed slightly different pattern. In the case of tiller number and number of leaves there was almost a steady decrease with increase in shade intensities, while plant height went on increasing with increase in shading. The increase in plant height under shade may be due to cell elongation and resulting internodal elongation. An increase in plant height under shade has earlier been reported in ginger (Bai and Nair, 1982) and cassava (Ramanujam et al., 1984 and Sreekumar et al., 1988). The relationship between shade levels and chlorophyll content of ginger varieties was direct. This is in agreement with the general trend of results of such studies as included in the review (Cooper and Qualls, 1967, Grant and Ryug, 1984, Radha, 1979, Bjorkman, 1968, Nayak et al., 1978, Bai, 1981, Vijayakumar et al., 1985 and Anderson, 1985).

Among the varieties, V_3 and V_9 recorded significantly higher rhizome yield. Among the growth parameters, plant height, number of tillers and number of leaves also were found to be generally higher in these varieties. Significant yield differences between varieties were brought about mainly by the inability to translocate carbohydrate produced into rhizome in varieties V_5, V_6 and V_{13} as indicated by the high drymatter yield of these varieties and low values of harvest index. The photosynthates produced was thus, inefficiently utilised by these varieties in which case more than two third of total carbohydrate synthesised contributed towards haulm yield. The low rate of drymatter production was found to be the reason for low yield in variety V_{11}. But both photosynthate production and its translocation were found to be the factors responsible for the low yield of varieties V_{10}, V_{12} and V_8.

Though the overall trend appeared to be one of advantage due to mild shading in nearly all the varieties, the shade responses of these were different as indicated by significance of interaction effects. The varieties V_9 and V_3 had proved their superiority over others by being high yielding in the open as well as under shade, as evidenced from the interaction table. Differential response of these varieties to shade may be explained due to the differences in the partitioning of assimilates because no significant interaction was noticed between shade levels and varieties in any other growth characters other than harvest index.

One of the main objectives of the present study was to find out whether there exists appreciable intervarietal differences in shade response and if they do, to select varieties for different shade situations. Though such a final selection is difficult based on these data collected from small plots, the existence of appreciable varietal differences is clearly brought out from the significant interaction effects noted in the analysis carried out in three ways. Also, based on the available data, it was difficult to select a few superior varieties following a standard procedure because of variations noted in the ranking on fresh and dry weight basis. Added to this was the difficulty induced by the loss of a few varieties due to disease incidence. Because of these a few arbitrary criteria were used to select these. The six varieties with statistical parity in rhizome yield with the highest yielders at all shade levels were V_1, V_2, V_3, V_4, V_7 and V_9 (Analysis 3). All the varieties with parity in analysis (1) and (2) also appeared as superior in analysis (3), wherever these were included in comparison, the only exception being V_8. These six varieties thus may be tentatively selected as generally superior for all shade levels and may be carried forward for further trials. The best single variety for nearly all situations is V_9 (Valluvanad). Variety V_3 (Jamaica) appeared to be almost as good.

Though data are not adequate for drawing final conclusions, based on available data the best varieties for the different shade situations are as follows (based on parity).

Open	-	V_3, V_9, V_7 (Analysis 3)
25 per cent shade	-	V_9, V_4, V_3 (Analysis 2 and 3)
50 per cent shade	-	V_1, V_9, V_3 (Analysis 2 and 3)
75 per cent shade	-	V_9, V_3, V_1 (Analysis 2 and 3)

When more than one mode of analysis was done, those varieties that were common for both only are included in the preparation of the above list.

With regard to content of the three fertiliser nutrients, these followed different patterns. The tendency of potassium was to increase or to remain steady with increasing shade levels, while the nitrogen content showed decrease in haulm and increase in rhizome. Phosphorus content of the haulm and rhizome decreased steadily indicating the inability to absorb this nutrient under shade. A decrease in the 'P' efficiency ratio has been reported in winged bean grown under shade (Sorenson, 1984). Uptake of nutrients followed the same pattern as that of drymatter production except in phosphorus, and one valid conclusion out of the data is that the treatment giving the highest yield also recorded the highest uptake values. Calculated as percentages of the uptake in the open, the crop removal of nitrogen, phosphorus and potassium at 25, 50 and 75 per cent shade were 109, 75 and 51, 73, 46 and 26 and 118, 95 and 66, respectively. It may, therefore, be concluded that the requirement of nitrogen and potassium at 25 per cent shade will be around 115 per cent of that in the open while the requirement of nitrogen is only about 75 per cent at 50 per cent level of shade. The uptake of potassium at this level of shading was almost same as that in open. At the intense shade level of 75 per cent the requirement of these nutrients is only about half as much. The requirement of phosphorus at the increasing levels of shade was in proportion to the light intensity, the values being 74, 46 and 26 respectively. These results indicate the scope for bringing down the fertiliser doses at the medium and intense shade levels, where yields are comparatively low and the necessity of slightly increasing the doses of nitrogen and potassium under light shade.

There was a progressive decrease in the oleoresin content upto 50 per cent level of shade, after which there was a marginal increase. The higher oleoresin content in no shade condition can be explained as due to the unobstructed photosynthesis leading to accumulation of the secondary metabolites like resins, resin acids, and unoxidised sugars which are the major components of the acetone extracted oleoresin of ginger rhizome. With the increase in shade beyond the level of mild shading (25%) there was a proportionate decrease in the photosynthetic rate and the accumulation of abaove compounds. A marginal increase in the oleoresin at 75 per cent shade imposition may be explained by the retention of the volatile oil moiety which, otherwise undergose oxidation, degradation, isomerisation and polymerisation (Zacharia and Gopalam, 1987).

Among different varieites, the maximum oleoresin per cent was in varieties V_{10} (PGS 35), V_{12} (PGS 10), V_8 (Jugijan) and V_5

(Rio-de-jeneiro). This may be due to the lower content of starch in these varieties, as indicated by the limited photosynthesis and lower dry matter production. Starch content is known to be negatively correlated to oleoresin. In variety V_5 the lower starch content may be due to the poor translocation of photosynthates to rhizome and accumulation of resins and resin acids.

The salient features from the above discussion may be summarised as follows.

1. As the performance of most of the varieties is better under shade than in the open this crop may be considered as shade loving. Thus this crop is highly suitable for intercropping in coconut gardens.

2. Six varieties Jorhat, Nadiya, Jamaica, Kuruppampadi, Valluvanad and Pottangi selection 667 are selected as generally superior varieties for all shade situation.

3. Since the responses of these varieties to varying shade levels are different, as evidenced from the significance of interaction, varieties for different shade situations are selected. Thus there is scope for using varieties accordingly.

4. Since drymatter accumulation and harvest index followed the same pattern as that of rhizome yield, it may be inferred that, both synthesis of carbohydrate and its translocation had major role on the shade response of this crop.

5. Data on uptake of nutrients reveals the scope for bringing down the fertiliser at intense shade levels where yields are comparatively low and the necessity of slightly increasing these under mild shade.

6. Ginger varieties grown under shade give better yield as well as quality rhizomes upto 25 per cent since there was no appreciable reduction in the quality of rhizomes due to mild shading.

Turmeric

Shading decreased the rhizome yield of all the turmeric varieties. Plants grown at 0 per cent shade significantly differed from the rest and recorded the highest value. The yields at 25, 50 and 75 per cent shade levels expressed as percentages of that in the open are 74, 55 and 30 on fresh weight basis and 78, 63 and 36 on dry weight basis, respectively. As yields appeared to be in proportion to the light intensity, the turmeric varieties studied seem to fall in the category of shade intolerant plants. Results, reported by Ramadasan and Satheesan (1980) and Singh and Randhawa (1988) also agree with this. On the contrary, Bai and Nair (1982) recorded the highest yield of turmeric with plants grown at 50 per cent shade.

Data on drymatter accumulation and harvest index justify the observed trend in rhizome yield. The decrease in yield was consistent with the general growth performance of the crop in terms of drymatter accumulation. The above similarity in the trend of dry weight and rhizome indicates that light had a dominant role in deciding the observed response to shade. As had been concluded by Bai (1981) there was practically little influence of shade on translocation of photosynthates to rhizomes. There are reports of decrease in net carbon exchange due to shading (Wolf and Blaser, 1972 on alfalfa). Decreased leaf area index, crop growth rate and net assimilation rate have been reported in turmeric under shade compared to the same under open conditions (Ramadasan and Satheesan, 1980). These reasons also appear to apply for the results noted in the present study.

Among the varieties, V_9 (PCT 5) was found to be the best both on fresh and dry weight ba is. Synthesis of carbohydrate and its translocation were also found to the highest in this variety as evidenced from the data on drymatter accumulation and harvest index. Significant yield differences were noticed among varieties with respect to yield and yield components. All the highest yielding varieties except, V_{11} and V_{10} recorded higher values of harvest index and drymatter accumulation also. In V_{11} and V_{10} though the yield was high, the harvest index was significantly lower than the rest, indicating that this low harvest index was compensated by the higher rate of photosynthesis and greater drymatter accumulation. Another point noted was that the variety V_6 recorded very high harvest index. But the yield was comparatively lower than that of other varieties. Hence it appears that in this variety, photosynthesis was responsible for such a decrease in rhizome yield. But when the yield data were analysed on dry weight basis the yield of this variety was comparable with the rest of the high yielders. Results on percentage dryage also justify this. Hence the lower moisture content, in the rhizome in this variety at the time of harvest may also be a contributing factor for the low yield on fresh weight basis.

Effect of shade on growth characters like plant height, number of tillers and number of leaves followed the same pattern as that of ginger. Chlorophyll content and its fractions chlorophyll a and chlorophyll b were found to increase with shade, but decreased with age. With age chlorophyll a to b ratio tended to increase indicating that chlorophyll b was degraded more than chlorophyll a. Such results are earlier reported (Cooper and Qualls, 1967, Bjorkman, 1968, Nayak et al., 1978, Bai, 1981, Grant and Ryug, 1984, Vijayakumar et al., 1985 and Anderson et al, 1985).

Although the general trend was one of superiority of full light in most of the varieties, the shade responses of these were different as indicated by significance of interaction effects. Hence, keeping the objective in mind, an attempt was made to select six varieties as generally superior at all shade levels for the purpose of being carried forward for further testing. Basing the selection on statistical parity with the best variety at all shade levels was difficult as practically all varieties would then be included. Selecting the best varieties for each shade level would mean inclusion of V_9, V_8, V_{11} and V_1. Variety V_3 was also included as this variety came to be the second highest yielder at 25 and 75 per cent shade levels both on fresh and dry weight basis. Variety V_4 was included as this gave the second highest yield at 50 per cent shade and as no variety other than the highest yielder was chosen to represent this shade level.

With regard to nutrient contents nitrogen and potassium showed an increasing trend with increasing shade while the content of phosphorus remained almost same. An increase in the percentage of nitrogen due to shading has been reported in rice (Rai and Murthy, 1977). The role of potassium ions under stress conditions, is well established. The requirement and uptake of this nutrient under shade may be high may be because its role in the stomatal movement.

Uptake of nutrients followed almost the same trend of drymatter and yield except potassium, uptake of which was not much altered due to shading. The percentage crop removal of N, P and K at 25, 50 and 75 per cent shade levels were 89, 83 and 80, 62, 62 and 51 and 101, 105 and 85. One valid conclusion that can be drawn from this is that the application rate of fertiliser potassium is to be nearly the same as that of open, while that of phosphorus is to be only half as much. The requirement of nitrogen is also comparable to open. Hence there is no scope for brining down the fertiliser dose under shade, except for phosphorus.

Among the varieties, no relationship was noticed between uptake of nutrients and yield, indicating that the uptake values are not at all indication of yield. These are just an index of nutrient requirement. These differences in the requirement may be due to the differences in the genetic makeup.

The curcumin content had shown a progressive decrease with increase in shade. As the general growth of the plant is decreased with increase in shade, as indicated by the lower drymatter production, normally the synthesis of secondary metabolite also should decrease.

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

1. Since the yield is in proportion to the light intensity, these varieties may be grouped under the class of shade intolerant plants.

2. Varietal responses differed under shade as evidenced from the significance of interaction effects.

3. Six varieties were selected as generally superior for all shade situations.

4. Results indicated that there is no scope for bringing down the fertiliser doses at the increasing levels of shade where yields are comparatively low. The only exception appears to be phosphorus.

5. At the increasing levels of shade there is quality deterioration along with yield decline.

Summary

SUMMARY

A field experiment was designed for screening varieties of ginger and turmeric for shade tolerance during the year 1988-89 at the College of Horticulture, Vellanikkara, Trichur, Kerala, India. The objectives of the study were to select varieties suitable for varying shade levels and to study the changes in quality of crop produce induced by shading.

Observations on various plant characters were recorded to assess the performance of these varieties under shade. Chemical studies were also taken up to assess the content and uptake of fertiliser nutrients and quality changes induced by shading.

The results of the experiment carried out are summarised below:

The effect of shade on plant height and chlorophyll content was positive, while it was negative in the case of number of tillers and number of leaves in all the ginger varieties tried.

Most of the ginger varieties recorded the highest yield at 25 per cent shade. As yield tended to be higher at a certain level of shade than in the open ginger varieties tested were grouped in the category of shade loving plants.

Ginger varieties grown at 25 per cent shade gave the highest haulm yield and dry matter production. Highest value of harvest index was also noticed at 25 per cent shade. Though the harvest index was found the highest at 25 per cent shade, it was statistically on par with those at 50 and 75 per cent.

The percentage dryage of ginger rhizome increased with, increase in shading with the maximum dryage at 75 per cent shade.

With respect to ginger quality, varieties grown without shade yielded the best quality rhizomes.

The uptake of nitrogen and potassium increased from 0 per cent shade to 25 per cent and then showed a drastic decrease, while uptake of phosphorus steadily decreased with increasing shade intensities.

Six varieties Jorhat, Nadiya, Jamaica, Pottangi Selection 667, Kuruppampadi and Valluvanad were tentatively selected as generally superior for all shade levels and to be carried forward for further trials.

The best single variety for nearly all situations was found to be Valluvanad. Jama ca also appeared to be as good.

Significant interaction was noticed between shade levels and varieties on rhizome yield. The following varieties were selected for varying shade situations.

Open	-	Jamaica, Valluvanad and Kuruppampadi
25 per cent shade	-	Valluvanad, Pottangi Selection 667 and Jamaica
50 per cent shade	-	Jorhat, Valluvanad and Jamaica
75 per cent shade	-	Valluvanad, Jamaica and Jorhat.

All the turmeric varieties recorded the highest yield at 0 per cent shade except PTS 24. As yields tend to be in proportion to light intensity, these varieties were grouped as shade intolerant.

Plant height and chlorophyll content increased with, increasing shade, while number of tillers and number of leaves showed a drastic decrease in all the turmeric varieties.

Turmeric varieties grown at 0 per cent shade recorded the highest haulm yield and drymatter production. Harvest index was not altered by shading.

The percentage dryage increased with increase in shading from 0 to 75 per cent.

Curcumin content of rhizome showed a progressive decrease with increase in shading.

Uptake of all the nutrients was found to decrease with shade except potassium uptake of which was maximum at 50 per cent.

Significant interaction was noticed between shade levels and varieties on rhizome yield analysed on fresh and dryweight basis.

The varieties PCT 5 (V_9), PTS 24 (V_8), B S R I (V_{11}) and Myducker (V_1) were selected as superior varieties for 0, 25, 50 and 75 per cent shade, respectively.

Varieties Myducker (V_1,) PCT 2 (V_3), PTS 9 (V_4), PTS 24 (V_8) PCT 5 (V_9) and B S R I (V_{11}) were considered as generally superior for practically all situations.

Results indicated that the ginger varieties tested are highly suitable for intercropping in coconut gardens while turmeric varieties will be suitable for intercropping only under conditions of ample light infilteration.

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* Originals not seen

Appendices

Appendix 1 Meteorological data for the crop period (June 1988 to February 1989)

Week No.	Month and date	Maximum temperature °C	Minimum temperature °C	Soil temperature 5 cm FN	Soil temperature 5 cm AN	Rainfall (mm)	Humidity (%)	Sunshine hours (h)
26	June 25th to July Ist	29.7	22.6	26.6	31.3	154 3	84 5	3.9
27	2 8	30 4	23.1	27 4	33.5	19.7	82.5	6.6
28	9 15	29.6	23.4	26.0	32.9	105.4	86.5	4 0
29	16 22	28 2	22.8	25.0	28.8	245 9	93 0	0.3
30	23 - 29	27.6	23.3	24.8	30.5	134 9	88.0	0.5
31	30 - August 5th	29.9	24.5	25 8	33.3	89 9	86.0	3.6
32	6 - 12	28.9	23 9	25.7	32 9	61 2	87.5	2.9
33	13 19	28.2	24.3	25 2	30.6	177.6	89.0	3.2
34	20 - 26	29.7	24 6	26.1	34.2	72.1	83.5	5.1
35	27th - September 2nd	29.6	23 6	25.3	32.8	200 8	84.0	3.9
36	3 9	29.6	23.6	26.0	33 6	153 7	84.5	4 9
37	10 - 16	30.5	23.4	25 9	34.7	113.7	85.0	6.1
38	17 - 23	29 6	23.4	25 6	33.1	240.00	85.5	4.5
39	24 - 30	24 7	22.4	22 5	23.3	123.2	85.0	4.3
40	October 1 to 7th	30.4	23.4	26.3	33.9	29.8	32.0	6.5
41	8 - 14	31.8	23.3	26 5	36.4	19.6	78.0	7.7
42	15 - 21	31.8	24.0	26 8	37.0	6 8	78.5	7.6
43	22 - 28	31 9	22.8	25 70	35.6	60 4	77.5	6.0
44	29 - November 4th	33.3	23.4	26 40	36.4	6.8	71.0	8.1
45	5 - 11	31 3	23.9	24.8	35.7	2.0	70.0	5.6
46	12 - 18	33.2	23.2	26 1	40.7	2 2	67.5	9 3
47	19 - 25	32.6	22.6	26.1	40.5		65.5	7.7
48	26 - December 2nd	32.6	20.1	23 9	39.8		65.0	7.9
49	3 - 9	31.9	22.7	25.6	39.3		77.5	7.2
50	10 - 16	33.4	22.8	25.3	41.4		62.5	9.3
51	17 - 23	32.6	23.2	24.3	39 5		49.5	7.4
52	24 - 31	37.7	24 8	27.9	46.7		6.5	11 9
1	January Ist - 7	33.0	23 5	25 3	41 1		53 5	9 5
2	8 - 14	33.3	21.2	24.6	40.4		56.5	8.8
3	15 21	33.1	22.7	24.8	39.2		55.5	5.7
4	22 - 28	33.6	21.2	24 1	42.9		48.5	7.4
5	29 - February 4th	34.9	22.7	24 6	43.9		38.0	4 1
6	5 11	36.1	21 2	22.8	46.7		42.0	10.4
7	12 - 18	36 8	21 8	25.5	48.2		53.5	9.8

Source : Agromet observatory, College of Horticulture, Vellamkkara.

Appendix 2 Analysis of variance for plant height and number of tillers of ginger varieties

Source	DF	Mean squares							
		Plant height				Number of tillers			
		60 DAP	120 DAP	120 DAP	180 DAP	60 DAP	120 DAP	120 DAP	180 DAP
			(1)	(2)			(1)	(2)	
Replication	3	15.1	68.6	38.6	61.5	0.87	10.6	3.3	7.5
Mainplot	(1)3	1921.1**	2511.6**			32.3**	400.8**		
	(2)2			174.5	245.8			145.1**	118.1**
Error (a)	(1)9	98.1	99.6			2.3	12.8		
	(2)6			160.5	80.3			15.4	4.1
Subplot	(1)11		844.5**				20.1**		
	(2)12	1097.5**		653.6**	355.6**	2.5**		14.2	53.8**
Interaction	(1)36	20.9				0.94*			
	(2)24			23.8	22.5			2.0	7.6**
	(3)33		29.0				5.2		
Error (b)	(1)144	32.3				0.60			
	(2)108			42.9	43.4			2.4	3.5
	(3)132	35.8				4.4			

* Significant at 5% level

** Significant at 1% level

(1) Data analysed by deleting one subplot (V_5)

(2) Data analysed by deleting one mainplot (T_1)

Apendix 3 Analysis of variance for number of leaves and drymatter production of giner

Source		DF	Mean squares					
			Number of leaves				Drymatter production	
			60 DAP	120 DAP (1)	120 DAP (2)	180 DAP	(1)	(2)
Replication		3	135.7	1192.4	695.6	2324.9	274.0	309.5*
Mainplot	1)	3	575.1*	42289.4**			2164.4**	
	2)	2			21659.9*	4613.2		5133.2**
Error (a)	1)	9	110.6	1614.7			30.2	
	2)	6			2239.9	1251.2		47.5
Subplot	1)	12	153.8**		1677.8**	6379.1**		249.3**
	2)	11		2135.7**				
	3)	8					210.**	
Interaction	1)	36	28.3					
	2)	33		418.3				
	3)	24			269.8	563.9	42.4	80.8
Error (b)	1)	144	26.9					
	2)	108			274.6	527.5		83.1
	3)	96					63.4	
	4)	132		328.3				

* Significant at 5% level

** Significant at 1% level

(1) Data analysed by deleting subplots (V_1, V_5, V_6 and V_9)

(2) Data analysed by deleting mainplot (T_1)

Appendix 4 Analysis of variance for rhizome yield of ginger varieties

Source	DF	Mean squares					
		Fresh weight basis			Dry weight basis		
		(1)	(2)	(3)	(1)	(2)	(3)
Replication	(1) 3	88.3*	41.2		0.61	0.53	
	(2) 2			65.0*			1.0
Mainplot	(1) 3	472.9**		646.8**	7.7*		9.0*
	(2) 2		949.9**			16.8*	
Error (a)	(1) 9	15.5			0.52		
	(2) 6		21.2	9.7		0.42	0.61
Subplot	(1) 8	281.2**			5.6**		
	(2) 12		164.9**			4.8	
	(3) 11			228.1**			4.9**
Interaction	(1) 24	16.4**	10.2*		0.26	0.18	
	(2) 33			14.9**			0.24
Error (b)	(1) 96	6.4			0.23		
	(2) 108		5.5			0.18	
	(3) 88			6.8			0.20

* Significant at 5 % level

** Significant at 1% level

(1) Data analysed by deleting a few subplots (V_1, V_5, V_6, & V_9)

(2) Data analysed by deleting one mainplot (T_1)

(3) Data analysed by deleting one replication (R_1) and one subplot (V_5)

Appendix 5 Analysis of variance for haulm yield, harvest index, and percentage dryage of ginger varieties

Source		DF	Mean squares					
			Haulm yield		Harvest index		Percentage dryage	
			(1)	(2)	(1)	(2)	(1)	(2)
Replication		3	2.5*	3.2	0.01	0.01	13.7	10.6
	(1)	3	22.7**		0.03*		168.0**	
	(2)	2		51.2**		0.002		52.5
Error (a)	(1)	9	0.58		0.003		5.9	
	(2)	6		0.83				10.8
Subplot	(1)	8	4.3**		0.19**		122.3**	
	(2)	12		7.3**		0.16**		98.3**
Interaction	(1)	24	0.93	1.3	0.01	.006**	7.3	6.5
Error (b)	(1)	96	0.73		0.003		5.5	
	(2)	108		0.88		0.003		5.4

* Significant at 5% level

** Significant at 1% level

(1) Data analysed by deleting a few subplots (V_1, V_5, V_6, & V_9)

(2) Data analysed by deleting a mainplot (T_1)

Appendix 6 Analysis of variance for plant height and number of tillers of turmeric varieties

Source	DF	Mean squares					
		Plant height			Number of tillers		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180DAP
Replication	3	1106.3	286.4	204.0	0.44	1.7	2.7
Mainplot	3	2110.1*	7112.1**	7213.3**	1.7*	63.8**	38.9**
Error (a)	9	370.9	344.0	434.8	0.32	0.76	0.70
Subplot	11	249.9**	954.5**	1510.4**	0.31**	1.1**	1.43**
Interaction	33	67.5	262.6*	275.1*	0.12	0.89**	0.44
Error (b)	132	74.9	104.3	107.6	0.14	0.31	0.36

Appendix 7 Analysis of variance for number of leaves and dry matter production of turmeric varieties

Source	DF	Mean squares			
		Number of leaves			Drymatter production
		60 DAP	120 DAP	180 DAP	
Replication	3	8.79	34.6	42.6	440.5
Mainplot	3	31.02	460.9**	4.4	5339.1**
Error (a)	9	14.1	24.5	4.7	162.7**
Subplot	11	10.06**	37.9**	22.7**	237.4
Interaction	33	3.25	7.82	2 09	115.6
Error (b)	132	2.63	5.56	2.23	80.9

* Significant at 5% level

** Signicant at 1% level

Appendix 8 Analysis of variance for rhizome yield, haulm yield, harvest index and percentage dryage of turmeric varieties.

Source	DF	Mean squares				
		Rhizome yield		Haulm yield	Harvest index	Percentage dryage
		Fresh weight	Dry weight			
Replication	3	70.4	3.3	6.9	0.006	22.3
Mainplot	3	1547.5**	36.9**	78.7**	0.009	133.6**
Error (a)	9	37.2	0.79	2.17	0.008	14.1
Subplot	11	47.5**	4.6**	8.5**	0.12**	125.5**
Interaction	33	36.9*	2.1**	1.8	0.005	5.8
Error (b)	132	19.8	0.63	1.4	0.006	7.4

* Significant at 5% level

** Significant at 1% level

SCREENING OF VARIETIES OF GINGER AND TURMERIC FOR SHADE TOLERANCE

By

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ABSTRACT OF A THESIS

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ABSTRACT

The present study 'Screening of varieties of ginger and turmeric for shade tolerance' was conducted during May 1988 to February 1989 at the College of Horticulture, Vellamkkara, Trichur. The experiment was laid out in a split plot design with four replications.

Thirteen varieties of ginger and twelve varieties of turmeric were raised at shade levels of 0,25, 50 and 75 per cent. For providing shade *pandals* were erected on wooden frames and covered with coconut fronds to provide the required levels of shade. These were covered on all sides also leaving a clearance of 1 m from ground level. An Aplab lux meter was used for adjusting the shade intensities. Most of the ginger varieties recorded the highest yield at 25 per cent shade and hence these were grouped under the category of shade loving plants. This will qualify this crop as highly suitable for intercropping in coconut gardens. Other yield parameters such as drymatter production and harvest index were also found to be the highest at 25 per cent shade Ginger varieties grown without shade yielded the best quality rhizomes. Significant interaction was noticed between shade levels and varieties on rhizome yield. Valluvanad was selected as the best single variety for all situations. Jamaica also appeared to be almost as good. Three varieties each were selected as suitable for 0, 25, 50 and 75 per cent shade. These are Jamaica, Valluvanad and Kuruppampadi for 0 per cent shade; Valluvanad, Pottangi Selection 667 and Jamaica for 25 per cent, Jorhat, Valluvanad and Jamaica for 50 per cent and Valluvanad, Jamaica and Jorhat for 75 per cent shade.

All the turmeric varieties tested recorded the highest yield at 0 per cent shade thus enabling the tested varieties to be classified as shade intolerant. All the yield parameters were also found to be the highest in the open. Harvest index was, however, not altered by shading Significant interaction was noticed between shade levels and varieties on rhizome yield. Six varieties were selected as superior for nearly all situations. Varieties PCT 5, PTS 24, B S R I and Myduckur were selected for 0, 25, 50 and 75 per cent shade, respectively.

Plates

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

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

Plate 3 Ginger varieties at 0 per cent shade

Plate 4 Ginger varieties at 25 per cent shade


75% SHADE

Plate 7 Turmeric varieties at 0 per cent shade

Plate 8 Turmeric varieties at 25 per cent shade


0% SHADE


25% SHADE


50% SHADE


75% SHADE