EFFECT OF SHADE AND MULCH ON THE YIELD OF GINGER *(Zingiber officinale R.)*

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Effect of shade and mulch on the yield of ginger (*Zingiber officinale* R.)", is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "Effect of shade and mulch on the yield of ginger (*Zingiber officinale* R.)", is a record of research work done independently by Sri. P. BABU, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

The Agriculture of Kerala is characterised by the presence of small and marginal farm holders and it is estimated that about 97.3 per cent of the farm families come under this category. The average size of holding is 0.36 ha (Anon., 1993).

The availability of cultivated and cultivable land is getting constrained posing a severe threat to the food position. It is not practicable to increase the income and employment potential of small and marginal farmers, if they depend on monoculture of perennial crops. In this context, adoption of multiple cropping system is a viable proposition because this system helps in creating an environment ecologically sustainable and socially feasible. Higher efficiency of land, solar radiation and water can be achieved by adopting multiple cropping system (Rethinam, 1993). Increased production per unit area per unit time is the speciality of this cropping system which also makes it possible for increasing the income and employment. Multiple cropping would also ensure a built in insurance against price flexuations and total crop losses. Identification of the ideal crop components for such a cropping system and evolving suitable management practices need immediate attention.

Crop production is influenced by solar radiation, water and nutrients. Among this, solar radiation is the principal factor for photosynthesis. According to Watson (1958) the amount of light energy intercepted by a crop is a major discriminant in crop production.

Certain plants can efficiently utilize low light intensity. Better light use efficiency form an important adoptation for attaining higher yields, especially for the crops under intercropped situations.

The most promising intercrops under coconut and other perennial crops are reported to be tuberous and rhizomatous crops. Among these, ginger is one of the most important crops. It is to be remembered that historically ginger was one of the first oriental spice known to Europe having been obtained by Greek and Roman from Arab traders who kept a secret of their origin of the spice in India (Purseglove et al., 1981).

The available information suggests that ginger is a shade loving/tolerent plant and the ability to tolerate the shade makes them suitable for intercropping under tall tree crops, because the light filtered through the tree canopy is utilized for the growth of the crop.

According to Minoru and Hori (1969) ginger can efficiently utilize low light intensities. The screening of ginger cultivars at Vellanikkara, Kerala revealed that most of the cultivars are shade loving / tolerant giving maximum yield under 25 per cent shade. The enhanced growth and yield of ginger under shade were also observed by Susan Varughese (1989), Jayachandran et al. (1991), Ancy Joseph (1992) and George (1992).

Mulching is one of the important cultural practices recommended for ginger cultivation. The crop requires large quantities of mulch for higher yield. The positive influence of mulch on higher yield was emphasized by various workers (Jha et al., 1972; Mohanty, 1977; Mishra and Mishra, 1986 and Korla, 1990).

As per the "Package of practices recommendations" of the Kerala Agricultural University (Anon.,1989) the quantity of green leaf required for mulching is 30 t ha^{-1}. This is a general recommendation evolved based on the trials undertaken under open condition and therefore it needs assessment under shaded situations also.

At present, the evidences are lacking to modify the recommended dose of mulch for shaded situations. The situation assumes more importance because due to deforestation and intensive cropping the availability of green leaf is also becoming a problem (Valsala et al., 1990).

Hence the present investigation is taken up with the objective of assessing the effect of different levels of shade on the growth, yield and quality of ginger. The possibility of reducing the quantity of mulch material under different shade levels is also evaluated.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The review of literature is classified into two sections. The first section reviews the literature on the response of ginger and other crops to varying intensities of shade. The second section reviews the effect of mulches on growth, yield and quality.

A. Response of crops to varying intensities of shade

Solar radiation is the primary source of energy for plant growth and development. The efficiency of crop growth depends on the ability to absorb and utilize the photosynthetically active radiation for various metabolic activities and its efficiency in partitioning the assimilates into the sink effectively. The above condition is influenced by the surroundings in which the plant grows, besides the genetic make up. The growth, yield and quality of many crops are influenced by shade at various stages of growth and development. Differential response of crop varieties to shade has been studied for various crops including rhizomatous and tuberous crops.

Plant height

Cooper (1966) reported in birdsfoot trefoil and alfalfa exposed to various levels of shade (51, 76 and 92%) that the plant height decreased proportionately with increasing levels of shade. In groundnut, George (1982) observed an increase in plant height due to shading. Positive effect of shade on plant height was also reported by Lalithabai and Nair (1982) in turmeric, ginger, coleus and sweet potato; Sorenson (1984) in tomato; Kamaruddin (1983) in sweet red pepper; Rylski and Spingelman (1986) in broad bean; Xia (1987) in potato; De magante and Zaag (1988) in passionfruit; Menzel and Simposon (1989) and Prameela (1990) in colocasia and Pillai (1990) in clocimum.

In ginger, plant height was found to increase with increase in shade intensity from zero to 75 per cent (Susan Varughese, 1989 and Jayachandran et al., 1991). According to Ancy Joseph (1992) the plant height in ginger went on increasing with increasing shade levels (25, 50 and 75%). The plant height under open condition was the lowest. Increase in plant height with increase in shade intensities at all stages of growth of ginger (except 60 days after planting) was reported by George (1992). The highest plant height was observed under 75 per cent shade and lowest under open condition.

Number of tillers per plant

Beinhart (1963) reported an increased tillering at higher light intensities in whiteclover. In colocasia, there was no significant difference in tiller production among different shade levels (Prameela, 1990). Decrease in the number of tillers with increasing levels of shade in turmeric was observed by Susan Varughese (1989) and Jayachandran et al. (1992).

According to Aclan and Quisumbing (1976) tillering was not affected by shade in ginger. Contrary to this finding Susan Varughese (1989)observed a decrease in the number of tillers in ginger with increasing levels of shade at all the growth stages. In ginger cv. Rio-de-Janerio significantly higher tiller production capacity was noticed by Ancy Joseph (1992) under 25 per cent shade at 120 and 180 days after planting. The lower tiller production capacity was exhibited under heavy shade. George (1992) reported that the tiller production in ginger cv. Rio-de-Janeiro was maximum at 25 per cent shade.

Number and size of leaves

The leaf number and size of leaf of Amaranthus Spp. were found to be greater at the medium than at higher levels of shade (Simbolon and Sutarno, 1986). In sweet potato, leaf size increased as leaf number declined in response to higher shade levels, thus leaf areas were similar in all treatments (Laura et al., 1986). Sreekumari et al. (1988) reported that in cassava the leaf size increased and leaf number decreased and leaf longivity increased when grown under shade in coconut garden.

Aclan and Quisumbing (1976) reported reduced number of leaves per tiller in ginger grown under full sunlight compared to different levels of shade. In a shade study at Vellayani, Ancy Joseph (1992) observed maximum number of leaves per plant in ginger under 25 per cent shade at all the growth stages and the lowest number of leaves were recorded at 75 per cent shade.

Chlorophyll content

An earlier study by Shirley (1929) reported that shaded leaves generally had an enhanced chlorophyll levels per unit weight. Seybold and Egle (1937) observed an increase in chlorophyll 'b' content under low light intensity. Concentration of chlorophyll per unit area or weight of leaves increased with increase in light intensity until the intensity was low for the plant to survive (Gardner et al., 1952). An increase in chlorophyll content with increase in shade levels was reported by Evans and Murran (1953) in cocoa; Radha (1979) in colocasia; Bhat and Ramanujam (1975) in cotton; George (1990) in groundnut; Sorenson (1984) in winged beans; Anderson et al. (1985) in tobacco; Singh (1988) in potato and Prameela (1990) in colocasia.

An inverse relationship of shade and chlorophyll content had been reported in peanut (Rao and Mittra, 1988) and maize (Bhutani et al., 1989).

Instances where the chlorophyll content was unaffected by shading were also observed in crops like chick pea (Pandey et al.,1980) and kiwi fruit (Grant and Ryng, 1984).

Susan Varughese (1989) and George (1992) found that chlorophyll and its fractions (chlorophyll 'a' and chlorophyll 'b') of ginger increased steadily with increasing levels of shade at Vellanikkara, Thrissur. In a shade study in ginger at Vellayani, Thiruvananthapuram, Ancy Joseph (1992) also observed the same trend with respect of chlorophyll content.

Photosynthesis

Photosynthesis and considerable differences between varieties in their photosynthetic rate per unit leaf area had been found in many crops. Shading greatly reduced the photosynthetic rate in crops like alfalfa (Wolf and Blaser, 1972); bean (Crockson et al., 1975); grapes (Vasundara, 1981); cotton (Singh, 1986) and potato (Singh, 1988).

According to Hardy (1958) shade loving plants had a threshold illumination, beyond which the stomata tends to close. A linear relationship between photosynthesis and light intensities was reported by Gastra (1963). Crockson et al. (1975) recorded 38 per cent reduction in photosynthesis of bean leaves due to shading, may be due to the increase in stomatal and mesophyll resistance to diffusion of CO_2.

Ginger appeared to be efficiently utilizing low light intensity for its photochemical reaction (Minoru and Hori, 1969). A positive influence of shade on photosynthesis and organic matter accumulation had been reported in the case of ginger and turmeric (Lalithabai and Nair, 1982).

Tao and Zhang (1986) found that at 28°C the net photosynthetic rate of tea plants increased with light intensity and the light saturation and light compensation points of shaded plants were lower than that of unshaded plants. Although the photosynthetic efficiency of plants under open condition at higher light intensity was slightly above that of shaded plants, their photo-respiration at 80 k.lx, 34-38^{o}C and 40-60 per cent relative humidity were higher, so that the net photosynthetic rate decreased markedly.

Studies on cultivar resistance to transpiration influenced by different densities of shade (25, 50 and 75 per cent) in tea clones revealed that there was a progressive increase in cultivar resistance with increasing densities of shade (Harikrishnan and Sharma, 1980). Handique and Monivel (1987) also reported that low stomata resistance in tea under full sun compared to leaves under shade.

High light intensity warms the leaves and may increase respiration. If warming become too high the temperature rise may be sufficient to cause thermal inactivation of enzymes. This effect was reported in many plants. The chloroplast enzyme NADP Malate Dehydrogenase was totally inactivated. These were seen when chloroplast of peas, maize and spinach were illuminated with high light intensity (Miginiac Maslow et al., 1990).

Zhao *et al*. (1991) studied the photosynthetic characteristics of ginger and found that the rate was highest in the middle leaves of the plant and lower in the apical leaves than the basal leaves. It was also found that the rate decreased as the temperature increased from 20 to 40^{o}C and was low at a light intensity of 500 lx. increasing with increasing light intensity to 30,000 lx. and then decreasing slightly with further increase to 60,000 lx. Wilting markedly decreased the rate of photosynthesis.

Leaf area index (LAI)

Positive influence of shade on various growth ratios had been reported by many workers. Cooper and Qualls (1967) reported an increase in specific leaf area with increase in shade levels in birds foot trefoil and alfalfa.

Low leaf area index was observed at high light intensities in cotton (Bhat and Ramanujam, 1975). Fukai *et al*. (1984) reported an increase in specific leaf area as against a decrease in leaf area in cassava with high shade levels. Sorenson (1984) observed higher leaf area ratio with higher shade intensity in winged bean. According to Ono and Iwagaki (1987) reduced light intensity increased specific leaf area and leaf area index in Satsuma mandarin orange.

According to Lalithabai (1981) leaf area indices of ginger, turmeric and coleus were observed to be not influenced by different shade intensities. A high leaf area index was reported by Ravisankar and Muthuswamy (1988) when ginger was grown as an intercrop in six year old arecanut plantation. Ancy Joseph (1992) observed that the leaf area index was significantly lower under open condition compared to other shade levels in all growth stages. The highest leaf area index was recorded at 25 per cent shade.

Net assimilation rate (NAR) and crop growth rate (CGR)

In sweet potato, Laura et al. (1986) observed a low rate of NAR under shade. Jadhav (1987) reported a positive correlation of shade with leaf area ratio and relative growth rate in rice. Pandey et al. (1980) reported that the NAR of chick pea decreased with decrease in light intensities. Ramanujam and Jose (1984) found that the CGR and NAR of cassava grown under shade were reduced significantly when compared to those plants grown under normal light. Ramadasan and Satheesan (1980) reported highest leaf area index, crop growth rate and net assimilation rate with three turmeric cultivars grown in open condition compared to shaded condition.

The maximum individual CGR recorded in the study conducted by Whiley (1980) in ginger was 39.7 g m^{-2} day^{-1}. The net assimilation rate under 25 and 50 per cent shade levels were significantly high but showed a drastic decrease under heavy shade (Ancy Joseph, 1992). The crop growth rate was found to be maximum under 25 per cent shade at both growth phases (90 - 135 DAP and 135 - 180 DAP) followed by that under 50 per cent shade and open condition. George (1992) found significant differences in net assimilation rate between shade levels at both 60 and 120 days after planting. The highest value of NAR was observed at 50 per cent shade.

Harvest index (HI)

Prameela (1990) recorded highest harvest index at 25 per cent shade in colocasia and with further increase in shade levels the harvest index decreased significantly.

Susan Varughese (1989) observed no significant difference between shade levels with respect to harvest index in ginger. The highest harvest index was observed under open condition (Ancy Joseph, 1992) and a steady decrease in harvest index with increase in shade levels was resulted. However, George (1992) recorded highest harvest index at 25 per cent shade which was comparable with open condition.

Dry matter production (DMP)

The maximum amount of dry matter production by a crop was strongly correlated with the amount of light intercepted by its foliage (Monteith, 1969). Increase in dry matter production at higher shade levels were also reported in Xanthosoma sagittifolium (Caesar, 1970); in cocoa (Gopinathan, 1981); in cotton (Singh, 1986) and in coffee (Venkataraman and Govindappa, 1987).

According to Lalithabai and Nair (1982) dry matter production followed a quadratic pattern with an optimum shade of 20.11 per cent. Ravisankar and Muthuswamy (1988) recorded an increased level of dry matter production with decreased light intensity in ginger. This was further confirmed by Susan Varughese (1989), who recorded the highest dry matter production at 25 per cent shade in ginger.

Ancy Joseph (1992) observed significant variation among shade levels with respect to the dry matter production. Shade levels, 25 and 50 per cent, were found to be on par with each other but significantly superior to zero and 75 per cent shade. There was a drastic reduction in DMP at 75 per cent shade both at 135 and 180 days after planting, the extent of decrease being 17.8 and 22.2 per cent respectively of that under open condition.

Yield

Shading during the initial period had no effect on tuber formation in potato (Gracy and Holmer, 1970). Positive influence of shade on yield was reported in many crops. In Chinese cabbage, lettuce and spinach the highest fresh weight was at 35 per cent shade, beyond which the performance was poor than those in full sunlight (Moon and Pyo, 1981). In groundnut shading at maturity did not reduce yield though yield was affected by shading during flowering, pegging and filling stage (Rao and Mittra, 1988). Pushpakumari (1989) reported that tannia recorded highest yield under 25 per cent shade with an almost equal yield at 50 per cent shade.

Hanada (1991) found that covering crops with plastic net or nonwoven fabrics increased the yield of vegetables both in tropical and sub-tropical areas. The yield increase was found to be the combined results of shading, suppression of increase in soil temperature and conservation of soil moisture. Soil temperature at a depth of 5 cm were found to be lower by as much as 6°C under cover with a shading intensity of more than 67 per cent compared to control and this produced an underground environment more suitable for root growth.

In turmeric, the highest yield was recorded under 25 per cent shade (Susan Varughese, 1989). According to Jayachandran et al. (1992) yield of turmeric at 25 per cent shade was on par with open condition and therefore turmeric can be considered as a shade tolerant crop.

Ravisankar and Muthuswamy (1988) observed that fresh rhizome yield increased when ginger was grown as an intercrop in arecanut plantation. Susan Varughese (1989) obtained highest yield under 25 per cent shade. According to Jayachandran et al. (1991) ginger cv. Rio-de-Janeiro is a shade loving plant producing higher yield under low shade intensity (25%) and comparable yield with that of open under medium shade intensity (50%). However shade intensity beyond 50 per cent decreased the yield. Ancy Joseph (1992) recorded the highest green ginger yield under 25 per cent shade followed by 50, zero and 75 per cent shade.

Content and uptake of NPK

Kraybill (1922) observed higher content of N in shaded apple trees. According to Maliphant (1959) in cocoa, shading increased nitrogen content of leaf but the phosphorus content was decreased. The K content of grass species when grown under 80-90 per cent shade was nearly double than that grown under open (Rodriguez et al., 1973). Prameela (1990) recorded highest N, P and K contents under 25 per cent shade in colocasia. The N content in the leaf increased as shade increased upto 25 per cent and then showed declining trend with further increase in shade levels, while P and K were higher under 75 per cent shade in clocimum (Pillai, 1990).

Lalithabai (1981) observed an increase in the contents of N, P and K in coleus, colocasia, sweet potato, turmeric and ginger, with increase in shade. In ginger, George (1992) observed significant difference with respect to NPK content in haulm. The uptake of N, P and K in ginger increased from zero to 50 per cent shade and then showed a decrease at 75 per cent (Ancy Joseph, 1992).

Quality of the produce

According to Tikhnomirov et al. (1976) the light regimes received by plant determine the productivity and quality of its produce. Partial shading during fruit development improved the quality of pineapple fruit (Nayar et al., 1979). Under shaded conditions the quality of the products of tea, coffee, cinchona and rauvulfia was found to be improved (Feng, 1982).

The content of oleoresin under open and 25 per cent shade was higher than intense shade level (George, 1992). Ancy Joseph (1992) found that the non-volatile ether extract content under 25 and 50 per cent shade was on par with each other and significantly superior to that under zero and 75 per cent shade.

George (1992) found an increase in volatile oil content with increase in shade intensity and the highest value recorded was under 75 per cent shade. Ancy Joseph (1992) recorded the highest volatile oil content under 25 per cent shade followed by that under 50 per cent shade.

B. Response of crops to mulching

According to Adoms (1965) the practice of mulching is as old as agriculture. Mulching is the covering of top soil with some non-living material to get a favourable condition for crop growth.

De Silva Asp (1957) had studied the various phases of mulching and concluded the beneficial effects like conservation of soil moisture, prevention of erosion, increased thickness of aerable layer, reduction in soil temperature and elimination of weed competition.

Though sawdust mulches conserve maximum moisture, a number of workers have observed the retarding effect of sawdust on growth and yield of crops (Patel, 1965). The effect of mulching on soil properties and crop growth are reviewed.

Effect of mulching on soil moisture status

Mulches were applied for various crops from ancient periods in order to conserve soil moisture. Majority of the authors concluded the usefulness of mulches in moisture conservation and enhanced yield. There is an increasing interest towards multiple cropping even in rainfed lands and such system needs conserving soil moisture through mulching (Mandal and Vamadevan, 1975).

According to Bever (1960) the artificial mulches greatly retard the evaporation and protect the soil surface from direct rays of sun and wind current and ultimately the soil was kept cool and the vapour pressure of air in the mulches was nearly the same as that of soil air. In winter vegetables, the mulches reduced soil moisture losses and thus considerably reduced the irrigation requirement (Kashyap and Jyothishi, 1967). Donald and Jose (1972) found that the mulched plots have a higher soil moisture content throughout the growing season than the unmulched plots for 0-10 and

10-20 cm depth. In the same study they also reported that mulching indirectly influenced the water holding capacity and moisture release character of the soil. Umrani et al. (1973) have also reported that there was more moisture in the mulched plots and reduced evaporation loss from soil surface and increased infiltration, which reduced run off also. According to Mathan et al. (1984) the total porosity was significantly influenced by mulching.

In vanilla, mulching is an important cultural practice aimed at conserving soil moisture (Muralidharan, 1975). Ragothama (1981) reported that the soil moisture content in the rootzone have a direct influence on tillering of cardamom and this can be efficiently managed by suitable mulching.

Mishra and Mishra (1986) reported that the soil moisture content was always higher in green leaves mulched plots in ginger. Green leaves have significant effect on moisture conservation than other materials tried and have direct influence on tiller production in ginger (Jha et al., 1972).

The research works outlined above clearly indicate that the mulches can be efficiently used for moisture conservation. The efficiency of mulches in relation to moisture conservation depends on kind of mulch, depth of mulch materials applied, soil texture and amount and frequency of rain fall received.

Effect of mulching on soil temperature

Generally the mulches keep the soil warm in winter and cool in summer or it helps to prevent the escape of heat during winter months and penetration of solar energy into the soil during warm season.

Kashyap and Jyotishi (1967) established that the diurnal variation of soil temperature was less under mulched condition and the available N and P contents were increased. According to Srivastava et al. (1973) the natural organic mulches like oak leaves, pine needles and hay, in general, reduced the soil temperature, while synthetic polyethylene resulted in increased soil temperature, which indicates that organic mulches reduced the soil temperature when compared with black polyethylene. Mehta and Prihar (1973) reported progressive decrease in maximum soil temperature with increasing rate of wheat straw mulch from 2 to 6 t ha^{-1} and mulching reduced the temperature by $1^{o}C$ at a depth of 5 cm. According to Prihar et al. (1977) the straw mulch decreased the soil temperature.

It was proved that better soil moisture and more favourable soil temperature regimes as a result of mulching enhance nitrification (Myer, 1975). Moreover the mulching increased the root density and caused greater lateral spread of roots (Chaudhari and Prihar, 1974 and Singh et al., 1976). All these factors may improve the water and nutrient availability.

According to Dhesai et al. (1964) the potato crop grows best when the temperature ranges from 60-75^{o}F and high temperature increases respiration and thus reduces the available carbohydrates for translocation and tuber formation. In banana, low soil temperature and high relative humidity developed as a result of mulching (Bhattacharya and Rao, 1985).

The mulches have significant role in maintaining soil temperature. The effect of mulches on soil temperature appears to primarily depends upon the kind and depth of mulch covering, time of the year in which the mulch is applied and light reflecting or heat absorbing property of the mulch.

Effect of mulching on soil physical properties

Mulching improves the soil physical properties, soil nutritional status, increased availability of plant nutrients, and increased availability of soil microfauna (Lal, 1975, 1983; Lal et al., 1980; Sanchez and Salinas, 1981; Wade and Sanchez, 1983, Schomigh and Alkamper, 1984; Hulugalle et al., 1986 and Jayashree, 1987).

According to Lawson and Lal (1979) in Alfisol with less favourable soil physical properties, crop growth was enhanced more by surface application of mulch rather than incorporation. The high rate of decay of organic matter which is a character of humid tropics (IITA, 1982 and Muduakor et al., 1984) indicates a need for placement of mulch such that the crop will benefit to the greater extent.

Tuvelle and Mc Callat (1961) reported a lower bulk density and higher water table aggregation in soil, as a result of mulching. Lal (1978) found higher bulk density in unmulched plots. Kamalam Joseph and Kunju (1981) conducted studies on the effect of mulching on bulk density and found that the mulching decreases the bulk density. Lal (1983) reported that the bulk density of newly cleared tropical Alfisols decreased with increase in mulch. In yam plots mulched with leaves, bulk density was significantly decreased (Hulugalle et al., 1986).

Jayashree (1987) found that sawdust mulched soil showed maximum water holding capacity followed by straw mulch.

Lal *et al*. (1980) reported that the hydraulic conductivity of newly cleared tropical Alfisols was improved by mulching. Mathan *et al*. (1984) reported that the hydraulic conductivity was influenced by mulching. Among the mulches there were no significant differences.

The higher percentage of water stable aggregates in leaf mulched plot might be due to the addition of organic matter through leaf mulch (Harris *et al*., 1966). Higher soil aggregation as a result of addition of organic matter has been reported by Kumar and Ghidyal (1969).

Effect of mulching on soil chemical properties

According to Mohanakumar *et al*. (1973) the green leaf mulch was found to be efficient in increasing the content of soil nutrients. The increased availability of NPK content for leaf mulch over other mulch materials might be due to the nutrient addition by decomposition of the leaf mulch.

Hulugalle *et al*. (1986) established that N, P, K, Mg, exchangeable Ca and total cation were increased within the plant row treatment of surface mulching and the plant grown under mulched condition recorded a high content of above nutrients. They also reported that the total acidity was decreased by surface mulching.

The chemical analysis showed that the bhindi plants grown under paddy husk mulch showed high content of N, P and K but Ca and Mg contents were found to be maximum in leaf mulched plots (Jayashree, 1987).

Effect of mulch on yield and yield attributes

Kashyap and Jyotishi (1967) found increased height and girth in onion when paddy husk and straw mulch were used. Srivastava *et al*. (1969) reported that there was significant effect on using various mulches on height of plants. Jayashree (1987) reported minimum internodal length in dry leaf mulched plots and maximum in straw mulched bhindi crop. She also found that the leaf mulch treatment had higher leaf area index than unmulched control.

During the earlier stages of growth mulching had no significant effect on the leaf area index, but at later stages of growth leaf mulch had a positive and significant effect on leaf area index. This was reported by Enyl (1973) in cocoyam; Aina (1981) in maize and Mohan kumar and Sadanandan (1988) in taro.

Hulugalle et al. (1985) found that there was significant positive change in plant establishment of yam under mulched condition. According to Hulugalle et al. (1986) surface mulching with green leaves gave a higher rate of establishment (93.0%) in cocoyam than control (84.3 %).

Chandler and Mean (1942) reported that organic mulches favour the root growth, because the mulches usually favour high moisture level, more uniform temperature, better physical condition in the soil and less competition for nutrients. Hulngalle et al. (1986) observed a deeper and more extensive root system under all mulched conditions than the control.

According to Aiyadurai (1966) mulching ginger crop with 15,000 lb of green leaf per acre was sufficient to get increased yield and mulching the crop thrice with 5000 lb of green leaf once at planting time, again 30 days after planting and for the third time, 60 days after planting was optimum required for obtaining maximum yield.

Aclan and Quisumbing (1977) found increase in plant growth parameters, rhizome yield and starch content in ginger crop under leaf mulched condition. Mohanty (1977) obtained better plant growth parameters and rhizome yield under leaf mulched condition. This was further supported by Mishra and Mishra (1986).

Effect of mulching on weed growth

One of the most important advantage of mulching is their ability to suppress the weed growth, thereby eliminating competition. Mulches suppressed the growth of weeds to a greater extent and reduced the weed number and weight as compared to control (Gopalakrishna et al., 1982). The beneficial effects of mulching in suppressing weed growth were established by Donald and Joe (1970), Muralidharan (1975), Thomas (1975), Srivastava et al. (1973) and Mishra and Mishra (1986).

MATERIALS AND METHODS

MATERIALS AND METHODS

Studies were conducted to evaluate the effects of different levels of shade on the growth, yield and quality of ginger. The possibility of reducing the quantity of mulch material under different shade levels was also investigated.

Experimental site

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

Soil

The soil of the experimental site is red loam belonging to the Vellayani series and texturally classed as sandy clay loam. The physico-chemical characteristics of the soil are given in Table 1.

Table 1. Soil characteristics of the experimental field

A. Physical composition

Coarse sand	(%)	63.2
Fine sand	(%)	13.5
Silt	(%)	2.5
Clay	(%)	20.5

B. Chemical properties

Available nitrogen (kg ha^{-1})	:	189.70
Available phosphorus (kg ha^{-1})	:	34.60
Available potassium (kg ha^{-1})	:	105.90
pH	:	5.2

Season

The experiment was conducted from May 1992 to February 1993.

MATERIALS

Plant material

Ginger cultivar Rio-de-Janeiro was used for the experiment. Rhizome bits weighing 15g were treated with Mancozeb 0.3 per cent and Malathion 0.1 per cent for 30 minutes before planting.

METHODS

Layout of the experiment

The experiment was laid out in strip plot design with five replications (Fig. 1). The plot size was 5x1m. The treatments are given in Table 2.

Fig. 1. LAY OUT PLAN - STRIP PLOT DESIGN

III

S_0M_2	S_1M_2	S_3M_2	S_2M_2
S_0M_4	S_1M_4	S_3M_4	S_2M_4
S_0M_3	S_1M_3	S_3M_3	S_2M_3
S_0M_1	S_1M_1	S_3M_1	S_2M_1

I

S_2M_1	S_1M_1	S_3M_1	S_0M_1
S_2M_3	S_1M_3	S_3M_3	S_0M_3
S_2M_2	S_1M_2	S_3M_2	S_0M_2
S_2M_4	S_1M_4	S_3M_4	S_0M_4

II

S_1M_2	S_2M_2	S_0M_2	S_3M_2
S_1M_3	S_2M_3	S_0M_3	S_3M_3
S_1M_1	S_2M_1	S_0M_1	S_3M_1
S_1M_4	S_2M_4	S_0M_4	S_3M_4

IV

S_0M_3	S_2M_3	S_1M_3	S_3M_3
S_0M_2	S_2M_2	S_1M_2	S_3M_2
S_0M_1	S_2M_1	S_1M_1	S_3M_1
S_0M_4	S_2M_4	S_1M_4	S_3M_4

V

S_2M_4	S_1M_4	S_3M_4	S_0M_4
S_2M_2	S_1M_2	S_3M_2	S_0M_2
S_2M_1	S_1M_1	S_3M_1	S_0M_1
S_2M_3	S_1M_3	S_3M_3	S_0M_3

TREATMENTS

Levels of shade	Levels of mulch
S_0 - 0 % shade	M_1 - 25 % of the recommended dose
S_1 - 25 % shade	M_2 - 50 % of the recommended dose
S_2 - 50 % shade	M_3 - 75 % of the recommended dose
S_3 - 75 % shade	M_4 - 100 % of the recommended dose

Table 2. Details of the treatments combinations

A. Shade levels (major treatments)

S_0 - 0 per cent shade (open)

S_1 - 25 per cent shade (low)

S_2 - 50 per cent shade (medium)

S_3 - 75 per cent shade (high)

B. Mulch levels (minor treatments)

M_1 - 25 per cent of the recommended dose

M_2 - 50 per cent of the recommended dose

M_3 - 75 per cent of the recommended dose

M_4 - 100 per cent of the recommended dose

Treatment combinations - 16

T_1-S_0M_1	T_5-S_1M_1	T_9-S_2M_1	T_{13}-S_3M_1
T_2-S_0M_2	T_6-S_1M_2	T_{10}-S_2M_2	T_{14}-S_3M_2
T_3-S_0M_3	T_7-S_1M_3	T_{11}-S_2M_3	T_{15}-S_3M_3
T_4-S_0M_4	T_8-S_1M_4	T_{12}-S_2M_4	T_{16}-S_3M_4

Land preparation and planting

Beds of 5x1 m size and 25 cm height were prepared at a distance of 50 cm apart. Drainage channels were provided. Farm yard manure was applied to each bed at the rate of 30 t ha^{-1} by placing in small pits taken at a spacing of 25x25 cm and seed rhizomes were planted in the pits at a depth of 4-5 cm and then covered with soil. Except mulching, all other cultural practices were done as per the package of practices recommendations of the Kerala Agricultural University (Anon., 1989).

Mulching

Immediately after planting the beds were mulched with green leaves. The quantity of green leaves applied as per the minor treatment levels is given in Table 3. Half of the total quantity required was applied as basal. The remaining half was divided into two equal parts and was used for second and third mulching during second and fourth months after planting respectively.

Table 3. Quantity of green leaves used for mulching

Mulch levels	Period of mulching			Total quantity of green leaves ($t\ ha^{-1}$)
	Basal ($t\ ha^{-1}$)	2 MAP* ($t\ ha^{-1}$)	4 MAP ($t\ ha^{-1}$)	
M_1 (25%)	3.750	1.875	1.875	7.50
M_2 (50%)	7.500	3.750	3.750	15.00
M_3 (75%)	11.250	5.625	5.625	22.50
M_4 (100%)	15.000	7.500	7.500	30.00

* MAP - Months after planting

Artificial shading to the required levels as per the treatment was provided by using high density polyethylene shade materials. LI-COR LI-188 B Quantum radiometer with a photometric sensor was used for confirming the shading capacity of the high density polyethylene shade material to provide 25, 50 and 75 per cent shade.

Pandals were erected using casuarina poles to provide artificial shade. All sides of the pandals were covered with same shade materials except 1 m from ground, to avoid the sunlight of morning and evening hours. Sufficient space (3m) was provided between shade treatments so that mutual shading was avoided.

After cultivation

Hand weeding was done before each mulching and earthing up was done prior to first mulching.

Plant protection

The crop was free from diseases and pests. However periodic prophilatic spraying of Dimecron (0.05%) and Dithane M-45 (0.3%) were given.

Harvest

The crop under open condition exhibited symptoms of maturity by partial drying of leaves by seven months after planting. But under shaded conditions the drying of leaves started only eight months after planting. However, harvesting of the entire plots were carried out only eight months after planting. Yield from net plot area were used for calculating per hectare yield.

OBSERVATIONS

Observations on environmental factors (soil temperature, soil moisture, relative humidity near crop canopy and day temperature) and growth, yield and quality parameters were made.

Random sampling technique was adopted to select the sample plants for studying various growth characters. Five plants were selected at random as observation plants from each plot, from four replications. One replication was used for destructive sample study. The observation on various growth parameters were taken at 60, 120 and 180 days after planting.

I. Environmental factors

Soil temperature

Soil thermometers were used for measuring soil temperature. Soil temperature at 15 and 30 cm depth was measured from M_1 and M_4 levels at 0730 h. and 1330 h. during the entire crop season and the fortnightly averages were taken for interpretation and presented in Fig. 9 and Appendix III.

Soil moisture

Soil samp s from 15 and 30 cm depth were taken. After taking initial (wet) weight they were oven dried to a constant weight. From the loss in weight the moisture percentage were worked out and the fortnightly means were expressed as percentage and presented in Fig.10 and Appendix IV.

Relative humidity near the crop canopy

Relative humidity (RH) was measured using phychrometer on every day at 1330 h. and the fortnightly averages were taken and expressed as percentage (Fig. 8 and Appendix II).

Day temperature

Day temperature was recorded using the thermometer at 1330 h. The fortnightly mean was worked out and presented in Fig. 2 and Appendix I.

GROWTH AND YIELD PARAMETERS

Sprouting

From each treatment the number of plants sprouted were counted on 30, 45 and 60 days after planting. The mean was taken and expressed as percentage of sprouting.

Plant height

Height of the plant was measured from the base of the plant to the base of the youngest fully opened leaf and expressed in centimetre (cm).

Number of tillers

The number of aerial shoots arising around each plant was counted.

Number of leaves

Number of leaves produced was recorded by counting fully opened leaves of the tillers from each sample plant.

Leaf area

The number of leaves were counted from sample plants. The length and maximum width of leaves were measured and the leaf area was calculated based on the length and breadth method, (Ancy Joseph, 1992).

The relationship y = 0.6695 x -0.7607 (y is leaf area and x is the product of length and breadth) was utilized for computing the leaf area.

Leaf area duration

Leaf area duration (LAD) was calculated using the formula given by Power et al. (1967).

$$\frac{Li + (Li + 1) \times (t_2 - t_1)}{2}$$

Li = LAI at stage 1^{st}

Li+1 = LAI at stage 2^{nd}

$t_2 - t_1$ = Time interval between these stages

Dry matter production

Pseudostems, leaves and rhizomes of the uprooted plants were dried to a constant weight at 70^{o} - $80^{o}C$ in a hot air oven. The sum of the dry weights of component parts gave total dry matter production and expressed as g $plant^{-1}$.

Net assimilation rate

Net assimilation rate (NAR) refers to the change in dry weight of the plant per unit leaf area per unit time. The procedure given by Watson (1958) as modified by Buttery (1970) was used for calculating the NAR.

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

W_1 = total dry weight of plant, g at time t_1

W_2 = total dry weight of plant, g at time t_2

A_1 = LAI at time t_1

A_2 = LAI at time t_2

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

NAR is expressed as g m^{-2} day^{-1}

Crop growth rate (CGR)

Crop growth rate (CGR) was calculated using the formula of Watson (1958).

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

Bulking rate

The bulking rate (BR) of rhizome was worked out on the basis of increase in dry weight of rhizome (g) per plant per day and expressed as g day^{-1}.

$$BR = \frac{W_2 - W_1}{t_2 - t_1}$$

W_1 - Dry weight of rhizome at time t_1

W_2 - Dry weight of rhizome at time t_2

$(t_2 - t_1)$ - time interval in days

Top yield

The yield of top (pseudostems, leaves and inflorescences if any) was recorded from the net area and expressed in kg ha^{-1} on dry weight basis.

Rhizome spread

The horizontal spread of rhizomes was measured and the mean value expressed in centimetres (cm).

Utilization index

Utilization index (UI) is the ratio of the rhizome weight to the top weight. This is calculated from the dry weight of rhizomes and dry weight of top parts.

Harvest index

Harvest index (HI) was calculated as follows.

$$HI = \frac{Y\ econ.}{Y\ biol.}$$

where Y econ. = total dry weight of rhizome

Y biol. = total dry weight of plant

Rhizome yield

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

CHEMICAL ANALYSIS

Chlorophyll content of leaves

Chlorophyll 'a', chlorophyll 'b' and total chlorophyll content of leaves were estimated 150 days after planting. Spectrophotometric method as described by Starnes and Hadley (1965) was used to estimate the chlorophyll content.

Volatile oil

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

Non-volatile ether extract

Non-volatile ether extract (NVEE) was estimated by Soxhlet distillation method (A O A C., 1975) and expressed as percentage on dry weight basis.

Fibre content

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

Uptake of NPK

The plant samples were collected, dried and used for analysis of NPK. Nitrogen content of pseudostem, root and rhizome was determined by modified microkjeldahl method, phosphorus content by the vanado molybdo phosphoric yellow colour method (Jackson, 1967) and potassium by atomic absorption spectrophotometric method.

The total uptake of NPK by the plant was determined by adding the NPK content of different plant parts and expressed as kg ha^{-1}.

Soil analysis

The soil analysis was done to find out the content of available nitrogen, phosphorus and potassium, before and after the experiment. Composite soil samples were used for estimating available nutrients present in the soil at the time of laying out the experiment. Soil samples from each treatment were analysed after the experiment.

Available nitrogen

Alkaline permanganate method (Subbaiah and Asija, 1956) was followed to find out the available nitrogen.

Available phosphorus

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

Available potassium

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

RESULTS

RESULTS

The results of the field experiment and chemical analysis are presented below.

Sprouting

The effect of shade and mulch on the sprouting of ginger is presented in Table 4. Between 45 and 60 days after planting (DAP) an increasing trend of sprouting was observed with increased levels of shade. Significant differences were noticed between open and shaded conditions with respect of the sprouting percentage. The effect of various levels of mulch showed significant difference in the sprouting percentage of ginger at 30 DAP. The influence of mulch in enhancing sprouting percentage was more prominent at 45 and 60 DAP. The highest sprouting percentage was observed from M_4 (98.42 %) and the lowest from M_1 (89.29 %). Significant interactions between shade and mulch were also observed. A general increasing trend was observed at all shade levels with each increment dose of mulch. At all shade levels, M_4 gave the highest and M_1 the lowest sprouting percentage.

Table 4. Effect of shade and mulch level on the sprouting (%) of ginger

4-1 30 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	12.89(20.89)	17.70(24.56)	26.03(30.58)	35.50(36.76)	23.13(28.20)
S_1	9.37(17.79)	15.62(23.17)	27.08(31.21)	36.97(37.32)	22.27(27.37)
S_2	15.10(22.63)	28.09(31.68)	34.37(35.85)	37.99(37.99)	28.88(32.04)
S_3	12.57(20.62)	12.74(28.43)	31.24(33.93)	36.37(37.10)	23.23(30.02)
Mean M	12.48(24.48)	18.55(26.96)	29.65(32.89)	36.65(37.29)	
F test CD (.05)	S(S) 3.049	M(S) 2.453	SM(S) 4.741		

4-2 45 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	33.35(35.22)	43.75(41.38)	68.23(55.72)	77.08(61.40)	55.60(48.43)
S_1	49.47(46.67)	53.54(47.08)	77.60(41.80)	84.85(67.12)	66.36(55.17)
S_2	45.31(42.29)	67.71(55.49)	79.16(62.98)	86.46(66.57)	69.66(57.33)
S_3	43.23(41.08)	78.12(62.49)	85.44(67.75)	91.14(72.74)	74.48(60.93)
Mean M	42.84(40.82)	60.78(51.53)	77.61(62.06)	84.88(67.94)	
F test CD (.05)	S(S) 4.074	M(S) 1.866	SM(S) 4.254		

4-3 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	88.54(70.34)	93.23(74.91)	94.27(76.26)	96.29(79.05)	93.08(75.14)
S_1	85.31(77.80)	98.96(85.83)	98.96(85.83)	97.40(82.21)	95.14(82.92)
S_2	95.83(81.59)	98.47(85.81)	99.47(87.91)	100.00(90.00)	98.44(86.33)
S_3	87.47(75.53)	96.87(82.74)	98.96(87.91)	100.00(90.00)	95.82(84.05)
Mean M	89.29(76.32)	96.88(82.33)	97.91(84.48)	98.42(85.31)	
F test CD (.05)	S(S) 3.659	M(S) 3.859	SM(S) 6.324		

Plant height

The data presented in Table 5 show the effect of shade and mulch on plant height. The plant height recorded was lowest under open condition and it showed an increasing trend with increasing shade intensities at all growth stages. The effect of mulch on plant height was also found to be significant. At all the growth stages, M_4 was found to be significantly superior to other treatments. In general, an increasing trend in plant height with each increment dose of mulch was noted at all the three growth stages studied. The shade and mulch interaction was significant at all growth stages. At 180 DAP, under open condition, M_4 was found to be significantly enhancing the plant height compared to M_1 and M_2 but M_4 was found to be on par with M_3. Under 75 per cent shade, M_4 was found to be significantly superior to M_3, M_2 and M_1, but M_3 and M_2 were found to be statistically on par.

Number of tillers per plant

The data on tiller production as influenced by varying levels of shade and mulch are presented in Table 6.

At 60 DAP, the number of tillers produced under different shade levels were found be significantly superior to open condition and among shade levels S_3 was found to be

Table 5. Effect of shade and mulch levels on the mean height of ginger plants (cm)

5-1 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	24.61	27.34	29.30	32.29	28.39
S_1	29.38	31.83	36.40	37.06	33.66
S_2	33.45	37.01	38.99	39.87	37.32
S_3	34.13	35.55	39.15	40.42	37.44
Mean M	30.85	32.93	35.96	37.53	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.764	0.570	0.968		

5-2 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	36.94	35.14	37.05	38.80	36.24
S_1	41.27	44.49	48.02	50.36	46.04
S_2	50.42	52.17	54.50	56.55	53.41
S_3	58.43	60.27	60.65	61.92	60.30
Mean M	46.01	48.01	50.06	51.91	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.573	0.684	0.921		

5-3 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	43.08	45.19	50.00	52.04	47.58
S_1	58.77	61.21	63.10	62.85	61.48
S_2	63.86	67.07	71.52	74.32	69.19
S_3	71.04	73.73	73.34	76.36	73.62
Mean M	59.19	61.80	64.49	66.39	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.906	1.034	1.565		

Table 6. Effect of shade and mulch levels on the mean number of tillers per plant (ginger).

6-1 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	2.40	3.35	3.80	4.10	3.41
S_1	3.68	3.95	4.20	5.00	4.20
S_2	3.55	3.80	4.65	4.50	4.13
S_3	4.15	4.25	4.45	4.60	4.36
Mean M	3.44	3.84	4.26	4.55	
F test	S(S)	M(S)	SM(NS)		
CD (.05)	0.291	0.371	0.645		

6-2 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	5.50	5.65	5.85	6.10	5.78
S_1	6.15	7.40	8.40	8.80	7.69
S_2	5.45	6.30	7.15	6.85	6.44
S_3	5.60	5.25	5.45	5.60	5.48
Mean M	5.68	6.15	6.71	6.84	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.284	0.406	0.546		

6-3 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	11.25	12.35	13.65	15.15	13.10
S_1	13.10	14.30	16.80	15.65	14.96
S_2	9.25	11.35	13.50	14.35	12.13
S_3	10.40	11.50	13.10	14.20	12.30
Mean M	11.00	12.38	14.28	14.84	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.428	0.463	1.135		

having the highest value with respect to tiller production. At 120 and 180 DAP, highest number of tillers were observed under 25 per cent shade. In the open condition, more tiller number was observed compared to 75 per cent shade at 180 DAP.

In general, an increasing trend in tiller production was observed with increasing mulch levels. The lowest number of tillers were observed in the lowest mulch level (M_1) in all the three growth stages studied. The highest number of tiller production was noticed in M_4, at all the growth stages, but it was found to be on par with M_3 during 60 and 120 DAP.

Effect of shade and mulch interaction was not significant at 60 DAP, but significant at 120 ad 180 DAP. During the period, under 25 per cent shade level, M_4 was found be superior to M_1 and M_2 but on par with M_3. At 180 DAP, under 25 per cent shade, M_3 was found to produce maximum number of tillers (16.80) but was on par with M_4 (15.65).

Number of leaves per plant

The data presented (Table 7) clearly show that there was significant variation in number of leaves per plant with different shade levels at all growth stages. The leaf

Table 7. Effect of shade and mulch levels on the mean number of leaves per plant (ginger)

7-1 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	33.55	34.50	35.10	36.75	34.96
S_1	37.40	44.80	45.60	44.45	43.06
S_2	33.26	33.93	33.25	35.25	43.92
S_3	32.95	34.40	35.60	35.85	34.70
Mean M	34.29	36.91	37.39	38.08	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.205	0.616	1.157		

7-2 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	66.55	74.15	79.90	81.90	75.63
S_1	85.55	89.80	105.80	105.63	96.69
S_2	81.73	87.85	88.15	92.30	87.51
S_3	76.25	86.50	87.70	89.15	87.90
Mean M	77.52	84.58	90.38	92.24	
F test	S(S)	M(S)	SM(S)		
CD (.05)	1.035	0.773	2.229		

7-3 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	162.80	181.40	188.20	193.65	181.51
S_1	200.15	254.45	290.45	290.75	261.20
S_2	168.35	171.00	170.20	165.30	168.71
S_3	148.40	149.70	170.33	167.70	159.03
Mean M	171.18	189.14	204.79	204.35	
F test	S(S)	M(S)	SM(S)		
CD (.05)	3.435	2.722	3.999		

production was maximum under 25 per cent shade (S_1) and was found to be significantly superior to other shade levels at 120 and 180 DAP. At 60 DAP, S_0 and S_3 were on par and at 120 DAP S_3 (87.9) and S_2 (87.51) were on par. At 180 DAP, S_1 produced maximum leaf numbers (261.2) followed by S_0 (181.51). The leaf number was lowest (159.03) under 75 per cent shade (S_3).

A general trend of increase in leaf number was noticed with increase in mulch levels at all growth stages. At 180 DAP M_4 and M_3 were on par with respect of leaf production.

Significant interaction between shade and mulch was found in all growth stages. At 60 DAP, under open condition (S_0) mulch level M_4 recorded the maximum leaf production. But under 25 per cent shade level, M_3 recorded the highest value. At 75 per cent shade M_2, M_3 and M_4 were found to be on par. An increase in leaf number with increased level of mulch was also observed at all growth stages under open condition.

Leaf area

Table 8 depicts the leaf area as affected by shade and mulch levels. Significant differences were observed among various shade levels with respect to leaf area when

Table 8. Effect of shade and mulch levels on the mean leaf area (cm^2) of ginger

8-1 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	1735.483	1753.310	1827.110	1881.780	1799.421
S_1	1838.270	1262.577	2328.714	2381.030	2202.648
S_2	1673.540	1779.677	1761.600	1819.420	1758.559
S_3	1726.380	1780.573	1826.007	1941.270	1818.558
Mean M	1743.419	1894.034	1935.858	2005.875	
F test	S(S)	M(S)	SM(S)		
CD (.05)	15.809	21.591	36.226		

8-2 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	2551.850	2835.537	3065.683	3421.037	2968.527
S_1	2567.854	3858.090	5535.084	5544.277	4376.324
S_2	5551.643	3662.870	4169.053	4362.393	3936.490
S_3	3476.873	3558.560	4048.877	4047.857	3783.047
Mean M	3037.055	3478.765	4204.680	4343.890	
F test	S(S)	M(S)	SM(S)		
CD (.05)	34.203	57.788	115.236		

8-3 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	5061.414	5638.754	5900.640	6750.587	5837.848
S_1	8155.437	10211.410	11288.560	11575.290	10307.680
S_2	6251.030	7041.787	7849.761	7450.744	7148.330
S_3	6247.399	6759.754	7585.883	7490.797	7020.956
Mean M	6428.818	7412.928	8156.213	8616.555	
F test	S(S)	M(S)	SM(S)		
CD (.05)	160.119	245.665	385.194		

open and shaded conditions were compared. Highest leaf area was produced by shade levels at 120 and 180 DAP. At 60 DAP, 25 per cent shade registered the maximum leaf area per plant (4376.3 cm^2), followed by S_3, S_0 and S_2. At 120 and 180 DAP maximum leaf area was observed under S_1 followed by S_2, S_3 and minimum leaf area under open condition. Among shade levels 25 per cent (10307.6 cm^2) was significantly superior to 50 (7148.3 cm^2) and 75 (7020.9 cm^2) per cent shade levels.

A general increasing trend in leaf area was observed with increasing mulch levels, at all stages. The M_4 was significantly superior to other mulch levels at all stages. The lowest values were recorded from M_1.

Significant shade and mulch interaction was also observed. Under open condition leaf area showed an increasing trend with increasing mulch levels at all growth stages. Under 25 per cent shade, M_4 recorded the highest value of leaf area during 120 and 180 DAP but were found to be on par with M_3. Under heavy shade (75 %) at 120 and 180 DAP, M_3 and M_4 were found to be on par.

Leaf area duration

The data presented in Table 9 indicate that there was significant variation in the leaf area duration (LAD)

Table 9. Effect of shade and mulch levels on the mean leaf area duration (LAD) of ginger

9-1 Between 60-120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	205.39	220.75	234.82	255.02	228.99
S_1	212.59	293.80	377.37	382.79	316.63
S_2	249.91	260.51	285.14	296.23	272.94
S_3	249.57	256.20	281.96	285.83	268.39
Mean M	229.36	257.81	294.82	304.96	
F test	S(S)	M(S)	SM(S)		
CD (.05)	3.984	2.540	6.667		

9-2 Between 120 - 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	365.38	410.03	430.34	468.86	418.65
S_1	484.69	675.34	821.53	824.99	701.63
S_2	468.63	512.93	576.92	567.00	531.37
S_3	466.74	495.78	558.44	548.46	517.23
Mean M	446.36	523.39	596.80	602.33	
F test	S(S)	M(S)	SM(S)		
CD (.05)	19.033	18.411	35.732		

with varying shade levels at the two growth phases (60-120 and 120-180 DAP). At both phases, S_1 recorded the highest value of leaf area duration followed by S_2, S_3 and S_0.

Significant variation was observed among various mulch levels at two growth phases, and the LAD showed an increasing trend with each increment dose of mulch level.

Significant shade and mulch interaction was also found at two phases. The leaf area duration during the first phase showed an increasing trend with each increment dose of mulch under all shade levels. At second phase under S_0, M_4 was found to be superior to M_3 and M_3 was found to be on par with M_2. Under S_1, M_4 was on par with M_3. Under S_2 and S_3, M_3 recorded the highest value but at S_3, M_3 was found to be on par with M_4.

Chlorophyll content

The content of chlorophyll 'a' chlorophyll 'b' and total chlorophyll were found to show significant increasing trend with increasing shade intensities (Table 10 and Fig. 2). Total chlorophyll content varied from 0.621 (S_0M_1) to 1.856 (S_3M_2) mg g^{-1} fresh weight of the leaves 150 days after planting. Significant variation was observed in chlorophyll 'a' and chlorophyll 'b' contents with respect to various

Table 10. Effect of shade and mulch levels on the mean chlorphyll content of ginger leaves 150 days after planting (mg g^{-1} fresh weight)

10-1 chlorphyll a

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.407	0.408	0.409	0.410	0.409
S_1	0.512	0.514	0.514	0.515	0.514
S_2	0.959	0.963	0.95	0.966	0.963
S_3	1.361	1.283	1.253	1.257	1.267
Mean M	0.785	0.792	0.787	0.787	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.0015	0.0024	0.0069		

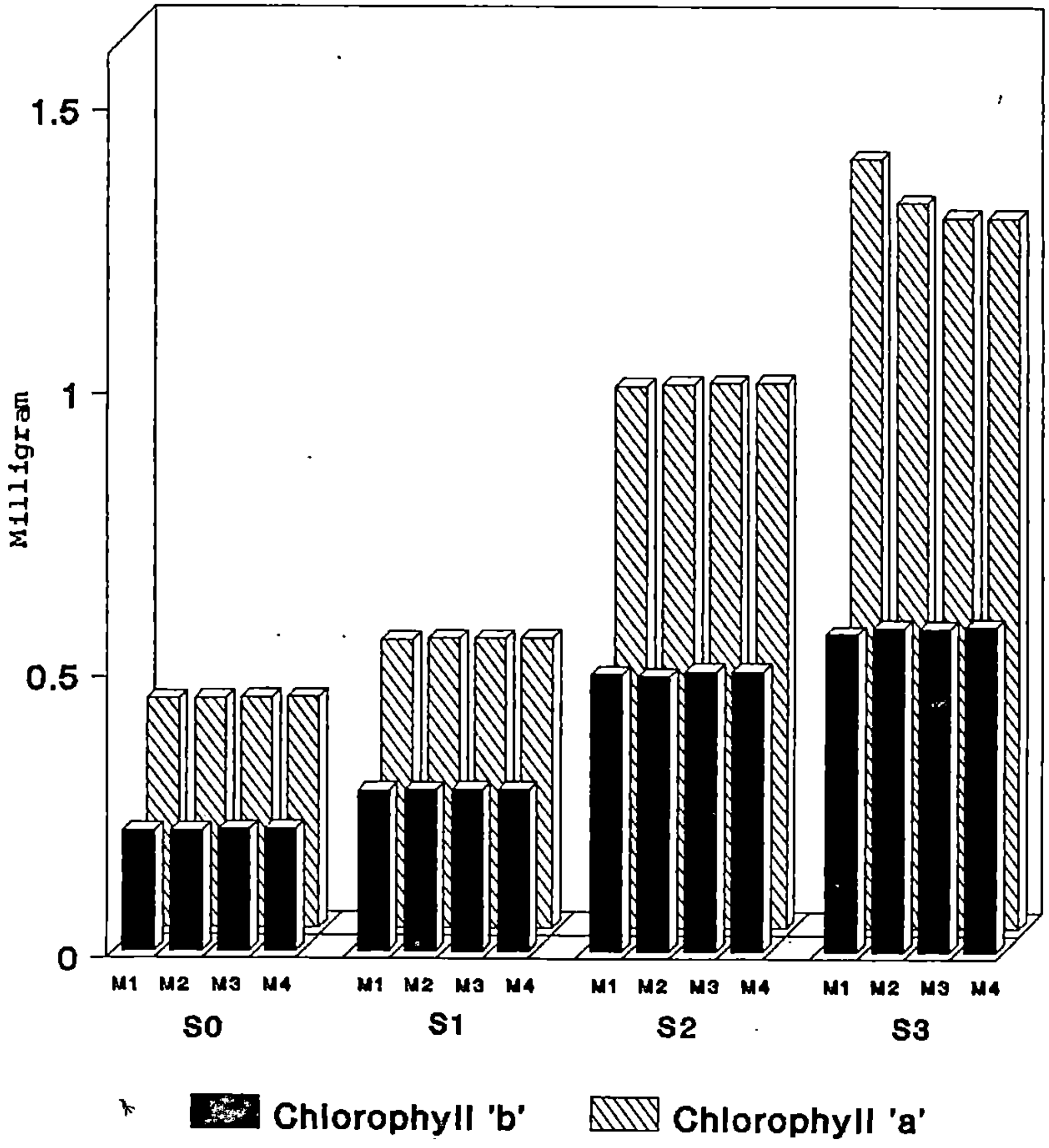
10-2 chlorphyll b

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.214	0.214	0.216	0.217	0.215
S_1	0.286	0.287	0.288	0.288	0.287
S_2	0.492	0.489	0.498	0.498	0.495
S_3	0.564	0.575	0.574	0.578	0.573
Mean M	0.389	0.391	0.394	0.395	
F test	S(S)	M(S)	SM(NS)		
CD (.05)	0.0025	0.0021	0.0058		

10-3 chlorphyll a+b

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.621	0.623	0.626	0.626	0.624
S_1	0.800	0.804	0.802	0.804	0.802
S_2	1.118	1.459	1.464	1.464	1.376
S_3	1.826	1.856	1.831	1.835	1.838
Mean M	1.091	1.186	1.181	1.182	
F test	S(S)	M(NS)	SM(NS)		
CD (.05)	0.117	0.115	0.265		

Fig. 2 . Effect of shade and mulch on the chlorophyll content of ginger leaves
(150 DAP)



mulch levels. Chlorophyll 'b' showed an increasing trend with increasing mulch levels. The effect of mulch on total chlorophyll content was not significant. In general, the interaction between shade and mulch on chlorophyll content was not significant.

Dry matter production

Dry matter production (DMP) showed significant variation with respect to different shade levels (Table 11 and Fig.3). At all growth stages studied, ginger plants under low shade (25 %) produced highest DMP and plants under heavy shade (75 %) produced the lowest DMP.

The effect of various levels of mulch on DMP was found to be significant. An increasing trend in DMP was observed with each increment dose of mulch. At 180 DAP, M_3 was found to be on par with M_4.

At all stages, significant shade and mulch interaction was also observed. At 60 DAP, S_0, S_2 and S_3 showed an increasing trend in DMP with increasing mulch levels. Similarly at 120 and 180 DAP, under S_0, S_1 and S_2, DMP showed an increasing trend with increasing mulch levels. Maximum dry matter production (56.1 g plant^{-1}) was obtained from S_1M_4 and minimum (33.3 g plant^{-1}) from S_0 M_1 at 180 DAP.

Table 11. Effect of shade and mulch levels on the mean dry matter production of ginger (g $plant^{-1}$)

11-1 60 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	4.63	6.66	7.96	8.36	6.90
S_1	6.31	6.65	9.56	9.45	7.99
S_2	6.29	7.49	7.49	8.21	7.37
S_3	5.76	6.20	6.29	7.01	6.31
Mean M	5.75	6.74	7.82	8.25	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.194	0.221	0.499		

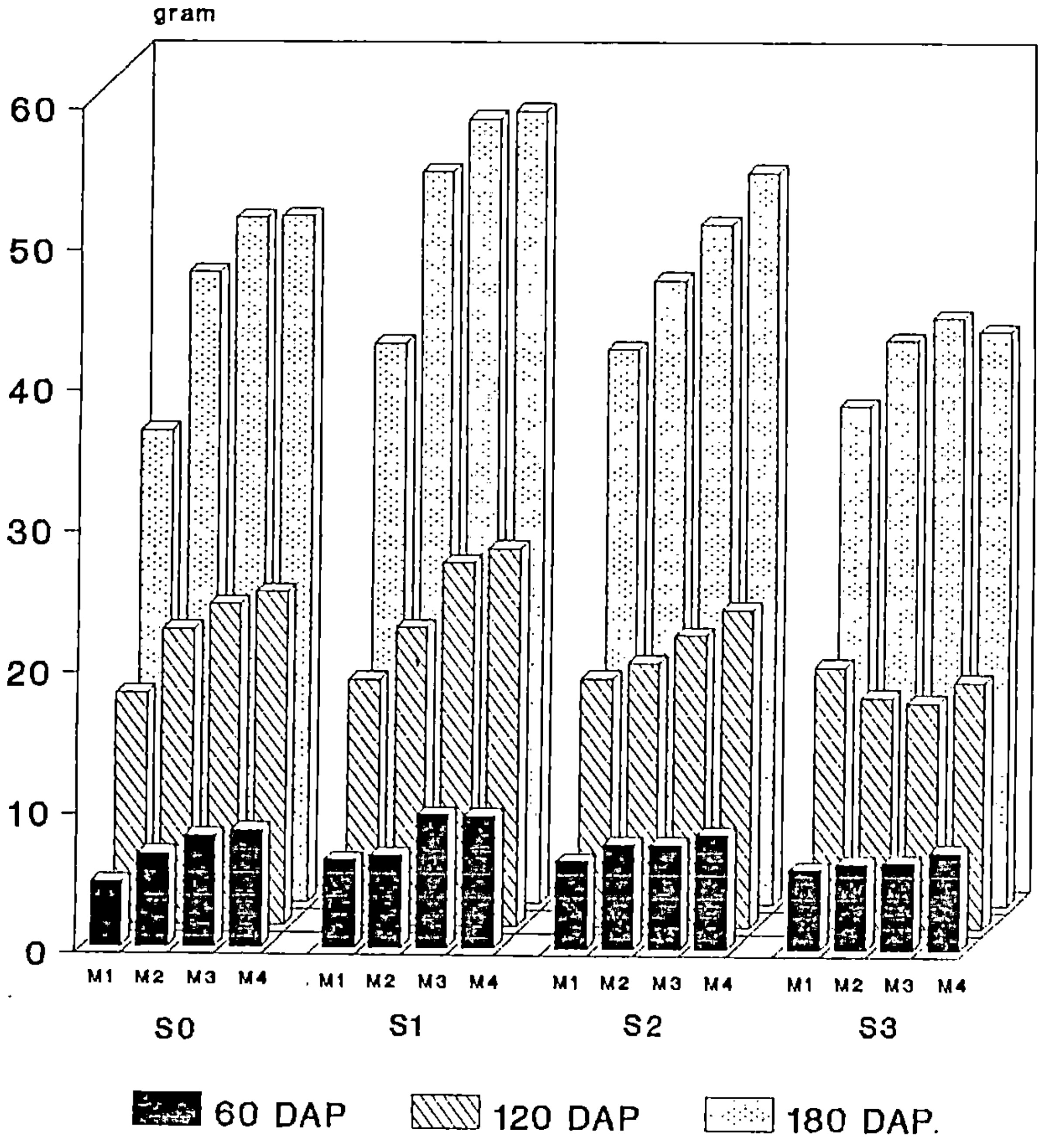
11-2 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	16.48	20.99	22.79	23.65	20.98
S_1	17.46	21.16	25.78	26.75	22.77
S_2	17.59	18.67	20.67	22.55	19.86
S_3	18.47	16.37	16.03	17.46	17.09
Mean M	17.50	19.29	21.32	22.60	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.398	0.397	0.945		

11-3 180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	33.33	44.65	48.51	48.64	44.28
S_1	39.57	51.83	55.56	56.10	50.77
S_2	39.19	44.12	48.07	51.82	45.80
S_3	35.19	39.87	41.53	40.58	39.30
Mean M	37.32	45.12	48.42	49.29	
F test	S(S)	M(S)	SM(S)		
CD (.05)	1.263	1.293	1.908		

Fig. 3. Effect of shade and mulch on dry matter production of ginger (g plant^{-1})



Net assimilation rate

The data on net assimilation rate (NAR) are presented in Table 12. NAR showed a decreasing trend with increasing shade intensities during the first growth phase (60-120 DAP) studied. The NAR recorded under open condition was found to be significantly superior to other shade levels. At second phase (120-180 DAP) 25 per cent shade registered a significantly higher NAR than other shade levels. At both phases, heavy shade (75 %) recorded the lowest NAR. Mulch produced significant difference on NAR in both phases. At phase two, M_3 recorded the highest NAR (0.945 g m^{-2} day^{-1}) which was found to be on par with M_2 (0.939 g m^{-2} day^{-1}) and M_4 (0.915 g m^{-2} day^{-1}). The lowest NAR was recorded by M_1 (0;716 g m^{-2} day^{-1}).

Shade and mulch interaction was also found to be significant. In the early phase, under 25 (S_1) and 75 (S_3) per cent shade levels, the NAR showed a decreasing trend with increasing mulch levels. At phase two under S_1M_4 recorded the highest NAR (1.353 g m^{-2} day^{-1}) which was found be on par with M_3 (1.323 g m^{-2} day^{-1}) and M_2 (1.270 g m^{-2} day^{-1}).

Table 12. Effect of shade and mulch levels on the net assimilation rate (NAR) of ginger (g m^{-2} day^{-1})

12-1 Between 60 - 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.981	1.058	1.011	0.957	1.002
S_1	0.832	0.793	0.752	0.723	0.775
S_2	0.739	0.665	0.702	0.795	0.725
S_3	0.710	0.627	0.538	0.547	0.606
Mean M	0.81	0.78	0.75	0.75	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.039	0.0432	0.069		

12-2 Between 120-180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.836	0.932	0.967	0.819	0.889
S_1	0.719	1.270	1.323	1.353	1.166
S_2	0.735	0.792	0.760	0.821	0.777
S_3	0.569	0.759	0.730	0.668	0.681
Mean M	0.716	0.939	0.945	0.915	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.237	0.104	0.213		

Crop growth rate

The data on crop growth rate (CGR) as influenced by shade and mulch levels are presented in Table 13 . At two growth phases, the effect of shade on CGR was found to be significant. The highest value of CGR (4.02 and 11.79 g m^{-2} day^{-1}) was obtained under 25 per cent shade (S_1) and lowest from heavy shade (S_3) at both phases. At latter phase, S_2, S_0 and S_3 were found to be on par. In both the phases the effect of various levels of mulch gave significant differences and it showed an increasing trend with increasing levels of mulch. At phase two, M_4 (8.85 g m^{-2} day^{-1}) was found to be on par with M_3 (8.84 g m^{-2} day^{-1}) and M_1 (7.85 g m^{-2} day^{-1}).

Significant interaction between shade and mulch was also observed in both the phases. At first phase, under S_0, M_4, M_3 and M_2 were found to be on par. At S_1, M_3 recorded the highest value of CGR but was on par with M_4. At heavy shade, M_2, M_3 and M_4 were found to be on par. At second phase under S_0, M_2, M_3 and M_4 were found to be on par. Under S_1, M_4 recorded the highest value (15.23 g m^{-2} day^{-1}), but it was on par with M_3 (14.42). Under S_2 and S_3, M_2, M_3 and M_4 were found to be on par.

Table 13. Effect of shade and mulch levels on the crop growth Rate (CGR) of ginger (g m^{-2} day^{-1})

13-1 Between 60 -120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	3.400	3.880	3.884	4.076	3.810
S_1	2.945	3.814	4.728	4.603	4.022
S_2	3.081	3.893	3.240	3.933	3.287
S_3	2.978	2.664	2.617	2.601	2.715
Mean M	3.101	3.313	3.617	3.803	
F test	S(S)	M(S)	SM(S)		
CD(.05)	0.255	0.170	0.319		

13-2 Between 120-180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	5.068	6.365	6.876	6.434	6.186
S_1	5.938	11.575	14.423	15.234	11.792
S_2	3.798	6.779	7.313	7.679	6.393
S_3	4.755	6.712	6.784	6.079	6.080
Mean M	4.889	7.858	8.849	8.855	
F test	S(S)	M(S)	SM(S)		
CD (.05)	1.206	1.012	1.952		

Bulking rate

At both growth phases (60-120 and 120-180 DAP) bulking rate (BR) was found to be maximum under 25 per cent shade (Table 14). During the first phase data on BR show that S_1 was followed by S_2, S_0 and S_3. At second phase, (BR) showed a decreasing trend with increasing shade intensities.

The effect of mulch on BR was significant. At first phase, BR showed an increasing trend with increasing mulch application. At second phase, the highest bulking rate was recorded from M_3 followed by M_4 and M_2.

Significant shade and mulch interaction was observed only at second phase. At all the shade levels, levels of mulch showed an increasing trend of BR. At 25 per cent shade, M_3 was on par with M_4.

Top yield

The top yield was significantly higher (2249.14 kg ha^{-1}) under 25 per cent shade and the lowest top yield (1435.89 kg ha^{-1}) was recorded under open condition (Table 15). The top yield of S_1 was followed by S_3, S_2 and S_0. An increasing trend of top yield with increasing levels of mulch was observed. The highest top yield was under M_4, which was significantly superior to M_2 and M_1 but on par with M_3.

Table 14. Effect of shade and mulch levels on the bulking rate of (BR) of ginger (g day^{-1})

14-1 Between 60 - 120 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.112	0.125	0.130	0.133	0.125
S_1	0.126	0.163	0.268	0.399	0.239
S_2	0.097	0.169	0.127	0.122	0.129
S_3	0.113	0.092	0.097	0.105	0.102
Mean M	0.112	0.137	0.156	0.189	
F test	S	M(S)	SM(S)		
CD (.05)	0.088	0.052	0.125		

14-2 Between 120-180 DAP

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.173	0.267	0.277	0.262	0.246
S_1	0.261	0.301	0.326	0.328	0.304
S_2	0.273	0.389	0.327	0.278	0.291
S_3	0.235	0.243	0.252	0.265	0.248
Mean M	0.236	0.275	0.296	0.283	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.006	0.006	0.013		

Table 15. Effect of shade and mulch levels on the mean top yield of ginger (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	1253.07	1454.93	1474.63	1560.94	1435.89
S_1	1957.10	2086.50	2452.22	2500.73	2249.14
S_2	1801.69	2128.06	2124.05	2135.29	2047.27
S_3	2055.60	2166.14	2305.83	2188.93	2178.62
Mean M	1766.87	1958.91	2088.68	2096.47	
F test	S(S)	M(S)	SM(S)		
CD (.05)	24.152	29.007	48.422		

Significant interaction was also observed between shade and mulch. In general, the mulch levels produced an increasing trend of top yield. The treatment combination S_1M_4 (2500.73 kg ha^{-1}) was found to be significantly superior to other treatment combinations which produced maximum top yield. Under 50 per cent shade M_2, M_3 and M_4 were found to be on par. Under 75 per cent shade M_3 showed significant superiority over the other mulch treatments, while M_4 and M_2 were on par.

Rhizome spread

The data presented in Table 16 indicate significant differences in rhizome spread among various degrees of shade. Rhizome spread under 25 per cent shade (19.72 cm) was found to be significantly superior to other shade levels. Rhizome spread under 75 per cent shade was superior to 50 per cent and open. Plants under open condition recorded the lowest rhizome spread (15.64 cm)

The effect of various mulch treatments on rhizome spread was also found to be significant. M_4 and M_3 were found to be on par, but significantly superior to M_2 and M_1. M_1 recorded the lowest rhizome spread (15.97 cm).

Table 16. Effect of shade and mulch levels on the mean rhizome spread of ginger (cm)

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	14.10	16.01	16.35	16.09	15.64
S_1	18.09	18.45	21.16	21.19	19.72
S_2	14.59	18.15	19.17	19.15	17.77
S_3	17.10	18.28	19.29	19.54	18.55
Mean M	15.97	17.72	18.99	18.99	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.355	0.354	0.573		

Significant shade and mulch interaction was also observed. Under open condition M_2, M_3 and M_4 were found to be on par but superior to M_1. The maximum rhizome spread was recorded at M_4 (21.19 cm) under 25 per cent shade which was on par with M_3 (21.16 cm). M_1 and M_2 were on par but significantly inferior to M_3 and M_4. Under 25 per cent shade, M_4 registered the maximum rhizome spread followed by M_3, M_2 and M_1. But under 50 per cent shade M_3 recorded the highest value but under 75 per cent shade, M_4 was found to be on par with M_3.

Utilization index

Significant variation was observed among shade levels with respect to utilization index (UI) (Table 17). The UI was found to be superior (2.33) at open condition and showed a steady decrease with decrease in light intensities. The effect of mulch on UI was found to be significant. A general trend of significant increase in UI was observed with increase in mulch levels. M_1 recorded the lowest value of UI (1.82) and M_4 the highest (2.16).

Significant shade and mulch interaction was observed. At S_0, the highest value of UI was recorded in M_4 and was found to be significantly superior to M_3, M_2 and M_1. Under 25 per cent shade (S_1), M_3 gave the highest value but

Table 17. Effect of shade and mulch levels on utilization index of ginger

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	2.181	2.036	2.497	2.631	2.336
S_1	1.873	2.099	2.146	2.101	2.055
S_2	1.739	1.585	1.912	1.989	1.806
S_3	1.791	1.782	1.789	1.950	1.748
Mean M	1.821	1.871	2.086	2.168	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.081	0.046	0.117		

found to be on par with M_2 and M_4. At 50 per cent shade M_4 gave the highest and M_2 the lowest UI. Under 75 per cent shade, M_4 was found to be highest followed by M_3. Among different treatment combinations the highest UI was recorded by M_4 under open condition.

Harvest index

Harvet index (HI) showed significant variation with varying shade intensities (Table 18). The highest value of HI was noted from open. HI showed a decreasing trend with increasing shade intensity, but an increasing trend was observed with increasing doses of mulch. M_4 was found to be significantly superior to M_2 and M_1 but was on par with M_3. Significant shade and mulch interaction was also observed with respect to HI. The highest HI was recorded from M_4 under open condition which was on par with M_3 but inferior to M_1 and M_2. Under 25 per cent shade, M_3 gave the highest HI, but on par with M_4 and M_2. At S_3 and S_2, M_4 recorded the highest HI.

Green ginger yield

Significant variation was observed in green ginger yield at various levels of shade (Table 19 and Fig. 4). The

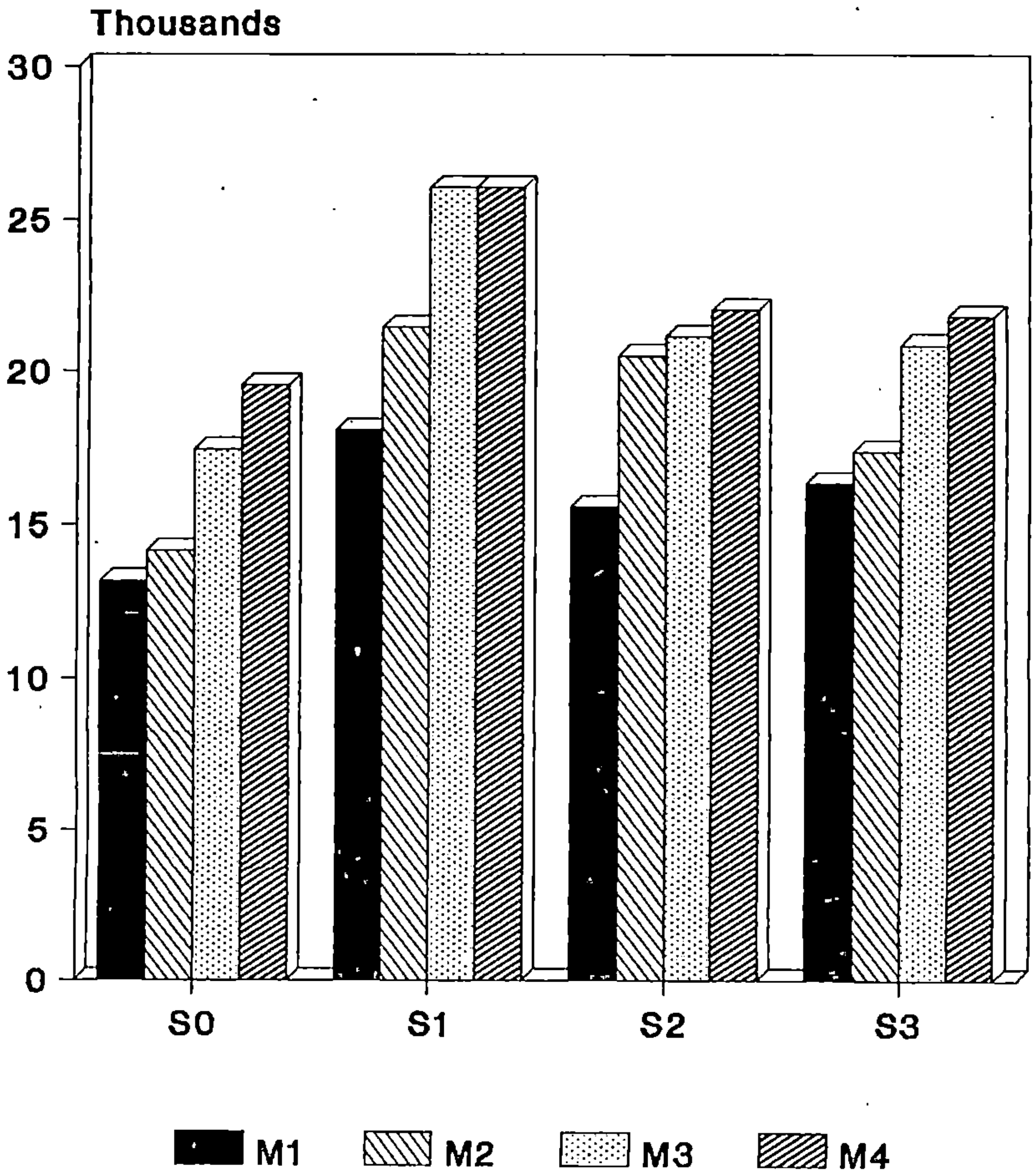
Table 18. Effect of shade and mulch levels on the harvet index (HI) of ginger

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	0.653	0.674	0.714	0.733	0.694
S_1	0.642	0.660	0.681	0.676	0.665
S_2	0.657	0.622	0.656	0.665	0.650
S_3	0.596	0.648	0.640	0.660	0.636
Mean M	0.637	0.651	0.673	0.684	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.0205	0.023	0.0288		

Table 19. Effect of shade and mulch levels on the mean ginger yield (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	13164	14145	17398	19517	16056
S_1	18029	21439	26030	26036	22883
S_2	15535	20492	21123	22007	19789
S_3	16292	17303	20839	21786	19055
Mean M	15755	18345	21347	23337	
F test	S(S)	M(S)	SM(S)		
CD (.05)	476.3	290.7	568.6		

Fig. 4 . Effect of shade and mulch on green ginger yield (kg ha^{-1})



highest green ginger yield (22,883 kg ha^{-1}) was recorded from 25 per cent shade, followed by 50 (19789 kg ha^{-1}) and 75 (19,055 kg ha^{-1}) per cent shade levels. The lowest green ginger yield (16,056 kg ha^{-1}) was recorded from open condition. The yield obtained from all shade levels were significantly superior to open condition.

The effect of mulches on green ginger yield was found to be significant. Mulch level M_1 gave the lowest yield (15575 kg ha^{-1}) and showed a steady increase with each increment dose of mulch. M_4 was found to be superior (23337 kg ha^{-1}) to other mulch levels. M_3 was superior to M_2 and M_1, but inferior to M_4.

Significant interaction between shade and mulch was also observed. At all shade levels a general increasing trend in green ginger yield with each increment dose of mulch was observed. Among the treatment combinations the highest value of green ginger yield (26,036 kg ha^{-1}) was obtained from M_4 followed M_3 (26,030 kg ha^{-1}) under 25 per cent shade and the lowest (13,164 kg ha^{-1}) from M_1, under open. Under open condition, 48 per cent increase in green ginger yield was obtained as a result of increasing mulch level from 25 to 100 per cent of the recommended dose. Under low shade (25%) the yield increase was 44 per cent as a result of increasing mulch level from 25 to 100 per cent. The corresponding increase under 50 and 75 per cent shade levels as a result of increasing mulch level from M_1 to M_4 was 41 and 38 per cent respectively. Under 25 per cent shade, M_3 and M_4 were on par and under 50 and 75 per cent shade, M_3 and M_4 were comparable with respect to green ginger yield.

Dry ginger yield

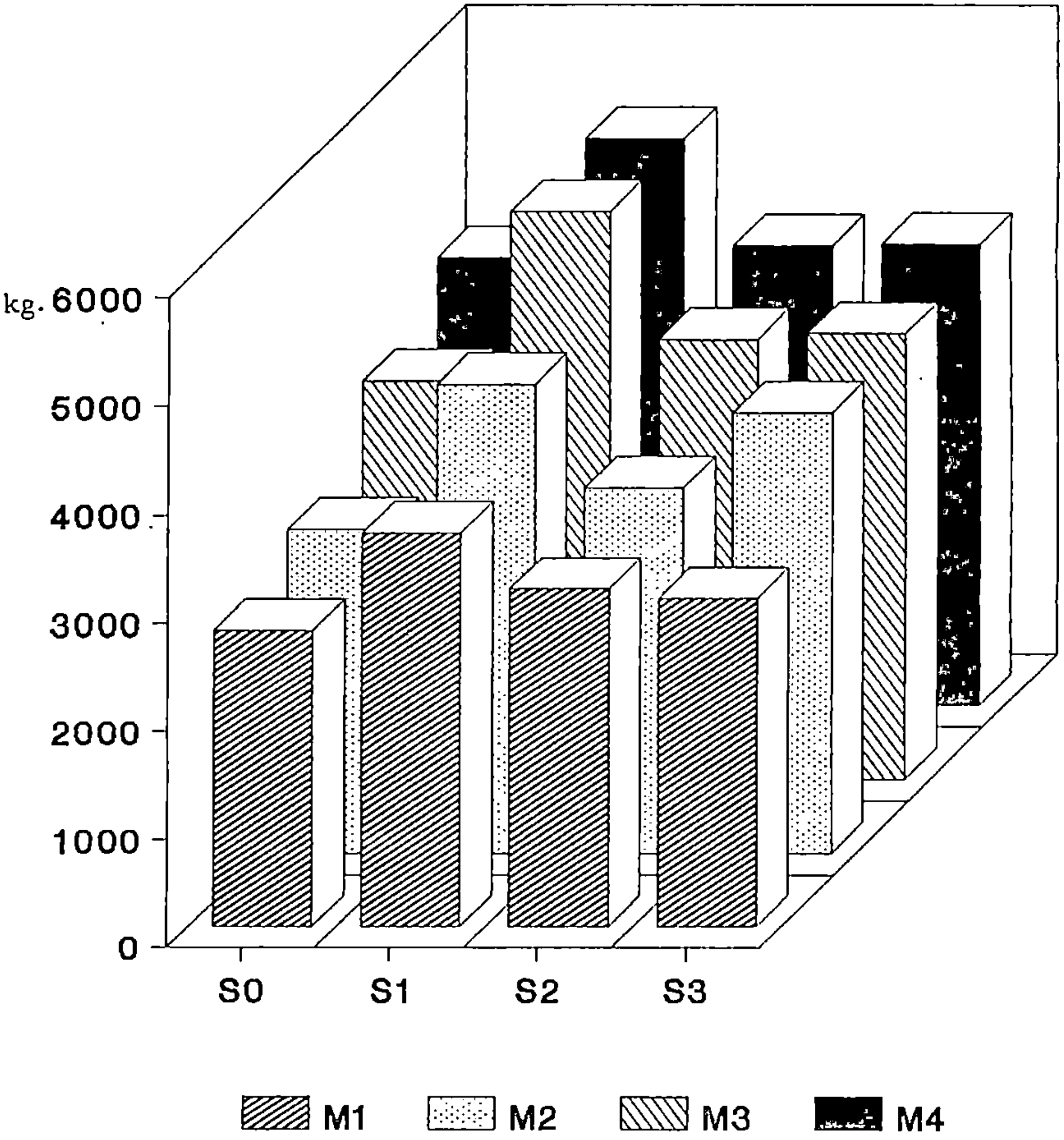
The Table 20 and Fig.5 present the effect of shade and mulch on dry ginger yield. Dry ginger yield under al shade levels were significantly higher to open condition The maximum dry ginger was obtained from 25 per cent shad which was followed by 50 and 75 per cent shade. The increas in dry ginger yield under 25, 50 and 75 per cent shade level compared to open, were 41.6, 14.1 and 9.2 per cen respectively. The effect of mulch on dry ginger yield was significant and showed an increasing trend with increasing mulch levels. Maximum dry ginger yield was obtained from M_4 and M_3 (100 and 75 % of the recommended dose respectively) whivh gave 36.6 per cent increase compared to M_1 (25 % of the recommended dose). M_4 and M_3 were found be superior to M_2 and M_1.

Significant shade and mulch interaction was also observed with respect to dry ginger yield. Under all shade

Table 20. Effect of shade and mulch levels on the mean dry ginger yield (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	2736	2996	3685	4141	3389
S_1	3639	4328	5246	5256	4617
S_2	3029	4063	4117	4266	3869
S_3	3119	3375	4063	4248	3701
Mean M	3131.31	3690.31	4278.21	4278.25	
F test	S(S)	M(S)	SM(S)		
CD (.05)	101.4	65.9	98.9		

Fig. 5 . Effect of shade and mulch levels on dry ginger yield (kg ha^{-1})



levels, dry ginger yield showed an increasing trend with increasing levels of mulch. At S_1, M_4 gave the highest dry ginger yield, but it was found to be on par with M_3. Among the treatment combinations, the highest dry ginger yield was obtained from M_4 (5256 kg ha^{-1}) under low shade (25 %) closely followed by M_3 (5246 kg ha^{-1}).

Under open condition the dry ginger yield increase as a result of increasing mulch level from 25 per cent to 100 per cent of the recommended dose was 51.35 per cent. The corresponding yield increase under 25, 50 and 75 per cent shade levels were 44.40, 40.81 and 36.18 per cent respectively. The dry ginger yield under open as a result of increasing mulch from 75 per cent to 100 per cent of the recommended dose was only 12.37 per cent. The corresponding increase in yield under 25, 50 and 75 per cent shade levels was 0.18, 3.60 and 5.94 per cent respectively.

Volatile oil

A significant change in volatile oil content of rhizome was found under various degree of shade treatments (Table 21). The lowest content of volatile oil was recorded from 25 per cent shade and it was on par with open. The volatile oil content increased with increasing levels of shade. Significantly superior volatile oil content (16,5 %

Table 21. Effect of shade and mulch levels on volatile oil content of ginger (v/w)% on dry weight basis

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	1.720	1.833	1.827	2.006	1.847
S_1	1.873	1.910	1.316	2.173	1.818
S_2	2.063	2.123	2.150	2.166	2.126
S_3	2.080	2.136	2.150	2.240	2.152
Mean M	1.937	2.000	1.860	2.147	
F test	S(S)	M(NS)	SM(NS)		
CD (.05)	0.237	0.230	0.524		

increase cmpared to open condition) was obtained from heavy shade (S_3). The effect of mulch treatments and shade mulch interaction were observed to be not significant.

Non-volatile ether extract

Significant variation was observed among the shade levels with respect to non-volatile ether extract (NVEE). The data (Table 22) showed a decreasing trend in NVEE with increasing shade intensities. The effect of mulching on NVEE also showed an increasing trend with each increment dose of mulch. Significant shade and mulch interaction was also observed. Under open condition M_3 was found to be significantly superior to M_1, M_2 and M_4 but M_2 was found to be on par with M_4. Under S_1, the content of NVEE showed an increasing trend with increasing levels of mulch. Under 75 per cent shade, M_4 exhibited significant superiority over other mulch treatments.

Fibre content

The data presented in Table 23 depict the effect of shade and mulch on the fibre content of ginger. The effect of shade on fibre content was significant, exhibiting a decreasing trend with increasing shade intensities. The

Table 22. Effect of shade and mulch levels on the non-volatile ether extract of ginger (%) on dry weight basis

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	5.420	6.020	6.226	6.033	5.918
S_1	5.503	5.676	5.920	6.090	5.798
S_2	5.923	5.413	5.310	5.737	5.596
S_3	4.423	4.823	5.606	6.183	5.259
Mean M	5.317	5.498	5.765	6.003	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.074	0.044	0.129		

Table 23. Effect of shade and mulch levels on the fibre content of ginger rhizomes (%) on dry weight basis

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	6.800	6.663	7.400	8.646	7.378
S_1	6.833	7.170	7.257	7.863	7.281
S_2	5.900	5.750	6.887	8.850	6.847
S_3	6.050	6.446	6.673	7.563	6.683
Mean M	6.395	6.507	7.054	8.230	
F test	S(S)	M(S)	SM(S)		
CD (.05)	0.094	0.0120	0.236		

maximum fibre content was obtained from open and the minimum from the heavy shade. The effect of mulch on fibre content was significant exhibiting an increasing trend and the maximum content exhibited from M_4. Shade and mulch interactions was also significant.

Uptake of nutrients

Data on uptake of nutrients as influenced by shade and mulch are presented in Table 24 and Fig 6 .

The effect of shade on the uptake of N was observed to be significant at all levels of shade and the uptake was found to be increasing with increasing shade intensities. The various levels of mulch also showed a significant increasing trend with increasing mulch levels. Shade and mulch interaction was also significant. At S_0, M_4 was superior to M_2 and M_1.

The effect of shade on P uptake was found to be significant. The highest P uptake was recorded from 50 per cent shade. When the shade level increased from 50 to 75 per cent the uptake decreased from 16.68 to 12.68 kg ha^{-1}. The effect of mulches on P uptake and interaction with shade were not found to be significant.

Table 24. Effect of shade and mulch levels on NPK uptake of ginger plants kg ha^{-1}

24-1 Uptake of N

Shade levels	Mulch levels M_1	M_2	M_3	M_4	Mean S
S_0	46.60	47.38	54.73	55.99	51.17
S_1	49.47	59.39	64.36	70.34	59.89
S_2	48.64	54.77	66.97	72.72	60.78
S_3	53.97	63.16	57.58	69.28	63.49
Mean M	49.67	55.17	63.41	67.08	
F test CD (.05)	S(S) 0.430	M(S) 0.864	SM(S) 1.358		

24-2 Uptake of P_2O_5

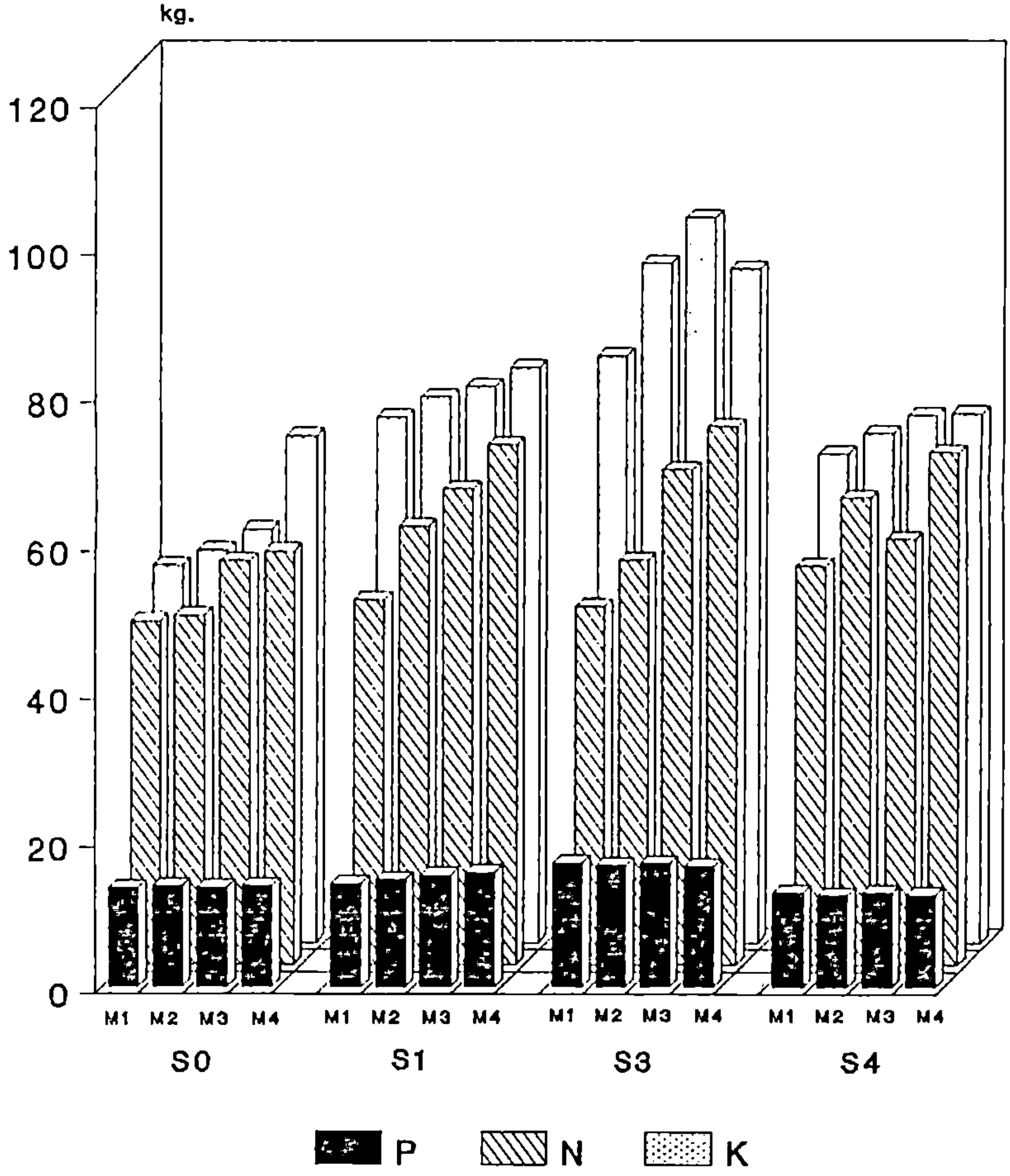
Shade levels	Mulch levels M_1	M_2	M_3	M_4	Mean S
S_0	13.53	13.77	13.55	13.72	13.64
S_1	14.09	14.63	15.24	15.61	14.89
S_2	16.91	16.58	16.83	16.40	16.68
S_3	12.88	12.48	12.84	12.53	12.68
Mean M	14.36	14.36	14.61	14.56	
F test CD (.05)	S(S) 0.272	M(NS) 0.262	SM(NS) 0.897		

24-3 Uptake of K_2O

Shade levels	Mulch levels M_1	M_2	M_3	M_4	Mean S
S_0	51.08	53.15	55.91	68.50	57.16
S_1	70.98	73.69	75.07	77.72	74.36
S_2	79.28	91.82	97.93	91.06	90.02
S_3	66.06	68.85	71.24	71.52	69.42
Mean M	66.85	71.88	75.04	77.20	
F test CD (.05)	S(S) 0.492	M(S) 0.461	SM(S) 1.407		

Fig. 6. Effect of shade and mulch on nutrient uptake of ginger

(kg ha^{-1})



Uptake of K showed an increasing trend from open condition to 50 per cent shade and then showed a decrease at 75 per cent shade. The K uptake was lowest under open. A significant increasing trend was observed with increasing levels of mulch. Significant shade and mulch interaction was also observed in K uptake. Under S_0, S_1 and S_3, mulch produced an increasing trend in K uptake with each increment addition of mulch but under S_2, M_3 was significantly superior to other mulch levels and M_2 and M_4 were found to be on par.

Soil N, P and K content

The effect of shade on N content of the experimental field after the experiment was found to be significant and showed an increasing trend with increasing shade levels (Table 25). The soil N content under mulch level, M_4 (222.84 kg ha^{-1}) was found to be superior to M_1 (216.86 kg ha^{-1}), but was on par with M_3 (221.91 kg ha^{-1}). Significant shade and mulch interaction was also observed at various treatments combinations. At all levels of shade each additional dose of mulch produced an increasing trend of soil N content.

Table 25. Effect of shade and mulch levels on the available N, P and K content of the soil (kg ha^{-1}) after the experiment.

25-1 Available N (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	200.68	205.03	208.99	210.13	206.25
S_1	217.93	218.36	219.18	219.32	218.70
S_2	219.11	221.30	222.57	225.81	222.20
S_3	229.74	236.10	236.90	235.91	234.66
Mean M	216.86	220.20	221.91	222.84	
F test CD (.05)	S(S) 1.188	M(S) 2.201	SM(NS) 4.370		

25-2 Available P_2O_5 (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	45.01	45.75	48.31	48.56	46.90
S_1	35.06	36.63	38.01	39.52	37.38
S_2	35.38	36.00	37.45	38.60	36.86
S_3	42.65	44.81	49.04	49.36	46.46
Mean M	39.52	40.80	42.70	44.12	
F test CD (.05)	S(S) 0.922	M(S) 0.574	SM(S) 1.318		

25-3 Available K_2O (kg ha^{-1})

Shade levels	Mulch levels				Mean S
	M_1	M_2	M_3	M_4	
S_0	126.18	127.71	129.45	130.27	128.40
S_1	118.36	119.58	120.53	121.43	119.98
S_2	117.74	119.39	118.88	120.89	119.22
S_3	141.37	141.84	143.43	143.99	142.65
Mean M	125.91	127.13	128.07	129.15	
F test CD (.05)	S(S) 0.789	M(S) 0.789	SM(S) 1.451		

Data on the content of P showed a significant variation with varying shade intensities (Table 25). The P content under S_0 was significantly superior to S_1 and S_2 but was on par with S_3. Among different levels of mulch, M_4 was found to be superior (44.12 kg ha^{-1}) to M_1, M_3 and M_2. M_1 (39.52 kg ha^{-1}) recorded minimum P content. Significant shade and mulch interaction was also observed in the soil P content.

Availability of K showed significant differences among shade treatments (Table 25). The availability was maximum under intense shade. K availability showed an increasing trend with increasing mulch application. Shade and mulch interaction was also found to be significant. The highest value of K availability (143.99 kg ha^{-1}) was observed in M_4 under S_3.

DISCUSSION

DISCUSSION

Sunlight is the primary source of energy for photosynthesis. The economic produce of a crop is mainly determined by light, since it plays an important role in photosynthesis, photorespiration and translocation of assimilates to economic parts. The growth, yield and quality of many crops are influenced by shade at various stages of growth and development.

The differential response of ginger to shade, based on the studies conducted so far revealed that ginger is a shade loving plant giving increased yield under low shade (25 per cent). Relatively low light intensity in combination with low soil and air temperature and fairly high soil moisture exhibited under shaded situations were more conducive for the successful ginger cultivation.

The main yield components like plant height, number of leaves, tillers, leaf area and rhizome characters like bulking rate, rhizome spread and fresh rhizome yield are found to be influenced by varying levels of shade. The probable interpretations for these effects of shade are discussed.

Mulching is one of the important cultural operations practised in ginger cultivation. In Kerala, substantial area of ginger cultivation is under partially shaded conditions and therefore the possibility of reducing the quantity of present day recommendation of the green leaf mulch is discussed.

Sprouting

The sprouting percentage of ginger under shade levels was significantly superior to open condition as evidenced by the sprouting counts (Table 4) taken at 45 and 60 days after planting (DAP). All shade levels reduced the atmospheric temperature (Appendix I and Fig. 2), increased relative humidity near the crop canopy (Appendix II and Fig. 8), reduced soil temperature (Appendix III and Fig.9) and increased soil moisture (Appendix IV and Fig.10). Therefore, low soil and atmospheric temperature, high relative humidity and soil moisture provided by shade levels might have produced very conducive condition for enhnced sprouting.

Mulching enhanced sprouting, and maximum sprouting percentage was observed from M_4 (100 % of the recommended dose) and minimum from M_1 (25 %). Increased levels of mulch

Fig. 7. Day temperature near the crop canopy

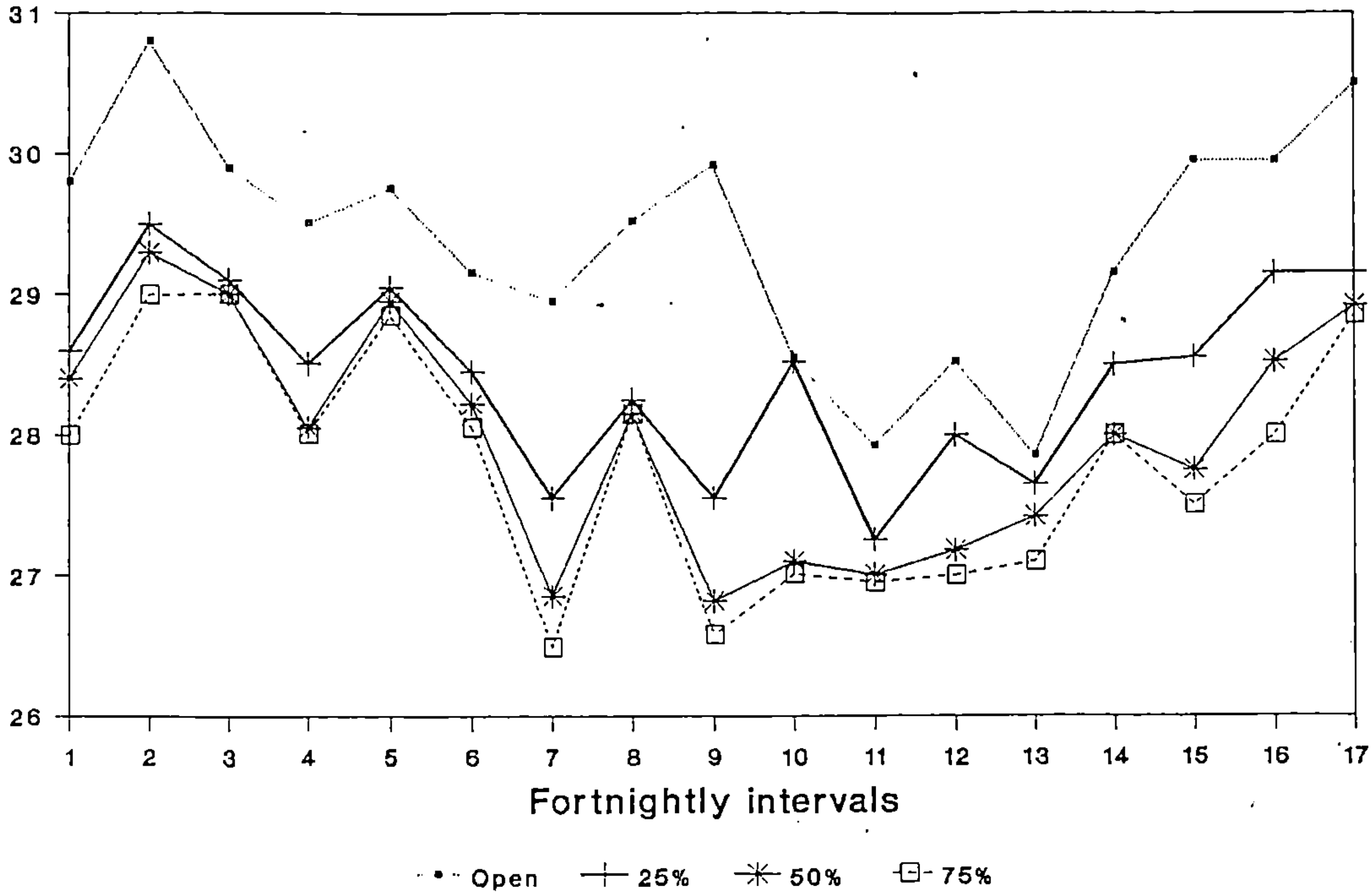


Fig. 8. Relative humidity near the crop canopy (%)

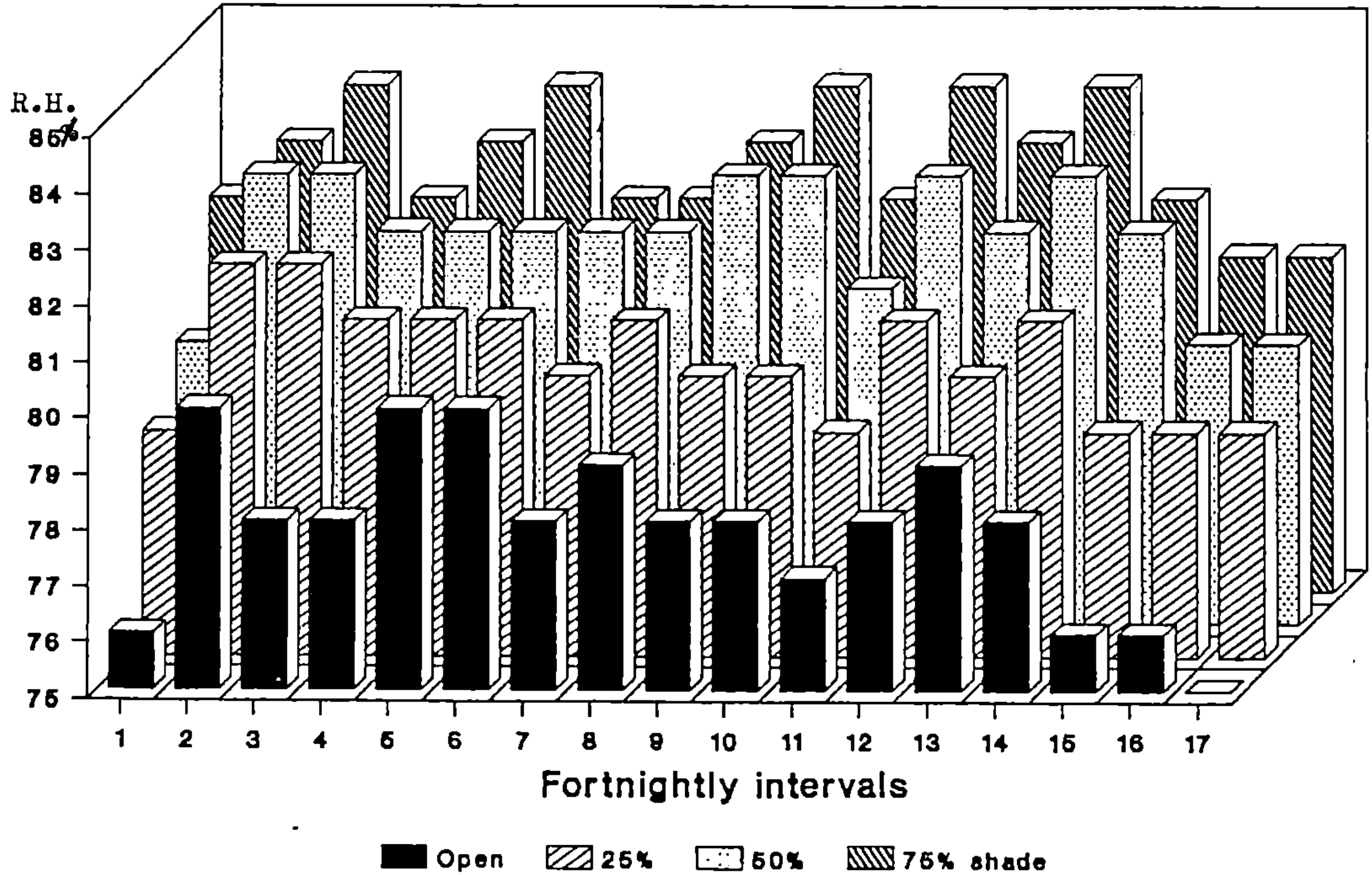
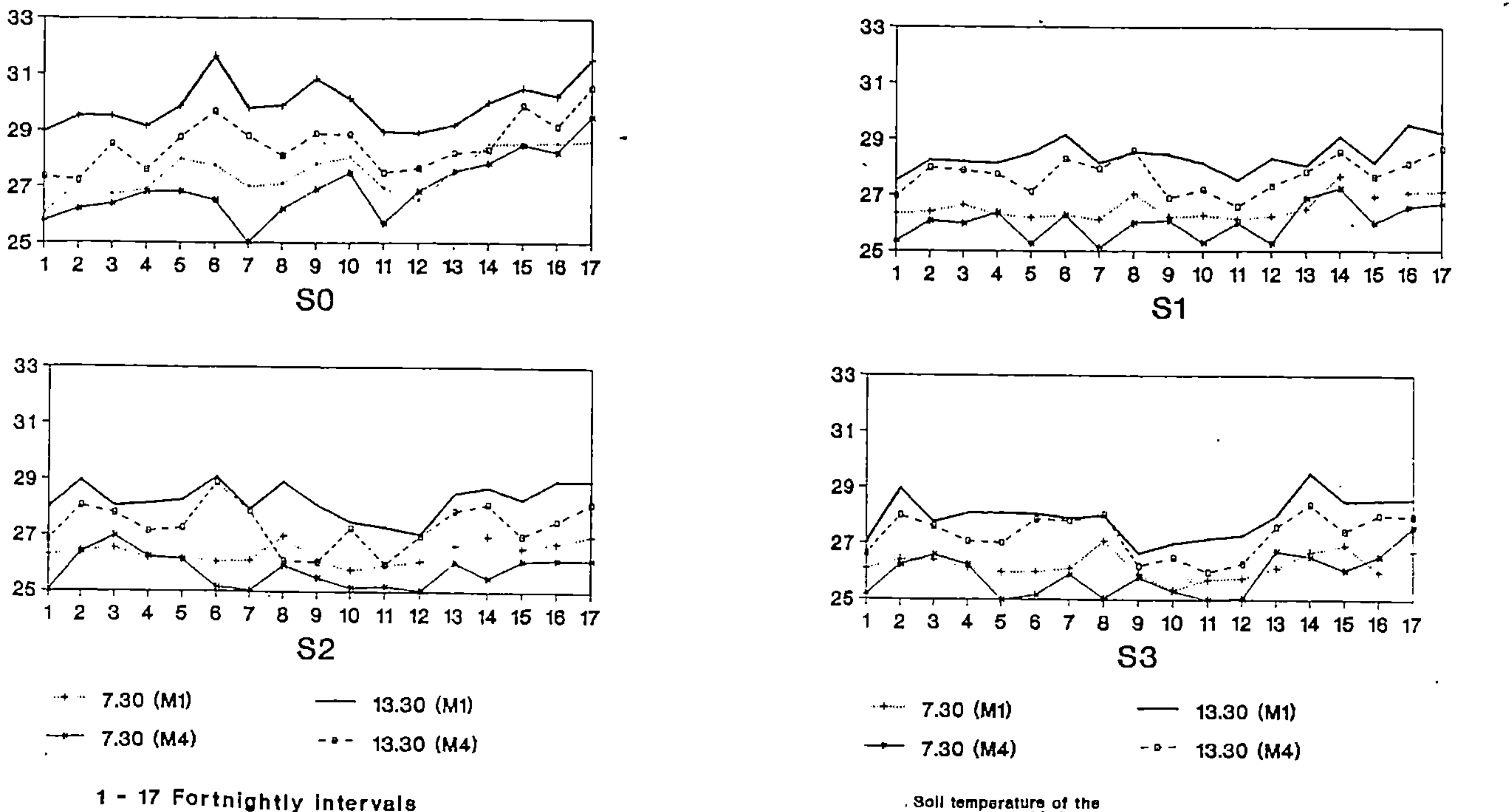
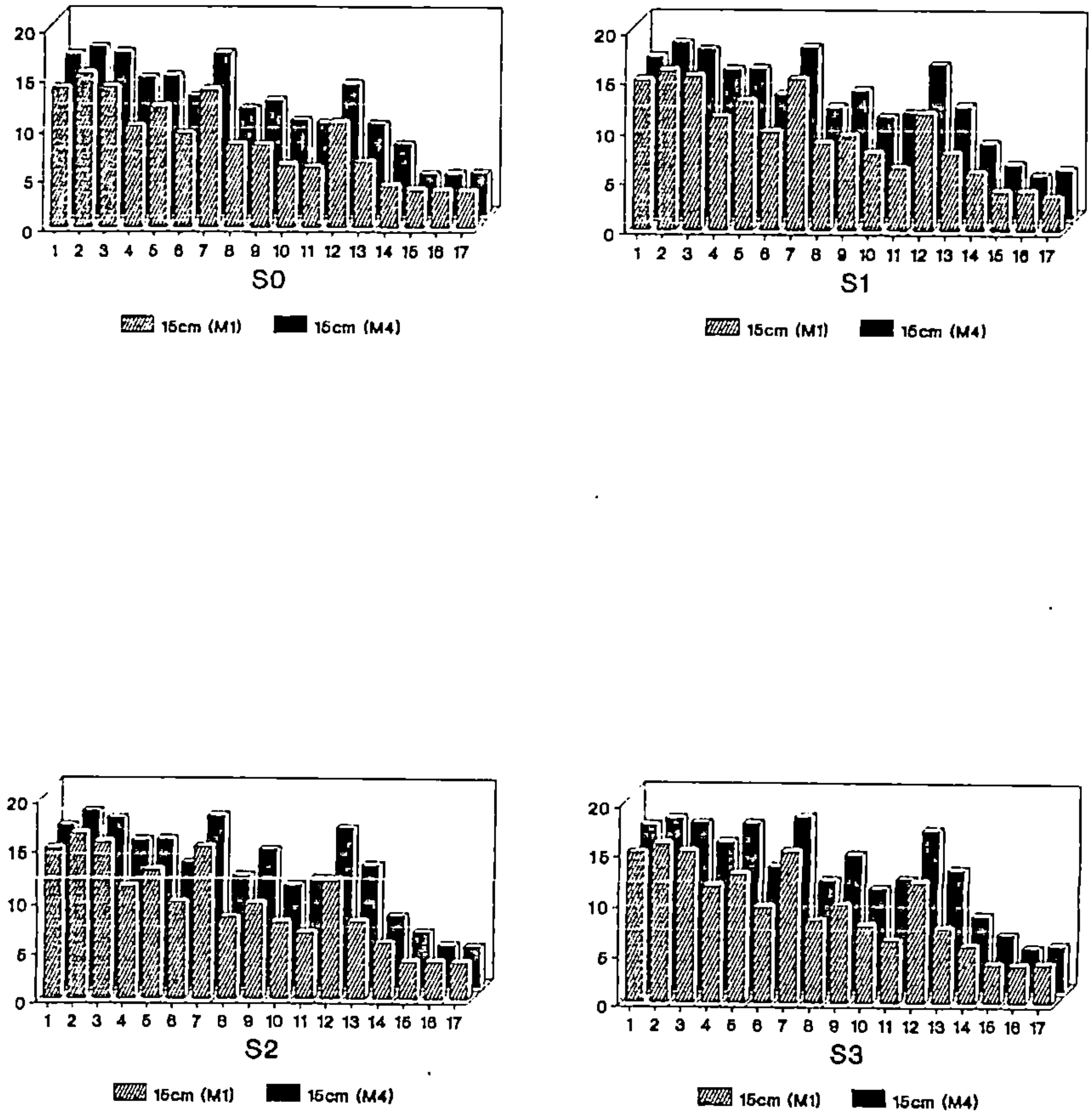


Fig. 9. Soil temperature of the experiment field (°C)



. Soil temperature of the experiment field (°C)

Fig. 10. Soil moisture of the experimental field (%)



1 - 17 Fortnightly intervals

1 - 20 Moisture %

was found to enhance early sprouting (counts taken at 30 and 45 DAP) but at 60 DAP the effect seems to be nullified. The favourable effect of mulching on sprouting might be due to increased rate of moisture conservation (Appendix IV and Fig. 10) and reduced soil temperature (Appendix III and Fig. 9).

Plant height

The effect of shade levels on plant height was significant. An increasing trend in plant height with increasing shade intensity from zero to 75 per cent, was observed (Table 5). This finding was in agreement with the results reported by Aclan and Quisumbing (1976). Lalithabai and Nair (1982) in coleus, sweet potato, ginger and turmeric also observed the similar effects. The findings of Susan Varughese (1989), Ancy Joseph (1992) and George (1992) that the height of ginger plants under shaded conditions was higher than that in open, support the result of the present investigation.

According to Meyer and Anderson (1952) high irradiance may result in high rates of transpiration which are likely to result in internal deficiencies of water and consequent retardation of cell division and cell enlargement which ultimately results in a low plant height at open.

Under various shade levels mulch treatments showed a positive influence on plant height, as reported in various crops by Kashyap and Jyotishi (1967), Srivastava et al. (1969) and Jayashree (1989). At all growth stages, M_4 was found to be superior. Increased levels of mulch helps to maintain a high soil moisture content, especially under shaded conditions, indirectly favour for cell enlargement and elongation which ultimately resulted in more plant height. Plants developed under low soil water condition are always dwarfed and stunted (Meyer et al., 1973).

Number of tillers per plant

There was significant difference between shade levels with respect to tiller production (Table 6). According to Aclan and Quisumbing (1976) and Lalithabai (1981) the tiller production was not influenced by shade. However, in the present experiment the number of tillers per plant was found to be significantly low under medium and heavy shade and the highest number (14.96) of tillers were observed under low shade (25 %). Similar results were also reported by Ancy Joseph (1992) and George (1992) in ginger. A limitation in energy supply resulting from decreased proportion of incident radiation available per tiller may also be partly responsible for decrease in tiller production under heavy shade.

Increased levels of mulch exhibited an increasing trend in tiller production. The positive influence of mulch on tiller production was also reported by Ragothama (1981) in cardamom. According to him, the soil moisture content in the root zone as a result of mulching have a direct influence on tillering. In ginger, Jha et al. (1986) recorded maximum tiller number under green leaf mulch condition. The higher tiller production under low shade (25 %) might be due to the existence of higher soil moisture and favourable microclimate (Appendices I to IV) and higher photosynthesis compared to other levels of shade. Under heavy shade, though there was higher soil moisture and favourable microclimate the low availability of photosynthates might have resulted in reduced number of tillers per plant.

Number of leaves per plant

The leaf number at 180 DAP was found to be maximum under 25 per cent shade (Table 7) followed by open and medium shade. In agreement with results of the present investigation, Ancy Joseph (1992) also observed higher number of leaves per plant under 25 per cent shade. Aclan and Quisumbing (1976) also recorded reduced number of leaves per plant in ginger grown under full sunlight. Low irradiance under heavy shade might have led to the retarded development of plants because of the resulting low rate of photosynthesis (Meyer and Anderson, 1952).

Under all shade levels increasing levels of mulch resulted in increased leaf production. The positive influence of mulch on leaf production in ginger was also recorded by Aclan and Quisumbing (1976) and Mishra and Mishra (1986). Though the leaf number under 25 per cent shade was found to be increasing as a result of increased levels of mulch, M_3 and M_4 were on par. The increased leaf production under low shade might be mainly due to more tillers.

Leaf area

In general, ginger plants grown under shaded conditions produced significantly higher leaf area (Table 8). Among the shade levels, low shade produced the maximum leaf area (10307.6 cm^2) followed by medium shade (7148.3 cm^2). Minimum leaf area of 5837 cm^2 was obtained from open. An increased leaf area under reduced light intensity was reported in ginger by Ravisankar and Muthuswamy (1988), Ancy Joseph (1992) and George (1992). Contrary to this, Lalithabai (1981) reported that leaf area was not influenced by different intensities of shade in ginger, turmeric and coleus.

The increased leaf area under shade may perhaps be a plant adaptation to expose larger photosynthetic surface under limited illumination (Attridge, 1990). Under low light intensities reduced irradiation may prevent scorching or wilting of leaves caused by marked increase in temperature within leaf tissue from strong sunlight (Aasha, 1986) and thereby increases leaf area under shade resulting the retention of more number of leaves at any stage of the crop growth. But under medium and heavy shade leaf area was found to be again decreasing and this might be due to decreased rates of leaf production and low photosynthetic efficiency. Under open condition high irradiance may result in high rates of transpirations which are likely to lead internal deficiencies of water within the plant. This may lead to retardation or cessation of cell enlargement which adversely affect the leaf size. This may be the reason for low leaf area under open condition eventhough the leaf number was found to be higher than medium and heavy shade.

The positive influence of mulches on leaf area was reported by Enyl (1973) and Hulugalle *et al*. (1986) in cocoyam; Aina (1981) in maize and Jayashree (1986) in bhindi.

Under open as well as all shade levels the application of higher quantities of mulch enhanced total leaf area. This may be mainly because of increased vegetative growth and consequent production of more tillers and leaves when more mulch is applied. Thus, application of mulch increased the number of leaves per plant. Significant interaction between shade and mulch levels was also observed.

Chlorophyll content

The chlorophyll 'a', chlorophyll 'b' and total chlorophyll content exhibited an increasing trend with increasing shade intensities (Table 10 and Fig. 2). This is in agreement with the findings of Shirley (1929), Evans and Murran (1953) and Radha (1979) in different crops. An increase in chlorophyll 'a', chlorophyll 'b' with increase in shade intensities was also reported by Susan Varughese (1989), Ancy Joseph (1992) and George (1992) in ginger.

According to Attridge (1990) this increase in chlorophyll content under shade is an adaptive mechanism commonly observed in plants to maintain the photosynthetic efficiency. The positive influence of mulch on chlorophyll content might be due to enhanced photosynthetic efficiency as a result of improved soil physical condition and nutritional status. The effect of mulch on total chlorophyll and its interaction was found to be not significant.

Dry matter production

The maximum dry matter production (DMP) was obtained from low shade level followed by medium (Table 11 and Fig. 3). An increased dry matter production in ginger under shaded condition (as an intercrop in arecanut garden) was reported by Ravisankar and Muthuswamy (1988). Susan Varughese (1989), Ancy Joseph (1992) and George (1992) observed increased dry matter production in ginger under 25 per cent shade. The influence of growth parameters like more number of leaves, tillers and leaf area might have reflected in increased dry matter production. The low dry matter production under heavy shade might be due to low tiller and leaf number and low rate of photosynthesis. The dry matter production under 50 per cent shade was comparable with that of open. Eventhough chlorophyll content of leaves under heavy shade was the highest, very low light intensity might have limited the efficient utilization of increased chlorophyll content for dry matter production.

Under all shade regimes, higher doses of mulch resulted in increased dry matter production. DMP under M_4 was found to be higher and M_4 closely followed by M_3. The influence of mulch for increased DMP might be due to deeper and more extensive root system more uniform soil temperature and better physical condition in the soil (Hulugalle *et al.*, 1986) which might have positively influenced for better nutrient uptake thereby enhanced photosynthesis and assimilate partitioning. Shade and mulch created a cool condition near the leaf surface thereby reduction in respiration occured which ultimately might have resulted in a high rate of dry matter accumulation.

Net assimilation rate

During the first phase of study (60-120 DAP) the high net assimilation rate (NAR) was recorded from open condition, but at second phase (120-180 DAP) maximum NAR was obtained from low shade level (Table 12). The next higher NAR was obtained from open and minimum from heavy shade level. According to Okoli and Owasu (1975) high net assimilation rate at low shade was due to high rate of photosynthesis. At open condition, high value of NAR at initial stages might be due to transfer of assimilates from relatively large sized seed rhizome to the developing plant and vertical leaf orientation during these periods (Milthrope, 1963). The high rate of NAR under low shade intensity might be due to the higher rate of photosynthesis. Shade beyond 25 per cent produced a decreasing trend in NAR. This result is in agreement with the findings of Ancy Joseph (1992). With increase in shade level the photosynthetically active radiation falling on the leaf surface may be less compared to open and 25 per cent shade and this might have probably reflected in the net assimilation rate.

In the present investigation, NAR decreased when shade level increased (50 and 75 per cent). Crockson <u>et</u> <u>al</u>. (1975) found a reduction (38 %) in photosynthesis of bean leaves due to shading. Stomatal and mesophyll resistance to diffusion of CO_2, also be a reason for low rate of NAR under increased shade intensity (Meyer et al., 1973). The positive influence of mulch on NAR might be due to low soil temperature and high moisture content. A relatively cool microclimate produced as a result of mulching (Appendices I to IV) might have negatively influenced the respiration rate and increased the accumulation. The leaf mulch on decomposition liberates CO_2 which also favours enhanced photosynthesis (Allison, 1973).

Crop growth rate

Significantly superior crop growth rate (CGR) was observed under 25 per cent shade at both phases studied (Table 13). This finding is in agreement with the result of Ancy Joseph (1992). The findings of Zhao et al. (1991) the highest photosynthetic efficiency was obtained from leaves c the middle and lower portion of the ginger plant which are under different degrees of mutual shading support the results of the present investigation. He also reported minimum photosynthetic efficiency from apical portion of the plant which received full sunlight. The higher leaf area index under 25 per cent shade also might have reflected in the higher CGR. Compared to low shade, medium and heavy shade produced lower CGR. Contrary to these, reduced CGR under shaded condition was reported in turmeric (Ramadasan and Satheesan, 1980); in cassava (Ramanujam and Jose 1984) and in sweet potato (Roberts Nkrumah et al., 1986).

Mulch treatment under all shade levels gave a regular trend of increasing CGR. This might be due to the increased leaf area index. In the present investigation low shaded condition (25 %) seems to be very favourable for enhanced CGR.

Bulking rate

The bulking rate (BR) recorded was maximum under low shade level (25 %) at both the growth phases (Table 14). This might be due to increased NAR (2^{nd} phase), CGR, leaf area and efficient assimilate partitioning to rhizome. The similar trend was also reported by Ancy Joseph (1992). The bulking rate recorded from medium shade (50 %) was fairly high compared to open and heavy shade. A fairly high leaf area and better CO_2 assimilation may be the reason for this. Eventhough the NAR under open condition was fairly high the low bulking rate recorded might be due to low leaf area. Under intense shade also bulking rate was found to be low, due to reduced photosynthetic efficiency as evident from dry matter production. Similar results were also reported by Zara et al. (1982) and Robert Nkrumah et al. (1986) in cassava and Ancy Joseph (1992) and George (1992) in ginger.

A general increasing trend in bulking rate was observed with increasing mulch levels under all shade regimes. The possible reason may be due to the increased availability of nutrients at higher levels of leaf mulch, evident from nutrient uptake analysis (Table 24 and Fig. 10). One of the important influences of mulch on soil is the reduction of soil temperature. The reduction in soil temperature favours the tuberization in potato (Prihar et al., 1977) and ginger (Ravisankar and Muthuswamy 1987). The positive correlation of increased levels of mulch on bulking rate indicates its favourable effect on rhizome development in Zingiberacious crops. This was further supported by Jha et al. (1972), Mohanty (1977), Mishra and Mishra (1986), Roy and Wamanan (1988) and Korla et al. (1990) in ginger; Ragothama (1981) in cardamom and Purseglov et al. (1981) in turmeric.

Rhizome spread

The ginger plants under shaded conditions recorded more rhizome spread (Table 16). Among the shade levels, low shade level gave maximum spread which may be due to higher rate of accumulation of photosynthates. Under open condition, relatively high soil temperature and high evoparation rate might have resulted in low spread. The possible reason for low spread under medium and heavy shade might be due to low photosynthetic efficiency. Rhizome spread exhibited an increasing trend with increasing mulch and the positive influence of mulch on rhizome spread was due to low soil temperature and increased availability of soil moisture. Favourable effect of mulch on root density and lateral spread (Chaudhari and Prihar, 1974 nd singh et al., 1976), more favourable soil condition, leaf area and bulking rate, might have resulted in high rhizome spread under 25 per cent shade level especially under M_3 and M_4.

Top yield

Top yield under shaded conditions was significantly high and this was due to high vegetative growth (Table 15). Low shade gave the highest value (2249 kg ha^{-1}) because the number of tillers and leaves were found to be always higher under this situation. The reduced radiation would have prevented scorching or wilting of leaves. This resulted in increased leaf tissues and fairly high vegetative growth. Increased yield under shaded condition was recorded by Ramanujam et al. (1984), Hirota and Moritani (1980) in different crops. Open condition recorded significantly low top yield (1435 kg ha^{-1})compared to shaded conditions.

Harvest index and Utilization index

Both harvest index and utilization index were found to show a decreasing trend with increasing shade intensities but increasing mulch levels produced an increasing trend (Tables 17 and 18). This might be due to the increased top and rhizome yield at higher mulch levels. The higher rhizome yield under 25 and 50 per cent shade was due to higher leaf area, DMP and bulking rate. Under heavy shade reduced NAR and poor assimilate partitioning might be also responsible for reduced rhizome yield and major portion of the assimilates might have utilized for top growth.

Green ginger yield

Significant differences were noticed between open and shaded conditions with respect to fresh rhizome yield. In general, shaded conditions gave higher yield compared to open (Table 19 and Fig. 8). Highest quantity of green ginger was obtained from 25 per cent shade. Highest green ginger yield under 25 per cent shade was also reported by Susan Varughese (1989), Jayachandran et al. (1991), Ancy Joseph (1992) and George (1992). Zhoa et al. (1991) observed that a range of 500 to 30,000 lx. was more favourable for increased photosynthetic efficiency. If the light intensity is increased beyond 30,000 lx. the photosynthetic efficiency decreased. He also observed that top leaves receiving full illumination is inferior with respect to photosynthetic efficiency. Better performance of crop under low light intensities than in open may be due to the fact that in open there is a threshold of illumination intensity beyond which the stomata of shade loving plants tends to close (Hardy, 1958). Assuming that this was one of the reason for shade response of crop, it may be deduced that stomata closure had a dominant influence upto the low shade of 25 per cent, beyond which the availability of light for photosynthesis probably become the decisive limiting factor. According to Minoru and Hori (1969) ginger can efficiently utilize low light intensities. Under low shaded conditions the higher leaf area, bulking rate, NAR and CGR were noted and it indicates the better performance of ginger under shaded conditions than in open. The low yield under open might be due to low leaf area exhibited throughout the growth period which might have reduced the total photosynthates accumulated.

Since the yield is a function of DMP and bulking rate the trend in these two parameters have been analysed to understand the respective contribution to yield. DMP and BR followed the same trend as that of rhizome yield recorded from shaded conditions. The data on DMP and BR showed that shading did not result in any appreciable decrease in the rate of photosynthesis and accumulation under 25 and 50 per cent shade levels. These are in agreement with the findings of Ravisankar and Muthuswamy (1986) and Ancy Joseph (1992) in ginger.

With regard to effect of mulch on green ginger yield, the data exhibited an increasing trend with increasing rate of mulching. For ginger, mulching is one of the important cultural operations for better growth and yield (Jha et al., 1972, Mohanty 1977, Mishra and Mishra 1986, Roy and Wamanan, 1988 and Khorla et al., 1990). Most of the tuber forming corps need low soil temperature for better growth and tuberization. This was in conformity with the findings of Prihar et al. (1977) in potato, Ravisankar and Muthuswamy (1986) in ginger. The soil temperature recorded from present experiment showed that M_4 always gave a low value than M_1. Besides reducing the soil temperature, the mulch have vital role in conserving soil moisture which also has a direct influence on tiller production (Ragothama, 1981).

Mulching improves soil physical properties, soil nutritional status, increased availability of soil microfouna (Lal, 1975, 1983; Lal et al., 1980; Hulugalle et al., 1986 and Jayashree, 1987), reduces evoparation loss (Prihar et al., 1968) and helps in maintaining a higher soil moisture level. The oxygen diffusion rate in the mulched condition was always found to be high (Khan and Dutta, 1991). All these factors have positive influence on root density and root spread (Chaudhary and Prihar 1974 and Singh et al., 1976) which ultimately resulted in better crop growth and yield.

Under open condition, mulching gave significantly increasing trend on yield with increasing levels of mulch. The green ginger yield obtained from M_1, M_2, M_3, and M_4 were 13146, 14145, 17398, 19517 kg ha^{-1} respectively. The yield increase as a result of increasing mulch from M_1 to M_2, M_1 to M_3 and M_1 to M_4 were 7, 32 and 48 per cent respectively. The differences in yield increase between M_1 to M_2, M_2 to M_3, and M_3 to M_4 were 7, 23 and 12.2 per cent respectively. From these it is clear under open condition that, there is a general increasing trend in green ginger yield with increasing mulch levels. Therefore the present recommendation of 30 t ha^{-1} is necessary for open condition.

Under low shade (25 %) the yield increase from M_1 to M_2 is 19 per cent and M_1 to M_3 and M_1 to M_4 gave almost same value (44 %). The percentage increase from M_2 to M_3 was 21.1 while M_3 to M_4 was only 0.002 %. In other words there was no difference in yield as a result of increasing M_3 to

M_4. Therefore it is clear that under 25 per cent shade level, M_3 (75 %) is sufficient for getting maximum green ginger yield. Thus, under shaded situation (25 %) the total quantity of green leaf mulch required is 22.5 t ha^{-1}, thereby a saving of green leaves (7.5 t ha^{-1}) can be achieved.

The yield increase as a result of increasing mulch levels from M_3 to M_4 under S_1, S_2 and S_3 were 0.002, 4.1 and 4.5 per cent respectively. Under S_1 (25 %) full photosynthetic efficiency was achieved and under this circumstances M_3 and M_4 were on par. Under S_2 and S_3 (50 and 75 % shade) full photosynthetic efficiency was not obtained as evidenced by the green ginger yield data but an increase to a tune of 4.1 and 4.5 per cent respectively was achieved when M_3 is increased to M_4. In otherwords full amount of mulch seems to be helpful for enchancing green ginger yield under medium and heavy shade. The possible reasons for the this increase have to further investigated. Standardisation study using different levels of mulch (50, 62.5, 75, 87.5 and 100 per cent of the recommended dose) seems to be necessary.

Dry ginger yield

The highest quantity of dry ginger yield was obtained from 25 per cent shade level which was followed by 50 and 75 per cent shade levels (Table 20 and Fig. 5). The lowest dry ginger yield was recorded from open, but while calculating the driage, open condition gave slightly higher (20.10 %) recovery. The lowest recovery (19.42 per cent) was from heavy shade. Early maturity, reduced soil moisture and increased soil temperature might have resulted for this slight increase in driage under open. Dry ginger yield also showed an increasing trend with increasing mulch at all shade levels. This is probabily due to increased green ginger yield under the respective treatments. Under S_0, the data on dry ginger yield obtained from M_4 was comparable with M_3 under S_2.

The differences in dry ginger yield as a result of increasing mulch levels from 25 to 100 per cent of the recommended dose under S_0, S_1, S_2 and S_3 were 51.45, 44.4, 40.81 and 36.18 per cent respectively which again indicates the importance of mulch in increasing the yield of ginger. The differences in dry ginger yield as a result of increasing mulch from M_3 to M_4 under S_0, S_1, S_2 and S_3 were 12.37, 0.0018, 3.6 and 4.5 per cent respectively, which again follows the same trend as in green ginger yield. So it is clear, as mentioned in green ginger yield, that the differences between M_3 and M_4 was negligible under 25 per cent shade and we can reduce 25 per cent of the recommended dose of mulch.

Quality of the produce

Volatile oil content showed an increasing trend with increasing levels of shade (Table 21). The positive influence of volantile oil content with increasing shade intensity was also reported by George (1992) in ginger. The influence of mulch on volantile oil content was found to be not significant.

The highest content of non-volatile ether extract (NVEE) was recorded from open condition followed by 25 per cent shade. George (1992) also recorded higher content of NVEE at open condition but Ancy Joseph (1992) reported a higher value at 25 per cent shade. According to Ravisankar and Muthusamy (1987) ginger grown under shade in an intercropped condition produced good quality rhizomes with high NVEE.

High fibre content was observed under open condition and it showed a decreasing trend with increasing shade intensity. The higher fibre content at open condition might be due to early maturity of the plant under open condition. Ancy Joseph (1992) recorded higher percentage of fibre at open condition but according to Aclan and Quisumbing (1976) the fibre content of rhizome was not affected by light intensities.

Nutrient analysis

The uptake of N showed an increasing trend with increasing mulch levels (Table 24 and 25). P and K also showed an increasing trend upto 50 per cent, then showed a sudden decrease. Increased level of mulch also exhibited a general increasing trend in nutrient uptake. The availability of nitrogen after the experiment was found to be significant and showed an increasing trend with increasing shade levels. Under all shade levels M_4 gave highest value. The maximum phosphorus content was observed in open. Under shaded condition potassium showed a general increasing trend with increasing shade levels. Both P_2O_5 and K_2O exhibited a general increasing trend with increasing mulch levels.

The increased availability and uptake of N, P and K under leaf mulched condition might be due to the nutrient addition by decomposition of leaf mulch. According to Mohan kumar et al. (1975) the green leaf mulch was found to be efficient in increasing content of soil nutrients. This was further supported by Hulugalle et al. (1986) and Jayashree (1987).

From the results of the present investigation it is understood that ginger cv. Rio-de-Janeiro performs better under shade with respect to growth, yield and quality of the crop. It is also observed that under shaded situations, reduced rate of mulching is sufficient. As mentioned elsewhere shade loving nature of different cultivars of ginger was reported by researchers. Among these, the observation of Zhao et al. (1991) that photosynthetic efficiency of middle leaves of a ginger plant was the highest followed by lower leaves and that minimum photosynthetic efficiency was observed in apical leaves gives a clear evidence that the crop is shade loving. They also found that light intensity beyond 30,000 lx. was harmful.

The results suggest that ginger is an ideal crop suitable for intercropping situations which is a very common feature in Kerala. Further studies on standardisation of the management practices of ginger under different cropping systems and homesteads of Kerala are inevitable for increasing the production and productivity of the crop.

SUMMARY

SUMMARY

An experiment was conducted at the College of Agriculture, Vellayani, for studying the effects of different levels of mulch (25, 50, 75 and 100 per cent of the recommended dose) on the growth, yield and quality of ginger under varying levels of shade adopting strip plot design with five replications. Green leaves were used as mulch material and high density polyethylene shade materials were used for providing shade (25, 50 and 75 %) at the required level. The salient findings are summerised below.

The sprouting percentage of ginger under shade levels was found to be superior to open. Increased levels of mulch were found to enhance early sprouting and the maximum sprouting percentage was observed from m_4, but M_4 and M_3 were found to be on par.

The plant height recorded from open condition was significantly low. Under shade the plant height showed an increasing trend with increasing shade intensity. Under all shade levels there was an increasing trend in plant height with increasing mulch levels.

The highest number of tiller production was noted under 25 per cent shade at all growth phases and at 180 DAP the tiller production was found to be maximum. Heavy shade recorded the lowest tiller number. Increasing levels of mulch produced a significant increasing trend in tiller number. Among the treatment combinations, M_3 under S_1 recorded maximum tiller number followed by M_4.

The number of leaves per plant was found to be maximum under 25 per cent shade and was significantly superior to other shade levels. Under heavy shade the leaf number was low but the size of leaf was larger than that of open which resulted for a higher leaf area than open. Under all shade levels mulch produced an increased leaf number. The highest leaf number (290.75) was obtained from M_4 under S_1, and it was found to be on par with M_3 (290.45).

The chlorophyll 'a', chlorophyll 'b' and total chlorophyll were found to be increasing progressively with increasing levels of shade. The effect of mulch on total chlorophyll content was not significant.

Dry matter production was observed to be higher under 25 per cent shade followed by 50 per cent. Under open condition DMP was found to be higher than that under heavy shade. Significant differences in DMP were noted among all mulch and shade levels. DMP under all shade levels showed a general increaseing trend with each increment dose of mulch.

Net assimilation rate showed a general decreasing trend with increasing shade intensities. A positive response of mulch on NAR was noticed in the early phase (60-120 DAP) with increase in mulch application.

Crop growth rate recorded was maximum under 25 per cent shade followed by 50 and open. The lowest CGR was observed under heavy shade. The CGR also showed a general increasing trend with increasing mulch levels. Significant interaction between various shade and mulch levels on CGR was also observed.

At both phases studied (60-120 and 120-180 DAP) bulking rate was found to be maximum under 25 per cent shade. The effect of mulch on bulking rate was also found to be significant.

The utilization index and harvest index exhibited a decreasing trend with increasing shade intensities, but positive increasing response was noted with increasing mulch levels.

The highest green ginger yield was recorded under 25 per cent shade followed by 50 and 75 per cent shade. Open condition recorded the lowest green ginger yield. Under all shade levels, significant increase in green ginger yield was recorded with each increment dose of mulch. under 25 per cent shade, M_3 was on par with M_4. Under 50 per cent shade M_3 and M_4 were comparable.

The data on dry ginger yield also registered the same trend observed in the case of green ginger yield. The maximum dry ginger yield was obtained from M_4 and minimum from M_1. Among the treatment combinations the highest value (5256 kg ha^{-1}) of dry ginger yield was obtaied from M_4 closely followed by M_3 (5246 kg ha^{-1}) under S_1 and the lowest from M_1 (2736 kg ha^{-1}) under open.

Utilization index and harvest index were found to be highest under open condition compared to shaded conditions. Both UI and HI showed a general decreasing trend with increasing shade intensities.

The volatile oil content was found to be the lowest under open condition and it showed an increasing trend with increasing shade levels. The effect of mulch on volatile oil content was not significant.

Higher content of non-volatile ether extract was recorded from open condition. The highest fibre content was observed under open condition and it showed a decreasing trend with increasing shade intensities.

Uptake of nutrients (NPK) revealed an increasing trend with increasing shade intensities except phosphorus under heavy shade. Increasing levels of mulch also showed an increasing trend with each unit addition of mulch. The soil analysis data after the experiment was found to significant, with various mulch levels. Increasing levels of mulch contributed an increasing soil nutrient status.

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* Originals not seen

APPENDICES

APPENDIX - I

Day temperature (^{o}Celsius) near the crop canopy

Fortnightly intervals	Open	Shade Levels 25 %	50 %	75 %
27-05-92 to 10-06-92	29.80	28.60	28.40	28.00
11-06-92 to 25-06-92	30.80	29.50	29.30	29.00
26-06-92 to 10-07-92	29.90	29.10	29.0	29.00
11-07-92 to 25-07-92	29.51	28.51	28.05	28.01
26-07-92 to 09-08-92	29.75	29.05	28.95	28.85
10-08-92 to 24-08-92	29.15	28.45	28.22	28.05
25-08-92 to 08-09-92	28.95	27.55	26.85	26.49
09-09-92 to 23-09-92	29.52	28.25	28.15	28.15
24-09-92 to 08-10-92	29.92	27.95	26.82	26.58
09-10-92 to 23-10-92	28.55	28.52	28.10	27.01
24-10-92 to 01-11-92	27.92	27.25	27.00	26.95
02-11-92 to 22-11-92	28.52	28.00	27.18	27.00
23-11-92 to 07-12-92	27.85	27.65	27.42	27.10
08-12-92 to 22-12-92	29.15	28.50	28.00	28.00
23-12-92 to 06-01-93	29.95	28.55	27.75	27.50
07-01-93 to 21-01-93	29.95	29.15	28.52	28.00
22-01-93 to 31-01-93	30.50	29.15	28.92	28.85

APPENDIX - II

Relative humidity (%) near the crop canopy

Fortnightly intervals	Open	Shade Levels 25 %	50 %	75 %
27-05-92 to 10-06-92	76	79	80	82
11-06-92 to 25-06-92	80	82	83	83
26-06-92 to 10-07-92	78	82	83	84
11-07-92 to 25-07-92	78	81	82	82
26-07-92 to 09-08-92	80	81	82	83
10-08-92 to 24-08-92	80	81	82	84
25-08-92 to 08-09-92	78	80	82	82
09-09-92 to 23-09-92	79	81	82	82
24-09-92 to 08-10-92	78	80	83	83
09-10-92 to 23-10-92	78	80	83	84
24-10-92 to 01-11-92	77	79	81	82
02-11-92 to 22-11-92	78	81	83	84
23-11-92 to 07-12-92	79	80	82	83
08-12-92 to 22-12-92	78	81	83	84
23-12-92 to 06-01-93	76	79	82	82
07-01-93 to 21-01-93	76	79	80	81
22-01-93 to 31-01-93	75	79	80	81

APPENDIX III

Soil temperature of the experimental field (°C)

Fortnightly intervals	S_0				S_1				S_2				S_3			
	M_1		M_4		M_1		M_4		M_1		M_4		M_1		M_4	
	0730	1330	0730	1330	0730	1330	0730	1330	0730	1330	0730	1330	0730	1330	0730	1330
27-05-92 to 10-06-92	26.05	28.95	25.78	27.35	26.34	27.52	25.35	26.95	26.30	27.98	25.02	26.83	26.10	27.02	25.17	26.63
11-06-92 to 25-06-92	27.11	29.52	26.21	27.23	26.41	28.25	26.08	27.98	26.48	28.95	26.38	28.06	26.42	28.95	26.25	28.03
26-06-92 to 10-07-92	26.72	29.51	26.39	28.51	26.66	28.19	26.00	27.88	26.55	28.05	26.98	27.00	26.41	27.77	26.60	27.60
11-07-92 to 25-07-92	26.91	29.15	26.80	27.61	26.31	28.15	26.38	27.75	26.21	28.15	26.25	27.15	26.15	28.08	26.00	27.08
26-07-92 to 09-08-92	27.98	29.88	26.84	28.76	26.21	28.50	25.27	27.13	26.20	28.26	25.15	27.28	26.00	28.09	25.00	27.03
10-08-92 to 24-08-92	27.76	30.65	26.52	29.68	26.30	29.15	26.30	28.30	26.05	29.09	25.15	28.88	26.00	28.05	25.17	27.86
25-08-92 to 08-09-92	27.00	29.79	25.02	28.80	26.13	28.15	25.12	27.95	26.11	27.95	25.05	27.87	26.11	27.91	25.02	27.82
09-09-92 to 23-09-92	27.11	29.89	26.80	28.10	27.05	28.55	26.02	28.60	27.00	28.00	25.95	26.92	27.01	28.10	25.07	28.03
24-09-92 to 08-10-92	27.81	30.85	26.90	28.90	26.22	28.45	26.10	26.40	26.12	28.10	25.50	26.05	25.92	26.66	25.80	26.20
09-10-92 to 23-10-92	28.05	30.15	27.50	28.85	26.28	28.15	25.30	27.20	25.78	27.50	25.16	27.27	25.35	27.00	25.30	26.50
24-10-92 to 01-11-92	26.95	28.96	25.70	27.50	26.16	27.55	26.01	26.59	25.95	27.30	26.20	26.00	25.72	27.18	25.92	26.00
02-11-92 to 22-11-92	26.52	28.92	26.04	27.67	26.25	28.33	25.27	27.33	26.90	29.04	25.05	26.88	25.78	27.30	26.55	26.30
23-11-92 to 07-12-92	27.56	29.21	27.00	28.21	26.51	28.05	26.00	27.85	26.65	28.50	26.05	27.88	26.15	28.01	26.00	27.60
08-12-92 to 22-12-92	28.52	30.01	27.84	28.33	27.70	29.11	27.25	28.55	26.99	28.71	25.50	28.11	26.71	29.51	26.55	28.40
23-12-92 to 06-01-93	28.55	30.52	28.00	29.90	26.95	28.17	26.01	27.66	26.55	28.30	26.10	27.00	26.95	28.50	26.05	27.45
07-01-93 to 21-01-93	28.56	30.25	28.21	29.15	27.11	29.55	26.58	28.15	26.75	28.95	26.15	27.53	26.00	28.55	27.00	28.03
22-01-93 to 31-01-93	28.63	31.55	29.51	30.55	27.15	29.25	26.71	28.68	27.00	28.95	26.15	28.15	26.75	28.59	27.61	28.00

APPENDIX IV

Soil moisture of the experimental field (%)

Fortnightly intervals	S_0				S_1				S_2				S_3			
	M_1		M_4		M_1		M_4		M_1		M_4		M_1		M_4	
	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm	15cm	30cm
27-05-92 to 10-06-92	14.07	14.05	16.07	16.04	15.03	15.02	16.08	16.05	15.05	15.09	16.03	16.08	15.06	15.08	16.60	16.90
11-06-92 to 25-06-92	15.50	15.20	16.80	16.50	16.01	16.01	17.50	17.30	16.55	16.52	17.51	17.40	16.01	16.11	17.25	17.25
26-06-92 to 10-07-92	14.20	14.25	16.30	16.40	15.40	15.35	16.80	16.60	15.70	15.90	16.80	16.70	15.21	15.26	16.81	16.82
11-07-92 to 25-07-92	10.25	10.29	13.78	13.72	11.41	11.49	14.78	14.78	11.50	11.56	14.58	14.80	11.75	11.76	14.88	14.78
26-07-92 to 09-08-92	12.15	11.13	13.90	13.75	12.95	12.91	14.88	14.81	12.96	12.93	14.68	14.65	12.94	12.90	16.75	16.72
10-08-92 to 24-08-92	9.55	9.67	11.90	11.96	9.95	9.89	12.35	12.35	9.85	9.84	12.38	12.39	9.68	9.85	12.45	12.75
25-08-92 to 08-09-92	13.85	14.71	16.15	16.05	15.15	15.13	17.05	17.01	15.25	15.25	17.08	17.05	15.26	15.28	17.45	17.21
09-09-92 to 23-09-92	8.45	8.46	10.71	10.66	8.80	8.82	11.05	11.04	8.35	8.32	11.08	11.08	8.35	8.38	11.03	11.07
24-09-92 to 08-10-92	8.35	8.60	11.45	11.25	9.61	9.63	12.73	12.13	9.75	9.81	13.68	13.13	9.85	9.83	13.62	13.18
09-10-92 to 23-10-92	6.35	6.32	9.51	9.45	7.81	7.32	10.13	10.03	7.85	7.80	10.25	10.10	7.82	7.90	10.21	10.11
24-10-92 to 01-11-92	6.11	6.05	9.21	9.08	6.28	6.20	10.53	10.28	6.85	6.32	10.78	10.55	6.41	6.32	11.20	11.25
02-11-92 to 22-11-92	10.58	10.50	13.15	13.45	11.75	11.80	15.35	15.75	12.00	12.10	15.85	15.70	12.15	12.21	16.05	16.05
23-11-92 to 07-12-92	6.58	6.75	9.15	9.28	7.77	7.29	11.18	11.18	7.90	7.88	12.15	12.08	7.53	7.50	12.15	12.45
08-12-92 to 22-12-92	4.20	4.20	7.15	7.18	5.80	5.75	7.52	7.29	5.80	5.70	7.15	7.35	5.80	5.80	7.50	7.55
23-12-92 to 06-01-93	3.80	3.85	4.10	4.18	3.90	3.95	5.35	5.38	3.88	3.75	5.60	5.62	3.89	3.96	5.68	5.65
07-01-93 to 21-01-93	3.68	3.72	4.15	4.19	3.91	3.93	4.22	4.28	3.90	3.95	4.26	4.31	3.91	3.95	4.32	4.35
22-01-93 to 31-01-93	3.61	3.70	4.19	4.25	3.33	3.85	4.85	4.86	3.80	3.81	4.11	4.25	3.98	3.95	4.55	4.85

EFFECT OF SHADE AND MULCH ON THE YIELD OF GINGER *(Zingiber officinale R.)*

BY

P. BABU

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN HORTICULTURE
FACULTY OF AGRICULTURE
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DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1993

ABSTRACT

An experiment was conducted at the College of Agriculture, Vellayani during the year 1992-1993 to study the effect of shade and mulch on the yield of ginger cv. Rio-de-Janeiro. The experiment was laid out in strip plot design with five replications. High density polyethylene shade materials were used for providing shade at required levels. The shade treatments were open (S_0), 25 (S_1), 50 (S_2) and 75 (S_3) per cent and mulch treatments were 25 (M_1), 50 (M_2), 75 (M_3) and 100 (M_4) per cent of the recommended dose.

The effect of shade on enhancing sprouting was found to be significant mainly during the early stages. The effect of mulch was also found to be significant and increasing levels of mulch increased sprouting.

The effect of shade and mulch on growth parameters: leaf number, leaf area, plant height, tiller number, chlorophyll content, DMP, NAR, CGR, BR, UI, HI and top yield under low shade (25%) exhibited significant superiority with respect to growth and yield contributing factors. Most of the parameters from open were inferior to shaded conditions. In general, mulching retained more moistue, reduced soil temperature and produced positive changes in growth and yield contributing factors.

Maximum green ginger and dry ginger yield were resulted from low shade (25 %) followed by medium (50 %) and heavy shade (75 %). The trend in green and dry ginger yield obtained from open condition was significantly inferior to all shade regimes. The effect of mulch on green ginger yield was also found to be significant. Under low shade (25 %) M_3 and M_4 were on par. Under medium and heavy shade M_3 and M_4 were comparable.

In general the quality of the produce was found to be superior under shaded conditions. The uptake of N showed an increasing trend with increasing shade intensities but P and K showed an increasing trend upto 50 per cent and then a decrease. A general increasing trend in NPK uptake was also observed with increasing mulch levels.

The study suggests that ginger is a shade loving plant giving maximum yield under low shade followed by medium and heavy. Under open condition, mulching gave a progressively increasing trend in yield, and therefore the existing recommendation (30 t ha^{-1}) is necessary. But under low shade 25 per cent of the mulch requirement can be reduced without affecting the final yield.