EVALUATION OF SHADE TOLERANT MORPHOTYPES OF COLOCASIA

By

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THESIS

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requirement for the degree of

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DECLARATION

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

Vellanikkara,
22.2.1992.

S. Hemalatha
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CERTIFICATE

Certified that this thesis entitled 'Evaluation of shade tolerant morphotypes of colocasia' is a record of research work done independently by Mrs.Hemalatha, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
22.2.1992.

Dr.E. TAJUDDIN
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CERTIFICATE

We, the undersigned members of the Advisory Committee of Mrs.Hemalatha, S., a candidate for the degree of Master of Science in Agriculture agree that the thesis entitled 'Evaluation of shade tolerant morphotypes of colocasia' may be submitted by Mrs.Hemalatha, S., in partial fulfilment of the requirement for the degree.

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S. Hemalatha

HEMALATHA, S.

Dedicated to
My Beloved Mother

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Introduction

INTRODUCTION

Crop production is dependent on the availability of solar radiation, water and nutrients. With the present trend of growing tree crops like coconut wherever possible, the area available for monocropping has diminished. Sun light, the primary source of energy for the photophosphorylation, varies drastically in both quantity and quality under coconut plantations.

Preliminary studies conducted at the Central Plantation Crops Research Institute, Kasaragode, Kerala have indicated that the amount of light that infilters through the coconut canopy is markedly affected by the spacing and age of coconut palm. The light infiltration ranges from 10-70 per cent depending upon the age of the palm in a space planted coconut plantation. This factor is to be considered while recommending intensive cropping systems like intercropping and multiple cropping along with coconut, as the returns from the associated crops would depend on their response to shade. To get reasonable profit from the associated crops, they have to be selected for shade tolerance and the extent of tolerance will be the criteria for fitting these crops under varying shade situations. In a similar study taken up during the previous year at the College of Horticultúre, Vellanikkara, Thrissur, eleven colocasia morphotypes were screened for shade tolerance. The present study is conducted to evaluate six morphotypes of colocasia which were found to be performing better under shade.

Colocasia is an adaptable crop and grows on a wide range of soils. Its capacity to produce abundant food at low cost, the ability to give economic yield even in marginal soils, the possibility to cultivate them in lands of irregular topography etc., are some of the factors which stand in favour of their cultivation in Kerala. Corms and cormels are the major economic parts of the crop, though occasionally leaves and petioles are used as vegetable. The tubers are rich in carbohydrate (13-29%), proteins (1.4-3.0%), fat (0.16-0.36%), vitamins B & C and minerals like calcium (Coursey, 1968).

The study conducted to screen the colocasia morphotypes for shade tolerance revealed that colocasia is a shade tolerant plant, though, it yields more under open conditions. M_2, M_8, M_{10}, M_{15}, M_{16} and M_{17} were the promising morphotypes in terms of total yield. The performance of these morphotypes varied widely under different shade levels. The starch content and the oxalate content of the crop produce, which determines the quality, also changed under different shade levels.

Considering the above situations, the present investigation has been taken up to evaluate the performance of different morphotypes of colocasia, screened for varying shade levels, under artificial shade and also under existing coconut plantation. It has also been intended for studying the changes in quality of crop produce as induced by shading and to predict the yield of different morphotypes under various shade levels. Assessment of the changes of light infiltration in coconut plantations as influenced by spacing and height of the palm is another objective of this experiment.

Review of Literature

REVIEW OF LITERATURE

As early as in 1903, Rolfs elucidated the importance of light factor in plant communities. The influence of shade on various aspects such as photosynthesis, vegetative characters, dry matter accumulation, yield, flowering, fruiting etc. has been studied in many crops. Although Colocasia esculenta is grown as a subsistence crop in many parts of the country, little attention has been given to its ability to tolerate shade. Research work on shade tolerance of colocasia is meagre, hence available literature on the effect of shade, irrespective of the crop is reviewed.

2.1. Varietal variations to shade response

Caiger (1986) studied the effect of 0 and 50 per cent shade on three Colocasia esculenta cultivars. The yield of cultivars, Dalokena, Manua and Manua Kula in the open were 21.7, 16.3 and 16.9 kg fresh weight/plot and at 50 per cent shade were 12.6, 12.4 and 11.6 kg/plot, respectively. Yield differences between shaded and unshaded plants were significant for all three cultivars, but yield differences between cultivars were not significant. Simbolon and Sutarno (1986) reported that all the seven species of amaranthus responded in a similar way to various light intensities. Experiments conducted by Vijayalakshmi et al. (1987) and Jadhav (1987) revealed that rice varieties varied in their response to different light intensities. Demagante and Zaag (1988) evaluated the performance of seven potato cultivars under field conditions with light intensities ranging from full light to 42 per cent and observed that there was high variation in varietal response. Sreekumari et al. (1988) identified seven shade tolerant cultivars of cassava.

Varughese (1989) observed appreciable varietal differences in shade response of ginger and turmeric and Prameela (1990) observed variation in shade response of colocasia morphotypes.

2.2. Vegetative characters

2.2.1. Plant height

Einert and Box (1967) noticed greater stem elongation under 50 and 75 per cent intensities of light in Lolium longiflorum. Similar positive influence of shade on plant height was noticed in beans (Crookston et al., 1975), ginger and turmeric (Bai and Nair, 1982 and Varughese, 1989), groundnut (George, 1982), tomato (Kamaruddin, 1983), winged bean (Sorenson, 1984), Cassava (Ramanujam et al., 1984; Okoli and Wilson, 1986 and Sreekumari et al., 1988), amaranthus (Simbolon and Sutarno, 1986), broad bean (Xia, 1987), potato (Demagante and Zaag, 1988) and colocasia (Prameela, 1990).

Cooper (1966) noticed negative influence of shading on plant height in brid's foot trefoil and alfalfa. George (1982) observed reduction in plant height by shading in redgram. Plant height remained unaffected by shading in cucumber (Kaname and Tagi, 1970), cowpea, black gram and colocasia (George, 1982 and Bai and Nair, 1982).

2.2.2. Girth and number of tillers per plant

Shading up to 50 to 73 per cent by black cloth reduced stem diameter in cucumber (Kaname and Tagi, 1970). Boyer (1974) reported that cambial activity measured as girth increment was greater in unshaded cacoa trees. Sreekumari et al. (1988) reported that girth of cassava remained the same under open and shaded conditions but there was reduction in the number of shoots produced per sett in the shaded condition. In colocasia, there was an increase in girth under shaded condition but there was no significant difference between shade levels with respect to number of tillers (Prameela, 1990).

2.2.3. Leaf area and number of leaves

Rolfs (1903) reported that citrus plants grown under 50 per cent shade developed thinner leaves with a greater leaf area but with considerably reduced total leaf area per plant. Lazenby (1906) noticed increased leaf area in the case of salad crops such as tomato, cabbage and lettuce under shaded conditions. According to Thompson and Miller (1963) light intensity influenced cell enlargement and differentiation and thus influenced leaf size and structure of leaves in pea. But in cucumber, size and number of leaves were not influenced by shade (Kaname and Tagi, 1970). Cuer (1971) reported that cocoa leaves exposed to direct sun light were smaller and thicker than shaded leaves. Martin (1985) observed increase in foliage growth of sweet potato under lower light intensities. The leaf number and leaf size of amaranthus were found greater at the intermediate than at high light level (Simbolon and Sutarno, 1986). In cassava also leaf area increased under shade (Sreekumari et al., 1988). In rice, leaf area was reduced due to shade (Venkateswaralu, 1978), and in Vicia faba, leaf number was reduced by shade (Xia, 1987).

2.2.4. Photosynthesis and dry matter production

Shade greatly reduced photosynthesis, growth rate and dry matter accumulation in lettuce (Tibbitts and Rao, 1968), alfalfa (Wolf and Blaser, 1972), beans (Crookston et al., 1975), colocasia (Caesar, 1980 and Prameela, 1990), cotton (Singh, 1986), rice (Vijayalakshmi et al., 1987) and potato (Singh, 1988).

Increased dry matter production under shade was reported in Xanthosoma saggittifolium (Caesar, 1980), ginger (Bai and Nair, 1982; Ravisankar and Muthuswamy, 1986 and Varughese, 1989), turmeric (Bai and Nair, 1982 and Varughese, 1989) and coffee (Venkataramanan and Govindappa, 1987).

2.2.5. Growth analysis

When a crop of grain sorghum was subjected to 0, 25 or 50 per cent shade, the LAI was found to decrease with increase in shade (Palis and Bustrillos, 1976). Leaf area index, crop growth rate and net assimilation rate were found to decrease, in turmeric cultivars, with increase in shade (Ramadasan and Satheesan, 1980). The NAR and AGR of chickpea were found to decrease with decrease in Sunlight from 100 per cent to 15 per cent, while the leaf weight ratio and RGR remained unaffected (Pandey et al., 1980). Gopinathan (1981) observed that NAR in cocoa was not influenced by increase in shade intensity ranging from 25 to 75 per cent. Shade increased leaf area ratio in winged bean (Sorenson, 1984) and decreased leaf area index in cassava (Fukai et al., 1984). Jadhav (1987) reported that in field pea, CGR, LA and NAR decreased with increase in shade and RGR, LAR, LWR and SLA increased with shade. In maize, leaf area index was significantly increased by artificially provided supplementary light (Mali and Singh, 1989).

2.3. Chlorophyll content

Certain optimum intensity of light was found to be necessary for chlorophyll production in plants (Clark, 1905). He noticed that direct sunlight of high intensity reuslted in destruction of chlorophyll in strawberry plants. Tsankov et al. (1976) observed the occurrance of less number of large sized chloroplasts in shaded leaves of grapes. In colocasia, chlorophyll content increased under shade (Bai, 1981 and Prameela, 1990). Singh (1988) recorded an increased leaf chlorophyll in potato under 25 per cent of normal Sunlight. Mali and Singh (1989) observed that chlorophyll content of maize leaves significantly increased by artifically provided light over control. Pandey et al. (1980) observed that chlorophyll content of chickpea leaves remained the same at varying shade levels.

2.4. Yield and harvest index

Venkateswarlu and Srinivasan (1978) conducted a trial to study the influence of low light intensities on rice and observed that yield loss was greatest with continual shading at 40-50 per cent of natural light. Vijayalakshmi et al. (1987) observed that harvest index of rice was also reduced by shading. Joseph (1979) reported that the tea clones under shade gave much higher yield than in exposed plots. Caesar (1980) observed that Xanthosoma produced only corms under shade and the growth of cormels was negligible. Highest yield of colocasia was recorded under full sun (Caesar, 1980; Bai, 1981; Caiger, 1986 and Prameela, 1990). There was no significant difference between the harvest indices (HI) of colocasia at various shade levels. George (1982) observed a drastic decline in yield of pulse crops due to shading. Okoli and Wilson (1986) reported yield reduction upto 80 per cent under 70 per cent shading in cassava. Sreekumari et al. (1988) reported that there was considerable yield reduction due to shade in all the genotypes of cassava, which ranged from 63.2 to 77.8 per cent. Harvest index was also found reduced from 50.5 to 15.2. Highest yield of ginger with low light intensity was reported by Bai and Nair (1982), Ravisankar and Muthuswamy (1986 and 1987) and Varughese (1989). There was more than 50 per cent reduction in the yield of pepper due to shading (Ramadasan, 1987). In maize, grain yield and HI were significantly increased by artificially provided supplementary light over control (Mali and Singh, 1989).

2.5. Nutrient content

Cuers (1971) observed a higher content of nitrogen in shaded cocoa leaves. Radha (1979) observed that the uptake pattern of major nutrients in pineapple was not greatly influenced by shading. Bai (1981) reported that in all the plant components of the different crops tried, viz., coleus, colocasia, sweet potato, turmeric and ginger, content of nitrogen, phosphorus and potassium increased with increasing intensities of shade. Gopinathan (1981) noticed higher percentage of nitrogen, phosphorus and potassium in plants grown under direct sunlight than in shaded plants. However, between the plants exposed to different shade intensities, the nutrient content showed no significant difference. George (1982) observed increased potassium content under high shade in cowpea and groundnut. But in blackgram, nutrient status was unaffected by shading. Prameela (1990) reported that nitrogen content of colocasia was highest under 50 per cent shade, but decreased under high shade. Phosphorus was more under 25 per cent shade which decreased with increase in shading. Potassium content increased with shade.

2.6. Quality of produce

The response of shade on quality of produce varies widely. Generally protein content increases and carbohydrate content decreases with shading.

Palis and Bustrillos (1976) observed that, in sorghum plants subjected to 0, 25 and 50 per cent shade, protein content increased while carbohydrate decreased with decrease in light. Radha (1979) observed that quality of fruits in general decreased in pineapple under shaded conditions. While the acidity of fruits increased, there was a general reduction in sugar and ascorbic acid contents. Leelavathi (1979) reported that shading in blackgram resulted in increased carbohydrate status of the seed and a larger pool of soluble nitrogen. Varughese (1989) recorded a reduction in oleoresin content in ginger and curcumin content in turmeric grown under shade. Prameela (1990) reported that starch and oxalic acid contents of colocasia decreased with shading.

2.7. Disease intensity

Higher humidity and slower drying under shade were found to favour incidence of several diseases. The incidence of Phytophthora palmivora on Amazon cocoa was significantly higher in plots with medium and dense shade regimes (Dakwa, 1979). Blister blight of tea increased under shade (Owuor and Othieno, 1989). Colocasia blight also increased under shaded conditions (Prameela, 1990).

The above literature indicates that generally plant height, number of leaves and leaf area increase with decrease in light intensity in most crops. Though low light intensity increases the dry matter production and yield in some crops, intense shading results in poor yield. The microclimate prevailing under shade usually favours disease incidence especially during rainy period.

Materials and Methods

MATERIALS AND METHODS

During the year 1990-91, field experiments were conducted under artificial shade and under existing coconut plantation, to evaluate the performance of six promising morphotypes of colocasia (Colocasia esculenta (L.) Schott) for shade tolerance. A survey was also conducted in coconut plantations to estimate the changes of light infiltration as influenced by spacing and height of the palms.

The experiment under artificial shade was laid out at the College of Horticulture, Vellanikkara and the experiment under natural shade was laid out at the Instructional Farm, Vellanikkara, Thrissur, Kerala, India. Both the locations are situated at 10°32' N latitude, 76°10' E longitude and at an altitude of 22.25 m above mean sea level.

The meteorological data for the experimental period (May to December 1990) are furnished in Appendix I. The crop under artificial shade received 2451.8 mm of total rainfall during the period from 18th May to 28th December 1990 and the relative humidity ranged from 69 to 95 per cent.

3.1. Artificial shade

Rainfed crop of colocasia was raised from 18th May 1990 to 28th December 1990. During the previous year, the experimental area was under a similar experiment with soybean, turmeric and colocasia. Six promising morphotypes of colocasia were planted on ridges giving a spacing of 1 m x 1 m.

The soil of the experimental area was deep, well drained, sandy clay loam. The physico-chemical characteristics of the soil are furnished in Table 1.

Table 1. Physico-chemical characteristics of the soil in the experimental site of artificial shade

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

Sand	- 64 per cent
Silt	- 14.7 per cent
Clay	- 21.3 per cent
Texture	- Sandy clay loam

2. Chemical composition

Constituent	Content	Rating	Methods used for estimation
Total nitrogen	0.086 per cent	medium	Microkjeldahl (Jackson, 1958)
Available phosphorus (Bray-I extract)	3.6 ppm	low	Chlorostannous reduced molybdo phosphoric blue colour method (Jackson, 1958)
Available potassium (Neutral normal ammonium acetate extract)	120.8 ppm	high	Flame photometry (Jackson, 1958)
pH (1:2.5, soil-water)	4.9	strongly acidic	pH meter method (Jackson, 1958)

3.1.1. Planting material

Healthy cormels of six morphotypes of colocasia which were selected as the better yielding ones based on the screening trial conducted during 1989-90 at the College of Horticulture were used for this experiment. The cormels harvested during December 1989 were treated with captafol 80 per cent WDP (7 g l^{-1}) and stored in saw dust. Dried leafy twigs were spread over the seed materials to conserve moisture.

3.1.2. Manures and fertilisers

Manures and fertilisers were applied as per the package of practice recommendations of the Kerala Agricultural University (1989). Urea, super phosphate and muriate of potash were the fertilisers used. Mulching was done using green leaves for retension of soil moisture and to control weeds.

3.1.3. After cultivation

Weeding and earthing up were done one month and two months after planting. Paraquat was sprayed to control the weeds growing in between the main plots.

3.1.4. Plant protection

The crop suffered severe incidence of blight during the heavy rainfall months. Bordeaux mixture (1%) and Mancozeb (2 g l^{-1}) were sprayed at periodical intervals for controlling the disease. For controlling aphids, BHC (5%) was applied forty days after planting.

3.1.5. Layout and design

The experiment was laid out in a split plot design with four replications. The layout plan is given in Fig. 1. The treatments included factorial combinations of four shade levels and six morphotypes. Shade levels were assigned to main plots and morphotypes to sub plots. Main plot size was 120 m^2 and sub plot size was 20 m^2.

Main plot treatments

T_1 - 0 per cent shade (open)

T_2 - 25 per cent shade

T_3 - 50 per cent shade

T_4 - 75 per cent shade

Sub plot treatments

V_1 - Morphotype 1

V_2 - Morphotype 2

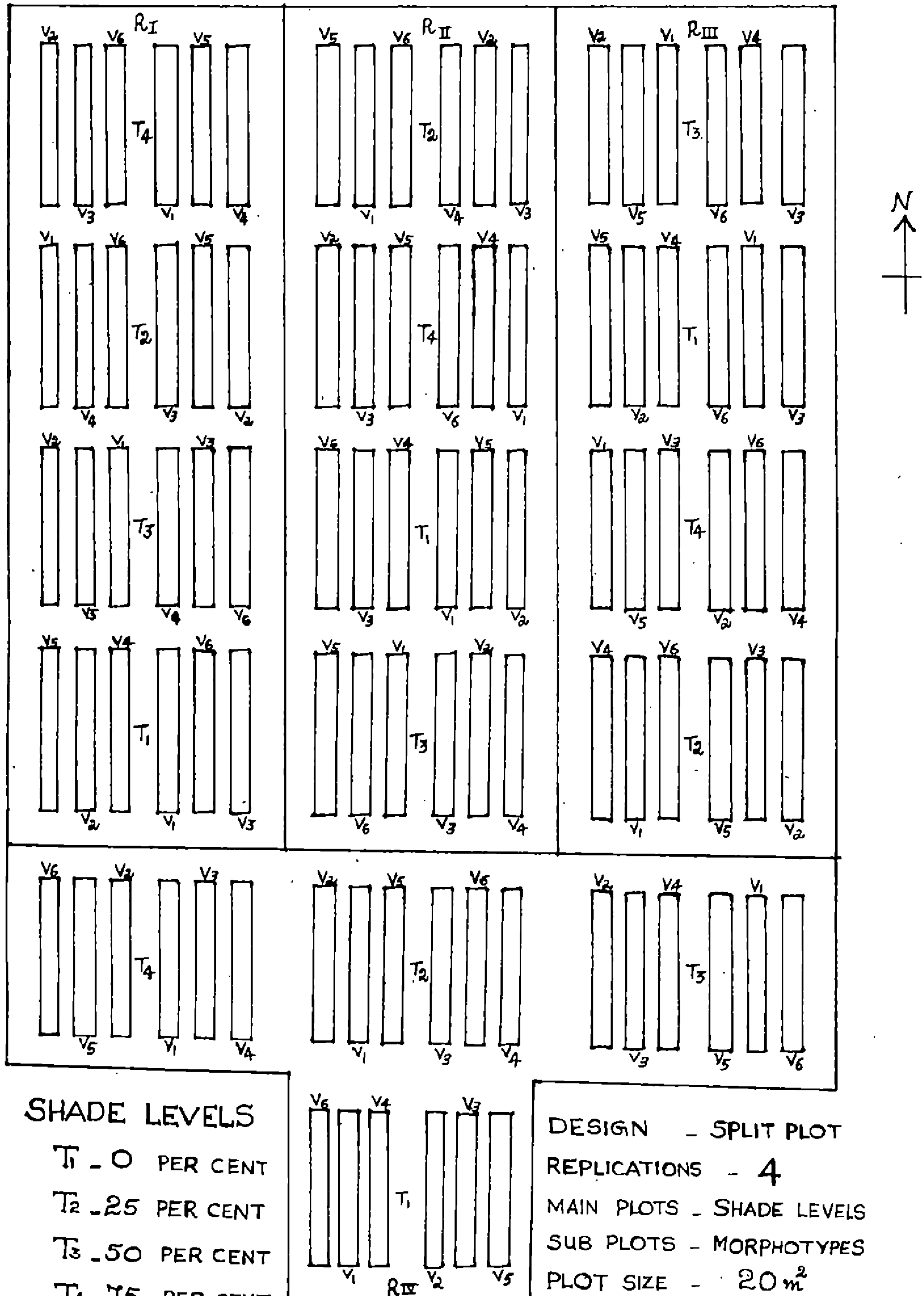
V_3 - Morphotype 9

V_4 - Morphotype 10

V_5 - Morphotype V_{17}

V_6 - Morphotype 16

The prominent characters of these morphotypes are given below:


RI
RII
RIII
RIV
N
SHADE LEVELS
T1 - 0 PER CENT
T2 - 25 PER CENT
T3 - 50 PER CENT
T4 - 75 PER CENT
DESIGN - SPLIT PLOT
REPLICATIONS - 4
MAIN PLOTS - SHADE LEVELS
SUB PLOTS - MORPHOTYPES
PLOT SIZE - 20 m²

Morphotype 1

Plant medium tall semi erect, leaves drooping and medium thick, petioles light green, margins of leaf medium wavy, tuberisation very high, corm small to medium, cormels oblong, spherical to thickly spatulate, tubers non acrid. North Indian type cultivated under rainfed as well as irrigated conditions.

Morphotype 2

Plant type same as the above, leaves similar but with purple pigmented petiole, leaf margin purple and wavy tuberisation very high, corms small to medium, tubers oblong, spherical to thickly spatulate, non acrid. Cultivated all over upto Northern Kerala and Tamilnadu.

Morphotype 9

Plant dwarf to medium tall, semi erect, leaves cup shaped in the early stages, semi drooping later on, margin highly wavy, purple coloured, petiole green, purple spot (spreading) present at the centre of leaf. Tuberisation high, corm small, spherical, cormels small to medium oblong, spatulate and scaley. This belongs to Kannan group and is from Kerala.

Morphotype 10

Medium high to tall plants, cup shaped drooping leaves with dark purple petiole tip, tubers are similar to that of Kannan group, cultivated in Kerala.

Fig. 1. Lay out of the field for artificial shade experiment

Morphotype 16

Largest plant type known as 'Kuda Chembu' or 'Malaraman' in Kerala, found also in Tamilnadu. It is characterised by purple petioles, very large drooping leaves, light purple leaf centre, purple and less wavy leaf margin. Tuberisation is less but corms are very large and edible.

Morphotype 17

Small to medium semi erect plants, very dark purple petioles, dark green leaves, purple leaf centre and dark purple leaf margin. Tuberisation high, corms small to medium, cormels oblong, spatulate. Cultivated mostly in Kerala and called 'Karutha chembu'.

3.1.6. Provision of shade

Pandals of size 27 m x 11 m were erected on wooden frames and covered with unplaited coconut leaves. The leaves were arranged in such a way to get desired levels of shade. These were covered on all sides leaving a clearance of 1 m from the ground level. Sides were covered to prevent the direct entry of slant rays and clearance was given to facilitate air movements. Shade levels were adjusted using LI-COR Integrating quantum radiometer with line quantum sensor.

3.2. Natural shade

On 5th June 1990, colocasia was planted under coconut palms having an average height of 5.4 m. The interspaces of palms were previously occupied by leguminous green manure crops. The very same six morphotypes of colocasia planted under artificial shade were planted in the interspace area around the coconut palms. Cormels were planted on ridges at a spacing of 1 m x 1 m. Each morphotypes was planted around one coconut palm.

The soil of the experimental area was deep, well drained sandy clay loam. The physico-chemical characteristics of the soil are furnished in Table 2.

Table 2. Physico-chemical characteristics of the soil in the coconut plantation

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

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

2. Chemical composition

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

3.2.1. Planting material

Healthy cormels stored for planting under artificial shade were used as the seed material.

3.2.2. Manures and fertilisers

Cultural and manurial practices were the same as those adopted for plants under artificial shade.

3.2.3. Plant protection

One prophylactic spraying with Bordeaux mixture (1%) was given to prevent the incidence of colocasia blight before the heavy rainfall period. No other pest attack was noted.

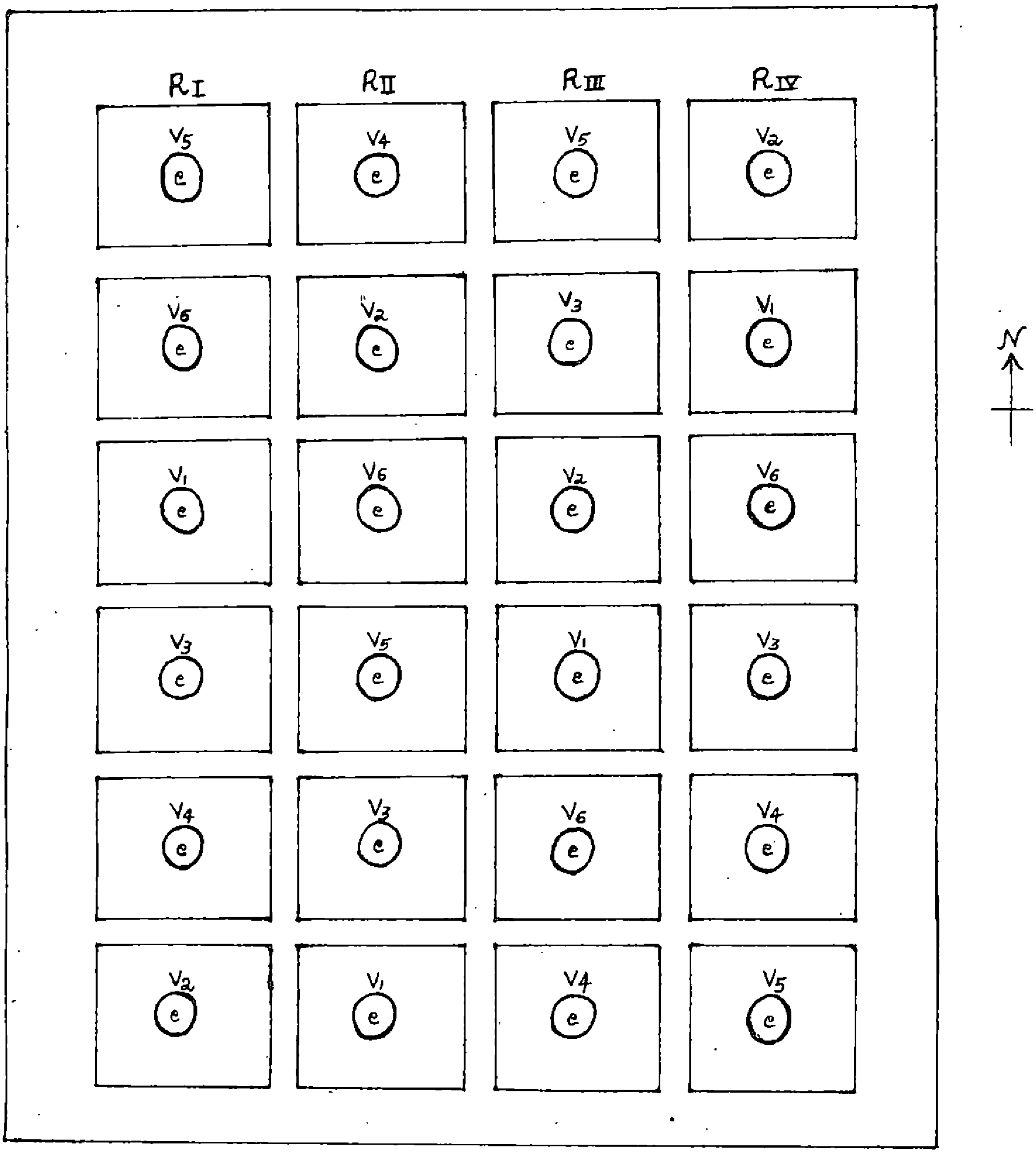
3.2.4. Layout and design

The six morphotypes were planted in randomised block design with four replications. The layout plan is given in Fig. 2. Each morphotype was planted around one coconut palm leaving a basin area of 12.56 m^2. Net area around one palm planted with colocasia was 30 m^2. Treatments consisted of six morphotypes of colocasia viz., M_1, M_2, M_9, M_{10}, M_{16} and M_{17}.

3.2.5. Shade

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

Fig. 2. Lay out of the field for natural shade experiment



DESIGN - RBD

REPLICATIONS - 4

TREATMENT - MORPHOTYPES

PLOT SIZE - 30 m^2

c - COCONUT PALM

3.3. Observations

Five plants were selected at random from each varietal plot for recording biometric observations. Observations were recorded at 60, 120 and 180 days after planting (DAP). Destructive sampling was done for calculating leaf area, leaf weight and total dry weight. After 130 DAP, all colocasia plants under coconut plantation were completely damaged by wild boar attack, so no observation could be taken thereafter from that plot.

A. Biometric observations

1. Plant height

The height of the selected plants was measured from the collar region to the tip of the top most petiole and the mean value computed.

2. Number of tillers per plant

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

3. Chlorophyll content of the leaves

Part of the second terminal leaf of a few plants selected at random constituted the samples. Chlorophyll a, chlorophyll b and total chlorophyll content of leaves were estimated 130 DAP by spectrophotometric method as described by Starnes and Hadley (1965).

4. Total dry weight

Leaves, pseudostem and under ground portions of two uprooted plants were separated and oven dried at 70°C to 80°C to constant weight. The sum of the dry weights of component parts gave the total dry weight of the two plants. From this total dry matter yield was computed and expressed as g plant^{-1}.

5. Leaf area ratio

All the leaves of the two sample plants were assembled in random positions and circular leaf discs of known area were cut and oven dried at 70°C to 80°C to constant weight. The dry weight of remaining parts of the lamina was also found out. Total leaf area of the two plants of each morphotype was calculated from the number of leaf discs, disc area, dry weight of discs and total dry weight of lamina.

Leaf area ratio was computed as follows and expressed as cm^2 g^{-1}.

$$\text{Leaf area ratio} = \frac{\text{Leaf area of two plants}}{\text{Dry weight of two plants}}$$

6. Leaf weight ratio

The dry weight of leaves of two uprooted plants was divided by the total dry weight of the two plants and expressed as LWR.

7. Leaf area index

The total leaf area of the two uprooted plants was divided by the land area occupied by these plants and expressed without any unit.

8. Net assimilation rate

It was calculated from the difference in dry weight and the difference in leaf area, using the following formula and expressed as $g\,m^{-2}\,day^{-1}$.

$$NAR = \frac{w_2 - w_1}{t_2 - t_1} \quad \frac{\log_e LA_2 - \log_e LA_1}{LA_2 - LA_1}$$

w_2 = total dry weight of plants g at time t_2

w_1 = total dry weight of plants g at time t_1

$t_2 - t_1$ = time interval in days

LA_1 and LA_2 = Leaf area index at time t_1 and t_2

9. Tuber yield

Fresh weight of corms and cormels was recorded separately from each sub plot and was expressed as $t\ ha^{-1}$. The sum of corm and cormel yield gave tuber yield in $t\ ha^{-1}$.

10. Haulm yield

The dry weight of aerial part of five observation plants was recorded and expressed as $t\ ha^{-1}$.

11. Harvest index

It was calculated as follows

Harvest index = $\frac{Y\ econ}{Y\ biol}$ where Y econ and Y biol were dry weight of tuber and total dry weight of plant, respectively.

B. Chemical studies

1. Content of fertiliser nutrients

Dried plant samples were powdered and digested. Nitrogen was estimated after digestion with sulphuric acid and catalyst mixture (K_2SO_4 - 100 g, $CuSO_4$ - 10 g and Selenium powder - 1 g) by microkjeldahl method. Plant samples for estimating phosphorus and potassium were digested using triacid mixture of sulphuric acid, perchloric acid and nitric acid (4:1:10). Phosphorus was estimated by Vanadomolybdo phosphoric yellow colour method and potassium by using Flame photometer (Jackson, 1958).

2. Uptake of fertiliser nutrients

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

3. Quality analysis

The tubers were washed, peeled, sliced and oven dried to constant weight at 70°C to 80°C. The dried samples were ground and sieved through a 60 mesh sieve.

A. Starch content in tubers

Starch content was found out following the standard procedure stated in A.O.A.C. (1960). One gram of dry sample was weighed into 100 ml conical flask containing 25 ml of 80 per cent ethanol. The flask was left overnight and filtered using Whatman No.1 filter paper. The residue was washed with distilled water twice and transferred quantitatively into a 100 ml conical flask, 20 ml 2 N HCl was added and hydrolysed by heating for 20 minutes in a water bath. Completion of hydrolysis was checked by the absence of blue colour with $\frac{N}{10}$ iodine solution. The hydrolysed solution was made up to 100 ml and glucose formed was estimated by Fehling's titration method.

B. Oxalic acid content in tubers

The total oxalic acid content was determined following the method suggested by CTCRI (1983). Two grams of the sample was weighed, 15 ml of 0.25 N HCl was added and extracted around 60°C in a water bath. It was centrifuged and supernatent was collected. The extraction was repeated and the supernatent was pooled. Five ml of Tungstophosphoric acid was added as a clarifying agent, left overnight and centrifuged. The pH of the supernatent was adjusted to 4.5 with dilute ammonia solution, 5 ml of calcium chloride reagent (acetate buffer) was added to it and kept overnight. The solution was centrifuged and the precipitate collected was washed with 5 ml of wash solution. It was again centrifuged and the precipitate was collected. The precipitate was dissolved in 10 ml of hot 2 N H_2SO_4. The solution was heated around 80°C and was titrated against standard $KMnO_4$ using a microburette.

C. Reducing sugar content in tubers

It was estimated colorimetrically by Nelson's method.

D. Cooking quality

Acridity of cooked samples was assessed organoleptically.

4. Disease intensity

Symptoms of colocasia blight appeared 50 days after planting. Due to heavy rainfall received, the disease reached its severity. Disease was graded from zero to five based on the number of spots on leaves.

Grade	Symptom
0	No spot
1	1-10 spots
2	11-15 spots
3	16-25 spots
4	1-2 leaves rotten
5	3-5 leaves rotten

Disease intensity was scored 90 and 170 days after planting.

5. Statistical analysis

The data were subjected to analysis of variance following the method of Panse and Sukhatme (1985).

6. Light infiltration percentage

LI-COR integrating quantum radio-meter with line quantum sensor was used for measuring light intensity at hourly intervals from various coconut plantations which differed in spacing and height of palms. Hourly observations were taken from 9 am to 5 pm by keeping the line quantum sensor, in the east-west direction, at three positions in between four coconut palms and point quantum sensor in the open. Percentage light infiltration values were calculated and average was computed.

Results

RESULTS

Observations on various plant characters were recorded to evaluate the performance of six promising morphotypes of colocasia screened for shade tolerance. Light infiltration observations were taken from farmers' field to assess the changes of light infiltration as influenced by spacing and height of the coconut palm. The results are presented in this chapter.

4.1. Artificial shade experiment

4.1.1. Biometric observations

4.1.1.1. Plant height (Table 3, Appendix II)

Height of the plants increased progressively from 60 DAP to 180 DAP. After 180 DAP, there was reduction in plant height due to drying of aerial parts. In all the growth stages, plants at 0 per cent shade recorded the minimum height and it differed significantly from all other shade levels at 60 and 120 DAP. At 60 DAP, plants at 50 per cent recorded the maximum height whereas at 120 and 180 DAP, plants at 75 per cent shade recorded the maximum height. Plant height at 25, 50 and 75 per cent shade levels did not differ significantly at 60, 120 and 180 DAP.

Highest plant height values were recorded by morphotypes M_2 and M_9 at 60, 120 and 180 DAP and the values were on par. Lowest plant height values were recorded by morphotypes M_1 and

Table 3 Effect of shade on plant height and tiller number of colocasia morphotypes

Treatment	Plant height (cm)			Number of tillers		
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Shade level (per cent)						
T_1 (0)	60.3	69.7	81.0	2.8	5.8	6.2
T_2 (25)	74.7	86.4	93.5	3.3	6.0	6.3
T_3 (50)	78.2	86.0	93.9	2.9	6.0	6.2
T_4 (75)	73.7	94.3	95.0	2.1	4.6	4.8
SEm±	3.27	6.98	9.42	0.28	0.55	0.57
CD (0.05)	7.39	15.79	NS	0.64	NS	NS
Morphotype						
V_1 M_1	69.4	62.6	74.7	3.3	7.6	8.0
V_2 M_2	78.4	100.3	105.3	4.0	5.7	6.3
V_3 M_9	77.6	102.7	106.1	1.3	6.2	6.3
V_4 M_{10}	72.5	83.9	89.6	2.9	6.1	6.2
V_5 M_{17}	65.1	66.9	75.3	4.0	5.2	5.3
V_6 M_{16}	67.4	88.2	94.1	1.1	2.8	3.1
SEm±	2.39	2.84	2.96	0.26	0.49	0.55
CD (0.05)	5.10	6.06	6.32	0.56	1.04	1.17

Plant height

60 DAP	T_1	T_4	T_2	T_3	M_{17}	M_{16}	M_1	M_{10}	M_9	M_2
120 DAP	T_1	T_3	T_2	T_4	M_1	M_{17}	M_{10}	M_{16}	M_2	M_9
180 DAP	T_1	T_2	T_3	T_4	M_1	M_{17}	M_{10}	M_{16}	M_2	M_9

Number of tillers

60 DAP	T_4	T_1	T_3	T_2	M_{16}	M_9	M_{10}	M_1	M_2	M_{17}
120 DAP	T_4	T_1	T_2	T_3	M_{16}	M_{17}	M_2	M_{10}	M_9	M_1
180 DAP	T_4	T_1	T_3	T_2	M_{16}	M_{17}	M_{10}	M_9	M_2	M_1

M_{17} at all the three stages and the values were on par. Interaction effects were not significant at any stage.

4.1.1.2. Number of tillers (Table 3, Appendix II)

At 60 DAP, highest shade level (T_4) recorded the lowest tiller number and it differed significantly from all other shade levels which were on par. At 120 and 180 DAP, there was no significant difference between shade levels with respect to number of tillers.

At 60 DAP, all the six morphotypes could be grouped into 3 homogenous groups whereas at 120 and 180 DAP, morphotype M_1 recorded the highest tiller number and morphotype M_{16} recorded the lowest tiller number. These two morphotypes differed significantly from the others at 120 and 180 DAP.

Interaction effects were not significant at any stage.

4.1.1.3. Chlorophyll content (Tables 4, 5, 6, 7, 8, Appendix II)

Total chlorophyll and its fractions, chlorophyll a and chlorophyll b were maximum at 50 and 75 per cent shade levels and they differed significantly from the other two shade levels. The ratio of chlorophyll a to b was lowest in the open and it differed significantly from the other three shade levels.

Morphotype M_9 recorded the highest chlorophyll a, b and total chlorophyll content whereas morphotypes M_2 and M_{16} recorded

Table 4 Effect of shade on contents of chlorophyll fractions of the leaves of colocasia morphotypes at 130 DAP

Treatment	Chlorophyll 'a' mg g^{-1} fresh weight	Chlorophyll 'b' mg g^{-1} fresh weight	Total chlorophyll (a+b) mg g^{-1} fresh weight	Chlorophyll a/b
Shade level (per cent)				
T_1 (0)	0.94	1.32	2.27	0.72
T_2 (25)	1.03	1.34	2.37	0.77
T_3 (50)	1.18	1.54	2.72	0.77
T_4 (75)	1.20	1.52	2.71	0.79
SEm±	0.01	0.01	0.02	0.02
CD (0.05)	0.03	0.03	0.04	0.04
Morphotype				
V_1 M_1	1.04	1.38	2.42	0.76
V_2 M_2	0.99	1.30	2.29	0.77
V_3 M_9	1.32	1.66	2.98	0.79
V_4 M_{10}	1.23	1.58	2.81	0.77
V_5 M_{17}	0.99	1.32	2.32	0.74
V_6 M_{16}	0.96	1.33	2.29	0.72
SEm±	0.02	0.03	0.03	0.02
CD (0.05)	0.04	0.05	0.06	0.05

Chlorophyll a

T_1 T_2 $\overline{T_3\ T_4}$ $\overline{M_{16}\ M_{17}\ M_2}$ M_1 M_{10} M_9

Chlorophyll b

$\overline{T_1\ T_2}$ $\overline{T_4\ T_3}$ $\overline{M_2\ M_{17}\ M_{16}}$ M_1 M_{10} M_9

Chlorophyll a/b

T_1 $\overline{T_2\ T_3\ T_4}$ $\overline{M_{16}\ M_{17}\ M_1\ M_2\ M_{10}}$ M_9

Total chlorophyll

T_1 T_2 $\overline{T_4\ T_3}$ $\overline{M_2\ M_{16}}$ M_{17} M_1 M_{10} M_9

Table 5 Mean chlorophyll 'a' content ($mg\ g^{-1}$) of colocasia morphotypes at different shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.09	0.96	1.05	1.07	1.04
M_2	1.00	1.03	1.02	0.92	0.99
M_9	0.98	1.43	1.50	1.37	1.32
M_{10}	1.08	0.87	1.31	1.67	1.23
M_{17}	0.84	0.92	1.08	1.10	0.99
M_{16}	0.67	0.98	1.14	1.06	0.96
Mean	0.94	1.03	1.18	1.20	

SE of difference between two sub plot means at the same level of main plot = 0.03

CD for the above at 5 per cent level = 0.07

SE of difference between two main plot means at the same level of sub plot = 0.04

CD for the above at 5 per cent level = 0.07

0% shade

M_{16} M_{17} M_9 M_2 M_{10} M_1

25% shade

M_{10} M_{17} M_1 M_{16} M_2 M_9

50% shade

M_2 M_1 M_{17} M_{16} M_{10} M_9

75% shade

M_2 M_{16} M_1 M_{17} M_9 M_{10}

M_1

T_2 T_3 T_4 T_1

M_2

T_4 T_1 T_3 T_2

M_9

T_1 T_4 T_2 T_3

M_{10}

T_2 T_1 T_3 T_4

M_{17}

T_1 T_2 T_3 T_4

M_{16}

T_1 T_2 T_4 T_3

Table 6 Mean chlorophyll 'b' content (mg g^{-1}) of colocasia morphotypes at different shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.53	1.24	1.36	1.38	1.38
M_2	1.21	1.37	1.41	1.22	1.30
M_9	1.43	1.66	1.83	1.70	1.66
M_{10}	1.52	1.21	1.70	1.89	1.58
M_{17}	1.19	1.23	1.43	1.43	1.32
M_{16}	1.02	1.31	1.51	1.47	1.33
Mean	1.32	1.34	1.54	1.52	

SE of difference between two sub plot means at the same level of main plot = 0.04

CD for the above at 5 per cent level = 0.08

SE of difference between two main plot means at the same level of sub plot = 0.05

CD for the above at 5 per cent level = 0.09

0% shade

M_{16} M_{17} M_2 M_9 M_{10} M_1

25% shade

M_{10} M_{17} M_1 M_{16} M_2 M_9

50% shade

M_1 M_2 M_{17} M_{16} M_{10} M_9

75% shade

M_2 M_1 M_{17} M_{16} M_9 M_{10}

M_1

T_2 T_3 T_4 T_1

M_2

T_1 T_4 T_2 T_3

M_9

T_1 T_2 T_4 T_3

M_{10}

T_2 T_1 T_3 T_4

M_{17}

T_1 T_2 T_3 T_4

M_{16}

T_1 T_2 T_4 T_3

Table 7 Mean total chlorophyll content (mg g^{-1}) of colocasia morphotypes at different shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	2.62	2.20	2.41	2.45	2.42
M_2	2.20	2.40	2.43	2.14	2.29
M_9	2.41	3.09	3.33	3.07	2.98
M_{10}	2.60	2.08	3.01	3.56	2.81
M_{17}	2.09	2.15	2.51	2.53	2.32
M_{16}	1.69	2.29	2.65	2.53	2.29
Mean	2.27	2.37	2.72	2.71	

SE of difference between two sub plot means at the same level of main plot = 0.05

CD for the above at 5 per cent level = 0.09

SE of difference between two main plot means at the same level of sub plot = 0.05

CD for the above at 5 per cent level = 0.10

0% shade

M_{16} M_{17} M_2 M_9 M_{10} M_1

25% shade

M_{10} M_{17} M_1 M_{16} M_2 M_9

50% shade

M_1 M_2 M_{17} M_{16} M_{10} M_9

75% shade

M_2 M_1 M_{16} M_{17} M_9 M_{10}

M_1

T_2 T_3 T_4 T_1

M_2

T_4 T_1 T_2 T_3

M_9

T_1 T_4 T_2 T_3

M_{10}

T_2 T_1 T_3 T_4

M_{17}

T_1 T_2 T_3 T_4

M_{17}

T_1 T_2 T_4 T_3

Table 8 Mean chlorophyll a/b content of colocasia morphotypes at different shade levels

Morphotye	Shade level (per cent)				Mean
	0	25	50	75	
M_1	0.72	0.77	0.77	0.78	0.76
M_2	0.85	0.75	0.72	0.76	0.77
M_9	0.69	0.86	0.82	0.81	0.79
M_{10}	0.71	0.73	0.77	0.89	0.77
M_{17}	0.67	0.75	0.75	0.77	0.74
M_{16}	0.66	0.75	0.76	0.73	0.72
Mean	0.72	0.77	0.77	0.79	

SE of difference between two sub plots means at the same level of main plot = 0.04

CD for the above at 5 per cent level = 0.08

SE of difference between two main plot means at the same level of sub plot = 0.04

CD for the above at 5 per cent level = 0.08

0% shade

$\overline{M_{16}\ \ M_{17}\ \ M_9\ \ M_{10}\ \ M_1}\ \ M_2$

25% shade

$\overline{M_{10}\ \ M_{17}\ \ M_{16}\ \ M_2\ \ M_1}\ \ M_9$

50% shade

$\overline{M_2\ \ M_{17}\ \ M_{16}\ \ M_{10}\ \ M_1}\ \ M_9$

75% shade

$\overline{M_{16}\ \ M_{17}\ \ M_2\ \ M_1\ \ M_9\ \ M_{10}}$

M_1

$\overline{T_1\ \ T_2\ \ T_3\ \ T_4}$

M_2

$\overline{T_3\ \ T_2\ \ T_4}\ \ T_1$

M_9

$T_1\ \ T_4\ \ T_3\ \ T_2$

M_{10}

$\overline{T_1\ \ T_2\ \ T_3}\ \ T_4$

M_{17}

$\overline{T_1\ \ T_2\ \ T_3}\ \ T_r$

M_{16}

$\overline{T_1\ \ T_4}\ \ T_2\ \ T_3$

the lowest chlorophyll contents. Total chlorophyll content ranged from 2.29 to 2.98 mg g^{-1} fresh weight in the various morphotypes.

Significant interaction between shade levels and morphotypes was noticed for chlorophyll a, b and total chlorophyll content. At 0 per cent shade, morphotype M_{16} recorded the lowest chlorophyll a content whereas at 25 per cent shade M_{10} and at 50 and 75 per cent shade M_2 recorded the lowest content. All the morphotypes recorded maximum chlorophyll b content at higher shade levels of 50 and 75 per cent. Morphotype M_1, M_2, M_9 and M_{10} recorded maximum total chlorophyll content at 0 per cent, 25 per cent, 50 per cent and 75 per cent shade, respectively. The ratio of chlorophyll a to b was maximum for morphotypes M_2, M_9, M_{16} and M_{10} at shade levels of 0, 25, 50 and 75 per cent, respectively.

4.1.1.4. Total dry weight (Table 9, Appendix IV)

There was no significant variation among shade levels in all the three growth stages, but at harvest the dry matter production varied significantly among the shade levels. The highest value was recorded at 25 per cent shade and the lowest was at 75 per cent shade.

Morphotype M_1 had the lowest dry matter production at all the three growth stages, but at harvest morphotype M_{17} recorded the lowest value. Morphotype M_2 was found to produce the highest dry matter at all the three growth stages and at harvest.

Table 9 Effect of shade on dry matter production of colocasia morphotypes

Treatment	Dry matter (g plant^{-1})			
	60 DAP	120 DAP	180 DAP	Harvest
Shade level (per cent)				
T_1 (0)	28.69	56.43	67.04	129.50
T_2 (25)	36.38	54.57	72.60	145.00
T_3 (50)	33.33	58.24	70.75	124.60
T_4 (75)	27.35	57.79	71.52	115.30
SEm±	5.57	5.41	5.31	0.79
CD (0.05)	NS	NS	NS	1.78
Morphotype				
V_1 M_1	24.28	36.11	51.14	107.30
V_2 M_2	37.51	62.64	92.81	169.80
V_3 M_9	38.89	64.33	61.71	116.60
V_4 M_{10}	29.02	59.93	68.39	123.70
V_5 M_{17}	31.61	46.96	62.92	103.30
V_6 M_{16}	27.31	70.57	85.89	151.10
SEm±	4.14	6.13	4.94	1.04
CD (0.05)	8.82	13.07	10.53	2.21

Dry matter production

60 DAP T_4 T_1 T_3 T_2 M_1 M_{16} M_{10} M_{17} M_2 M_9

120 DAP T_2 T_1 T_4 T_3 M_1 M_{17} M_{10} M_2 M_9 M_{16}

180 DAP T_1 T_3 T_4 T_2 M_1 M_9 M_{17} M_{10} M_{16} M_2

Harvest

T_4 T_3 T_1 T_2 M_{17} M_1 M_9 M_{10} M_{16} M_2

There was no significant interaction between the shade level and morphotypes in all the four stages.

4.1.1.5. Corm yield (Tables 10, 11, Appendix V and Fig. 3)

There was no significant difference among shade levels in respect of corm yield; but morphotypes differed significantly. The highest yield was recorded by M_{16} and the lowest was recorded by M_1.

The interaction between morphotypes and shade levels was noticed to be significant. While M_2 and M_{16} recorded the highest yield at 25 per cent shade, M_2 and M_{16} and M_{17} showed a steady decline in yield with increase in shade levels. With respect to the mean corm yield, M_{16} recorded the highest value and 25 per cent shade level recorded highest mean value.

4.1.1.6. Cormel yield (Tables 10, 12, Appendix V and Fig. 4)

The cormel yield did not show significant variation at different shade levels. Based on the yield of different morphotypes, it was possible to group the morphotypes into two homogenous classes. The group consisting of M_2 and M_9 recorded significantly higher yield than the group comprising of M_1, M_{17}, M_{16} and M_{10}.

Significant interaction between morphotypes and shade levels was noticed. While M_1 and M_9 recorded the highest cormel

Table 10 Effect of shade on yield and harvest index of colocasia morphotypes

Treatment	Corm yield (t ha^{-1})	Cormel yield (t ha^{-1})	Total yield (t ha^{-1})	Haulm yield (t ha^{-1})	Harvest index
Shade level (per cent)					
T_1 (0)	1.54	2.11	3.65	0.45	0.64
T_2 (25)	1.72	2.49	4.13	0.51	0.62
T_3 (50)	1.44	2.39	3.83	0.50	0.59
T_4 (75)	1.47	2.49	3.96	0.49	0.56
SEm±	0.10	0.19	0.22	0.02	0.03
CD (0.05)	NS	NS	NS	NS	NS
Morphotype					
V_1 M_1	0.98	1.88	2.86	0.49	0.52
V_2 M_2	2.02	3.29	5.31	0.61	0.65
V_3 M_9	1.22	2.98	4.10	0.41	0.63
V_4 M_{10}	1.57	2.28	3.85	0.44	0.62
V_5 M_{17}	1.15	1.89	3.04	0.43	0.57
V_6 M_{16}	2.31	1.91	4.22	0.54	0.63
SEm±	0.10	0.20	0.24	0.03	0.02
CD (0.05)	0.20	0.43	0.51	0.07	0.05

Corm yield	T_3 T_4 T_1 T_2	M_1 M_{17} M_9 M_{10} M_2 M_{16}
Cormel yield	T_1 T_3 T_2 T_4	M_1 M_{17} M_{16} M_{10} M_9 M_2
Total yield	T_1 T_3 T_4 T_2	M_1 M_{17} M_{10} M_9 M_{16} M_2
Harvest index	T_4 T_3 T_2 T_1	M_1 M_{17} M_{10} M_9 M_{16} M_2
Haulm yield	T_1 T_4 T_3 T_2	M_9 M_{17} M_{10} M_1 M_{16} M_2

Table 11 Mean corm yield (t ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	0.74	1.23	0.88	1.10	0.98
M_2	2.32	2.03	1.94	1.81	2.02
M_9	0.96	1.73	0.90	1.30	1.22
M_{10}	1.15	1.49	1.72	1.91	1.57
M_{17}	1.27	1.21	1.31	0.82	1.15
M_{16}	2.83	2.66	1.88	1.88	2.31
Mean	1.54	1.72	1.44	1.47	

SE of difference between two sub plot means at the same level of main plot = 0.17

CD for the above at 5 per cent level = 0.32

SE of difference between two main plot means at the same level of sub plot = 0.20

CD for the above at 5 per cent level = 0.39

0% shade

M_1 M_9 M_{10} M_{17} M_2 M_{16}

25% shade

M_{17} M_1 M_{10} M_9 M_2 M_{16}

50% shade

M_1 M_9 M_{17} M_{10} M_{16} M_2

75% shade

M_{17} M_1 M_9 M_2 M_{16} M_{10}

M_1

T_1 T_3 T_4 T_2

M_2

T_4 T_3 T_2 T_1

M_9

T_3 T_1 T_4 T_2

M_{10}

T_1 T_2 T_3 T_4

M_{17}

T_4 T_2 T_1 T_3

M_{16}

T_3 T_4 T_2 T_1

Fig.3 Corm yield for colocasia morphotypes at various shade levels

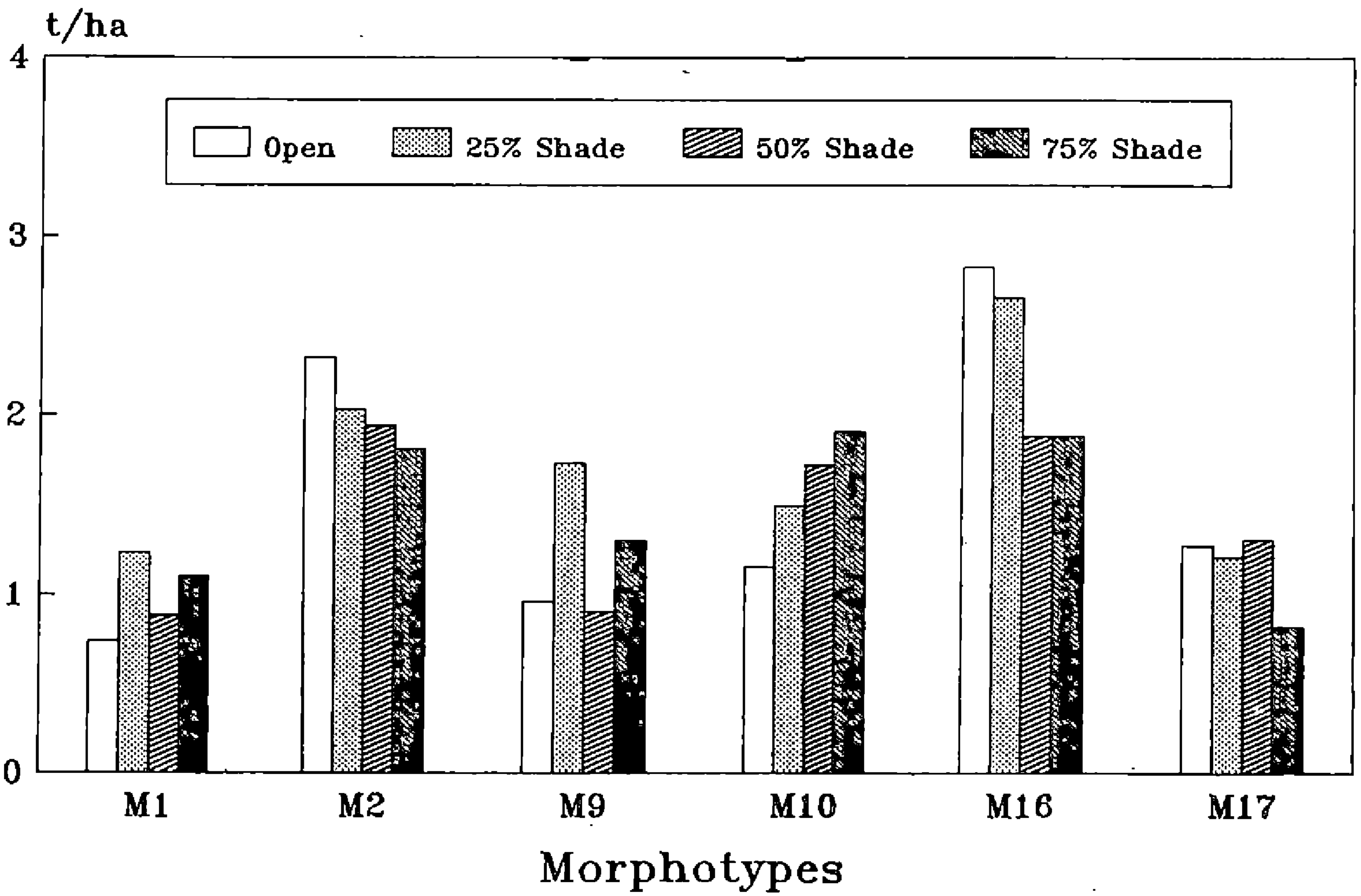


Table 12 Mean cormel yield (t ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.67	1.96	1.59	2.30	1.88
M_2	2.81	4.20	3.09	3.05	3.29
M_9	2.45	2.53	3.10	3.85	2.98
M_{10}	2.33	2.33	2.08	2.39	2.28
M_{17}	1.88	2.08	2.10	1.49	1.89
M_{16}	1.53	1.88	2.39	1.85	1.91
Mean	2.11	2.49	2.39	2.49	

SE of difference between two sub plot means at the same level of main plot = 0.35

CD for the above at 5 per cent level = 0.68

SE of difference between two main plot means at the same level of sub plot = 0.41

CD for the above at 5 per cent level = 0.81

0% shade

M_{16} M_1 M_{17} M_{10} M_9 M_2

25% shade

M_{16} M_1 M_{17} M_{10} M_9 M_2

50% shade

M_1 M_{10} M_{17} M_{16} M_2 M_9

75% shade

M_{17} M_{16} M_1 M_{10} M_2 M_9

M_1

T_3 T_1 T_2 T_4

M_2

T_1 T_4 T_3 T_2

M_9

T_1 T_2 T_3 T_4

M_{10}

T_3 T_1 T_2 T_4

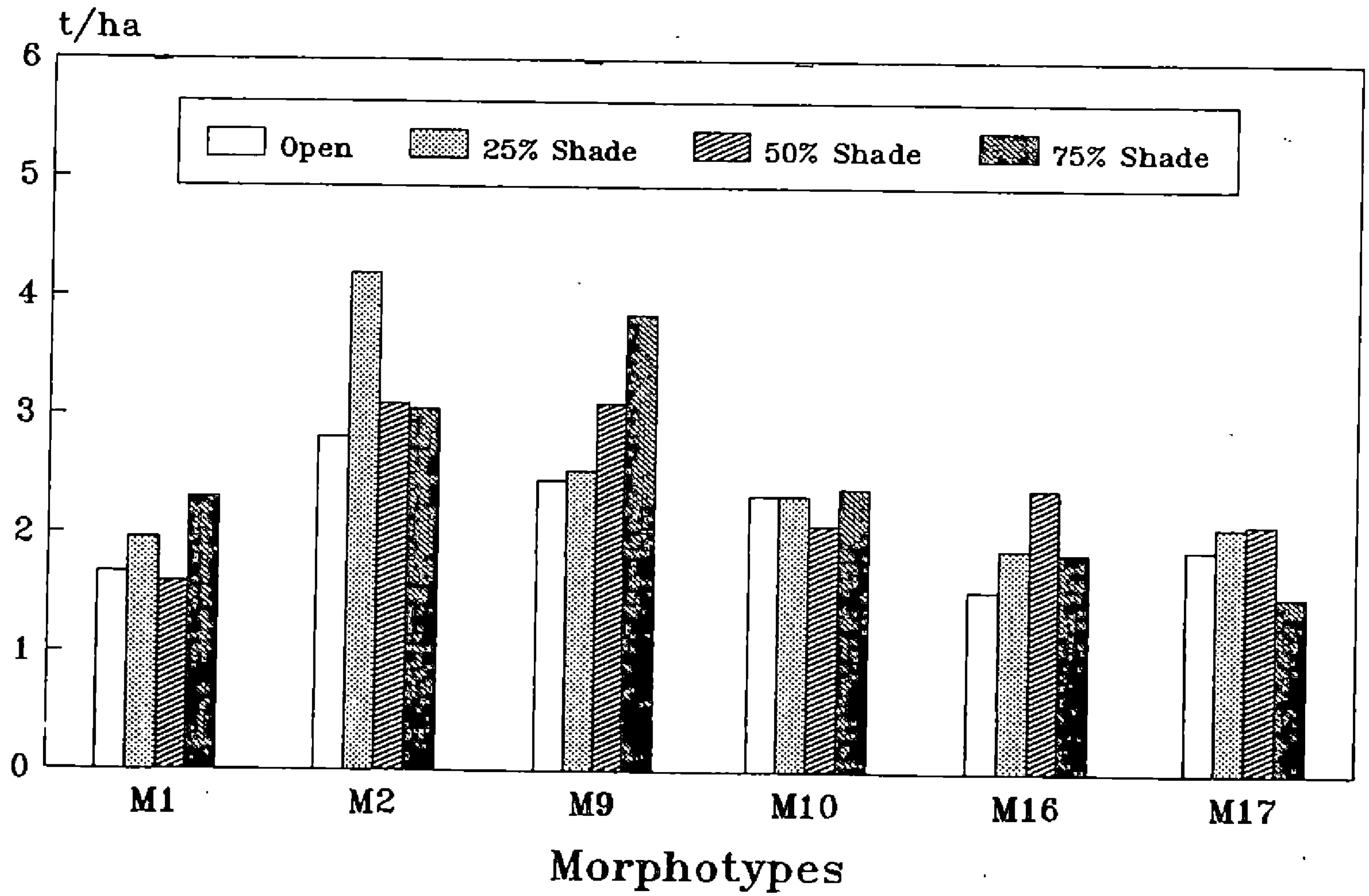
M_{17}

T_4 T_1 T_2 T_3

M_{16}

T_1 T_4 T_2 T_3

Fig.4 Cormel yield for colocasia morphotypes at various shade levels



yield at 75 per cent shade level, M_2 recorded the highest yield at 25 per cent shade level and this was significantly higher than yield at other shade levels. M_{10} did not show much variation in the yield at the different shade intensities. The morphotypes M_{16} and M_{17} recorded the highest yield at 50 per cent shade. With respect to mean cormel yield, M_2 recorded the highest value and M_1 recorded the lowest value.

4.1.1.7. Total yield (Tables 10, 13, Appendix V and Fig. 5)

The total yield among different shade levels did not differ significantly. The morphotype M_2 recorded the maximum yield and it differed highly from all other morphotypes. Yields of M_1 and M_{17} were on par and they recorded the lowest yield.

Interaction effect between shade levels and morphotypes was significant. M_1 and M_9 recorded significantly higher yields at 75 per cent shade. Though not significant, M_{10} also recorded the highest yield at 75 per cent shade. M_2, M_{17} and M_{16} recorded the highest yield at 25 per cent shade.

4.1.1.8. Haulm yield (Table 10, Appendix V)

There was no significant variation in haulm yield among the different shade levels. The lowest value was recorded at 0 per cent shade which was on par with the values at other shade levels.

Table 13 Mean total yield (t ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent) 0	25	50	75	Mean
M_1	2.41	3.18	2.46	3.39	2.86
M_2	5.12	6.23	5.02	4.85	5.30
M_9	3.41	3.75	3.99	4.90	4.01
M_{10}	3.47	3.82	3.80	4.30	3.85
M_{17}	3.15	3.29	3.26	2.30	3.00
M_{16}	4.36	4.53	4.26	3.72	4.22
Mean	3.65	4.13	3.80	3.91	

SE of difference between two sub plot means at the same level of main plot = 0.41

CD for the above at 5 per cent level = 0.81

SE of difference between two main plot means at the same level of sub plot = 0.49

CD for the above at 5 per cent level = 0.95

0% shade

M_1 M_{17} M_9 M_{10} M_{16} M_2

25% shade

M_1 M_{17} M_9 M_{10} M_{16} M_2

50% shade

M_1 M_{17} M_{10} M_9 M_{16} M_2

75% shade

M_{17} M_1 M_{16} M_{10} M_2 M_9

M_1

T_1 T_3 T_2 T_4

M_2

T_4 T_3 T_1 T_2

M_9

T_1 T_2 T_3 T_4

M_{10}

T_1 T_3 T_2 T_4

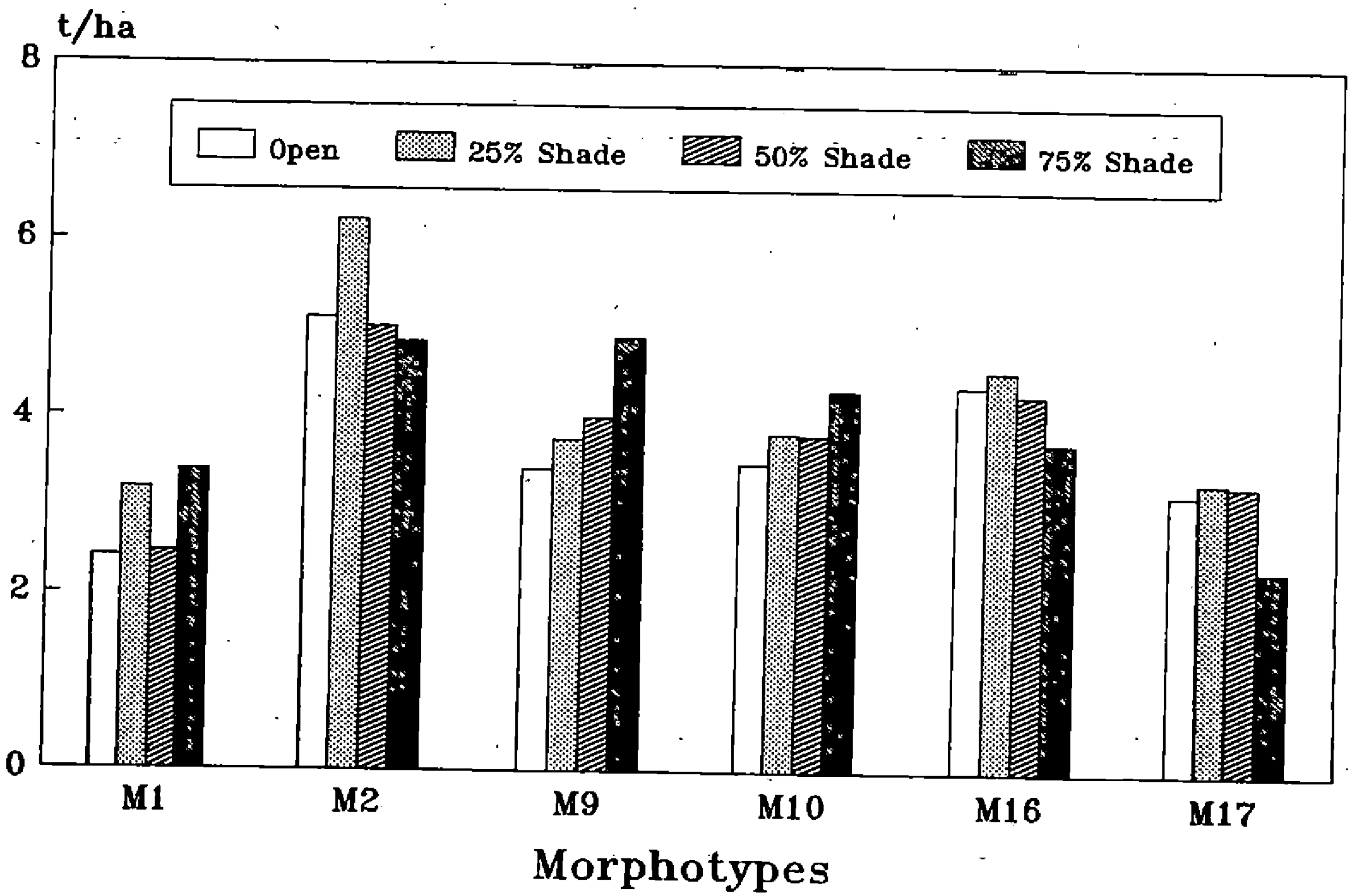
M_{17}

T_4 T_1 T_3 T_2

M_{16}

T_4 T_3 T_1 T_2

Fig.5 Total yield for colocasia morphotypes at various shade levels



There was significant variation among morphotypes. The highest value was recorded by M_2 (0.61 t ha^{-1}) and the lowest was recorded by M_9 (0.41 t ha^{-1}).

Interaction was not found to be significant.

4.1.1.9. Harvest index (Table 10, Appendix V)

Significant variation in harvest index was not noticed among shade levels. Among morphotypes M_2 recorded the highest value for harvest index which was on par with the values recorded by M_9, M_{10} and M_{16}. The lowest value was recorded by M_1. The values ranged from 0.52 to 0.65. There was no significant interaction between shade levels and morphotypes.

4.1.2. Chemical studies

4.1.2.1. Content of fertiliser nutrients (Tables, 14, 15, 16, 17, 18, 19)

Nitrogen content of haulm and tubers was maximum under 25 per cent shade and minimum under 75 per cent shade. Morphotype M_{16} recorded maximum N content in the haulm and M_9 recorded maximum content in the tuber. These two values were significantly different from the other values.

Interaction between shade levels and morphotypes was also significant. Morphotype M_9 recorded the highest N content in haulm under open conditions and the lowest N content in haulm under 75 per cent shade whereas M_{17} recorded lowest N content in the haulm under open conditions and highest under 75 per cent shade. The nitrogen content of tuber varied widely between the morphotypes and it ranged from 1.04 to 1.58 per cent.

There was no significant difference among the shade levels with respect to phosphorus content of the haulm but there was significant difference between the morphotypes. Morphotype M_{10} recorded the highest value and morphotype M_9 recorded the lowest value which was on par with the value recorded by M_{16}.

Interaction between shade levels and morphotypes was significant. The P content of haulms of M_2, M_9 and M_{16} did not differ significantly among the different shade levels. Morphotype M_1 recorded the lowest and M_{10} recorded the highest P content in tubers at all the four shade levels. The difference between the P content in tuber was relatively small with respect to shade levels within the same morphotype though this was statistically significant.

There was significant difference between the shade levels with respect to K content of haulms and tubers. High K content was observed at higher shade intensities. Morphotype M_9 recorded the highest K content in haulm as well as in tuber and the lowest was recorded by M_{16} and M_1 in the haulm and tuber, respectively.

There was no significant interaction between shade levels and morphotypes with respect to K content of haulm, but with respect to K content of tuber, there was significant interaction.

Table 14 Effect of shade on nitrogen, phosphorus and potassium contents of tubers and haulm of colocasia morphotypes

Treatment	N (per cent)		P (per cent)		K (per cent)	
	Haulm	Tuber	Haulm	Tuber	Haulm	Tuber
Shade level (per cent)						
T_1 (0)	1.91	1.20	0.36	0.40	3.47	2.31
T_2 (25)	1.96	1.26	0.37	0.36	3.76	2.43
T_3 (50)	1.85	1.25	0.36	0.35	3.63	2.43
T_4 (75)	1.82	1.17	0.36	0.35	3.75	2.40
SEm±	0.01	0.01	0.01	0.01	0.07	0.03
CD (0.05)	0.03	0.02	NS	0.02	0.17	0.06
Morphotype						
V_1 M_1	1.81	1.21	0.36	0.27	3.77	1.74
V_2 M_2	1.85	1.12	0.34	0.39	3.50	2.60
V_3 M_9	1.86	1.35	0.31	0.38	4.42	2.63
V_4 M_{10}	1.88	1.20	0.45	0.42	3.31	2.66
V_5 M_{17}	1.83	1.20	0.37	0.37	4.34	2.38
V_6 M_{16}	2.09	1.26	0.32	0.35	2.56	2.33
SEm±	0.02	0.01	0.01	0.01	0.13	0.04
CD (0.05)	0.05	0.02	0.02	0.02	0.27	0.09

N content haulm T_4 T_3 T_1 T_2 M_1 M_{17} M_2 M_9 M_{10} M_{16}

N content tuber T_4 T_1 T_3 T_2 M_2 M_{10} M_{17} M_1 M_{16} M_9

P content haulm T_1 T_3 T_4 T_2 M_9 M_{16} M_2 M_1 M_{17} M_{10}

P content tuber T_4 T_3 T_2 T_1 M_1 M_{16} M_{17} M_9 M_2 M_{10}

K content haulm T_1 T_3 T_4 T_2 M_{16} M_{10} M_2 M_1 M_{17} M_9

K content tuber T_1 T_4 T_2 T_3 M_1 M_{16} M_{17} M_2 M_9 M_{10}

Table 15 Mean nitrogen content of haulm (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.99	1.69	1.70	1.88	1.81
M_2	1.79	1.87	1.95	1.80	1.85
M_9	2.09	2.03	1.79	1.53	1.86
M_{10}	1.91	1.96	1.94	1.71	1.88
M_{17}	1.64	1.84	1.80	2.06	1.83
M_{16}	2.05	2.40	1.95	1.96	2.09
Mean	1.91	1.96	1.85	1.82	

SE of difference between two sub plot means at the same level of main plot = 0.04

CD for the above at 5 per cent level = 0.08

SE of difference between two main plot means at the same level of sub plot = 0.04

CD for the above at 5 per cent level = 0.08

0% shade

M_{17} M_2 M_{10} M_1 M_{16} M_9

25% shade

M_1 M_{17} M_2 M_{10} M_9 M_{16}

50% shade

M_1 M_9 M_{17} M_{10} M_2 M_{16}

75% shade

M_9 M_{10} M_2 M_1 M_{16} M_{17}

M_1

T_2 T_3 T_4 T_1

M_2

T_1 T_4 T_2 T_3

M_9

T_4 T_3 T_2 T_1

M_{10}

T_4 T_1 T_3 T_2

M_{17}

T_1 T_3 T_2 T_4

M_{16}

T_3 T_4 T_1 T_2

Table 16 Mean nitrogen content of tubers (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.06	1.06	1.26	1.47	1.21
M_2	1.04	1.16	1.24	1.04	1.12
M_9	1.35	1.58	1.47	1.02	1.35
M_{10}	1.33	1.17	1.04	1.26	1.20
M_{17}	1.05	1.26	1.24	1.25	1.20
M_{16}	1.41	1.37	1.26	1.01	1.26
Mean	1.20	1.26	1.25	1.17	

SE of difference between two sub plot means at the same level of main plot = 0.02

CD for the above at 5 per cent level = 0.04

SE of difference between two main plot means at the same level of sub plot = 0.02

CD for the above at 5 per cent level = 0.04

0% shade

$\overline{M_2\quad M_{17}\quad M_1}\quad \overline{M_{10}\quad M_9\quad M_{16}}$

25% shade

$M_1\quad \overline{M_2\quad M_{10}}\quad M_{17}\quad M_{16}\quad M_9$

50% shade

$M_{10}\quad \overline{M_{17}\quad M_2\quad M_1\quad M_{16}}\quad M_9$

75% shade

$\overline{M_{16}\quad M_9\quad M_2}\quad \overline{M_{17}\quad M_{10}}\quad M_1$

M_1

$\overline{T_1\quad T_2}\quad T_3\quad T_4$

M_2

$\overline{T_1\quad T_4}\quad T_2\quad T_3$

M_9

$T_4\quad T_1\quad T_3\quad T_2$

M_{10}

$T_3\quad T_2\quad T_4\quad T_1$

M_{17}

$T_1\quad \overline{T_3\quad T_4\quad T_2}$

M_{16}

$T_4\quad T_3\quad T_2\quad T_1$

Table 17 Mean phosphorus content of haulm (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	0.31	0.43	0.34	0.38	0.36
M_2	0.34	0.35	0.35	0.33	0.34
M_9	0.31	0.31	0.33	0.30	0.31
M_{10}	0.51	0.40	0.46	0.43	0.45
M_{17}	0.38	0.39	0.36	0.37	0.37
M_{16}	0.31	0.32	0.33	0.32	0.32
Mean	0.36	0.37	0.36	0.36	

SE of difference between two sub plot means at the same level of main plot = 0.02

CD for the above at 5 per cent level = 0.04

SE of difference between two main plot means at the same level of sub plot = 0.02

CD for the above at 5 per cent level = 0.04

0% shade

M_1 M_9 M_{16} M_2 M_{17} M_{10}

25% shade

M_9 M_{16} M_2 M_{17} M_{10} M_1

50% shade

M_{16} M_9 M_1 M_2 M_{17} M_{10}

75% shade

M_9 M_{16} M_2 M_{17} M_1 M_{10}

M_1

T_1 T_3 T_4 T_2

M_2

T_4 T_1 T_2 T_3

M_9

T_4 T_1 T_2 T_3

M_{10}

T_2 T_4 T_3 T_1

M_{17}

T_3 T_4 T_1 T_2

M_{16}

T_1 T_2 T_3 T_4

Table 18 Mean phosphorus content of tubers (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	0.31	0.29	0.25	0.25	0.27
M_2	0.40	0.38	0.39	0.40	0.39
M_9	0.40	0.40	0.40	0.35	0.38
M_{10}	0.45	0.40	0.41	0.41	0.42
M_{17}	0.39	0.36	0.37	0.37	0.37
M_{16}	0.43	0.35	0.31	0.32	0.35
Mean	0.40	0.36	0.35	0.35	

SE of difference between two sub plot means at same level of main plot = 0.02

CD for the above at 5 per cent level = 0.04

SE of difference between two main plot means at the same level of sub plot = 0.02

CD for the above at 5 per cent level = 0.04

0% shade

M_1 M_{17} M_2 M_9 M_{16} M_{10}

25% shade

M_1 M_{16} M_{17} M_2 M_9 M_{10}

50% shade

M_1 M_{16} M_{17} M_2 M_9 M_{10}

75% shade

M_1 M_{16} M_9 M_{17} M_2 M_{10}

M_1

T_3 T_4 T_2 T_1

M_2

T_2 T_3 T_1 T_4

M_9

T_4 T_1 T_2 T_3

M_{10}

T_2 T_3 T_4 T_1

M_{17}

T_2 T_3 T_4 T_1

M_{16}

T_3 T_4 T_2 T_1

Table 19 Mean potassium content of tubers (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	1.65	1.74	1.78	1.81	1.74
M_2	2.50	2.59	2.93	2.39	2.60
M_9	2.45	2.73	2.60	2.74	2.63
M_{10}	2.61	2.50	2.70	2.81	2.66
M_{17}	2.48	2.48	2.24	2.35	2.38
M_{16}	2.19	2.53	2.31	2.29	2.33
Mean	2.31	2.43	2.43	2.40	

SE of difference between two sub plot means at same level of main plot = 0.07

CD for the above at 5 per cent level = 0.14

SE of difference between two main plot means at same level of sub plot = 0.08

CD for the above at 5 per cent level = 0.16

0% shade

M_1 M_{16} M_9 M_{17} M_2 M_{10}

25% shade

M_1 M_{17} M_{10} M_{16} M_2 M_9

50% shade

M_1 M_{17} M_{16} M_9 M_{10} M_2

75% shade

M_1 M_{16} M_{17} M_2 M_9 M_{10}

M_1

T_1 T_2 T_3 T_4

M_2

T_4 T_1 T_2 T_3

M_9

T_1 T_3 T_2 T_4

T_{10}

T_2 T_1 T_3 T_4

M_{17}

T_3 T_4 T_1 T_2

M_{16}

T_1 T_4 T_3 T_2

Morphotype M_1 recorded the lowest K content in tubers at all the four shade levels and it was significantly lower than the content in all other morphotypes. There was no significant difference between the K content of tubers of M_1 among the different shade levels.

4.1.2.2. Uptake of nutrients (Tables 20, 21, 22, 23)

The uptake of nitrogen was maximum at 25 per cent shade and minimum at 75 per cent shade. The morphotypes also varied widely with respect to N uptake, the maximum recorded was by M_2 (27.13 kg ha^{-1}) and the minimum was by M_{17} (15.34 kg ha^{-1}).

The interaction effect between shade levels and morphotypes was also significant. At lowest light intensity M_9 and M_{10} recorded highest nitrogen uptake whereas at higher light intensities M_2 and M_{16} recorded highest nitrogen uptake.

The phosphorus uptake was also found to follow a similar pattern as that for nitrogen. The values under open and 25 per cent shade were on par. Morphotype M_2 recorded the highest P uptake value.

The interaction effect was also found to be significant. Under all shade levels except 75 per cent shade, M_2 recorded the highest uptake value and it was significantly different from all other morphotypes.

Table 20 Effect of shade on total uptake of nitrogen, phosphorus and potassium and on starch and oxalic acid contents

Treatment	Uptake (kg ha^{-1})			Starch (per cent)	Oxalic acid (per cent)
	N	P	K		
Shade level (per cent)					
T_1 (0)	18.94	4.66	35.13	27.57	0.34
T_2 (25)	24.13	4.85	39.42	28.09	0.34
T_3 (50)	20.54	4.37	39.38	26.97	0.37
T_4 (75)	16.58	4.00	34.69	28.24	0.35
SEm±	0.73	0.15	2.44	0.14	0.02
CD (0.05)	1.64	0.34	NS	0.32	NS
Morphotype					
V_1 M_1	17.21	3.26	28.44	27.84	0.33
V_1 M_2	27.13	6.38	53.63	28.58	0.39
V_3 M_9	19.45	3.97	38.69	27.75	0.32
V_4 M_{10}	18.33	4.97	34.86	27.87	0.33
V_5 M_{17}	15.34	3.78	32.99	27.54	0.36
V_6 M_{16}	22.82	4.47	34.34	26.71	0.37
SEm±	1.05	0.25	2.98	0.23	0.01
CD (0.05)	2.23	0.52	6.35	0.48	0.02

N uptake	T_4 T_1 T_3 T_2	M_{17} M_1 M_{10} M_9 M_{16} M_2
P uptake	T_4 T_3 T_1 T_2	M_1 M_{17} M_9 M_{16} M_{10} M_2
K uptake	T_4 T_1 T_3 T_2	M_1 M_{17} M_{16} M_{10} M_9 M_2
Starch content	T_3 T_1 T_2 T_4	M_{16} M_{17} M_9 M_1 M_{10} M_2
Oxalate content	T_1 T_2 T_3 T_4	M_9 M_{10} M_1 M_{17} M_{16} M_2

Table 21 Mean nitrogen uptake (kg ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	14.79	22.61	16.11	15.35	17.21
M_2	24.48	35.48	31.18	17.38	27.13
M_9	16.52	22.25	20.94	18.12	19.45
M_{10}	18.90	20.62	15.42	18.38	18.33
M_{17}	14.20	17.31	16.40	13.43	15.34
M_{16}	24.76	26.52	23.20	16.81	22.82
Mean	18.94	24.13	20.54	16.58	

SE of difference between two sub plot means at same level of main plot = 1.81

CD for the above at 5 per cent level = 3.55

SE of difference between two main plot means at the same level of sub plot = 2.04

CD for the above at 5 per cent level = 4.00

0% shade

M_{17} M_1 M_9 M_{10} M_2 M_{16}

25% shade

M_{17} M_{10} M_9 M_1 M_{16} M_2

50% shade

M_{10} M_1 M_{17} M_9 M_{16} M_2

75% shade

M_{17} M_1 M_{16} M_2 M_9 M_{10}

M_1

T_1 T_4 T_3 T_2

M_2

T_4 T_1 T_3 T_2

M_9

T_1 T_4 T_3 T_2

M_{10}

T_3 T_4 T_1 T_2

M_{17}

T_4 T_1 T_3 T_2

M_{16}

T_4 T_3 T_1 T_2

Table 22 Mean phosphorus uptake (kg ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	2.93	4.01	3.05	3.05	3.26
M_2	7.41	6.94	6.50	4.66	6.38
M_9	3.48	4.06	3.97	4.36	3.97
M_{10}	5.30	5.02	4.52	5.03	4.97
M_{17}	4.22	3.97	3.86	3.09	3.78
M_{16}	4.63	5.12	4.32	3.82	4.71
Mean	4.66	4.85	4.37	4.00	

SE of difference between two sub plot means at same level of main plot =0.42

CD for the above at 5 per cent level = 0.83

SE of difference between two main plot means at same level of sub plot = 0.47

CD for the above at 5 per cent level = 0.93

0% shade

M_1 M_9 M_{17} M_{16} M_{10} M_2

25% shade

M_{17} M_1 M_9 M_{10} M_{16} M_2

50% shade

M_1 M_{17} M_9 M_{16} M_{10} M_2

75% shade

M_1 M_{17} M_{16} M_9 M_2 M_{10}

M_1

T_1 T_3 T_4 T_2

M_2

T_4 T_3 T_2 T_1

M_9

T_1 T_3 T_2 T_4

M_{10}

T_3 T_2 T_4 T_1

M_{17}

T_4 T_3 T_2 T_1

M_{16}

T_4 T_3 T_1 T_2

Table 23 Mean potassium uptake (kg ha^{-1}) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	23.32	34.05	29.13	27.25	28.44
M_2	54.40	57.48	65.65	36.98	53.63
M_9	30.28	36.13	40.65	47.71	38.69
M_{10}	34.82	37.59	30.98	36.04	34.86
M_{17}	33.72	35.83	32.53	29.87	32.99
M_{16}	34.25	35.45	37.39	30.27	34.34
Mean	35.13	39.42	39.39	34.69	

SE of difference between two sub plot means at same level of main plot = 5.16

CD for the above at 5 per cent level = 10.12

SE of difference between two main plot means at same level of sub plot = 5.97

CD for the above at 5 per cent level = 11.69

0% shade

M_1 M_9 M_{17} M_{16} M_{10} M_2

25% shade

M_1 M_{16} M_{17} M_9 M_{10} M_2

50% shade

M_1 M_{10} M_{17} M_{16} M_9 M_2

75% shade

M_1 M_{17} M_{16} M_{10} M_2 M_9

M_1

T_1 T_4 T_3 T_2

M_2

T_4 T_1 T_2 T_3

M_9

T_1 T_2 T_3 T_4

M_{10}

T_3 T_1 T_4 T_2

M_{17}

T_4 T_3 T_1 T_2

M_{16}

T_4 T_1 T_2 T_3

There was no significant difference among the shade levels with respect to potassium uptake; but there was significant difference between the morphotypes. The highest value was recorded by M_2 and it was 53.63 kg ha^{-1}.

The interaction between shade levels and morphotypes was also significant. Morphotype M_2 recorded the highest value under all light intensities except at 75 per cent shade where M_9 recorded the highest value. Potassium uptake of all morphotypes except M_2 and M_9 was on par under all shade levels.

4.1.2.3. Starch content in tubers (Tables20, 24)

There was significant variation among the shade levels and the highest value was recorded under 75 per cent shade. Morphotype M_2 had the highest starch content of 28.58 per cent and the lowest content was in M_{16} (26.71 per cent).

The interaction effect was also significant. The starch content of M_2 was highest at 50 per cent and 75 per cent shade levels and it was significantly different from other morphotypes. There was not much significant difference between shade levels for same morphotype.

4.1.2.4. Oxalic acid (Table 20)

Oxalic acid content of all shade levels was on par. Morphotype M_2 recorded the maximum content (0.39 per cent) and it was

Table 24 Mean starch content (%) of colocasia morphotypes at various shade levels

Morphotype	Shade level (per cent)				Mean
	0	25	50	75	
M_1	27.50	28.58	27.55	27.75	27.84
M_2	28.08	27.83	28.82	29.60	28.58
M_9	27.95	28.45	26.45	28.15.	27.75
M_{10}	28.15	27.50	26.38	29.45	27.87
M_{17}	27.10	28.55	26.48	28.05	27.54
M_{16}	26.63	27.65	26.15	26.43	26.71
Mean	27.57	28.09	26.96	28.24	

SE of difference between two sub plot means at same level of main plot = 0.39

CD for the above at 5 per cent level = 0.77

SE of difference between two main plot means at same level of sub plot = 0.44

CD for the above at 5 per cent level = 0.86

0% shade

M_{16} M_{17} M_1 M_9 M_2 M_{10}

25% shade

M_{10} M_{16} M_2 M_9 M_{17} M_1

50% shade

M_{16} M_{10} M_9 M_{17} M_1 M_2

75% shade

M_{16} M_1 M_{17} M_9 M_{10} M_2

M_1

T_1 T_3 T_4 T_2

M_2

T_2 T_1 T_3 T_4

M_9

T_3 T_1 T_4 T_2

M_{10}

T_3 T_2 T_1 T_4

M_{17}

T_3 T_1 T_4 T_2

M_{16}

T_3 T_4 T_1 T_2

on par with that M_{16} (0.37 per cent). The lowest content was in M_9 (0.32 per cent).

4.1.2.5. Cooking quality

All the morphotypes tried had edible tubers. Morphotype M_2 alone had slight acridity. The mother corms of M_{10} and M_{16} were large and were edible. Corms of M_{10} had slight acridity which was lost when properly cooked.

4.1.2.6. Reducing sugar content

It was estimated to be negligible in all the morphotypes.

4.1.2.7. Disease intensity (Table 25)

Disease intensity was maximum during monsoon period. With increase in shade, intensity of disease also increased. The most affected morphotype was M_{17} and the least affected one was M_9. Most of the leaves of M_{17} and some parts of the pseudostem were damaged by the disease incidence and it reduced the dry matter at later stages. Only some leaf spots appeared on M_9, which could be controlled by Dithane spraying. At 170 DAP when the monsoon ended and the crop reached storage phase, the disease could be controlled.

4.2. Natural shade experiment

4.2.1. Plant height (Table 26, Appendix VI and Fig. 6)

Height of all morphotypes increased from 60 to 120 DAP.

Table 25 Effect of shade on disease intensity of colocasia morphotypes

Treatment	Disease intensity	
	90 DAP	170 DAP
Shade level (per cent)		
T_1 (0)	1.13	1.38
T_2 (25)	2.36	1.42
T_3 (50)	3.09	1.43
T_4 (75)	3.26	2.18
Morphotype		
V_1 M_1	2.66	1.61
V_2 M_2	2.74	1.58
V_3 M_9	1.58	1.05
V_4 M_{10}	2.41	1.90
V_5 M_{17}	3.1	1.96
V_6 M_{16}	2.84	1.49

This increase was similar to the trend shown by plants grown under artificial shade. Though at 60 DAP there was no significant difference between the height of different morphotypes, highest value was recorded by morphotype M_9 and the lowest was recorded by morphotype M_{17}. At 120 DAP, height of various morphotypes differed significantly and the maximum value was that of morphotype M_{16} and lowest was that of M_{17}.

4.2.2. Number of tillers (Table 26, Appendix VI and Fig. 7)

At 60 and 120 DAP, the tiller number of different morphotypes varied significantly and the lowest value was recorded by morphotype M_9 at both the growth stages. At 120 DAP, morphotype M_1 differed from all other morphotypes and recorded the highest value for tiller number.

4.2.3. Chlorophyll content (Table 27)

There was no significant difference between morphotypes in the case of chlorophyll a and total chlorophyll contents. However, chlorophyll b content and ratio of chlorophyll a to b of morphotype M_{16} differed significantly from other morphotypes.

4.2.4. Dry matter production (Table 26, Appendix VI and Fig. 8)

There was no significant difference among the dry matter produced by various morphotypes at 60 and 120 DAP. Morphotype M_{10} recorded the highest value at 60 DAP and M_2 recorded the

Table 26 Plant height, tiller number and dry matter production of colocasia morphotypes under natural shade

Treatment (morphotype)	Plant height (cm)		Tiller number		Total dry weight (g plant^{-1})	
	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP
V_1 M_1	61.20	97.60	0.35	6.35	8.20	50.15
V_2 M_2	62.45	108.05	1.25	3.55	12.88	78.38
V_3 M_9	69.40	103.95	0.25	1.70	15.25	51.60
V_4 M_{10}	59.50	86.60	0.90	1.85	16.63	47.55
V_5 M_{17}	54.20	80.10	1.00	3.95	12.70	47.70
V_6 M_{16}	60.60	113.90	0.35	2.30	11.40	55.33
SEm±	4.26	6.70	0.21	1.07	2.95	9.93
CD (0.05)	NS	19.44	0.60	3.11	NS	NS

Plant height 120 DAP: M_{17} M_{10} M_1 M_9 M_2 M_{16}

Tillter number 60 DAP: M_9 M_{16} M_1 M_{10} M_{17} M_2

Tillter number 120 DAP: M_9 M_{10} M_{16} M_2 M_{17} M_1

Fig.6 Plant height of colocasia morphotypes at 50% Natural(N) and Artificial(A) shade

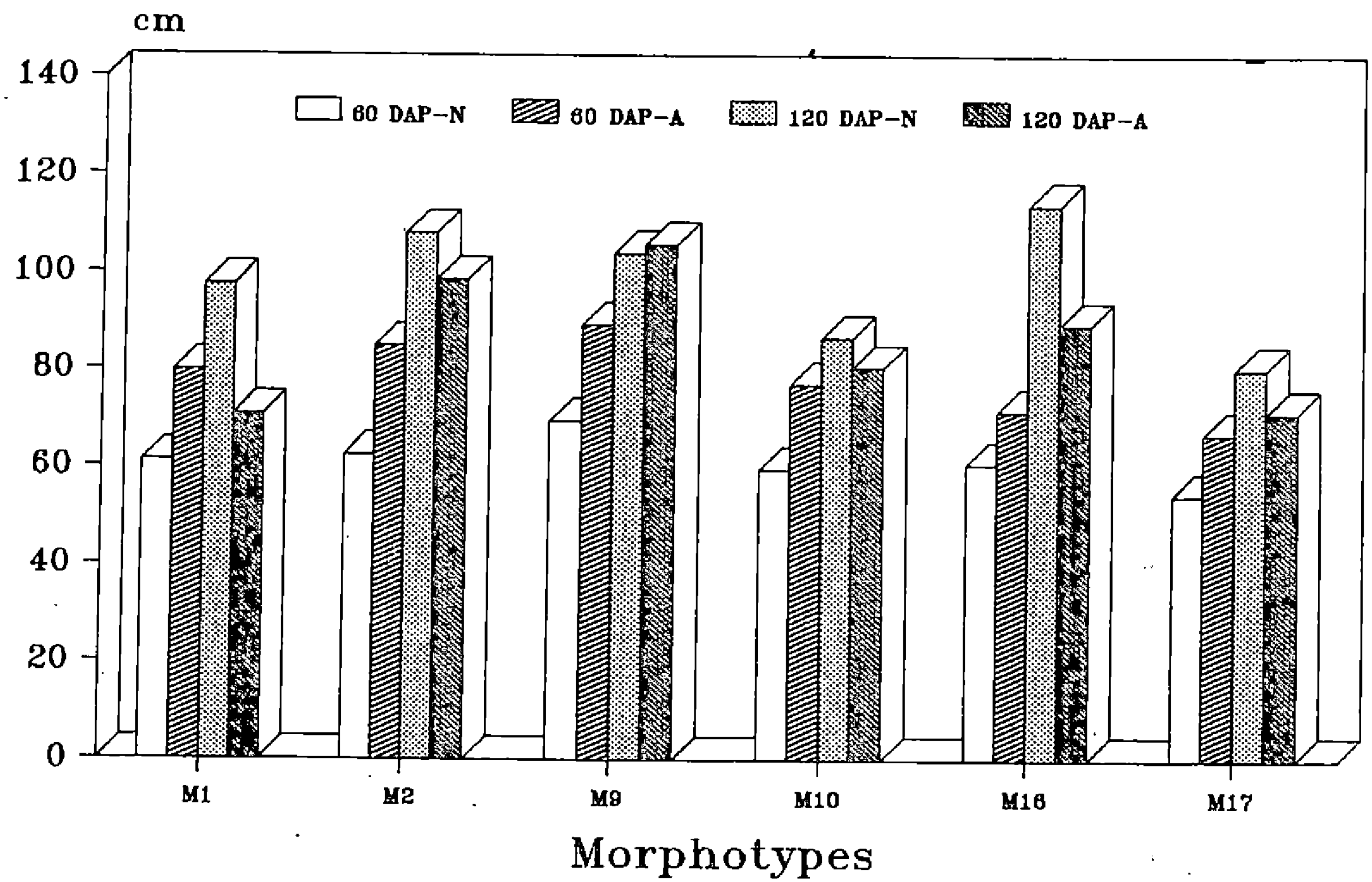


Fig.7 Tiller Nos. of colocasia morphotypes at 50% Natural(N) and Artificial(A) shade

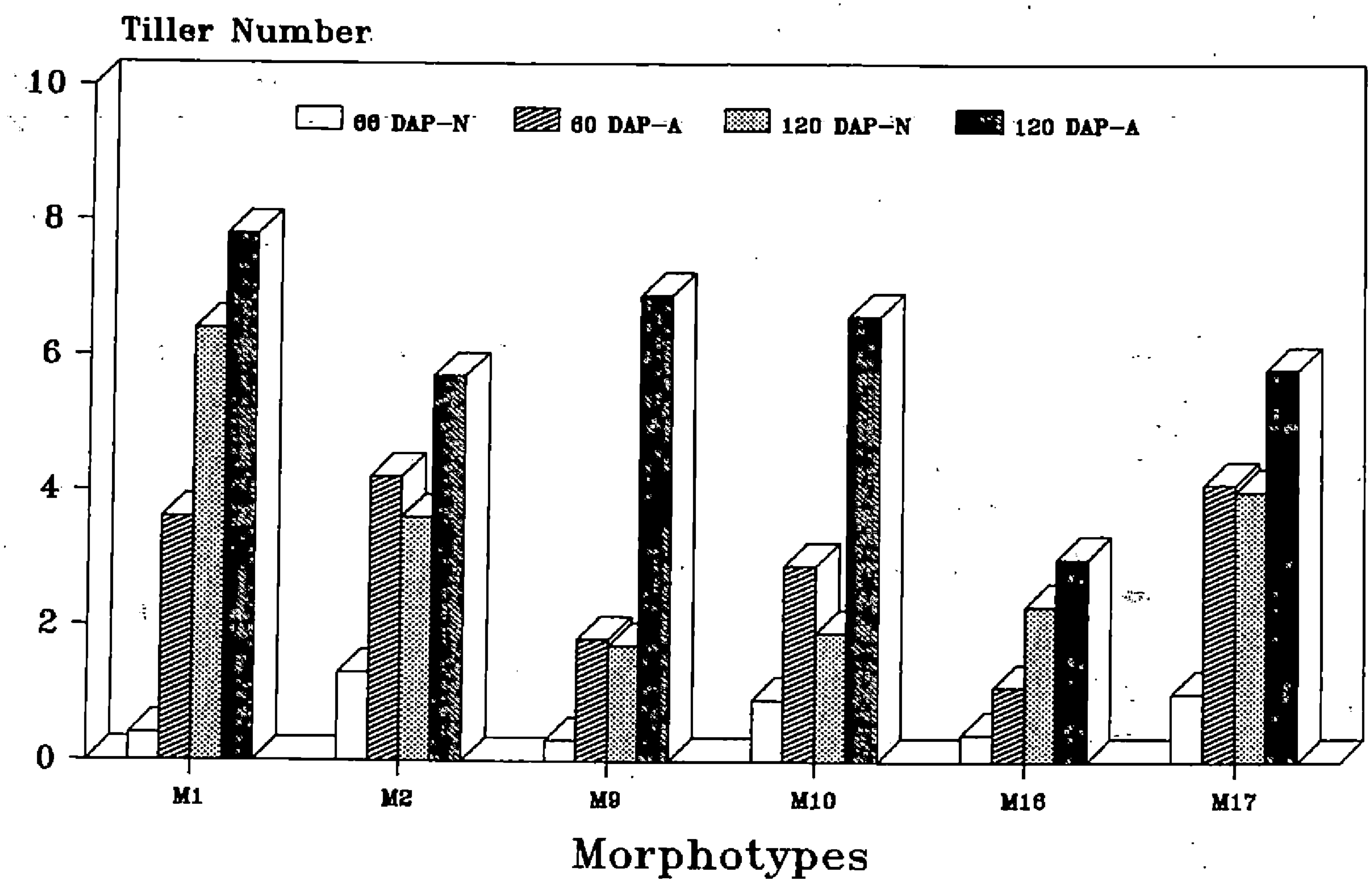


Fig. 8 Dry matter of colocasia morphotypes at 50% Natural(N) and Artificial(A) shade

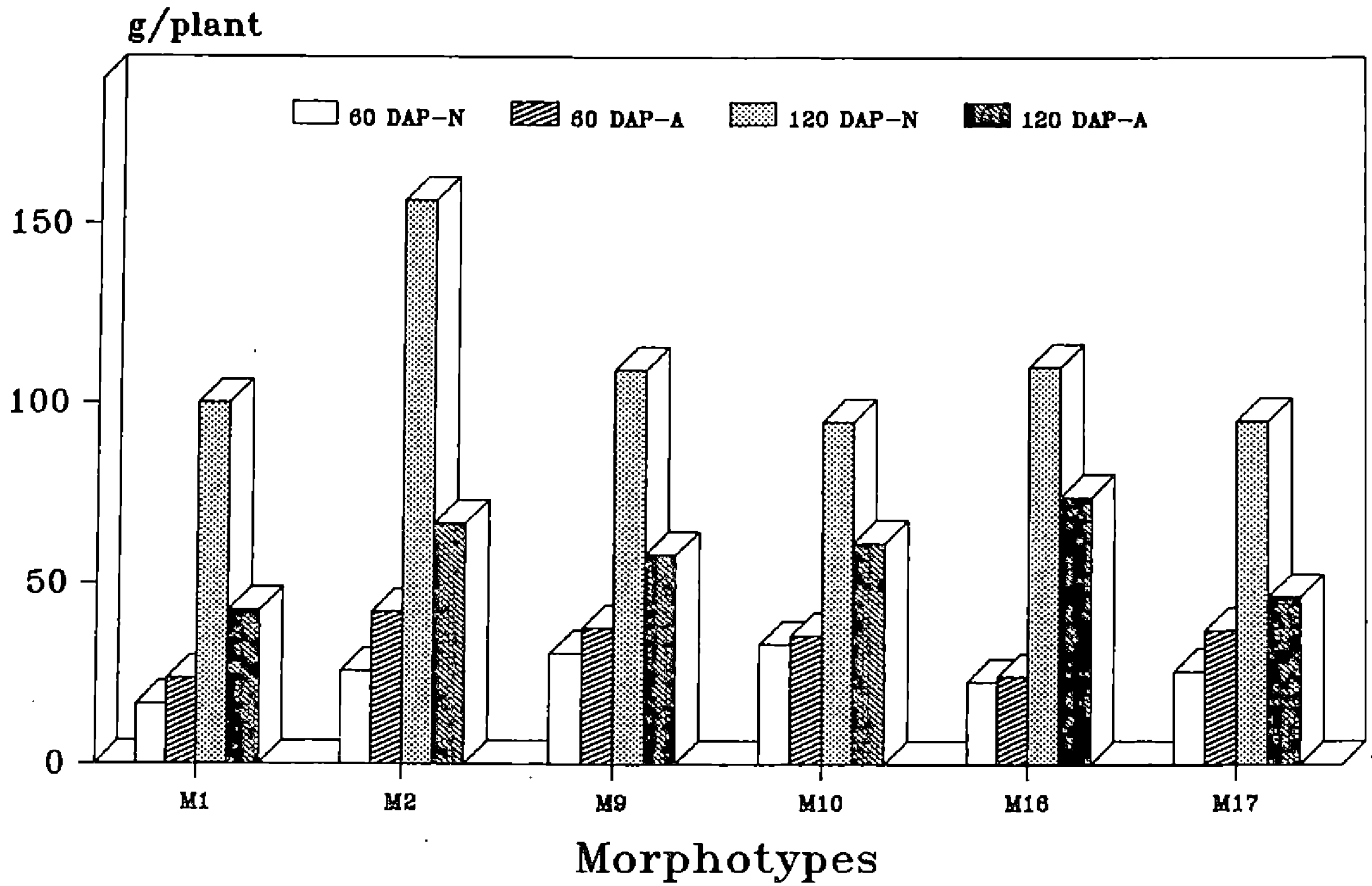


Table 27 Chlorophyll content of colocasia morphotypes under natural shade at 130 DAP

Treatment	Chlorophyll 'a' mg g^{-1} fresh weight	Chlorophyll 'b' mg g^{-1} fresh weight	Total chlorophyll (a+b) mg g^{-1} fresh weight	Chlorophyll a/b
V_1 M_1	0.97	1.20	2.18	0.81
V_2 M_2	0.96	1.26	2.26	0.72
V_3 M_9	0.93	1.32	2.28	0.71
V_4 M_{10}	1.06	1.37	2.45	0.78
V_5 M_{17}	0.93	1.21	2.18	0.77
V_6 M_{16}	1.00	1.10	2.15	0.91
SEm±	0.07	0.05	0.10	0.05
CD (0.05)	NS	0.15	NS	0.14

Chlorophyll b $\overline{M_{16} \quad M_1 \quad M_{17} \quad M_2} \quad M_9 \quad M_{10}$

Chlorophyll a/b $\overline{M_9 \quad M_2 \quad M_{17} \quad M_{10} \quad M_1} \quad M_{16}$

highest value at 120 DAP. The dry matter production varied from 8.2 to 16.6 g $plant^{-1}$ at 60 DAP and at 120 DAP, it varied from 47.5 to 78.4 g $plant^{-1}$.

4.2.5. Leaf area ratio (Table 28)

Both at 60 and 120 DAP, the leaf area ratio of all the six morphotypes were on par. It was noticed that leaf area ratio decreased with increase in growth stage. At 120 DAP, storage phase of the plant was in progress and leaf area was reduced.

4.2.6. Leaf weight ratio (Table 28)

At 60 DAP, there was significant variation among morphotypes. Morphotypes M_1 recorded the maximum value whereas M_9 and M_{10} recorded the minimum value. At 120 DAP, the values calculated for all the morphotypes were on par.

4.2.7. Leaf area index (Table 28)

There was no significant difference among the morphotypes at 60 and 120 DAP. An increase in leaf area index was noticed with increase in growth stage.

4.2.8. Net assimilation rate (Table 28)

No significant variation was noticed among morphotypes with respect to their assimilation rate. The lowest value was recorded by M_{10} (2.46 $g\,cm^{-2}day^{-1}$) and the highest value was recorded by M_2 (3.99$g\,cm^{-2}day^{-1}$).

Table 28 Leaf area ratio, leaf weight ratio, leaf area index and net assimilation rate of colocasia morphotypes under natural shade

Treatment (morphotype)	LAR ($cm^2\ g^{-1}$)		LWR		LAI		NAR ($g\ cm^{-2}\ d^{-1}$)
	60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP	60-120 DAP
V_1 M_1	165.5	52.6	0.40	0.19	0.13	0.25	3.91
V_2 M_2	177.2	46.7	0.38	0.18	0.22	0.36	3.99
V_3 M_9	129.8	48.6	0.30	0.16	0.19	0.25	2.98
V_4 M_{10}	132.0	47.2	0.30	0.17	0.21	0.22	2.46
V_5 M_{17}	143.0	57.2	0.35	0.22	0.18	0.25	2.72
V_6 M_{16}	136.0	57.2	0.38	0.25	0.15	0.30	3.42
SEm±	21.79	9.62	0.03	0.03	0.03	0.06	0.75
CD (0.05)	NS	NS	0.09	NS	NS	NS	NS

4.3. Yield prediction (Table 29)

Prediction models were worked out for all the six morphotypes. For morphotype M_9, quadratic model was found to be the best fitting type and for morphotype M_1 logarithmic cubic model was the best fitting one. For morphotypes M_{16} and M_{17}, the prediction model found to be the best fitting one was logarithmic quadratic. For morphotypes M_2 and M_{10}, the regression coefficients for all the models tried were very low and nonsignificant.

4.4. Light infiltration observations (Table 30)

The mean light infiltration percentage recorded ranged from 27.3 per cent to 80.7 per cent. Observations were taken from eleven locations varying in spacing and height of the palms. The height of the palms varied from 1.5 to 17 m and spacing adopted varied from 6 x 7 m^2 to 8.7 x 8.8 m^2. The limited number of observations taken showed that there is no consistent relation between light infiltration values and average height of the palms or spacing adopted.

Table 29 Prediction models for different colocasia morphotypes

Morphotype	Prediction equation	R^2 (%)
M_1	$\log y = 0.379802+2.9003\ \log_{10}x-12.14(\log_{10}x)^2+12.785(\log_{10}x)^3$	50.6*
M_2	$\log y = 0.704378+0.52487\ \log_{10}x-0.99486(\log_{10}x)^2$	22.2
M_9	$y = 3.545625-0.23912x+0.14187x^2$	41.3*
M_{10}	$\log y = 0.533620+0.081662\ \log_{10}x+0.10959(\log_{10})^2$	25.3
M_{17}	$\log y = 0.490356+0.49215\ \log_{10}x-1.1369(\log_{10}x)^2$	39.7*
M_{16}	$\log y = 0.634208+0.27209\ \log_{10}x-0.62156(\log_{10}x)^2$	43.4*

* Significant at 5 per cent level

Table 30 Mean light infiltration through coconut canopy as influenced by spacing and height of the palms

Spacing (m^2)	Average height of 4 palms (m)	Light infiltration percentage at different positions of the interspace			Mean
		I	II	III	
7.5 x 7.5	5.40	29.46	27.51	36.41	31.13
7.5 x 7.5	5.20	33.98	46.51	48.27	42.92
7.5 x 7.5	4.42	52.02	37.11	65.16	51.43
6.0 x 7.0	2.71	56.17	21.55	56.53	44.75
7.0 x 7.0	1.90	75.79	48.98	75.23	66.67
7.5 x 7.5	2.56	69.58	47.99	75.00	64.19
7.5 x 7.5	1.50	70.50	82.03	89.53	80.69
8.0 x 7.0	16.00	40.13	34.15	41.03	38.44
8.3 x 8.3	10.00	33.97	28.48	34.11	32.19
8.7 x 8.8	8.50	31.23	24.38	26.34	27.32
8.0 x 7.0	17.00	70.37	30.24	28.83	43.15

I - Data collected by keeping Line quantum sensor at side 1, in between to palms

II - Data collected by keeping Line quantum sensor at side 2, in between two palms

III - Data collected by keeping Line quantum sensor in the centre of four palms

Discussion

DISCUSSION

It was observed that plant height increased with shading at 60 DAP and 120 DAP and the lowest height was recorded in the open, the reason being the positive phototrophism. In later stages of growth ie., 180 DAP, there was no significant difference between the shade levels as the vegetative growth phase of the plant was almost over and storage phase was in progress. Increase in plant height under shade has earlier been reported in crops like ginger, turmeric (Varughese, 1989) and colocasia (Prameela, 1990). Among the morphotypes M_2 and M_9 were the tallest, M_1 and M_{17} were the shortest.

Shading had no effect on number of tillers except in the initial growth stages where intense shading resulted in reduction of tiller number. Low tillering under intense shading is reported also in crops like ginger and turmeric (Bai, 1981 and Varughese, 1989) and colocasia (Prameela, 1990). The morphotype M_1 and M_2 were found to have the maximum number of tillers which could be due to their short stature.

The value for chlorophyll a, b, a/b and total chlorophyll were observed to increase with increase in shade levels. Similar trend was observed in colocasia (Bai, 1981 and Premeela, 1990), ginger and turmeric (Bai, 1981 and Varughese, 1989). Among the morphotypes M_9 and M_{10} recorded the highest content of chlorophyll fractions.

Though the effect of shade on dry matter production of plants at 60, 120 and 180 DAP were non significant, there was an increase in dry matter with increase in shade. This is probably due to the increase in height and tiller number with increase in shade. However, at harvest, 25 per cent shade recorded the maximum value. Similar trend was observed earlier in colocasia (Bai, 1982 and Prameela, 1990).

In the present study though shading had no significant effect on cormel yield, corm yield, haulm yield and harvest index, there was an increase in all these parameters at 25 per cent shade. Prameela (1990) reported that the yield components and harvest index were maximum at 25 per cent shade which decreased with increasing intensities of shade. The slight difference in the pattern of results obtained in this study may be due to the reductionn in the number of morphotypes included. There was variation in corm yield, cormel yield, haulm yield and harvest index between the morphotypes. Morphotype M_2 recorded the maximum value for all these parameters. The better performance of this morphotype can be attributed to its high photosynthetic efficiency coupled with higher haulm yield.

Significant interaction effects were noticed between shade levels and morphotypes with respect to corm yield and total yield.

Morphotype M_2 and M_9 were the better yielders with respect to corm yield under all shade levels. M_{10} showed an increase in yield with increase in shade intensity. The high yielding character of these morphotypes may be due to its ability to tolerate shade and larger leaf area.

Prameela (1990) reported morphotypes M_1, M_2, M_{10}, M_{15}, M_{16} and M_{17} as the superior ones based on their mean yield.

In the present study, based on the total tuber yield the best morphotypes for each of the shade levels are as follows:

0 per cent shade - M_2, M_{16} and M_{10}
25 per cent shade - M_2, M_{16} and M_{10}
50 per cent shade - M_2, M_{16} and M_{10}
75 per cent shade - M_9, M_2 and M_{10}

Significant variation in harvest index was noticed among shade levels. The highest value was recorded under open condition. Bai (1981) and Prameela (1990) observed that photosynthetic mechanism as well as partitioning of photosynthates were affected by shading and so harvest index tended to decrease with increase in shading. Among morphotypes M_2 recorded the highest value, due to higher rate of photosynthesis coupled with higher dry matter accumulation. As all the morphotypes included in the present study performed better under shaded conditions also, they can be considered as shade loving morphotypes.

Nitrogen content of haulm and tubers was maximum under 25 per cent shade and minimum under 75 per cent shade. This reveals that protein synthesis of morphotypes decreases under intense shade and thereby quality of tubers decreases with shading. Shade did not have significant effect on phosphorus content of haulm but phosphorus content of morphotypes varied. Morphotype M_{10} recorded the highest value at all the four shade levels. Potassium content of haulm aand tubers was found maximum under 25 per cent shade revealing that shading decreased potassium accumulation.

Nitrogen, phosphorus and potassium contents of haulm and tubers was maximum under 25 per cent shade and their uptake was also maximum at that shade level due to steady increase in dry matter accumulation. With increase in shading at 50 and 75 per cent shade, the uptake of all the three nutrients decreased gradually. Similar results were noticed in colocasia by Premeela (1990). It was estimated that the requirement of nitrogen, phosphorus and potassium at 25 per cent shade will be to the tune of 127, 104 and 112 per cent of that in the open and at higher shade levels of 50 and 75 per cent, it will be 108, 94 and 112 per cent and 88, 86 and 99 per cent, respectively. Therefore, fertiliser applicat-ion rates can be reduced under intense shade of 75 per cent. The fertiliser doses for medium and slight shade levels should be, however, increased. At 25 and 50 per cent shade, morphotype M_2 recorded the highest uptake values. This was because M_2 being the best yielder, efficiently absorbed and translocated the nutrients. So fertiliser application dose for M_2 should be enhanced.

The highest value for starch content was recorded under 75 per cent shade. This reveals that carbohydrate metabolism and translocation of carbohydrates to tubers is more under intense shade. M_2, the highest tuber yielder recorded maximum starch content also. This can be attributed to its high photosynthetic efficiency. The oxalic acid content of tubers did not vary among shade levels but variation among morphotypes under same shade level occurred. Morphotype M_2 recorded maximum oxalic acid content and it had slight acridity, which reduced its cooking quality. Disease incidence was maximum for morphotype M_{17} which reduced the effective photosynthetic area and thereby dry matter production was decreased.

The results obtained from colocasia plants grown under coconut plantation showed same trend as that of colocasia plants grown under different shade levels provided artificially. At 60 DAP, height of various morphotypes did not differ significantly as all plants were in the initial growth stage. At 120 DAP, morphotype M_9 recorded the maximum height. Under artificial shade conditions also M_9 was found to record maximum height. Though under artificial shade conditions morphotype M_{16} recorded the lowest tiller number, under coconut plantation; morphotype M_9 recorded the lowest tiller number and M_1 recorded the highest tiller number.

The difference in behaviour of morphotype M_{16} under natural and artificial shade can be due to the variation in shade received by it. Under natural condition, the shade received was measured to be around 50 per cent. This reveals that morphotype M_{16} produce more tillers under medium shade than under intense shade.

Among morphotypes, there was no significant difference under natural shade with respect to chlorophyll content. Similar was the result obtained under artificial shade conditions also. In the case of dry matter also, there was no significant difference among the morphotypes. Morphotype M_2 recorded the highest value. Under artificial shade conditions also this morphotype was found to produce maximum dry matter.

Leaf area ratios of all morphotypes were on par. This indicates that the photosynthetic rate of those morphotypes are similar but leaf weight ratio at 60 DAP showed significant variation among morphotypes. Morphotype M_1 recorded the highest value and M_9 and M_{10} recorded the lowest values. Leaf area index, net assimilation rate and total dry matter production of all morphotypes were on par. The fact that morphotype M_1 having highest leaf weight ratio at 60 DAP did not produce more dry matter reveals that at early stages of growth the photosynthetic efficiency of this morphotype is less.

As the dry matter production and net assimilation rate of all morphotypes were on par, it is concluded that all the six morphotypes evaluated in this experiment will perform similarly under coconut trees. The dry matter production under 25, 50 and 75 per cent shade levels were also similar at 60, 120 and 180 DAP. These results indicate that the six morphotypes tested in this study are shade loving types and will continue to yield substantially high under light and moderate shade conditions.

One of the objectives of the present study was to predict the yield of different morphotypes of colocasia under various shade levels. Significant interaction effects were noticed between the different morphotypes and shade levels. Morphotype M_2 recorded highest tuber yield at 25 per cent shade (6.23 t ha^{-1}) and at 50 per cent shade (5.02 t ha^{-1}). The morphotypes, M_2, M_{10} and M_{16} produced 4 - 5 tonnes of tubers per hectare in the open conditions and these morphotypes continued to produce the same quantity of tubers even at 75 per cent shade. So we can predict that these three promising morphotypes are suitable for wide range of shade levels and they will produce 4 to 5 tonnes of fresh tubers from a hectare of interspace available in coconut plantations. Morphotype M_1 produced only 2-3 tonnes of fresh tubers and is most suitable for intense shade conditions (75 per cent shade). Morphotype M_9 is also most suitable for intense shade conditions and yielded only 3-4 tonnes per hectare. For morphotype M_1, logarithmic cubic model was the best fitting prediction model. For morphotype M_9, quadratic model was the best fitting prediction model and for morphotypes M_{16} and M_{17}, logarithmic quadratic model was the best fitting one. Regression coefficient for all the models tried, for morphotypes M_2 and M_{10} were very low. This reveals the fact that yield of M_2 and M_{10} is not only affected by shade but also affected by some other uncontrollable causes. So more number of models have to be tried to find out the best fitting prediction model for M_2 and M_{10}.

With the objective of arriving at the relation of light infiltration with spacing of palms and their height, observations of PAR in the interspace of coconut were taken. These observations, however, indicated large variations in percentage values depending on time of day and position at which observations were taken. As such, measurements were taken continuously at intervals of an hour for the whole day from 9 am. to 5 am. These measurements included light intensity in the open using the point quantum sensor and that in the interspace using the line quantum sensor taken at three positions each from each of the locations. The overall mean light infiltration was then calculated from these. Only eleven light infiltration percentage values could be collected from the different locations. Though range in spacing was from 6 x 7 m^2 to 8.8 x 8.7 m^2 and range in height from 1.5 m to 17 m, there was no consistent trend of variation in percentage light infiltration. The values however, varied widely from as low as 27 to as much as 81 per cent.

Necessity for taking larger number of observations for arriving at the relationship is thus indicated.

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

1. The crop yielded better under shade than in the open and hence this crop may be considered as shade loving crop and can be recommended for intercropping in coconut gardens.

2. Though shading had no significant effect on corm yield, cormel yield and harvest index, there was variation in all these parameters among the morphotypes and M_2 recorded the highest value.

3. Morphotypes M_2, M_{16} and M_{10} are selected as better yielders for all shade situations.

4. Content and uptake of fertiliser nutrients increase with increase in shade to 50 per cent shade and then decrease. This reveals that fertiliser doses for slight and medium shade levels should be more compared to open condition. M_2 being the highest yielder has high uptake and requires high dose of fertiliser also.

5. Starch content of tubers increases with increase in shade whereas oxalic acid content is unaffected by shading.

6. Colocasia plants grown under coconut plantation (50 per cent shade) showed same trend as that of colocasia plants grown under 50 per cent shade level provided artificially. This

confirms the fact that colocasia is a shade loving crop and it can be successfully cultivated as an intercrop in coconut gardens.

7. No consistent relationship between percentage light infiltration values and height of the palms or spacing adopted could be worked out.

Summary

SUMMARY

The field experiments were conducted for evaluating the performance of a few morphotypes of colocasia at different shade levels. Six promising morphotypes of colocasia already screened for shade tolerance were raised under four different shade levels provided artificially. The same morphotypes were also raised under exising coconut plantation. The experiments were carried out during 1990-91 at College of Horticulture and Instructional Farm, Vellanikkara, Thrissur, Kerala, India.

The objectives of the study were to evaluate the performance of different morphotypes of colocasia under various shade levels provided artificially and under existing coconut plantations; to study the changes in quality of economic produce as induced by shading and to predict the yield of different morphotypes under various shade levels. To study the changes in percentage light infiltration in coconut plantation as influenced by spacing and height of the palm was another objective.

Biometric observations were taken at bimonthly intervals to assess the performance of the crop under shade and chemical studies were taken up to assess the content and uptake of fertiliser nutrients and to assess the quality changes. Light infiltration observations were taken using Line quantum and Quantum sensors.

The results of the experiment are summarised below:

Plant height increased under shade and minimum height was recorded under open condition. Morphotype M_9 recorded maximum height under artificial as well as natural shade. Tiller number increased under light and medium shade provided artificially and morphotype M_{16} recorded the lowest tiller number.

Total chlorophyll and its fractions were more under medium and intense shade and morphotype M_9 recorded the maximum content. Under natural shade, there was no significant difference among the morphotypes.

Though the effect of shade on dry matter production of plants at 60, 120 and 180 DAP was non significant, maximum value was recorded at 25 per cent shade. Corm yield, cormel yield, total yield, haulm yield and harvest index were maximum at 25 per cent shade and morphotype M_2 was the best yielder.

The content and uptake of all the three fertiliser nutrients was highest at 25 per cent shade. The uptake of nitrogen, phosphorus and potassium at this level of shade was 127, 104 and 112 per cent, respectively of the uptake at 0 per cent shade. With further increase in shading, uptake of all the nutrients decreased. Morphotype M_2 being the highest yielder recorded the highest uptake values also.

Starch content was highest under 75 per cent shade and oxalic acid content was highest under 50 per cent shade.

Among the six morphotypes evaluated for shade tolerance, M_2 recorded the highest value for total yield, harvest index, starch content and oxalic acid content.

All the morphotypes evaluated performed similarly under artificial as well as natural shade. Colocasia yields substantially higher under light shade compared to open condition. This shows that colocasia is a shade loving crop and can be cultivated under coconut as an intercrop.

Based on the total tuber yield the best morphotypes for each of the shade levels are as follows:

0 per cent shade	-	M_2, M_{16} and M_{10}
25 per cent shade	-	M_2, M_{16} and M_{10}
50 per cent shade	-	M_2, M_{16} and M_{10}
75 per cent shade	-	M_9, M_2 and M_{10}

The light infiltration observations taken revealed that no consistent relationship between percentage light infiltration values and height of the palms or spacing adopted could be worked out.

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* Originals not seen

APPENDIX I

Meteorological data for the crop period (18-5-1990 to 31-12-1990)

Month and date	Temperature °C		Soil temperature at 5 cm depth		Humidity %		Rain mm	Sun-shine hours	Evpn mm
	Max.	Min.	FN	AN	FN	AN			
1	2	3	4	5	6	7	8	9	10
14-5-90 to 20-5-90	1.7	24.1	26.5	34.2	91	73	86.5	5.6	3.4
21-5-90 to 27-5-90	28.6	23.6	25.5	31.6	95	81	190.7	1.2	2.3
28-5-90 to 3-6-90	29.5	23.5	25.9	31.6	93	82	129.3	2.7	3.0
4-6-90 to 10-6-90	29.9	23.1	25.8	33.3	93	75	72.4	2.5	3.1
11-6-90 to 17-6-90	29.1	23.1	24.9	30.8	95	80	215.3	2.9	2.2
18-6-90 to 24-6-90	29.7	23.3	25.7	31.5	94	80	87.5	3.5	2.6
25-6-90 to 1-7-90	30.6	23.6	26.0	32.5	93	73	98.7	6.0	3.5
2-7-90 to 8-7-90	27.7	22.1	24.7	30.5	94	85	265.6	1.3	2.3
9-7-90 to 15-7-90	28.6	22.4	25.3	31.0	94	85	190.1	1.6	2.5
16-7-90 to 22-7-90	27.6	22.4	25.0	29.8	95	87	198.1	1.5	2.2
23-7-90 to 29-7-90	29.3	22.5	25.8	28.7	93	71	78.0	4.2	3.1
30-7-90 to 5-8-90	28.9	23.0	25.2	31.3	95	78	114.0	2.7	2.8
6-8-90 to 12-8-90	28.0	22.5	25.0	29.3	95	80	91.7	1.2	2.2
13-8-90 to 19-8-90	28.5	23.3	25.2	30.3	94	77	121.6	2.7	3.0
20-8-90 to 26-8-90	29.7	23.1	26.0	32.3	94	72	28.3	4.3	3.0
27-8-90 to 2-9-90	30.6	23.6	26.3	34.2	92	65	14.7	7.4	3.7
3-9-90 to 9-9-90	30.0	23.1	26.3	32.3	94	74	60.9	3.9	3.1
10-9-90 to 16-9-90	34.5	24.0	27.1	35.2	91	64	0	7.7	3.9
17-9-90 to 23-9-90	31.0	23.4	27.2	34.2	90	65	6.9	6.6	3.8

Contd.

Appendix I. Continued

1	2	3	4	5	6	7	8	9	10
24-9-90 to 30-9-90	31.1	23.1	26.5	35.2	89	69	16.6	6.5	3.5
1-10-90 to 7-10-90	30.6	22.5	25.4	33.3	93	70	26.9	6.3	3.6
8-10-90 to 14-10-90	32.4	23.7	26.9	39.5	92	63	14.4	8.8	4.1
15-10-90 to 21-10-90	33.5	23.2	26.5	39.0	88	62	22.3	7.3	4.1
22-10-90 to 28-10-90	31.8	23.3	26.0	33.4	92	78	133.9	5.5	3.0
29-10-90 to 4-11-90	29.1	22.4	24.9	30.4	95	76	184.2	3.1	2.1
5-11-90 to 11-11-90	31.2	21.1	24.6	33.9	89	62	0	7.8	3.5
12-11-90 to 18-11-90	31.1	22.8	25.4	34.6	92	65	0.6	5.3	2.9
19-11-90 to 25-11-90	33.1	23.2	25.9	38.0	84	54	0	7.6	3.7
26-11-90 to 2-12-90	31.8	23.4	24.7	35.1	75	52	0.8	5.8	5.0
3-12-90 to 9-12-90	31.9	24.8	25.2	36.0	71	48	1.8	7.4	5.9
10-12-90 to 16-12-90	31.9	22.3	24.3	37.7	70	43	0	8.3	6.3
17-12-90 to 23-12-90	32.7	22.0	24.8	37.9	76	46	0	7.7	4.4
24-12-90 to 30-12-90	32.5	23.7	25.4	38.9	69	44	0	8.2	7.0

Source: Agromet Observatory, College of Horticulture, Vellanikkara

APPENDIX II

Analysis of variance for plant height and number of tillers of colocasia morphotypes

Source	DF	Mean squares					
		Plant height			Number of tillers		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Replication	3	1081.0**	65.7	525.8	3.83*	10.66	18.04*
Main plot	3	1472.8**	2550.1*	1036.8	6.49*	10.97	12.70
Error (a)	9	128.2	584.5	1065.3	0.96	3.60	3.93
Sub plot	5	473.7**	4411.6**	3062.2**	26.81**	41.09**	41.61**
Interaction	15	67.1	98.7	95.9	0.86	1.30*	1.52
Error (b)	60	45.8	64.7	70.3	0.56	1.92	2.43

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

APPENDIX III

Analysis of variance for chlorophyll fractions of colocasia morphotypes

Source	DF	Mean squares			
		Chlorophyll a	Chlorophyll b	Total chlorophyll (a+b)	Chlorophyll a/b
Replication	3	0.000	0.001	0.003	0.001
Main plot	3	0.363**	0.327**	1.319**	0.023**
Error (a)	9	0.002	0.002	0.003	0.003
Sub plot	5	0.359**	0.367**	1.430**	0.011*
Interaction	15	0.116**	0.096**	0.405**	0.011**
Error (b)	60	0.003	0.005	0.006	0.004

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX IV

Analysis of variance of dry matter production of colocasia morphotypes

Source	DF	Mean squares			
		Total dry weight			
		60 DAP	120 DAP	180 DAP	Harvest
Replication	3	243.0	168.1	475.9	2470.0
Main plot	3	418.0	65.3	139.6	3710.0*
Error (a)	9	371.6	351.3	338.5	740.0
Sub plot	5	533.3**	2607.8**	3995.8**	11070.0**
Interaction	15	243.7	166.3	197.8	1230.0
Error (b)	60	137.1	301.0	195.2	860.0

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

APPENDIX V

Analysis of variance for corm yield, cormel yield, total yield, haulm yield and harvest index of colocasia morphotypes

Source	DF	Mean squares				
		Corm yield	Cormel yield	Total yield	Haulm yield	Harvest index
Replication	3	0.094	0.140	0.259	0.010	0.010
Main plot	3	0.398	0.766	0.981	0.019	0.033
Error (a)	9	0.122	0.434	0.592	0.006	0.009
Sub plot	5	4.442**	6.093**	12.750**	0.091**	0.040**
Interaction	15	0.447**	0.752*	1.006*	0.007	0.006
Error (b)	60	0.073	0.321	0.450	0.009	0.004

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

APPENDIX VI

Analysis of variance for plant height, tiller number and dry matter production of colocasia morphotypes

Source	DF	Mean square					
		Plant height		Tiller number		Total dry weight	
		60 DAP	120 DAP	60 DAP	120 DAP	60 DAP	120 DAP
Replication	3	70.59	38.83	0.078	2.99	2.86	466.43
Morphotype	5	96.84	671.15**	1.067**	12.36**	35.01	552.23
Error	15	36.25	89.84	0.087	2.29	17.40	197.06

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

Plates

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

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

Plate 3. Colocasia morphotypes at 0 per cent shade

Plate 4. Colocasia morphotypes at 25 per cent shade


0% SHADE

Plate 5. Colocasia morphotypes at 50 per cent shade

Plate 6. Colocasia morphotypes at 75 per cent shade

Appendices


75% SHADE

EVALUATION OF SHADE TOLERANT MORPHOTYPES OF COLOCASIA

By

HEMALATHA, S.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
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ABSTRACT

The present study 'Evaluation of shade tolerant morphotypes of colocasia' was conducted during May to December 1990 at the College of Horticulture and Instructional Farm, Vellanikkara, Thrissur, Kerala, India.

Experiment at College of Horticulture was laid out in split plot design with four shade levels in the main plot and six morphotypes in the sub plot. The experiment was carried out with four replications providing 0, 25, 50 and 75 per cent shade. For providing shade, pandals were erected on wooden frames and covered with unplaited coconut fronds on all sides leaving a clearance of 1 m from the ground level. Shade intensities were adjusted using Line quantum and Point quantum sensors.

Experiment at Instructional Farm, Vellanikkara was laid out in randomised block design with four replications. Six morphotypes of colocasia raised under artificial conditions at College of Horticulture, were raised in the interspaces of coconut garden; at the Instructional Farm.

Under artificial conditions, most of the colocasia morphotypes recorded the highest yield at 25 per cent shade and hence this crop is classed as shade loving corp. Though shading had no significant effect on corm yield, cormel yield and harvest index, there was variation in all these parameters among the morphotypes and

M_2 recorded the highest value. Morphotypes M_2, M_{10} and M_{16} were selected as better yielders for all shade situations. Starch content of tubers increased with shading whereas oxalic acid content remains unaffected.

Most of the morphotypes evaluated performed similarly under artificial as well as natural shade.

Eleven light infiltration observations from different locations were taken at hourly intervals from 9 am to 5 pm, using Line quantum and point quantum sensors and percentage values were worked out. Mean percentage light infiltration values obtained revealed that there is no consistent relationship between light infiltration and height of the coconut palms or spacing.