EVALUATION OF TURMERIC CULTIVARS FOR SHADE TOLERANCE

By

SHEELA PAUL

THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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Department of Agronomy
COLLEGE OF HORTICULTURE
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DECLARATION

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

Vellanikkara,

7-2-1992

Sheela P.

SHEELA PAUL.

CERTIFICATE

Certified that this thesis entitled "Evaluation of turmeric cultivars for shade tolerance" is a record of research work done independently by **Ms.Sheela Paul** 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,
7-2-'92

Dr.P. SREEDEVI
Associate Professor of Agronomy
Chairperson
Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.Sheela Paul**, a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Evaluation oof turmeric cultivars for shade tolerance" may be submitted by Ms.Sheela Paul, in partial fulfilment of the requirement for the degree.

Chairperson

Dr.P. Sreedevi

Members

Dr.E. Tajuddin

Dr.R. Vikraman Nair

25/4/92

Dr.V.K. Venugopal

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Dedicated to my parents

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Dedicated to my parents

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Introduction

INTRODUCTION

The duration and intensity of solar radiation received is a critical factor in deciding crop production. To make best use of the available solar radiation, multiple cropping systems including rapid sequencing of crops, relay cropping, intercropping etc. are advantageous. Further, increased population pressure on land also necessitates, the intensification of cropping for increasing agricultural production from unit area of land. In Kerala - the land of coconut - intensive cropping in coconut garden can bring about phenomenal increase in productivity per unit area and time. As coconut is an integral part of every homestead, and is grown as a widely spaced crop with the roots of individual palm confining mainly to 2 m radius from the base, there is ample scope for intensive cropping involving inter/mixed crops. But the success of any crop mixing programme under coconut depends mainly on the selection of compatible crop combinations. The most promising intercrops in coconut were reported to be tubers and rhizome species. Among the rhizome spp., turmeric is more important, for which India is the largest producer and export earner. Moreover, it is shade tolerant and at the same time not affected by serious pests and diseases under shade.

In the preliminary studies conducted at the College of Horticulture, Vellanikkara all the available cultivars of turmeric were screened for different shade levels ranging from 0 to 75 per cent (Varughese, 1989). Based on the study, four cultivars suited to different shade levels and two cultivars superior under all situations were selected. But the differential response of cultivars to different shade levels together with the high variability of light infiltration in coconut canopy with age of the palm necessitated the present study with the following objectives.

1) To evaluate the performance of different cultivars of turmeric screened for varying shade levels under artificial shade and also under existing coconut plantation.

2) To study changes in quality if any, of the crop produce as influenced by shading.

3) To predict the yield of the above cultivars at different shade intensities and to arrive at suitable prediction models for each cultivar.

Review of Literature

REVIEW OF LITERATURE

Solar radiation unlike water and nutrients has to be used instantaneously without storing for future use. Hence the harvest of as much solar energy as possible per unit, area and time is more important in intensive cropping systems involving inter/mixed cropping. But all the crops used for sole cropping may not be suitable for intercropping. Genotypic differences may also occur. Therefore, suitable genotypes are to be selected based on their performance in actual intercropped situations. Experimental evidences on the growth and yield of different intercrops under various light intensities - both artificial and natural - are available in plenty. But literature regarding the relative suitability of turmeric under such situations is limited. Hence an attempt is made hereunder to review the literature pertaining to the subject irrespective of the crop.

2.1. Response to light intensity

2.1.a. Under controlled light intensities

According to Singh (1967) exposure to intense light intensitiess is detrimental to photosynthesis. Significant reduction in tuber yield of cassava was observed under low light intensities (Ramanujam et al., 1984 and Okoli and Wilson, 1986). Ravishankar and Muthuswamy (1986, 1987) recorded highest yield of ginger with a low light intensity of 15.3 k lux. The average yield of tomato, cucumber and bean grown under shade tended to be higher than that in the open (El Aidy, 1984).

Shade tolerance in turmeric has been studied by many workers. Ramadasan and Sathees an (1980) observed significant yield increase in the open than under shade in turmeric. On the other hand, Bai and Nair (1982) recorded better growth and yield in turmeric grown under 50 per cent shade. Varughese (1989) registered highest yield of turmeric when grown in the open.

2.1.b. Under natural shade - turmeric as an intercrop

Rao and Reddy (1990) observed beneficial effect of turmeric and maize mixed cropping. But Singh and Randhawa (1988) noticed a reduction in rhizome yield due to intercropping of turmeric in pigeon pea, maize and green gram.

2.2. Genotypic response to light intensity

The varietal variability to shade tolerance has been studied in several crops. Martin (1985) observed significant difference in shade response of 18 cultivars of sweet potato.

Among the different rice varieties tried at Coimbatore, the variety Ponni performed better even at 25 per cent of normal light, where as IR-20 was the most susceptible one to low light intensity (Vijayalakshmi et al., 1987).

Brian et al. (1988) recorded highest tuber yield at high light intensity of 500 u mol m^{-2} s^{-2} PPF and medium light intensity of 455 u mol m^{-2} s^{-2} PPF in Norland and Russert Burbank respectively. Differential response of cultivars to shade was reported in ginger and turmeric as well (Varughese, 1989). Response of different morphotypes of colocasia to light intensity was found to be variable (Prameela, 1990).

2.3. Growth and growth attributes

2.3.1. Plant height

Increase in plant height due to shading has been reported in several crops. Plant height increased in cocoa upto 55 per cent shade and then decreased with further increase in shade (Gopinathan, 1981). In groundnut, George (1982) observed an increase in plant height due to shading. Positive effect of shade on plant height in cassava was reported by Ramanujam et al. (1984) and Sreekumari et al. (1988). Similar trend was reported in crops like ginger, turmeric, coleus and sweet potato (Bai and Nair, 1982), sweet red pepper (Rylski and Spigelman, 1986), rice (Jadhav, 1987), passion fruit (Menzel and Simpson, 1989). Increase in plant height with shading was also reported in colocasia (Prameela, 1990).

Negative influence of shade on plant height was noticed in red gram (George, 1982), bird's foot terfoil and alfalfa (Cooper, 1966). On the other hand plant height was unaffected by shading in cowpea, blackgram and colocasia (George, 1982).

2.3.2. Leaf development

A reduction on the rate of leaf development and leaf area was noticed in two dry bean (P. vulgaris) cultivars grown in controlled environmental chambers under standard light 390 E h m^{-2} s^{-1} and shaded light 55 E m^{-2} s^{-1} (Crookston et al., 1975). Vicea faba plants subjected to 50 and 20 per cent shade exhibited 30 per cent reduction in the number of leaves/plant (Xia, 1987). Varughese (1989) observed a decrease in the number of leaves with shading in ginger and turmeric.

On the contrary, leaf number and leaf size of Amaranthus spp. were found greater at the medium than at higher levels of shade (Simbolon and Sutarno, 1986). Venkataramanan and Govindappa (1987) also observed that clove seedlings kept under shade produced more number of leaves than seedlings exposed to sun.

Sannamarappa and Shankar (1988) reported no significant change in turmeric due to intercropping in arecanut. Armose (1989) noticed increased leaf length but decreased leaf width in pineapple with increase in light intensity. No significant effect of shade on number of leaves was noticed in colocasia (Prameela, 1990).

2.3.3. Dry matter production

Xanthosoma sagittifolium produced highest dry matter production under shade (Caesar, 1980). Venkataramanan and Govindappa (1987) also observed the same trend in coffee seedlings. Higher dry matter production was noticed in ginger and colocasia under shade (Bai and Nair, 1982, Varughese, 1989, Prameela, 1990).

A reduction in dry matter accumulation was reported in several crops like Crown vetch, Coronialla varialli (Langillee and Mckee, 1970), Colocasia esculenta (Caesar, 1980), rice (Vijayalekshmi et al., 1987; Adhikari et al., 1989) and turmeric (Varughese, 1989). But Radha (1979) observed no significant reduction in dry matter accumulation with increase in shade levels upto 75 per cent.

2.3.4. Growth analysis

An increase in shoot-root ratio was reported in 3 varieties of Crown vetch (Coronialla varialli) at low light intensity (Langille and Mckee, 1970). NAR increased with increase in shade in ginger (Bai, 1981). Low light intensity led to production of leaves with high specific leaf area in cassava (Fukai et al., 1984). Sorenson (1984) observed higher leaf area ratio in winged bean (Psophocarpus tetragonolobus) at shaded conditions. Jadhav (1987) opined that in field pea, CGR, LAI and NAR are positively correlated with PAR. According to Ono and Iwagaki (1987) satsuma mandarin trees subjected to reduced light intensities increased SLA and LAD. Vijayalakshmi et al. (1988) reported higher harvest index under low light intensity in Ponni. An increase in net Co_2 assimilation with increasing shade levels was noticed in mango (Schaffer and Gaye, 1989).

Contradictory to the above findings, NAR and AGR of chick-pea were found to decrease with a decrease in sunlight (Pandey et al., 1980). Ramadasan and Satheeshan (1980) recorded highest leaf area index, crop growth rate and net assimilation rate with three turmeric cultivars grown in the open compared to that under shade. According to Jadhav (1987) RGR, LAR, LWR and SLA were negatively correlated with shading in field pea. Decrease in light intensity resulted in a reduction in leaf area in passion fruit (Mensal and Simpson, 1988).

Pandey et al. (1980) opined that LWR and RGR were unaffected by different levels of shade in chickpea. Harvest index was unaffected by shading in ginger and turmeric (Varughese, 1989) as also in colocasia (Prameela, 1990).

2.4. Chlorophyll content

It has been established by several workers that shaded plants have a higher chlorophyll content compared to plants exposed to sun. An increae in chlorophyll content with increasing shade levels was reported by Bai (1981) and Varughese (1989). The same trend was also observed in crops like winged bean (Sorenson, 1984), rice (Singh et al., 1988), potato (Singh, 1988), colocasia (Prameela, 1990).

On the other hand, chlorophyll content was found to be unaffected by shading in crops like chickpea (Pandey et al., 1980), kiwi fruit (Grant and Ryug, 1984). Rao and Mittra (1988) observed an inverse relationship between chlorophyll content and shade levels in peanut.

2.5. Yield

Positive influence of shade on yield was reported in many crops. With Chinese cabbage, lettuce and spinach, the highest fresh weight were with crops grown at 35 per cent shade (Moon and Pyo, 1981). Bai and Nair (1982) recorded higher yield of turmeric at 50 per cent shade. Ravishankar and Muthuswamy (1986, 1987) recorded the highest yield of ginger at a low light intensity of 15.3 k. lux. Varughese (1989) observed highest yield of ginger at 25 per cent shade. Similar trend was noticed by Prameela (1990) also in colocasia.

Ramadasan and Satheeshan (1980) reported significantly higher yields of turmeric in the open. The same trend was noticed by Varughese (1989) in turmeric. A decrease in yield due to shading was reported in crops like Sorghum (Pepper and Prine, 1972). Xanthosoma sagittifolium, Colocasia esculenta var. antiquorum (Caesar, 1980), taro (Bai, 1981), groundnut (George, 1982), maize (Earley et al., 1966), and rice (Vijayalakshmi et al., 1987) also.

2.6. Quality of produce

Light regimes of a plant determine productivity and quality of its produce (Tikhomirov et al., 1976). The quality of the products of Camellia sinenses var. assamica, Coffea arabica, Cinchona ledgeriana and Rauvolfia guannansis was found to be improved when grown under shade. The quality of pineapple was improved by partial shade at the stage of fruit development (Nayar et al., 1979). Fong et al., (1980) also observed an improvement on the quality of green tea when grown under 75 per cent shade. In sweet red pepper, highest yield of high quality fruits was obtained at 12 to 26 per cent shade (Rylski and Spigelman, 1986). Ginger grown under shade produced better quality rhizomes (Ravishankar and Muthuswamy, 1987).

Contrary to the above findings a negative correlation of shade and quality of produce was also noticed. Bjorkman (1968) observed a comparitively lower content of soluble protein in shade plants. Protein yield of pulses viz., groundnut, cowpea, red gram and black gram was high in the open when compared to that under shade (George, 1982). Ginger varieties grown in the open produced the best quality rhizomes (Varughese, 1989). The starch and oxalic acid content were higher in colocasia grown in the open (Prameela, 1990).

No difference in starch or total sugar contents was observed in kiwi grown under shade (Snelgar and Hopkirk 1988). Crude fibre content of ginger was unaffected by shading (Ravishankar and Muthuswamy, 1987). Philip (1983) noticed significant variation in curcumin content among the turmeric varieties tested. Ramadasan and Satheesan (1987) observed higher curcumin and oil in Dugerrala and Cls-24 under intercropping in coconut than under monocropping.

Materials and Methods

MATERIALS AND METHODS

Two separate field experiments were conducted to evaluate the performance of turmeric cultivars under artificial and natural shade.

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

3.1. Evaluation of turmeric cultivars for shade tolerance under artificial shade

3.1.a. Cropping history of the field

A trial on shade intensity was conducted with ginger and turmeric as the crops during the year before last and a similar trial with colocasia during the previous year.

3.1.b. Soil

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

3.1.c. Season and climate

The experiment was conducted during the period May, 1990 to February, 1991. Turmeric cultivars were planted on 22nd May. Crop was harvested 240 days after planting.

Table 1. Physical and chemical properties of the soil

1. Mechanical composition

Sand	75.5 per cent	(Hydrometer method)
Silt	6.0 per cent	
Clay	16.5 per cent	(Bouyoucos, 1962)

2. Chemical properties

Constituent	Content	Rating	Method used for estimation
Total nitrogen	0.3 per cent	High	Microkjeldahal (Jackson, 1958)
Available Phosphorus (Bray-1 extract)	18 ppm	High	Chlorostannous reduced molybdo phosphorus blue colour method (Jackson, 1958)
Available Potassium (Neutral normal ammonium acetate extract)	90 ppm	Medium	Flame photometry (Jackson, 1958)
pH (1:2.5 soil : water ratio)	5.3		pH meter (Jackson, 1958)

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

The crop received a total 2643.5 mm of rainfall from May 1990 to February 1991. Relative humidity ranged from 51 to 88 per cent. In general, the weather conditions were conducive for the normal growth of the crop.

3.1.d. Provision of shade

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

3.1.e. Seed material and planting

Six cultivars of turmeric were used for the experiment. Healthy rhizomes free from pest and disease were selected. These rhizomes were soaked for 30 minutes in 0.2 per cent Dithane M-45 solution and spread under shade in dry the rhizomes. Finger rhizomes of turmeric each weighing 25 to 30 g were planted in small pits taken at a spacing of 30 x 15 cm on raised beds of size 3.0 x 0.9 m^2. Sufficient space was provided between beds of different cultivars.

3.1.f. Manures and fertilizers

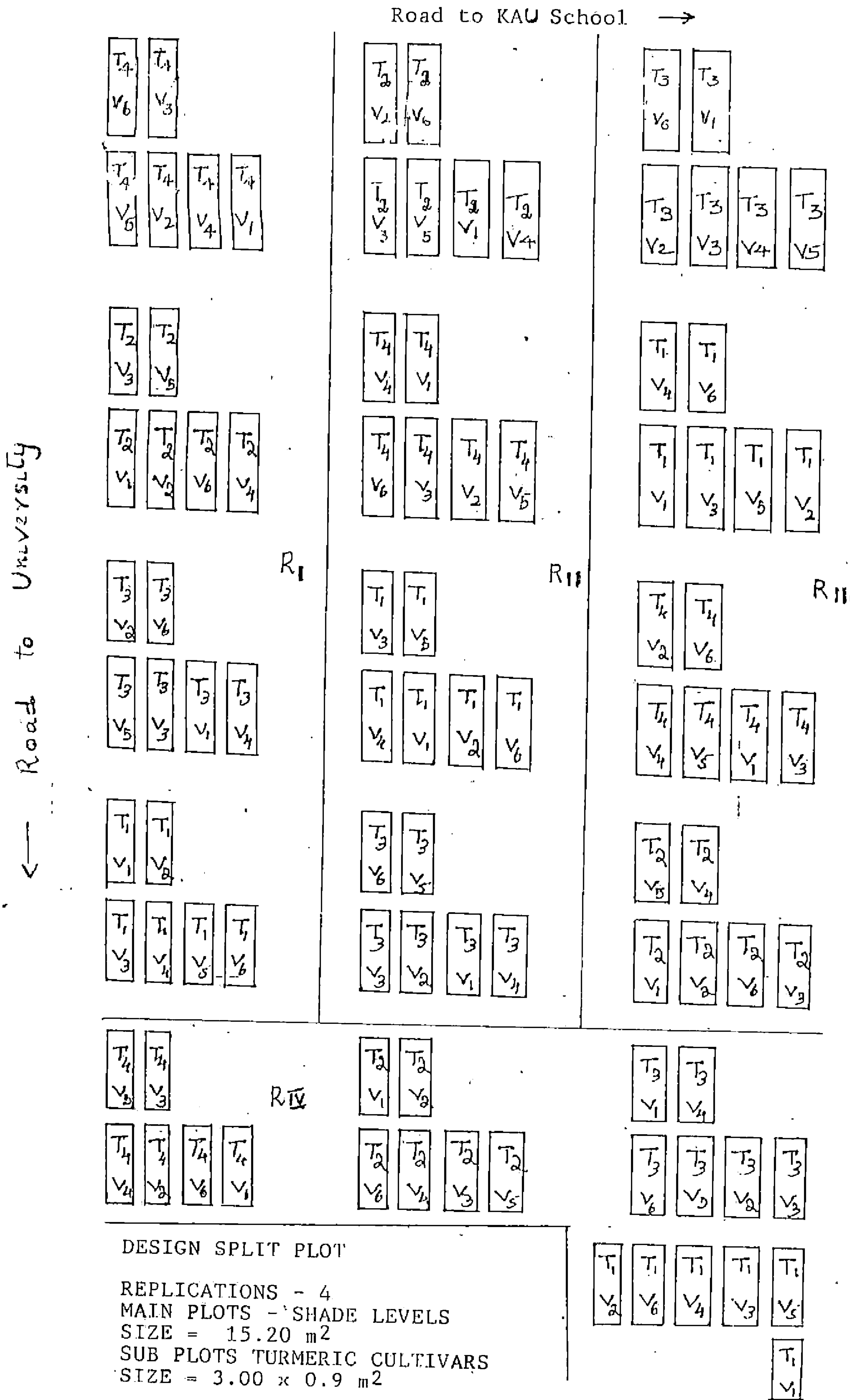
The crop received the respective cultural and manurial practices as per the package of practices recommendations of the Kerala Agricultural University (1989). Nitrogen, phosphorus and potassium were applied in the form of urea (46 per cent) superphosphate (16 per cent) and muriate of potash (60 per cent),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

3.1.g. After cultivation

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

3.1.h. Plant protection measures

The crop was sprayed with Ekalux 0.25 per cent three times at an interval of 25 days.



DESIGN SPLIT PLOT

REPLICATIONS - 4
MAIN PLOTS - SHADE LEVELS
SIZE = 15.20 m2
SUB PLOTS TURMERIC CULTIVARS
SIZE = 3.00 x 0.9 m2

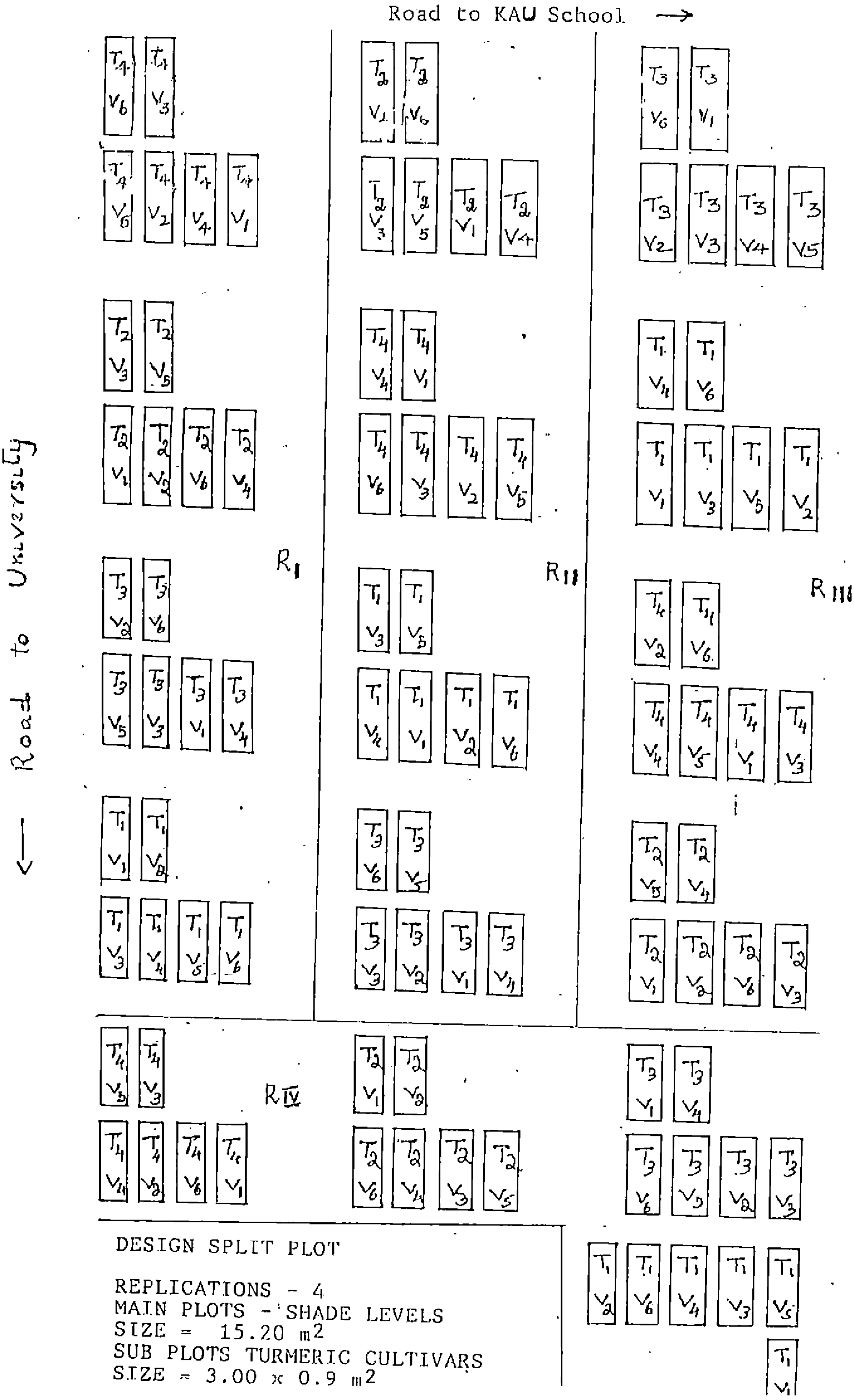
Shade Levels

T_1 0 per ce
T_2 25 per ce
T_3 50 per ce
T_4 75 per ce

Cultivars

V_1 - PCT-5
V_2 - PTS-9
V_3 - BSR 1
V_4 - Ethamukule
V_5 - PCT-8

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



DESIGN SPLIT PLOT

REPLICATIONS - 4
MAIN PLOTS - SHADE LEVELS
SIZE = 15.20 m2
SUB PLOTS TURMERIC CULTIVARS
SIZE = 3.00 x 0.9 m2

Shade Levels

T_1 0 per ce
T_2 25 per ce
T_3 50 per ce
T_4 75 per ce

Cultivars

V_1 - PCT-5
V_2 - PTS-9
V_3 - BSR 1
V_4 - Ethamukulo
V_5 - PCT-8

3.1.i. Lay out of the experiment

Design : Split plot

Number of replications : 4

Details of treatments

Main plot treatments - 4 shade levels	Sub plot treatments - Cultivars (6)
Notation	Notation
T_1 - 0 per cent shade	V_1 - PCT-5
T_2 - 25 per cent shade	V_2 - PTS-9
T_3 - 50 per cent shade	V_3 - BSR-1
T_4 - 75 per cent shade	V_4 - Ethamukulam
	V_5 - PCT-8
	V_6 - PTS-38

3.2. Evaluation of turmeric cultivars for shade tolerance under coconut

3.2.1. Cropping history of the field

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

3.2.2. Soil

The soil of the experimental site was deep well drained sandy clay loam. The data on physical and chemical properties of the soil are given in Table 2.

Table 2. Physical and chemical properties of the soil

1. Mechanical composition (Hydrometer method Bouyoucos, 1962)

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

Constituent	Content	Rating	Method used for estimation
Total Nitrogen	0.126 per cent	Medium	Microkjeldahl method (Jackson, 1958)
Available Phosphorus	7.5 ppm	Low	Chlorostannous reduced molybdo phosphorus blue colour method (Jackson, 1958)
Available Potassium (Neutral normal ammonium acetate extract)	159.8 ppm	Medium	Flame photometry (Jackson, 1958)
pH (1:25 soil : water)	5.0		pH meter method (Jackson, 1958)

3.2.3. Season and climate

The experiment was conducted during the period from May 1990 to February 1991. Turmeric cultivars were planted on June 11th, and was harvested on February 14th.

The meteorological data for the crop periods from June 1990 to February 1991 are presented in Appendix-1.

3.2.4. Seed material

All cultivars except PTS-38 raised under artificial shade were used for the trial. Seed treatment was the same as mentioned under artificial shade.

3.2.5. Manures and fertilizers

Same practice as that under artificial shade was followed.

3.2.6. After cultivation

Practices followed the same pattern as under artificial shade.

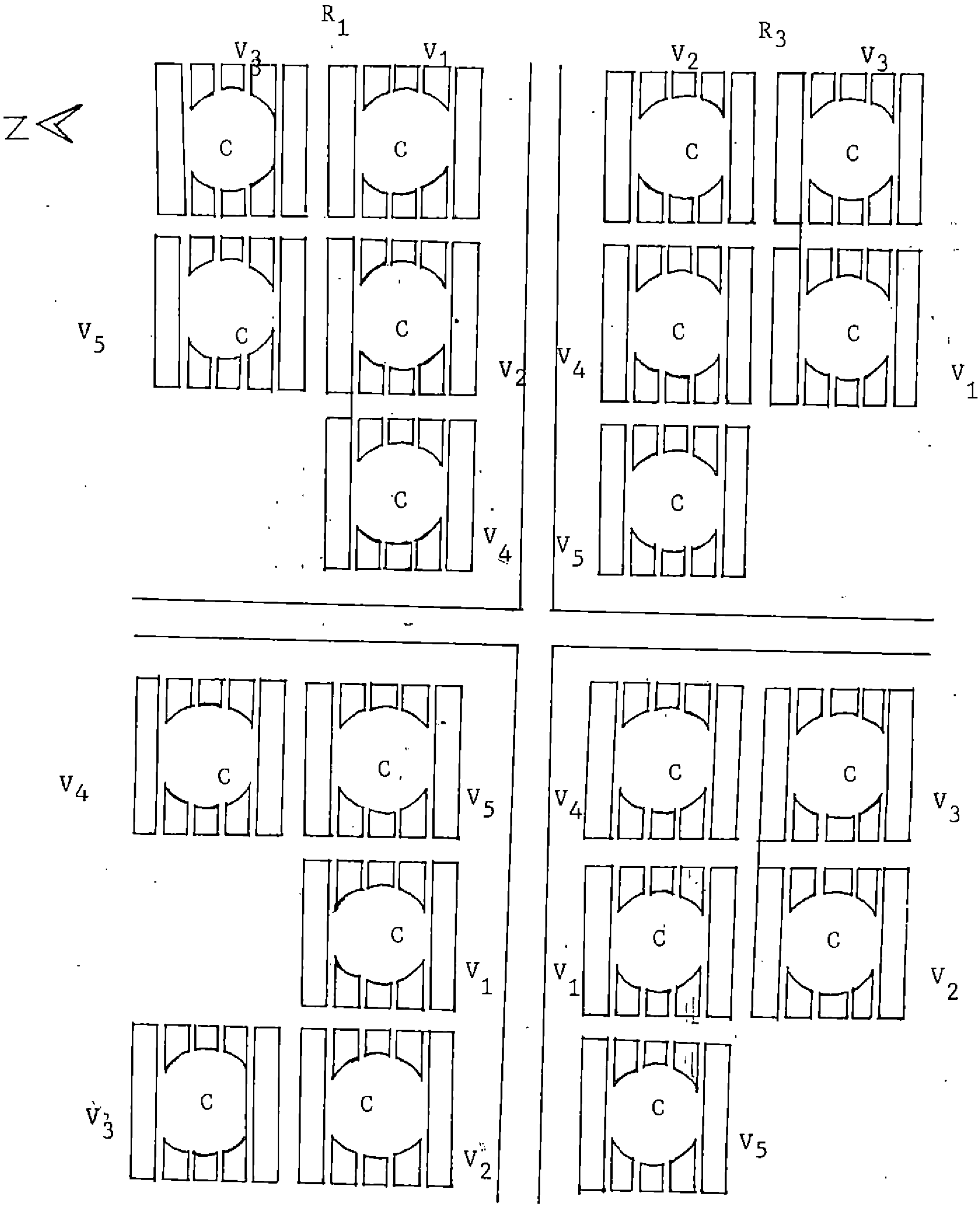
3.2.7. Plant protection

The same practice as that under artificial shade was followed.

3.2.8. Lay out and design

Design	:	RBD
Number of replications	:	4

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



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

V_1 - PCT-5
V_2 - PTS-9
V_3 - BSR-1
V_4 - Ethamukulam
V_5 - PCT-8

Treatments - Cultivars (5)

Notation

V_1 - PCT-5

V_2 - PTS-9

V_3 - BSR-1

V_4 - Ethamukulam

V_5 - PCT-8

Each of the turmeric cultivars was planted around a coconut palm leaving a basin area of 12.56 m^2. Net area around one palm planted with turmeric was 29.75 m^2.

3.2.9. Shade

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

3.3. Observations

3.3.A. Sampling technique

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

The following observations were recorded:

3.3.B. Biometric observations

1. Plant height: The height of the selected plants was measured from the base of the main pseudostem to the tip of the top-most leaf and the average worked out.

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

3. Number of leaves: The number of leaves was determined by counting the number of leaves of all the tillers of the five sample clumps and the average worked out.

4. Net assimilation rate (N.A.R.): This growth ratio refers to the change in dry weight of the plant per unit leaf area per unit time. Observations were recorded at 60 DAP and 120 DAP using the formula suggested by Williams (1946) and expressed as g m^{-2} day^{-1}.

5. Chlorophyll content of leaves: Chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a to b ratio of leaves of sample plants at 135 DAP were estimated by spectrophotometry (Starnes and Hadley, 1965). Second terminal leaf of five plants from each treatment selected at random constituted the sample.

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

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

8. Harvest index: Harvest index was calculated as follows

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

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

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

10. Total dry weight: Pseudostem and rhizomes of the uprooted plants were separated and dried to constant weight at 70°C to 80°C in hot air oven. From the dry weight of component parts for five plants, average dry weight per plant for these parts was worked out. The sum of dry weight of component parts gave total drymatter yield.

B. Chemical studies

1. Nutrient content of plants

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

2. Uptake of fertilizer nutrients

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

3. Quality analysis

Turmeric samples collected were cured and sundried. The dried samples were ground to pass through 60 mesh sieve.

1. Oleoresin content in rhizome

Oleoresin content was estimated by cold percolation method using 100 per cent acetone as solvent (ISI, 1974).

2. Curcumin content of rhizome

Curcumin content was estimated by the official analytical method suggested by American Spice Trade Association (1968) using methanol. Curcumin content was worked out and expressed as percentage on moisture free basis.

Disease incidence

Incidence of shoot borer attack was noticed about 100 days of planting. The extent of incidence was almost similar under shade and in the open. However, the attack was kept under check by spraying Ekalux (0.25 per cent) thrice at an interval of 25 days.

Statistical analysis

The experimental data were subjected to analysis of variance for split plot design and Randomised block design following the method of Panse and Sukhatme (1978) in the case of trial No.1 and 2, respectively.

Results

RESULTS

Observations on various plant characters were recorded to assess the performance of turmeric cultivars with respect to growth, yield and quality both in the artificial and natural shade trials to make a relative comparison between them. Different prediction models were also attempted for each cultivar. The results obtained are presented in this chapter.

A. Under controlled light intensities

4.1. Biometric observations

4.1.1. Plant height (Table 3)

Though no significant difference was observed between shade levels with respect to plant height, taller plants were observed at 75 per cent shade in the initial stages and at 50 per cent shade in the later stages.

Cultivars also exhibited the same trend. PCT-5 was taller at 60 and 180 days after planting.

Cultivar x shade interaction was also not significant at any of the stages.

Table 3. Effect of shade on plant height and number of leaves of turmeric cultivars

Treatments		Plant height (cm)			Number of leaves		
		60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Levels of shade (%)							
T_1	0	46.1	86.0	93.5	6.8	16.6	10.1
T_2	25	52.8	99.8	105.6	6.5	12.1	10.9
T_3	50	52.8	107.5	114.3	6.1	11.8	9.1
T_4	75	55.1	102.3	113.5	6.2	10.9	12.2
SEm±		3.01	3.8	4.3	0.23	0.82	3.83
CD (0.05)		NS	NS	NS	NS	2.33	NS
Cultivars							
V_1	PCT-5	55.6	101.7	109.7	6.4	10.6	9.0
V_2	PTS-9	52.0	98.7	106.5	6.3	12.6	9.0
V_3	BSR-1	51.0	97.4	106.8	6.4	15.6	12.4
V_4	Ethamukulam	54.3	99.8	104.6	6.6	15.7	11.9
V_5	PCT-8	51.6	102.5	107.6	6.4	10.5	9.2
V_6	PTS-38	51.3	93.7	105.3	6.2	12.2	11.4
SEm±		1.89	2.12	3.4	0.13	0.70	4.74
CD (0.05)		NS	NS	NS	2.82	NS	NS

4.1.2. Number of leaves (Table 3)

Shade levels had significant effect on number of leaves only at 120 DAP. Plants in the open recorded more number of leaves. All the other shade levels were comparable.

Cultivars also registered the same trend at 120 DAP where in BSR-1 and Ethamukulam were comparable and superior to other cultivars.

No significant shade x cultivar interaction was noticed.

4.1.3. Number of tillers (Table 4)

With regard to number of tillers, no significant difference was observed between the shade levels, cultivars and shade x cultivar interaction.

4.1.4. Net assimilation rate (NAR) (Table 4)

Though significant difference was not observed between shade levels, cultivars and shade x cultivar interactions at both the stages, there was an increase in NAR with increase in shade intensity at 120 DAP. But at 180 DAP no specific trend could be noticed.

4.1.5. Chlorophyll content (Table 5)

Total chlorophyll and its components, chlorophyll a and chlorophyll b increased steadily with increasing levels of shade

Table 4. Effect of shade on number of tillers, dry matter production and net assimilation rate

Treatments		Number of tillers			Dry matter production	Net assimilation	
		60 DAP	120 DAP	180 DAP		120 DAP	180 DAP
Levels of shade (%)							
T_1	0	1.7	2.7	2.8	36.62	1.47	2.53
T_2	25	1.4	1.9	1.9	39.46	1.65	2.28
T_3	50	1.6	2.7	2.8	43.48	2.00	2.04
T_4	75	1.5	2.3	2.4	41.61	2.09	2.44
SEm±		0.05	0.25	1.05	1.98	0.19	0.16
CD (0.05)		NS	NS	NS	NS	NS	NS
Cultivars							
V_1	PCT-5	1.3	1.8	1.9	37.79	1.61	2.14
V_2	PTS-9	1.6	2.0	2.4	40.38	1.73	2.05
V_3	BSR-1	1.6	2.7	2.8	39.03	1.60	2.60
V_4	Ethamukulam	1.5	2.0	2.5	39.43	2.05	2.29
V_5	PCT-8	1.7	2.6	2.6	44.40	1.83	2.91
V_6	PTS-38	1.4	2.1	2.2	42.60	1.96	1.99
SEm±		0.04	0.24	1.04	1.82	0.19	0.18
CD (0.050		NS	NS	NS	NS	NS	NS

Table 5. Effect of shade on content of chlorophyll fractions of turmeric cultivars at 135 DAP

Treatments	Chlorophyll a mg g^{-1} fresh weight	Chlorophyll b mg g^{-1} fresh weight	Chlorophyll a+b mg g^{-1} fresh weight	Chlorophyll a+b
Levels of shade (%)				
T_1 0	0.47	0.36	0.80	1.23
T_2 25	0.73	0.58	1.28	1.30
T_3 50	0.93	0.77	1.58	1.15
T_4 75	1.10	0.81	1.70	1.20
Cultivars				
V_1 PCT-5	0.78	0.62	1.29	1.22
V_2 PTS-9	0.78	0.62	1.30	1.19
V_3 BSR-1	0.81	0.64	1.35	1.20
V_4 Ethamukulam	0.80	0.63	1.33	1.27
V_5 PCT-8	0.81	0.66	1.37	1.26
V_6 PTS-38	0.79	0.62	1.30	1.24

Data not statistically analysed

at 135 DAP. There was no definite trend with respect to chlorophyll a to b ratio.

Cultivar PCT-8 recorded the highest chlorophyll content and PCT-5 the lowest.

4.1.6. Drymatter production (Table 4)

Though no significant effect of shade on cultivars was noticed, the drymatter production increased with increasing shade intensity upto 50 per cent shade and then declined. Among the cultivars, PCT-8 recorded the highest drymatter production at all the stages.

4.1.7. Yield (Tables 6, 7, 11, 12 and Fig. 3, 4, 5, 6)

Shade levels had significant effect on the rhizome yield on dry weight basis only. All the shade levels gave significantly higher yields than that the open. Though 75 per cent shade recorded the highest yield on dry weight basis, it was comparable with 50 per cent shade which in turn gave the highest yield on fresh weight basis.

Among the cultivars PCT-8 recorded the highest yield of 24.8 t ha^{-1} on fresh weight basis and 5.5 t ha^{-1} on dry weight basis. Though PCT-8 gave the highest yield in the open, it appears to be more suited to 50 per cent shade wherein it could record 28.1 t ha^{-1} (5.5 t ha^{-1} on dry weight basis) as against 24.8 t ha^{-1} in the open on fresh weight basis (3.7 t ha^{-1}). At 25 per

Table 6. Effect of shade in rhizome yield (fresh and dry weight) percentage dryage, haulm yield and harvest index of turmeric cultivars

Treatments		Yield (fresh weight) t ha^{-1}	Yield (dry weight) t ha^{-1}	Haulm yield t ha^{-1}	Harvest index	Percentage dryage
Shade levels (per cent)						
T_1	0	21.00	3.21	2.08	0.53	15.50
T_2	25	21.78	4.08	2.94	0.51	18.58
T_3	50	25.70	4.90	3.08	0.55	19.41
T_4	75	20.70	5.14	2.49	0.65	24.50
SEm±		1.45	0.23	0.21	0.027	0.51
CD (0.05)		NS	0.66	NS	NS	1.41
Cultivars						
V_1	PCT-5	21.86	3.96	2.52	0.55	18.80
V_2	PTS-9	22.40	4.25	2.87	0.55	19.10
V_3	BSR-1	22.02	4.18	3.15	0.56	18.80
V_4	Ethamukulam	21.90	4.25	2.82	0.58	19.40
V_5	PCT-8	24.80	5.30	2.35	0.66	22.40
V_6	PTS-38	20.70	4.00	3.08	0.52	18.40
SEm±		1.41	0.28	0.20	0.22	0.86
CD (0.05)		NS	0.66	NS	NS	2.26

FIG. 3.

Effect of shade on rhizome yield of turmeric

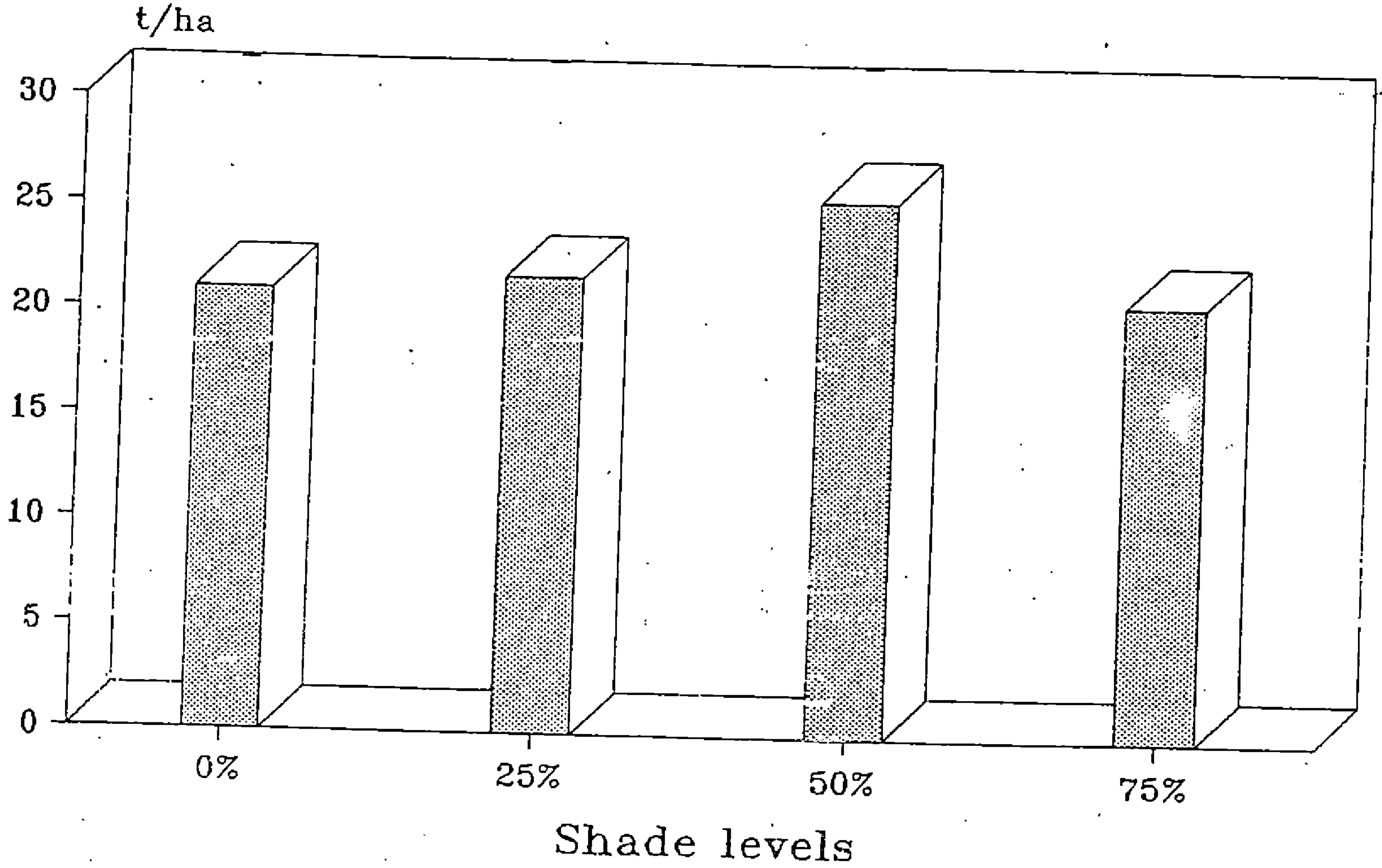


FIG. 4.

Rhizome yield of turmeric cultivars under artificial shade

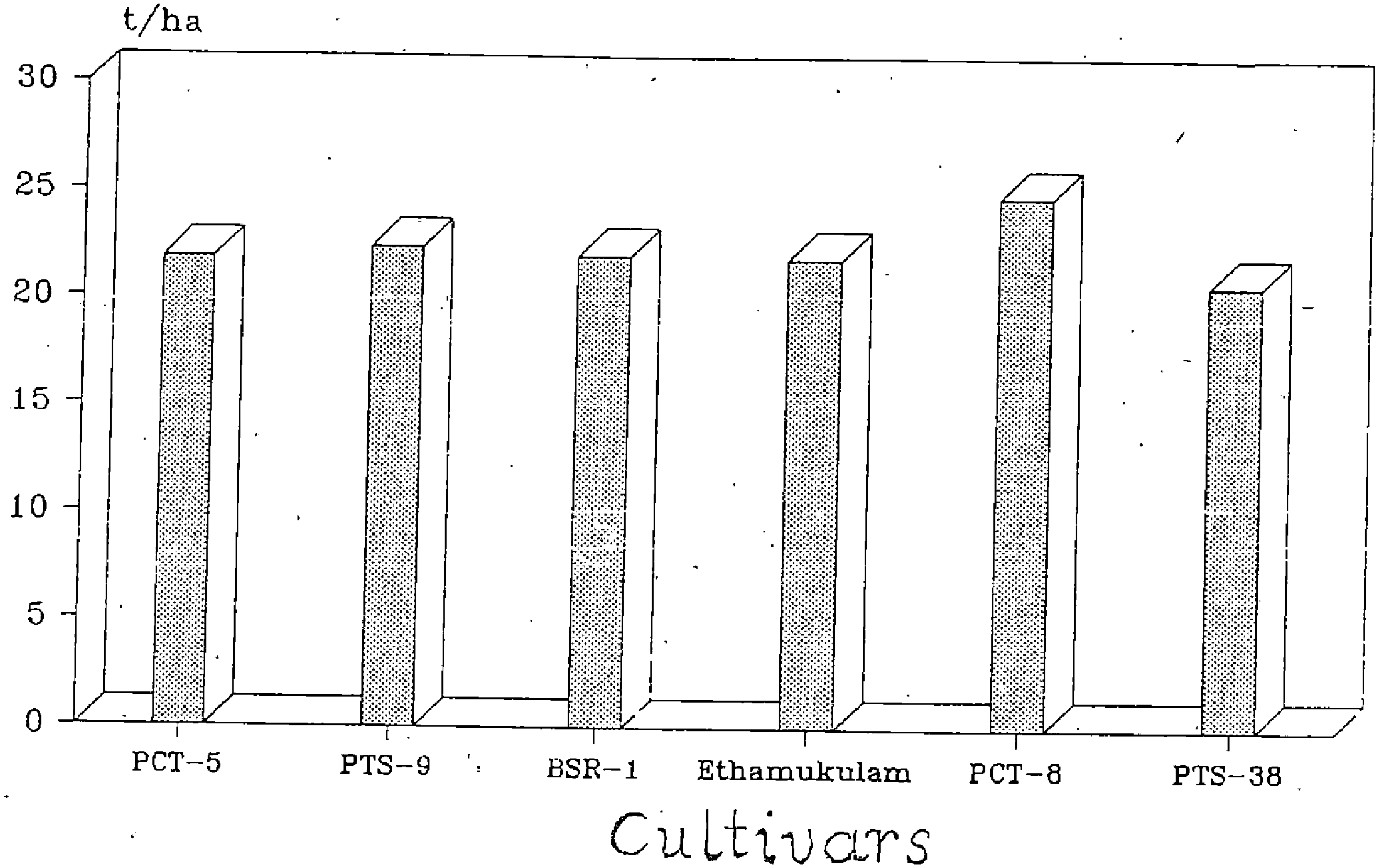


FIG. 5

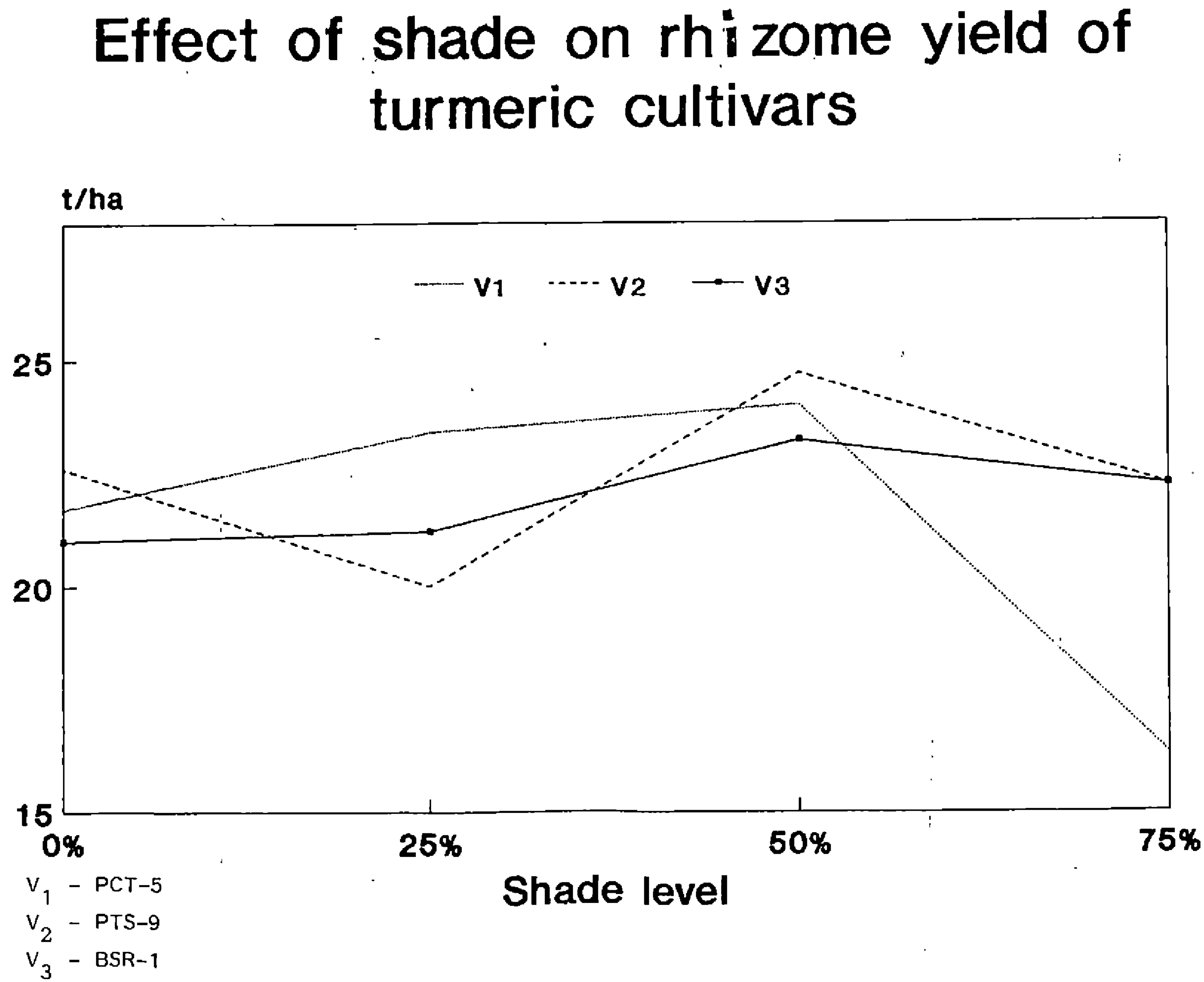
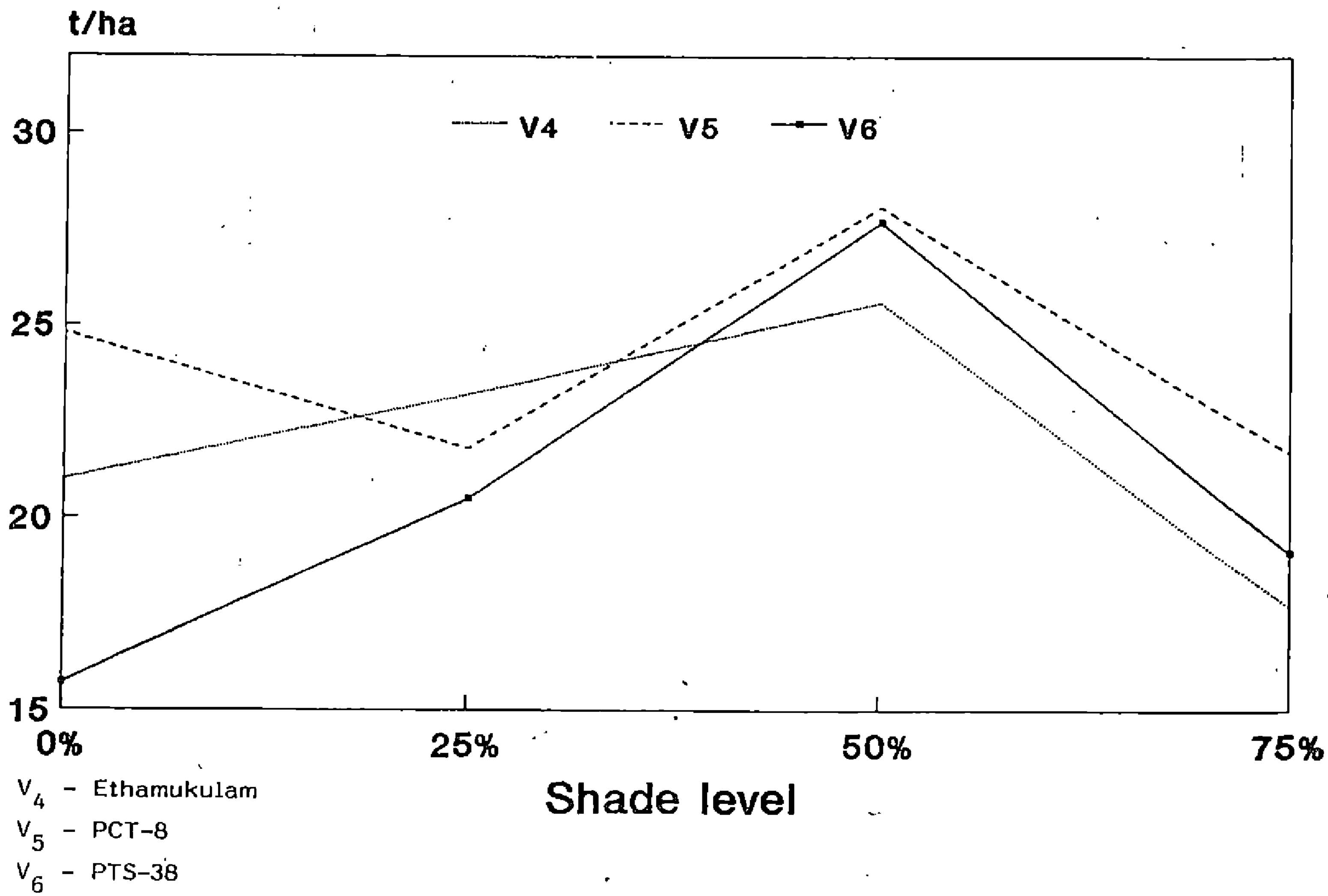

Effect of shade on rhizome yield of turmeric cultivars
t/ha
V1
V2
V3
25
20
15
0%
25%
50%
75%
Shade level
V1 - PCT-5
V2 - PTS-9
V3 - BSR-1

FIG. 6.

Effect of shade on rhizome yield of turmeric cultivars



cent shade PCT-5 recorded the highest yield of 23.4 t ha^{-1} on fresh weight basis while PTS-9 recorded the highest value of 4.5 t ha^{-1} on dry weight basis. At 75 per cent shade BSR-1 registered the highest rhizome yield of 22.2 t ha^{-1} on fresh weight basis. The highest rhizome yield of 4.9 t ha^{-1} on dry weight basis was also recorded by PTS-9 at 75 per cent shade.

Different prediction models such as quadratic cubic and logarithmic models were tried and the fitted equations along with R^2 values are given in Table 7 No model was found to be a good fit for the data, as could be inferred from the R^2 values. Hence only plot of the original data for shade levels are given in figure.

4.1.8. Haulm yield (Tables 6, 10)

Though no significant difference was observed between shade levels and cultivars in haulm yield, the mean values tended to increase with shade intensity upto 50 per cent and then decreased. The highest value of 3.08 t ha^{-1} was recorded at 50 per cent shade while the lowest value of 2.49 t ha^{-1} at 75 per cent. The interaction effects were not significant.

Among the cultivars, BSR-1 gave the highest mean value of 3.15 t ha^{-1} where as PCT-8 recorded the lowest value of 2.35 t ha^{-1}.

Table 7. Prediction models attempted to predict the influence of shade on yield of turmeric

Variety	Model tried	Fit for the data	R^2
V_1	a) $y = a+bx+c^2$	a) $y = 13.73+0.1016x-2.2x^2$	0.244
	b) $\log y = a+b \log(+1)+c \log(x+1)^2$	b) $\log y = 1.303+0.728 \log(x+1)-1.3 \log(x+1)^2$	0.203
V_2	a) $y = a+bx+cx^2$	a) $y = 19.57+2.818x-0.51x^2$	0.023
	b) $\log y = a+b \log(x+1)+c \log(x+1)^2+ d \log(x+1)^3$	b) $\log y = 1.34-0.9555 \log(x+1)+4.57 \log(x+1)^2- 5.01 \log(x+1)^3$	0.072
V_3	a) $y =a+bx+cx^2$	a) $y = 19.08+1.760-0.216$	0.021
	b) $\log y = a+b \log(x+1)+c \log(x+1)^2$	b) $\log y = 1.312-0.004 \log (x+1)+0.173 \log(x+1)^2$	0.018
V_4	a) $y = a+bx+cx^2$	a) $y = 10.98+0.123x-2.62x^2$	0.305
	b) $\log y = a+b \log(x+1)+c \log(x+1)^2$	b) $\log y = 1.303+0.736 \log(x+1)-1.33 \log(x+1)^2$	0.234
V_5	a) $y = a+bx+cx^2$	a) $y = 22.72+0.729x-0.022$	0.201
	b) $\log y = a+b \log(x+1)+c \log(x+1)^2+ d \log(x+1)^3$	b) $\log y = 1.38-2.29 \log(x+1)+9.94 \log(x+1)^2- 0.1017 \log(x+1)^3$	0.016
V_6	a) $y = a+bx+cx^2$	a) $y = 0.791+0.1912x-3.48x^2$	0.309
	b) $\log y = a+b \log(x+1)+c \log(x+1)^2$	b) $\log y = 1.17-1.549 \log(x+1)+0.105(x+1)^2$	0.336

4.1.9. Harvest index (Table 6)

Shade levels and cultivars had no significant effect on the harvest index. The highest values of 0.65 was noticed at 75 per cent shade level.

Among the cultivars, PCT-8, gave the highest value of 0.66 and PTS-38, the lowest, 0.52.

4.1.10. Percentage dryage (Tables 6, 13)

Shade levels, cultivars and shade x cultivar interactions had significant effect on percentage dryage. The highest percentage dryage of 24.5 was observed at 75 per cent shade where as the lowest value of 15.5 was noticed under direct sun.

Among the cultivars, PCT-8 recorded the highest value of 22.4 and PTS-38 the lowest, 18.4.

With respect to shade x cultivar interactions, PCT-8 at 75 per cent shade intensity gave the highest value of 31.75.

4.2. Chemical studies

4.2.1. Content of fertilizer nutrients (Table 8)

There was a progressive increase in N content of haulm and rhizome with increase in shade intensities. Seventy five per cent shade recorded the highest value of 1.6% N in haulm and 1.79%

Table 8. Effect of shade on N, P and K content of turmeric cultivars at harvest

Treatments		N content of haulm	N content of rhizome	P content of haulm	P content in rhizome	K in haulm	K in rhizome
Levels of shade (per cent)							
T_1	0	1.24	1.43	0.16	0.26	2.41	2.77
T_2	25	1.43	1.60	0.15	0.25	2.20	3.23
T_3	50	1.56	1.72	0.16	0.26	3.40	3.87
T_4	75	1.60	1.79	0.15	0.26	4.00	4.00
Cultivars							
V_1	PCT-5	1.42	1.58	0.16	0.24	3.03	3.36
V_2	PTS-9	1.46	1.61	0.18	0.23	3.10	3.31
V_3	BSR-1	1.51	1.76	0.14	0.26	3.32	3.54
V_4	Ethamukulam	1.46	1.72	0.13	0.17	3.37	3.66
V_5	PCT-8	1.48	1.63	0.15	0.20	3.17	3.46
V_6	PTS-38	1.41	1.50	0.16	0.20	3.23	3.60

Data not statistically analysed

in rhizome. Among the cultivars, BSR-1 registered the N contents of 1.51 and 1.76 in haulm and rhizome, respectively.

No clear trend could be obtained in the P content of haulm and rhizome at varying shade intensities. Among the cultivars, PTS-9 recorded the highest P content of 0.18 per cent in haulm while BSR-1 gave the highest value of 0.26 per cent in rhizome.

Potassium content exhibited a progressive increase with increase in shade intensity only in rhizome and the highest values of 4.0 per cent was observed at 75 per cent shade. Among the cultivars, Ethamukulam recorded the highest value of 3.66 per cent.

4.2.2. Uptake of nutrients (Table 9 and Fig. 7).

Uptake of N and P increased with increase in shade intensity upto 50 per cent and then declined, whereas the uptake of N had a progressive increase with increase in shade intensity. Expressed as percentage of that in the open, the N uptake at 25, 50 and 75 per cent shade levels were 150, 178 and 173, respectively.

The P uptake at 25, 50 and 75 per cent shade were 114, 142 and 123, respectively of that under direct sun.

The K uptake at 25, 50 and 75 per cent shade was found to be 136, 191 and 198, respectively of that in the open.

Table 9. Effect of shade on uptake of nutrients N, P, K, curcumin and oleoresin content in turmeric cultivars

Treatments		N $Kg\ ha^{-1}$	P $Kg\ ha^{-1}$	K $Kg\ ha^{-1}$	Curcumin (per cent)	Oleoresin (per cent)
Shade levels (per cent)						
T_1	0	76.9	14.2	158.4	1.7	0.4
T_2	25	114.6	16.0	215.9	2.1	0.6
T_3	50	137.4	20.3	304.1	3.1	0.4
T_4	75	132.6	17.5	314.0	2.4	0.9
Cultivars						
V_1	PCT-5	96.4	13.0	227.3	1.8	0.8
V_2	PTS-9	119.1	22.4	225.1	2.8	0.5
V_3	BSR-1	127.8	22.4	250.6	2.6	0.4
V_4	Ethamukulam	107.5	20.5	252.3	3.2	0.4
V_5	PCT-8	129.0	23.3	285.0	2.4	0.5
V_6	PTS-38	110.5	19.3	284.4	1.4	0.9

Data not statistically analysed

FIG. 7.

Effect of shade on NPK uptake of turmeric cultivars(Artificial shade)

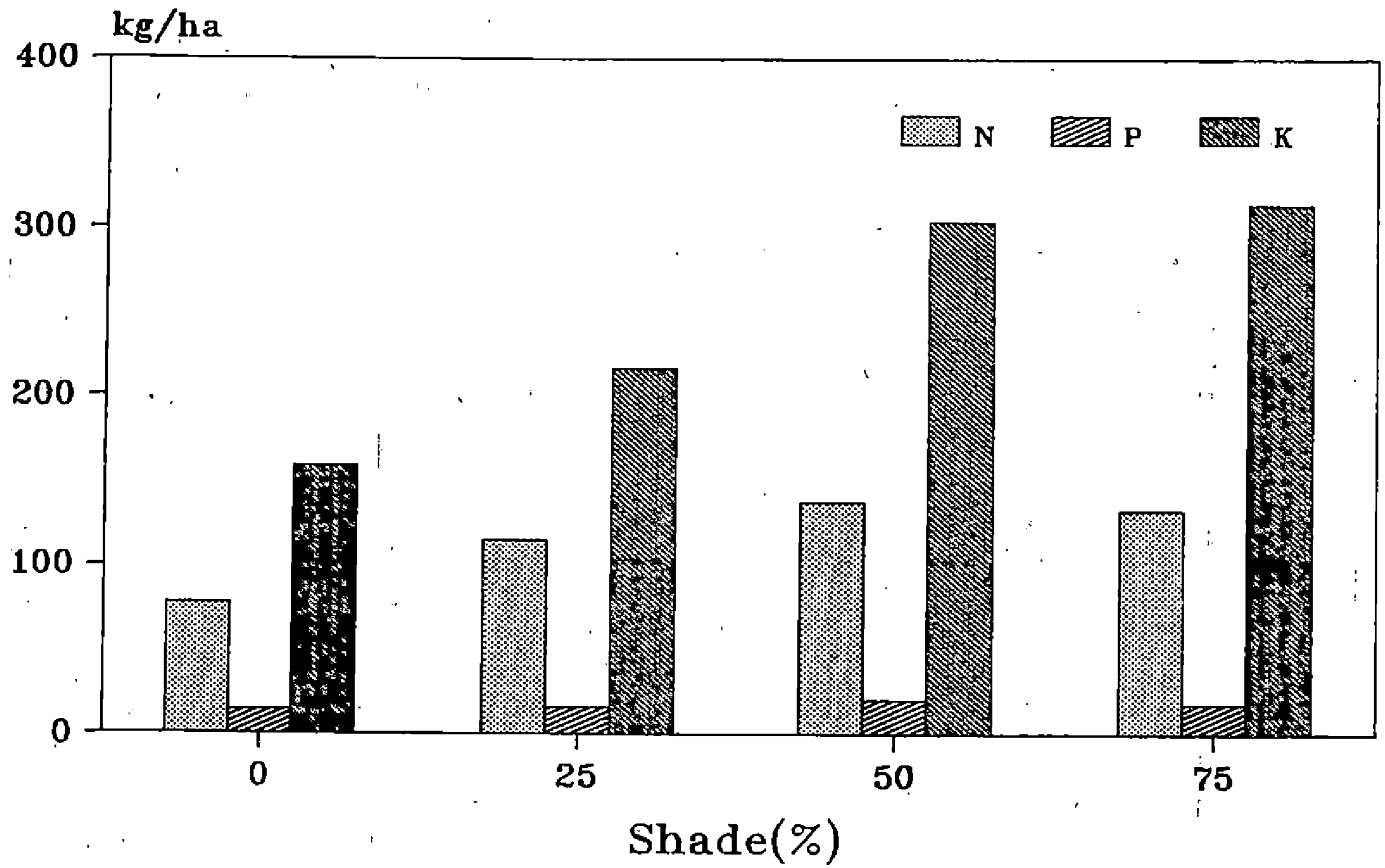


Table 10. Interaction effects of shade levels and turmeric cultivars on haulm yield

Cultivars		Shade levels (per cent) 0	25	50	75	Mean
V_1	PCT-5	2.32	3.42	2.32	2.02	2.52
V_2	PTS-9	2.82	2.70	3.50	2.40	2.87
V_3	BSR-1	3.50	2.80	3.80	2.42	3.15
V_4	Ethamukulam	2.65	3.10	3.10	2.50	2.80
V_5	PCT-8	2.10	2.10	2.30	2.90	2.30
V_6	PTS-38	2.70	3.50	3.40	2.60	3.10
Mean		2.68	2.94	3.08	2.49	

CD : NS

Table 11. Interaction effects of shade levels and turmeric cultivars on yield (fresh weight basis)

Cultivars		Shade levels (per cent) 0	25	50	75	Mean
V_1	PCT-5	21.69	23.4	24.0	16.25	21.86
V_2	PTS-9	22.6	20.0	24.7	22.2	22.4
V_3	BSR-1	21.0	21.2	23.2	22.2	22.0
V_4	Ethamukulam	21.0	23.2	25.6	17.7	21.9
V_5	PCT-8	24.8	21.8	28.1	21.7	24.8
V_6	PTS-38	15.7	20.5	27.7	19.1	20.7
Mean		21.0	21.7	25.5	20.7	

CD : NS

Table 12. Interaction effects of shade levels and turmeric cultivars on yield (dry weight basis)

Cultivars		Shade levels (per cent)				
		0	25	50	75	Mean
V_1	PCT-5	2.9	4.0	4.4	4.3	3.9
V_2	PTS-9	3.0	4.5	4.5	4.9	4.2
V_3	BSR-1	3.5	3.9	4.5	4.7	4.1
V_4	Ethamukulam	3.5	4.3	4.8	4.3	4.2
V_5	PCT-8	3.7	4.0	5.5	4.2	5.3
V_6	PTS-38	2.5	3.5	5.4	4.7	4.1
Mean		3.2	4.1	4.9	5.1	
CD : 0.72						

Table 13. Interaction effect of shade levels and turmeric cultivars on percentage dryage

Cultivars		Shade levels (per cent)				
		0	25	50	75	Mean
V_1	PCT-5	13.5	16.7	20.0	24.3	18.8
V_2	PTS-9	14.0	21.0	18.0	23.2	19.1
V_3	BSR-1	16.5	18.0	19.0	21.2	18.8
V_4	Ethamukulam	16.7	17.0	19.5	24.2	19.4
V_5	PCT-8	16.0	22.0	19.7	31.7	22.3
V_6	PTS-38	16.2	16.0	19.2	22.3	18.4
Mean		15.5	18.5	19.4	24.5	

CD : 8.3

Among the cultivars, PCT-8 recorded the highest value of N, P and K uptake.

4.2.3. Curcumin content (Table 9)

With shading, there was a progressive increase in curcumin content upto 50 per cent shade, after which a marginal decrease was noticed. The extent of increase at 25, 50 and 75 per cent shade levels as compared to that in the open were 12, 18 and 14 per cent, respectively. Among the cultivars, Ethamukulam recorded the highest value of 3.2 per cent.

4.2.4. Oleoresin content (Table 9)

The highest oleoresin content of 0.9 per cent was observed at 75 per cent shade intensity and in the cultivar PTS-38.

4.3. B. Under natural shade

4.3.1. Plant height (Table 14)

There was no significant difference between cultivars with respect to plant height at any of the stages. Ethamukulam, BSR-1 and PTS-9 were taller at 60 DAP, 120 DAP and 180 DAP, respectively.

4.3.2. Number of tillers (Table 14)

Cultivars did not show any significant difference in tiller production. However, PTS-9 and BSR-1 produced more number of tillers at all stages of plant growth.

Table 14. Plant height and number of tillers of turmeric cultivars under natural shade

Treatment	Plant height			Number of tillers		
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
V_1 PCT-5	32.5	100.1	104.5	0.7	2.9	6.8
V_2 PTS-9	32.8	83.3	111.7	1.1	3.2	7.1
V_3 BSR-1	35.35	103.4	109.2	1.1	3.3	7.0
V_4 Ethamukulam	38.2	101.3	104.9	0.6	3.0	6.8
V_5 PCT-8	34.3	94.4	97.7	0.6	3.0	6.5
SEm±	4.0	5.2	5.5	0.97	1.04	1.09
CD (0.05)	NS	NS	NS	NS	NS	NS

4.3.3. Number of leaves (Table 15)

No significant difference was noticed between cultivars with respect to number of leaves also. At 120 DAP, Ethamukulam produced more number while at 180 DAP PCT-8 recorded more number of leaves.

4.3.4. Net assimilation rate (Table 15)

There was no significant difference among cultivars in net assimilation rate. PCT-8 and PTS-9 recorded the highest values at 120 and 180 DAP, respectively.

4.3.5. Chlorophyll content of leaves (Table 16)

Chlorophyll a and total chlorophyll were highest in BSR-1 at 135 DAP, whereas chlorophyll b and chlorophyll a to b ratio were highest in PTS-9 and PCT-5, respectively.

4.3.6. Rhizome yield (Table 17) (Fig. 8)

In the case of rhizome yield also, no significant difference was noticed between the cultivars. However, BSR-1 recorded the highest mean yield of 12.8 t ha^{-1} on fresh weight and 2.53 t ha^{-1} on dry weight basis. The lowest yields of 9.3 t ha^{-1} on fresh weight and 1.93 t ha^{-1} on dry weight basis were recorded by PCT-8 which in turn gave the highest yield under controlled light intensities.

Table 15. Number of leaves, net assimilation rate and drymatter production of turmeric cultivars under natural shade

Treatment		Number of leaves			Net assimilation rate		Drymatter production of plant
		60 DAP	120 DAP	180 DAP	120 DAP	180 DAP	
V_1	PCT-5	7.9	11.9	14.1	2.3	2.1	25.8
V_2	PTS-9	6.75	11.7	14.1	2.9	2.0	28.3
V_3	BSR-1	7.1	12.8	14.4	2.2	1.6	27.0
V_4	Ethamukulam	8.2	12.9	14.0	3.1	2.0	27.4
V_5	PCT-8	5.9	10.2	15.2	2.4	1.3	31.2
CD (0.05)		NS	NS	NS	NS	NS	NS

Table 16. Contents of chlorophyll fractions of turmeric cultivars under natural shade at 135 DAP

Treatment	Chlorophyll a mg g^{-1} fresh weight	Chlorophyll b mg g^{-1} fresh weight	Chlorophyll a+b mg g^{-1} fresh weight	Chlorophyll a/b
V_1 PCT-5	0.81	0.60	1.39	1.25
V_2 PTS-9	0.87	0.72	1.49	1.10
V_3 BSR-1	0.90	0.70	1.68	1.18
V_4 Ethamukulam	0.88	0.70	1.48	1.15
V_5 PCT-8	0.83	0.68	1.41	1.12

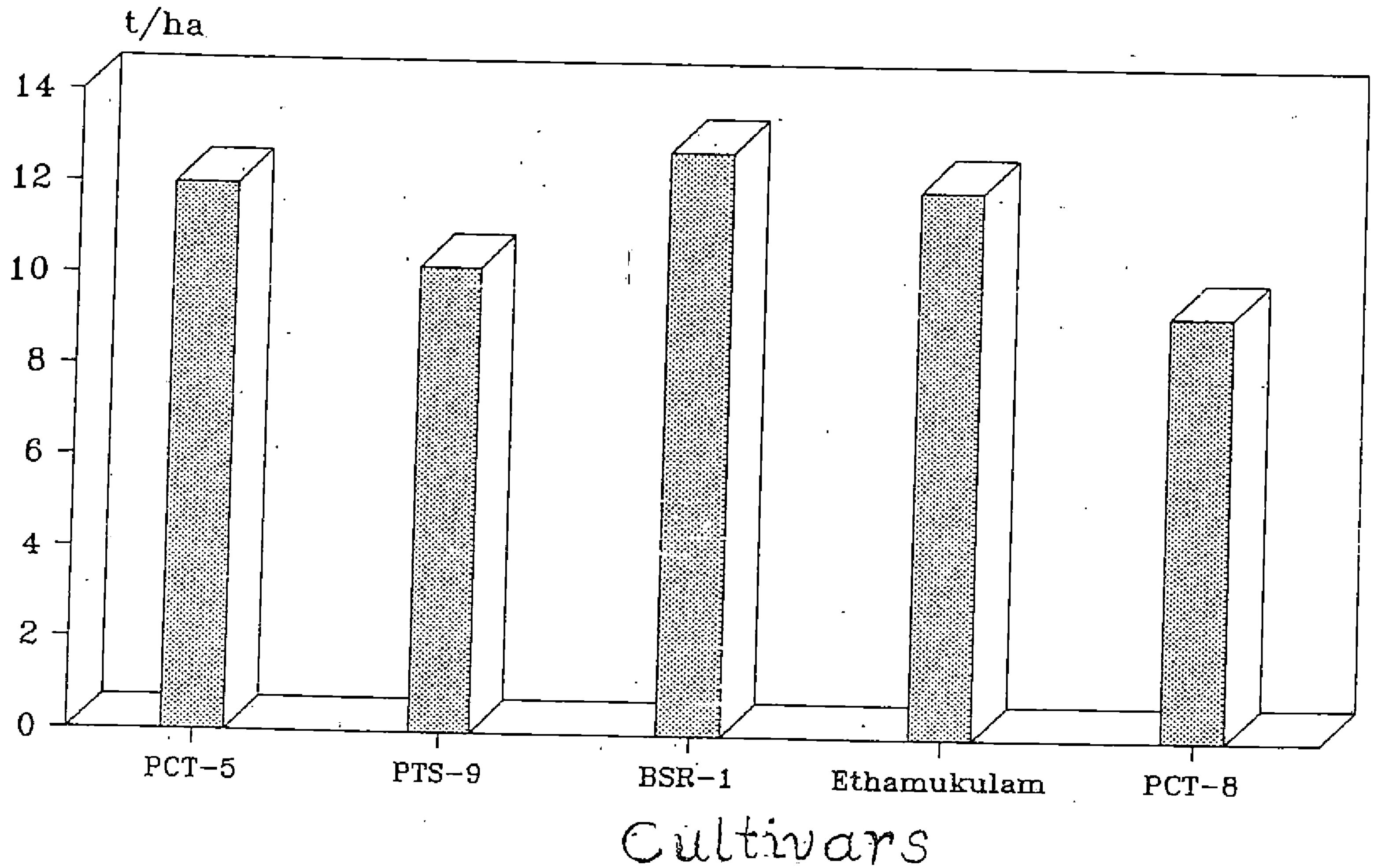
Data not statistically analysed

Table 17. Rhizome yield (fresh and dry weight), haulm yield, percentage dryage and harvest index of turmeric cultivars under natural shade

Treatments		Yield (fresh weight) t ha^{-1}	Yield (dry weight) t ha^{-1}	Haulm yield t ha^{-1}	Harvest index	Percentage dryage
V_1	PCT-5	12.0	2.40	2.33	0.51	20.50
V_2	PTS-9	10.2	2.09	2.43	0.46	20.00
V_3	BSR-1	12.8	2.53	2.19	0.53	19.75
V_4	Ethamukulam	12.0	2.46	2.30	0.51	21.50
V_5	PCT-8	9.3	1.93	2.25	0.46	20.50
CD (0.05)		NS	NS	NS	NS	NS

FIG. 8

Rhizome yield of turmeric cultivars under natural shade



4.3.7. Haulm yield (Table 17)

The cultivars did not show any significant difference with regard to haulm yield. PTS-9 and Ethamukulam gave the highest and lowest values, respectively.

4.3.8. Harvest index (Table 17)

Cultivars showed the same trend as that of rhizome yield with BSR-1 recording the highest value of 0.53.

4.3.9. Percentage dryage (Table 17)

Though the cultivars did not exhibit significant difference in percentage dryage, Ethamukulam gave the highest value of 21.5.

4.3.10. Dry matter production (Table 15)

There was no significant difference between cultivars in dry matter production. However, highest value of 28.3 t ha^{-1} was noticed in PTS-9.

4.4. Chemical studies

4.4.1. Content of fertilizer nutrients (Table 18)

No marked variation on the nutrient content was observed between cultivars. PCT-5 gave the highest N content in both rhizome and haulm whereas PCT-8 and PTS-9 recorded the lowest values in rhizome and haulm, respectively. P content in rhizome and haulm

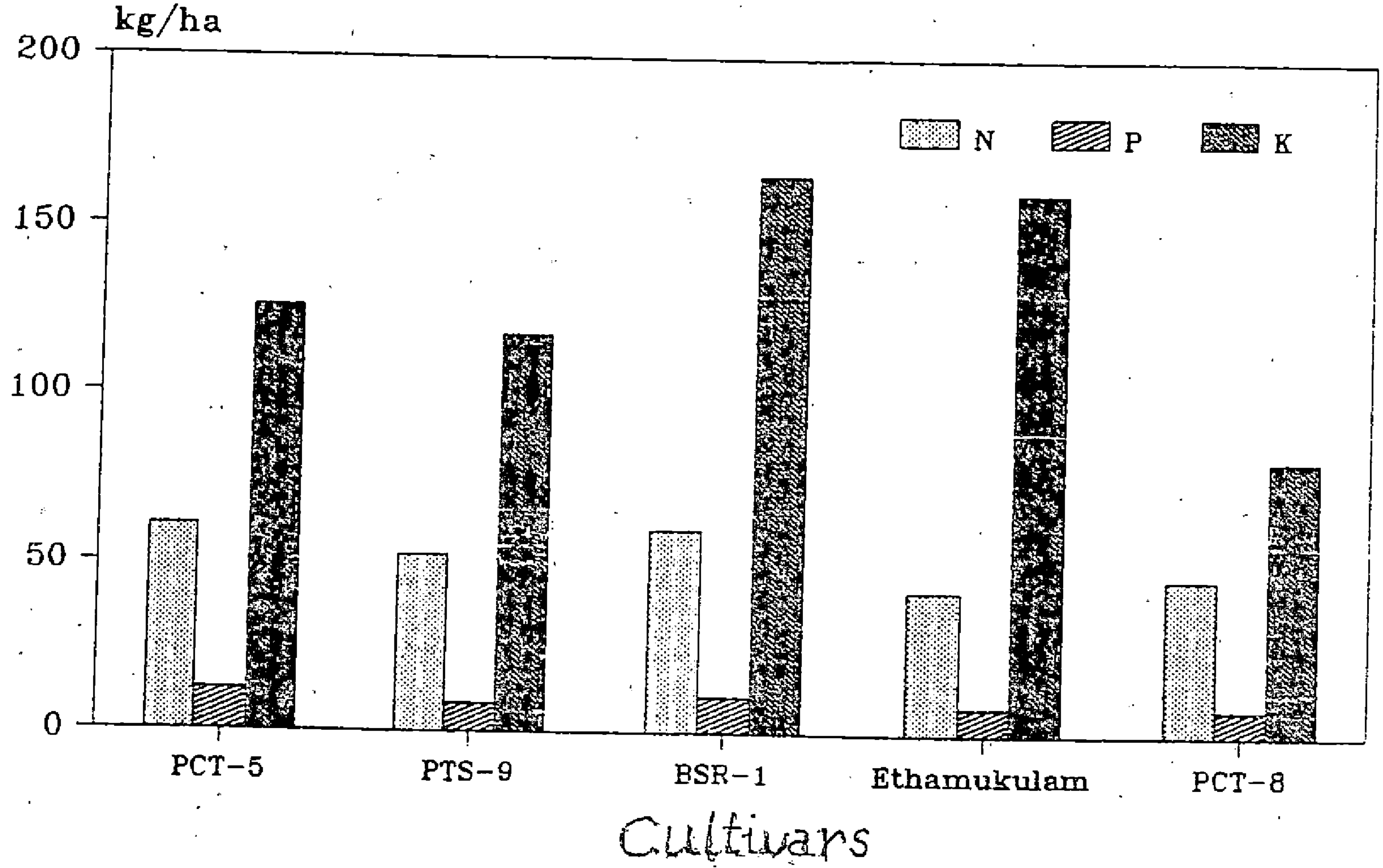
Table 18. Content and uptake of nutrients N, P and K in turmeric cultivars under natural shade

Treatment	Nitrogen %		Phosphorus %		Potassium %		Uptake kg ha^{-1}		
	Haulm	Rhizome	Haulm	Rhizome	Haulm	Rhizome	N	P	K
V_1 PCT-5	1.25	2.4	0.20	0.26	3.4	3.52	60.8	12.2	125.9
V_2 PTS-9	1.23	1.9	0.16	0.18	3.4	3.40	52.3	8.3	117.5
V_3 BSR-1	1.19	1.8	0.13	0.14	3.9	3.90	59.9	10.6	165.3
V_4 Ethamukulam	1.19	2.2	0.23	0.27	4.4	4.45	42.3	8.2	160.4
V_5 PCT-8	1.24	1.7	0.16	0.19	2.4	2.90	46.1	7.7	81.3

Data not statistically analysed

FIG. 9

NPK uptake of turmeric cultivars under natural shade



was also more in PCT-5 with Ethamukulam giving slightly higher values. On the other hand, Ethamukulam gave the highest value followed by BSR-1 and PCT-5 with respect to K content.

4.4.2. Uptake of nutrients (Table 18)

Regarding the uptake of all the three nutrients, PCT-5 recorded the highest values. The lowest values were registered by Ethamukulam with respect to N and PCT-8 with respect to P and K.

4.4.3. Oleoresin content (Table 19)

The highest oleoresin content of 1.5 per cent was recorded in PCT-8 while the lowest of 0.9 per cent was noticed in BSR-1.

4.4.4. Curcumin content (Table 19)

Curcumin content was highest in Ethamukulam (3.7 per cent) and lowest in PCT-5 (2.5 per cent).

Table 19. Curcumin and oleoresin content of turmeric cultivars under natural shade

Treatments	Oleoresin (%)	Curcumin (%)
PCT-5	1.2	2.5
PTS-9	0.9	3.0
BSR-1	0.9	2.6
Ethamukulam	1.2	3.7
PCT-8	1.5	3.1

Discussion

DISCUSSION

The chapter gives an overall assessment of the performance of turmeric cultivars under artificial shade and under natural shade in coconut plantation.

From the results, all the cultivars were found to give higher yields at 50 per cent shade though the differences were not statisfically significant. The yields at 25, 50 and 75 per cent shade expressed as percentage of that in the open were 103, 121 and 98 on fresh weight basis and 127, 153 and 162 on dry weight basis, respectively. Similar results were reported earlier by Bai and Nair (1982). The increased yields of the cultivars at 50 per cent shade level indicates the ability of the crop to tolerate shade. Thus turmeric can be classified as a shade tolerant/shade loving crop and slight shade is needed for the better performance of the crop. Hardy (1958) explained the better performance of some crops under shade due to the presence of a threshold illumination intensity beyond which the stomata of shade loving plants tend to close. Data on dry matter accumulation substantiate observed trend in rhizome yield. The increase in yield was consistent with the general growth performance of the crop in terms of dry matter accumulation. The percentage value of dry matter accumulation at 25, 50 and 75 per cent shade levels were 107, 119 and 113, respectively, when compared to that in the open. The data on dry matter accumulation show that shading did not result in any appreciable decrease in photosynthesis upto 50 per cent. Not only that there was no decrease in photosynthesis, shading also tended to increase the dry matter accumulation by plants.

Regarding harvest index, higher values were found at 75 per cent shade. Hence it appears that translocation of carbohydrates to economic part was increased by shading. This is in confirmation with the finding of Varughese (1989) and Prameela (1990) where light shading increased the harvest index of ginger and colocasia. Cultivar PTS-38 produced the lowest yield on fresh weight basis, with lowest values of harvest index. Percentage dryage also increased with increase in shade. This is in agreement with the finding of Varughese (1989).

On analysing the performance of different cultivars at varying shade intensities it was found that PCT-8 and PTS-9 performed better both unde shade and in the open. However, they were better suited to 50 per cent shade. All the other cultivars also perormed better at 50 per cent shade above which there was a declining trend on yield. In general, all the cultivars preferred a medium shade level of 50 per cent. It is, however, to be noted that the differences neither of the overall means nor of the interactions were statistically significant.

Though different prediction models were tried, no model was found to be a good fit for the data indicating that yield prediction in turmeric could not be effected based on shade levels.

Among the cultivars, PCT-8 the highest yielder, recorded greater values for dry matter production, harvest index, chlorophyll content and percentage dryage. On the other hand PTS-38 with its lowest yield recorded low value for harvest index but high value for dry matter production. Though the total dry matter production was high in PTS-38, the poor translocation of photosynthates to the storage organ might be the reason for low HI value and thereby poor yield.

Plant charcters like plant height, number of leaves and number of tillers followed different patterns. General trend was an increase in height with increase in shading. Taller plants were observed at intense shade levels of 75 per cent in the initial stages and at 50 per cent in the later stages, at which shade level all the cultivars performed better with respect to the rhizome yield. An increase in plant height under shade has earlier been reported in giner (Bai and Nair, 1982) and turmeric (Varughese, 1989).

Significant effect of shade on number of leaves was noticed only at 120 DAP, and plants in the open recorded more number of leaves. This is in confirmity with the findings of Xia (1987) and Varughese (1989). The tiller number was not effected by shade levels.

No significant difference between cultivars was noticed in the growth characters like plant height, tillers and NAR. But regarding the number of leaves, significant difference was noticed with BSR-1 and Ethamukulam recording comparable values in the open.

With respect to chlorophyll content, an increasing trend with increase in shade levels was noticed. The very low value of total chlorophyll in the open when compared to that under shade may be due to the photooxidation at strong light intensities. This is in agreement with the finding of Anderson (1985), Varughese (1989) and Prameela (1990).

With regard to the content of fertilizer nutrients, there was a progressive increase in nitrogen in haulm and rhizome and the highest value was observed at 75 per cent shade indicating better absorption of nutrients under shade. The mean contents in the case of haulm ranged from 1.24 to 1.6 and from 1.43 to 1.79 in rhizome. No definite trend could be noticed in the P content of haulm and rhizome at varying shade intensities. Increase in K content in the rhizome with shading was also noticed. Potassium content was more in haulm at the most intense shade level of 75%, though a definite trend could not be observed. Uptake of nutrients followed the same pattern as that of dry matter production and yield and one valid conclusion out of the data is that the treatment giving the highest yield also recorded the highest uptake values. Calculated as percentages of the uptake in the open, the crop removal of nitrogen, phosphorus and potassium at 25, 50 and 75 per cent were 149, 178, 172 for N, 112, 142 and 123 for P and 136, 191 and 198 for K, respectively. It can therefore be inferred that requirements of N and P increase upto the medium shade of 50 per cent and then there is a general decrease. (Requirement of K increased with increase in shade intensity with 75 per cent shade level recording the highest values. This agrees with the finding of Gopinathan (1981) who recorded higher uptake of K by cocoa seedlings in shade compared to that in the open. Thus the results reveal no scope for reducing the rate of application of fertilizer nutrients with shading.)

Among the cultivars, PCT-8, which produced the highest yield gave higher uptake values, but no specific trend could be noticed between uptake of nutrients and yield of other cultivars.

There was no definite trend in oleoresin content, and the highest values were recorded at 75 per cent shade. Higher values may be explained by the retention of volatile oil which otherwise undergoes oxidation, degradation, isomerisation and polymerisation (Zacharia and Gopalan, 1987). Increase in volatile oil, non volatile acetone extract, starch and protein with shading was observed in ginger with shading (Ravishankar and Muthuswamy, 1987).

Curcumin content showed a progressive increase upto 50 per cent after which a slight decrease was noted. Ramadasan and Sathees an (1977) reported differential response of cultivars in curcumin and oil content under monocropping and under intercropping with coconut.

Natural shade

In coconut plantations with a natural shade of about 50 per cent, similar performance was exhibited by all the five cultivars tested. Though no significant difference was noticed between cultivars, BSR-1 recorded the highest rhizome yield. But the general performance of all the cultivars was poor under intercropping in coconut garden. Among the cultivars, BSR-1, the highest yielder recorded more chlorophyll content and high HI value. However, the growth attributes such as plant height, tiller number and NAR appears to have no direct influence on rhizome yield in this cultivars.

With regard to harvest index also cultivars showed the same trend with BSR-1, recording the highest values. The highest dry matter accumulation was noticed in PTS-9, which also produced the lowest values of harvest index. The highest value of percentage dryage was given by Ethamukulam.

With regard to plant characters like number of leaves, tillers and plant height, no significant difference was noticed between cultivars. Chlorophyll a and total chlorophyll content were more in BSR-1 which recorded the highest yield.

With respect to nutrient content in both rhizome and haulm, PCT-5, recorded higher values for N and P, whereas Ethamukulam gave the highest values for K followed by BSR-1 and PCT-5. The N and P uptake also followed the same trend. But in the case of K uptake, highest value was observed in the case of BSR-1 followed by Ethamukulam and PCT-5. Rhizome yield and K uptake of the above cultivars exhibited similar trend. The higher values for both K uptake and yield under shade indicates the specific role of K in increasing yields. In general uptake values were much lower when compared to that under controlled conditions. This might be due to the comparitively lower dry matter production under intercropped situation with low soil nutrient status. Late planting of the crop under natural shade might be another reason for reduction in rhizome yield. Yield reduction in ginger due to late planting was reported earlier by Aiyadurai (1966).

Regarding curcumin and oleoresin content, PCT-8 and Ethamukulam recorded the highest and lowest values, respectively. BSR-1, the best yielder recorded comparatively lower values for oleoresin and curcumin.

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

1) Not much variation in the performance of cultivars was noticed under shaded conditions and in the open. However, the cultivars preferred a medium shade level of 50 per cent with respect to rhizome yield.

2) As the yields of all the cultivars were more at medium shade level compared to that under direct sun, turmeric can be classified as a shade tolerant or shade loving crop.

3) Among the cultivars, PCT-8 fared well under artificial shade while BSR-1 outyielded other cultivars under natural shade in coconut plantation.

4) The curcumin content was highest at 50 per cent shade while oleoresin content was highest at 75 per cent shade.

5) The oleoresin and curcumin contents were more under natural shade than that under artificial shade.

Summary

SUMMARY

Two field experiments were conducted, one under artificial shade and another under natural shade in coconut plantation at the College of Horticulture, Vellanikkara, Thrissur, Kerala, India during the year 1990-91. The trial under artificial shade was aimed at evaluating the performance of turmeric cultivars under different shade levels and that under natural shade was to test the fitness of these cultivars as intercrops in coconut garden. The results of the experiments are summarised below.

All the cultivars recorded highest rhizome yield at 50 per cent shade on fresh weight basis while on dry weight basis highest yields were observed at 75 per cent shade. In general the performance of the crop was better in terms of rhizome yield under medium shade level of 50 per cent. Hence, turmeric can be classified as a shade tolerant crop.

On analysing the performance of different cultivars, at varying shade intensities, all the cultivars were found to perform better at 50 per cent shade, above which there was a declining trend in yield. The treatment differences were, however, not significant.

Though a number of prediction models were tried, none of the models seemed to be a good fit for the cultivars.

Effect of shade on plant height and chlorophyll content was positive. More number of leaves were produced in the open, whereas no definite trend could be observed in the number of tillers.

Cultivars grown at 50 per cent shade gave the highest haulm yield and drymatter production whereas highest value of harvest index was noticed at 75 per cent shade.

Uptake of N and P increased with increase in shade intensity upto 50 per cent, and then declined, whereas the uptake of K had a progressive increase with increase in shade. Fifty per cent shade recorded highest values for curcumin content while 75 per cent recorded highest ~~values for curcumin content while 75 per cent recorded highest~~ values for oleoresin. Thus the quality of turmeric was found to be improved when grown under shade.

Natural shade

In coconut plantation where there is a natural shade of about 50 per cent all the five cultivars PCT-5, PTS-9, BSR-1, Ethamukulam and PCT-8 tested exhibited similar performance in terms of rhizome yield. Though no significant difference was noticed between cultivars, BSR-1 recorded the highest rhizome yield. The highest values of harvest index and chlorophyll content were also recorded by this cultivar. Highest values for drymatter accumulation was noticed in PTS-9, while the highest value of percentage dryage was seen in Ethamukulam. With regard to plant height, no significant difference was noticed between cultivars. The highest value of N and P uptake was given by PCT-5, and in the case of K uptake, highest value was observed in the case of BSR-1. Regarding curcumin and oleoresin contents, PCT-8 and Ethamukulam recorded the highest and lowest values, respectively. However, the curcumin and oleoresin contents were more under natural shade than under artificial shade. In general, the performance of all the cultivars was poor under intercropping in coconut garden.

Plate 1. General view of the experimental field after providing shade

Plate 2. Turmeric cultivars at 0 per cent shade

Plate 3. Turmeric cultivars at 25 per cent shade


0% SHADE


25% SHADE

Plate 4. Turmeric cultivars at 50 per cent shade

Plate 5. Turmeric cultivars at 75 per cent shade


50% SHADE


75% SHADE

References

REFERENCES

Aiyadurai, S.G. 1966. A review of research on spices and cashewnut in India, Ernakulam-6. Indian Council of Agric. Res.

Anderson, R.A., Karperbauer, M.J. and Burton, H.R. 1985. Shade during growth, effects on chemical composition and leaf colour of air cured burley tobacco. Agron. J. 77: 543-546.

Armose, O. 1989. Light intensity response in pineapple seedlings. Phyton 49(1-2):161-165.

ASTA, 1968. Official Analytical Methods. 2nd ed. American Spice Trade Association, New York, pp.38.

Bai, E.K.L. 1981. Shade response of common rainfed intercrops of coconut. M.Sc.(Ag) thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Bai, E.K.L. and Nair, R.V. 1982. Shade response of some common rainfed intercrop. Proceedings of the Fifty Annual Symposium on Plantation Crops. Indian Society for Plantation Crops. pp.394-401.

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. Agron. J. 54:464-465.

Björkman, O. 1968. Carboxy dismutasc activity in shade adapted and sun adapted species of higher plants. Physiol. Plantarum 21:1-10.

Brian, S.Y., Amina, N., Raymond, W. and Theodore, W.T. 1988. Modelling effects of light, Co_2 and temperature on the growth of potato. Crop Sci. 28:811-818.

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

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

Crookston, R.K., Treharne, K.J., Ludford, P. and Ozbun, J.L. 1975. Response of beans to shading. Crop Sci. 15:412-416.

Earley, E.B., Miller, R.J., Reichert, G.L., Hageman, R.H. 1966. Effect of shade on maize production under field conditions. Crop Sci. 6:1-7.

*El. Aidy, F. 1984. Research on the use of plastics and shade nets on the production of some vegetable crops in Egypt. Acta Hort. 154:109-113.

Fong, C.H., Shu, I.J. and Wu, C.T. 1980. Studies on the effect of shading on shoot characteristics, chemical composition and quality of green tea. Taiwan Agriculture Bimonthly. 16(6): 65-75.

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

George, S. 1982. Shade response of common rainfed intercrops of coconut. Part III. Legumes. M.Sc.(Ag) thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Gopinathan, P. 1981. Effect of shade and moisture regimes on the growth of cocoa (Theobroma cacao L) seedlings. M.Sc.(Ag) thesis - Kerala Agricultural University, Vellanikkara, Trichur, Kerala.

Grant, J.A. and Ryug, O.K. 1984. Influence of within canopy shading on net photosynthetics rate, stomatal conductance and chlorophyll content of Kiwi fruit leaves. Hort. Sci. 19:834-836.

Hardy, F. 1958. The light relation of cocoa. Cocoa Manual Inter. Am. Inst. agric. Sci. Turrialba, Costarica. 85-91.

ISI 1974. Indian Standard Methods of Sampling Test for Spices and Condiments. ISI, 797, Indian Standard Institution, New Delhi, India.

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

Jadhav, B.B. 1987. Effect of partial shading on the yield of rice. Indian J. Agric. Sci. 57(7):515-516.

KAU. 1989. Package of Practices Recommendations. Kerala Agricultural University, Directorate of Extension, Mannuthy, Kerala.

Langille, A.R. and McKee, G.W. 1970. Early growth of crown vetch under reduced light. Agron. J. 62:552-554.

Martin, F.W. 1985. Difference among sweet potatoes in response to shading. Trop. Agric. 62(2):161-165.

Menzel, C.M. and Simpson, D.R. 1988. Effect of continuous shading on growth, flowering and nutrient uptake of passion fruits. Scientia Hort. 35:77-88.

*Moon, W. and Pyo, H.K. 1981. Effect of various shade levels on the growth of some cool season vegetables. J. Korean Soc. hort. Sci. 22:153-159.

Nayar, N.K., Aravindakshan, M. and Mathew, V. 1979. Effect of shading on fruit characters in pineapple. South Indian Hort. 27(1&2):57-60.

Okoli, P.S.O. and Wilson, G.F. 1986. Response of cassava (Manihot esculenta Crants) to shade under field conditions. Fld. Crops Res. 14:349-359.

*Ono, S. and Iwagaki, I. 1987. Effect of shade treatment on the productivity of satsuma mandarin trees. Bull. Fruit Tree Res. Station, Kuchinotsu, Japan, (9):13-24.

Pandey, R.K., Singh, V.B. and Singh, B.K. 1980. Effect of reduced sunlight on growth and yield of chick pea. Indian J. agric. Sci. 50:405-411.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical methods of agricultural workers. ICAR, New Delhi, pp.187-197.

Pepper, G.E. and Prine, G.M. 1972. Low light intensity effects on grain sorghum at different stages of growth. Crop Sci. **12**: 590-593.

Philip, J. 1983. Studies on growth, yield and quality components in different turmeric types. Indian Cocoa, Arecanut, Spices J. 6(4):93-97.

Prameela, P. 1990. Screening different morphotypes of colocasia (Colocasia esculenta L. Scott) for shade tolerance. M.Sc.(Ag.) thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Radha, T. 1979. Effect of shade on growth and fruiting in pineapple. M.Sc.(Hort) thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Ramadasan, A. and Satheesan, K.V. 1980. Annual Report, CPCRI, Kasargode, Kerala, India. pp.813.

Ramadasan, A. and Satheesan, K.V. 1987. Curcumin and essential oil contents of 3 turmeric cultivars grown in monoculture and as intercrop in coconut gardens. J. Plant. Crops. 16(1):1-72.

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

Rao, A.M. and Reddy, M.L. 1990. Population and fertilizer requirement of maize in turmeric and maize intercropping system. J. Plant. Crops 18(1):44-49.

Rao, L.J. and Mittra, B.N. 1988. Growth and yield of peanut as influenced by degree and duration of sheding. J. Agron. Crop Sci. 160(4):260-265.

Ravisankar, C. and Muthuswamy, S. 1986. Drymatter production and recovery of dry ginger in relation to light intensity. Indian Cocoa, Arecanut, Spices, J. 19(4-6)

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

*Rylski, I. and Spigelman, M. 1986. Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of light temperature and radiation. Scientia Hort. 29:31-35.

Sannamarappa, M. and Shankar, K. 1988. Performance of turmeric and sweet potato - cowpea planted as intercrops at two crop intensities under four different densities of arecanut. J. Plant. Crops. 16(1):19-25.

*Schaffer, B. and Gaye, G.O. 1989. Gas exchange, chlorophyll and nitrogen content of mango leaves as influenced by light environment., J. hort. Sci. 24(3):501-509.

*Simbolon, H. and Sutarno, H. 1986. Response of Amaranthus spp. to various light intensities. Bulletin Penalitian Hortikultura 13(3):33-42.

Singh, A. 1967. Plant Physiology. Asia Publ. House, India, P. 614, Varghese (1989).

Singh, J. and Randhawa, G.S. 1988. Effect of intercropping and mulch on yield and quality of turmeric (*Curcuma longa* L.). Acta. Hort. 18: 183-186.

Singh, L. 1988. Adaption and yield of potato under low light intensity. Indian J. Pl. Physiol. 31: 114-116.

Singh, V.P., Dey, S.K. and Murthy, K.S. 1988. Effect of low light stress on growth and yield of rice. Indian J. Pl. Physiol. 31: 84-91.

*Simbolon, H. and Sutarno, H. 1986. Response of *Amaranthus* spp. to various light intensities. Bulletin Penelitian Hortikultura 13(3): 33-42.

Snelgar, W.P. and Hopkirk, G. 1988. Effect of overhead shading on yield and quality of kiwi fruit (*Actinidia deliciosa*). J. hort. Sci. 63(4): 731-742.

Sorenson, E.J. 1984. The effect of phosphorous and light intensity on the growth of winged bean (*Psophocarpus tetragonolobus*) Diss. Abstr. int. (S 7 E) 45: 737.

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

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

*Tikhomirov, A.A., Zolutukhin, J.C. and Yasid'ko, F. 1976. Effect of light regime on productivity and quality of the harvest of raddish. Soviet Pl. Physiol.23: 27-31.

Varughese, S. 1989. Screening of varieties of ginger and turmeric for shade tolerance. M.Sc.(Ag) thesis submitted to Kerala Agricultural University, Vellanikkara, Trichur, Kerala, India.

Venkataramanan, D. and Govindappa, D.A. 1987. Shade requirement and productivity of coffee. J. Coffee Res. 17(2):16-39.

Vijayalakshmi, C., Natarajarathnam, N. and Sreerangaswamy, S.R. 1987. Effect of light stress on yield attributes in rice. Madras agric. J. 74:550.

Williams, R.F. 1946. The physiology of plant growth with special reference to the concept of net assimilation rate. Ann. Bot. 10:41-47.

*Xia, M.Z. 1987. Effect of various light intensities on nitrogen fixation and sugar distribution of broad bean. Pl. Physiol. Commun. 3:21-23.

Zacharia, T.J. and Gopalan, A. 1987. Nature, production and quality of essential oils of pepper, ginger, turmeric, cardamom and tree species. Indian Performer 31(3): 188-205.

*Originals not seen

Appendices

APPENDIX-I

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

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

Contd.

Appendix-I. Continued

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

EVALUATION OF TURMERIC CULTIVARS FOR SHADE TOLERANCE

By

SHEELA PAUL

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara, Thrissur
Kerala - India

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ABSTRACT

An experiment, 'Evaluation of turmeric cultivars for shade tolerance' was conducted during May 1990 to February 1991 at the College of Horticulture, Vellanikkara, Thrissur, Kerala, India. Two separate trials were carried out one under artificial shade and the other under natural shade in coconut garden. The trial under artificial shade was to assess the performance of turmeric cultivars under different shade levels, whereas that under natural shade was to test the fitness of these cultivars as intercrops in coconut garden.

Trial under artificial shade was laid out in split plot design with four shade levels, 0, 25, 50 and 75 per cent in the main plots and six cultivars PCT-5, BSR-1, Ethamukulam, PTS-9, PCT-8 and PTS-38 in the subplots. For providing shade, pandals were erected on wooden frames and covered with unplaited coconut fronds to provide desired levels of shade. LI-COR integrating quantum radiometer with line quantum sensor was used for adjusting the shade intensities. Though no significant difference was observed between cultivars at different shade levels, all cultivars gave highest rhizome yield at 50 per cent shade. Hence turmeric may be calssified as a shade tolerant/shade loving crop. Yield parameters such as drymatter production and harvest index were also more at 50 and 75 per cent shade, respectively. Among the cultivars PCT-8, the highest yielder gave higher values for drymatter production, harvest index, chlorophyll content and

percentage dryage. On analysing the performance of different cultivars at varying shade intensities, all the cultivars were found to be better at 50 per cent shade, above which there was a declining trend in yield. The treatment differences were, however, not significant. In general, PCT-8 and PTS-9 performed better both under shade and in the open.

Though different prediction models were tried, no model was found to be a good fit for the cultivars. Under natural shade, similar performance was exhibited by all the five cultivars tested with respect to rhizome yield, growth and yield attributes. However, BSR-1 outyielded the other cultivars. The same cultivar recorded more content of chlorophyll, curcumin and oleoresin. In general, the performance of all the cultivars was poor under intercropping in coconut garden.