CROP WEATHER RELATIONSHIP OF RAINFED BANANA UNDER DIFFERENT TIMES OF PLANTING

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THESIS

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Kerala Agricultural University

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Kerala - India

1990

DEDICATED TO MY PARENTS

DECLARATION

I hereby declare that this thesis entitled "Crop weather relationship of rainfed banana under different times of planting" is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other university or society to me.

Vellanikkara,

Venugopalan, K.

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Certified that this thesis entitled "Crop weather relationship of rainfed banana under different times of planting" is a record of research work done independently by **Mr. Venugopalan, K.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dr. P. Balakrishna Pillai,
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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Venugopalan, K.,** a candidate for the Degree of Master of Science in Agriculture agree that the thesis entitled "Crop weather relationship of rainfed banana under different times of planting" may be submitted by him in partial fulfilment of the requirements for the degree.

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Venugopalan, K.

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Introduction

INTRODUCTION

India occupies the second position in the world for production of banana with its cultivation in more than two lakh hectares. In India, banana is grown under varying soil and climatic conditions, exploiting the wide variability existing in the crop. Of the total area under cultivation, 54 per cent is being shared by Kerala, Tamil Nadu and Maharashtra. Kerala ranks first among these states with an area of 53,278 ha and a production of 3,62,339 tonnes/year (F.I.B., 1989).

Southwest monsoon is the predominent rainy season in Kerala and about 67% of the annual rainfall is received in this season. About 19 per cent falls in the post monsoon season, from October to January, and the rest 14 per cent in the remaining period from February to May. Thus, the rainfall is effective only for a period of five to seven months, with a distinct dry spell occurring during the remaining period. In Kerala, approximately 80 per cent of the banana cultivation is reported to be under rainfed condition.

Of the several popular dessert types, 'Palayankodan' is the most widely cultivated single clone because of its drought tolerance. It is the most important commercial cultivar in Kerala. The crop gives an attractive net income and the production is largely market oriented.

The growth and yield of banana vary greatly with the prevailing weather conditions. A combination of temperature, sunshine duration, humidity etc. determine the growth period, crop performance, and productivity. The effect of these meteorological parameters on the crop can be studied by varying the planting dates. Date of planting is a non-monetary input and by planting the crop at the correct time, the growth and yield of the crop can be enhanced, with no extra effort on the part of the farmer. So far no detailed studies were undertaken to study the crop weather relationship of rainfed banana in Kerala.

The present investigation was, therefore, undertaken on the cultivation of banana var. palayankodan during 1986-'88 at the College of Horticulture, Kerala Agricultural University, Vellanikkara with the following objectives.

1. To correlate the various morphological characters with weather parameters.

2. To determine the phenologic phases of banana and their climatic needs.

3. To study the microclimate of the crop enviornment.

4. To correlate morphological characters with yield with a view to develop statistical models for forecasting the yield.

5. To correlate meteorological parameters with yield and evolve regression equations for the yield of banana.

6. To study the influence of time of planting on growth, yield and quality of the rainfed banana palayankodan.

7. To find out the optimum time of planting of rainfed banana palayankodan and to make recommendation based on the above study.

Review of Literature

REVIEW OF LITERATURE

Over the past few decades, research into crop weather relationships has received considerable attention. Simulating, analysing and assessing crop responses to weather and climate have found an important place in research and operational field assessment. A considerable effort has been made in recent years towards the practical application of crop weather models on a regional scale, to increase agricultural production. Numerous publications on specific aspects of weather and climate in relation to crop yields particularly cereals have appeared in recent times. However, not much work has been reported on the crop weather relationship of banana. Banana a herbaceous mesophyte has got a reputation for requiring the plentiful supply of water. Though, banana is more sensitive to moisture stress compared to many other fruit crops, the cultivar palayankodan can withstand waterstress to some extent. Hence it is cultivated mainly under rainfed conditions in Kerala. Studies on the relationship between weather and rainfed banana are very meagre. Experimental evidence on the effect of time of planting on banana is also not widely available. Hence, the relevant literature available on these aspects for banana along with few other important crops is briefly reviewed.

2.1 Effect of time of planting on plant characters and yield

2.1.1 Plant characters

Turner (1970) reported that the total number of leaves produced prior to bunch emergence vary with the time of planting. The investigation carried out by Chakrabarty and Rao (1980) revealed that summer planting promoted the leaf production in banana more significantly than winter planting. They observed that in Tamil Nadu May plantings produced greater leaf number and leaf area than those planted in December. The enviornment associated with summer planting had a significant bearing on the production of leaf number and leaf area in summer planted peepers. The pseudostem girth measurements showed relatively higher values in summer planted crops upto the seventh month.. Beyond this period, winter planted crops recorded higher values. Winter planting was conducive to produce greater leaf area with a widening trend in Robusta and Monthan, but in Poovan, this increase was of lower magnitude. For all the cultivars, winter planting was helpful in maintaining a larger number of functional leaves than summer planting. These differences were found to be a function of cultivar characteristic. They have also observed that with regard to the duration of opening of female phase, there was no influence of the time of planting.

Chattopadhyay et al. (1980) observed significant variation in plant height between December and other periods of planting both in plant and ratoon crops in Tamil Nadu. Plant height was maximum for August planting in plant crop and for February planting in ratoon crop. The pseudostem girth was maximum in February planting both in plant and ratoon crops. While it was minimum in August planting in plant crop and December planting in ratoon crop. Peepers planted in December in the case of plant crop and in August in the case of ratoon crop showed least increase in plant girth as compared to other months of planting. Highest leaf number was found in April planting of peepers, August planting of rhizomes and by planting suckers in February. Largest number of suckers were produced in October planting and the lowest in August and June plantings. The suckers produced inflorescences in 336 to 405 days after planting, depending on the planting time. Planting of suckers in February showed the earliest flowering.

Robinson (1981) reported that in subtropical banana growing areas, such as Burgershall in South Africa, a temperature induced growth periodicity limits the planting season and, especially in ratoon cycles, creates a natural tendency for overproduction in spring/summer and a shortage in the autumn.

Flores et al. (1982) studied the seasonal variation in the foliar system of banana cultivars during the dry and rainy seasons. They found that the leaf number, area and thickness, and stomata density decreased during the dry season. Robinson et al. (1983) observed that the annual growth potentials of banana in South Africa is mainly pre-determined by climate.

Robinson (1984) found that mid-December planting enabled 72% of the plant crop to be harvested during the autumn (March-May) when prices are high; with mid-September planting, 94% of the crop was harvested during the summer (Dec.-Feb.) but mid-March planting was unsuitable, with 95% of the crop being harvested in spring. They also observed that the times from planting to harvest were 16.6, 17.2 and 19.7 months, respectively.

Reddy *et al.* (1984) reported that August to February plantings had taken more number of days for harvesting while March-July plantings required comparatively less number of days. The more number of fruits/bunch were observed in the plantings of April to July.

According to Sathyanarayana *et al.* (1984), July to September plantings recorded the highest germination percentage, plant height, plant girth, sucker production, number of fruits and bunch yields with optimum duration.

2.1.2 Yield characters

a. Banana

Wills and Berril (1953) reported that in Southern Queensland, banana planting takes place from September to February and usually late December or early January planting produces the best results. Bananas planted in March/April have grown better and gave higher yields than those planted later, upto December. Gowder *et al.* (1960) observed that the suckers planted in the month of October gave the highest average yield, while those planted in June gave the least. He also observed that the months of

August, September, November and December did not differ significantly from October, the best month for planting, indicating thereby that the period from August to December was a favourable season for planting.

Bhakthavatsalu et al. (1973) studied the effect of planting in September, December and February on the yield of banana at Aduthurai. October and November plantings were not taken up as they are normally rainy months. Planting during September gave good yields though a bit late in shooting. December planted crop produced poor and ill filled bunches and the crop raised during February was found to be highly susceptible to leaf spot.

Chattopadhay et al. (1980) reported that planting of banana between February and August in the Gangetic plains of West Bengal gave better yields. They also observed that planting in February and August recorded heavier bunches irrespective of the planting material used.

Turner (1983) found that with November planting, the proportion of fruit harvested in autumn and winter was high in the plant crop, and much less in ratoon crops; over 3 crop cycles, the proportional distribution between seasons was uniform. With January planting, the proportion of fruit harvested in autumn and winter was low in the plant crop and high in the ratoon crops; over 3 crop cycles, spring harvested fruit predominated and the proportion of summer harvested fruit was the lowest. With March planting, summer harvests predominated in all three crops.

Chundawat et al. (1984) observed that the yields ranged from 25.6 t/ha from banana plants planted in mid-December to 50.1 t/ha from those planted in mid-June. The next highest yield was from plants planted in mid-May. Haque (1984) reported that the yields ranged from 37-37.5 t/ha for plots planted in September/October to 26.8 t/ha for plots planted in February. Yields from plots planted in March and April/May were 0.88-5.3 t/ha.

Obiefuna (1985) observed that yield of plant-crop plantains increased from February to October plantings, though with significant variations. Robinson et al. (1986) observed that the yield per ha per year for the plant crop and first ratoon cycle, showed a small but significant decrease (4%) as planting date was delayed from September to December; and a large decrease (18%) with a delay from December to March. They also observed that December planting was optimal and September planting intermediate from a crop-timing view point.

Turner et al. (1987) found that each month's delay in planting after traditional date of November resulted in a 2-month delay in harvest date. The January planting had the greatest productivity and most bunches were harvested during the winter months when prices were expected to be high.

b. Other crops

Majumdar (1971) reported that the sowings on the 16th June and 16th July were more or less equally effective on the yield attributes in rice and were significantly better than the August sowings. Lingegowda et al. (1971) found that sowings in first and third week of June and first week of July recorded the highest yield in Sorghum. Pathak et al. (1971) observed that the sowing after break of monsoon was better for open pollinated maize varieties. Raj et al. (1971) found that optimum sowing in sesame was in the middle of July, after this the yield reduced significantly.

Singh *et al.* (1979) observed that delay in plantings often reduces the sowing season which adversely affects the growth and reduces grain yield in cereals. Rao *et al.* (1979) suggested that the long duration variety of rabi cereals should be sown early and short duration varieties late in the season for getting good yield.

Bajpai *et al.* (1981) found that 30th September and 15th October were the best sowing dates for seed yield and the maximum number of pods/plant in mustard.

Subbian *et al.* (1983) revealed that sowing on early February and early July were optimum for getting maximum yields in sorghum under Bhavanisagar conditions for summer and kharif seasons. Owen (1983) observed differences in yields of sunflower among planting dates. He found that mid to late July plantings produced less yield than late May and mid to late June plantings. Patel *et al.* (1983) reported that sowing dates had significant influence on grain yield of wheat. Wheat sown on 15th November registered the maximum grain yield which was significantly higher over rest of the sowing dates.

Desai _et al._ (1984) found that the higher fruit number/ha and the highest yield/ha in watermelon were obtained when sowing was done on 30th December and 20th January. It was the lowest in 20th November sowing. Reddy _et al._ (1984) observed that sowing of bunch groundnut in first fortnight of July was best under rainfed conditions in Andhra Pradesh, while delayed sowings gave lower yield. Ramshe _et al._ (1985) observed that sowing on 18th June was best for all the varieties of pearl millet. Ghosh _et al._ (1985) observed that in sesamum maximum yield (17 q/ha) was obtained in March sown crop followed by February and August sown crop. The October sown crop produced the lowest yield.

Sarah (1986) studied the effect of date of sowing on growth and yield of bittergourd variety priya and revealed that bittergourd can be raised successfully in summer season at Vellanikkara by sowing on December 1st. Experiment conducted by Patel _et al._ (1986) revealed that with delay in sowing pod yield of groundnut decreased significantly due to reduction in number of pods per plant. Rajput _et al._ (1986) found that maximum grain yield was obtained in 15th November sowing in chickpea.

Ramaiah *et al.* (1987) revealed that transplanting on 15th July increased the dry matter production, total number of tillers and panicles per m^2, panicle weight, number of filled grains/panicle, grain and straw yield as compared to other dates of planting in rice.

Bhosle *et al.* (1987) revealed that the yield due to sowing from 1st February to 15th February were comparable and significantly more as compared to the yield obtained with sowing on 2nd March in groundnut. Bainade *et al.* (1987) revealed that forage maize sown in 39th meteorological week (24th to 30th September) or latest by 41st meteorological week (8th to 14th October) produced significantly highest green forage.

2.2 Effect of plant characters on yield

The studies conducted by Hartman and Bailey(1929) on the effect of defoliation on banana weights revealed that when a plant is grown under favourable conditions, it may have 10-14 good foliage leaves to support the rapid growth and 'filling-out' of its bunch and the formation of its daughter suckers. If at the time of shooting, only 5 to 7 functional leaves remain, the growth of the bunch to harvesting maturity is likely to be more or less seriously delayed and fruit of commercial quality may not be obtained.

According to Berril (1956), poor filling of banana fruits can be prevented if the plants have an efficient root system and a large healthy crown of leaves. Murray (1961) reported after his investigations on shade and fertilizer relations in the banana that a strong correlation existed between the size of the third leaf at the age of six months and the final weight of the bunch in a plant crop of 'Dwarf Cavendish'. Lossois (1964) showed a high correlation between yield and the circumference of the pseudostem of flowering time at 1 m above soil level. Turner (1970) reported that the differentiation of the bunch occurs after a certain number of leaves are produced by the plant. He also opined that the four leaves preceding to shooting influence the maturation and weight of bunch.

Lassoudiere (1978) reported after his investigations on some aspects of growth and development of the Poyo banana conducted at Ivory Coast that a strong correlation existed between the quality of roots produced and bunch weight, the critical period was during establishment. The studies conducted by Chakrabarthy et al. (1980) on the influence of planting seasons on certain growth and morphological characters of banana revealed that the leaf area is an important index of vigour which influence the consequential yielding capacity of a cultivar. Stover (1981) reported after his investigations on plant and foliage characteristics of a proposed banana ideotype that at a population density of 1730 plants/ha the leaf area index for Grand Nain was 3.21, compared with 4.33 for Valery. Grand Nain plants were upto 98 cm shorter, resulting in fewer wind losses and higher yields.

The studies conducted by Krishnan et al. (1983) on correlation studies in banana revealed that the height and girth of the pseudostem at shooting and the total leaf area showed a significant positive correlation with bunch weight. However, the days to shooting and to harvest showed a significant negative correlation with bunch weight. The number of hands and fingers/bunch and finger weight were positively and significantly correlated with bunch weight. Robinson et al. (1984) found that bananas flowering from November to March have a naturally smaller bunch size than those from April to September flowering plant.

Vijayaraghavakumar et al. (1984) reported after their investigations on comparitive study of the contribution of biometric characters on yield in dessert varieties of banana that the number of fingers has the maximum direct effect towards yield. Daniells et al. (1985) reported that the bunch weight increased with increase in the number of fingers per bunch, with no change in finger size. The studies conducted by Sathyanarayana (1985) on the effect of number of functional leaves on growth and yield of basarai banana revealed that with regard to plant height, and girth, day to flowering, bunch weight, hands/bunch, fruits/bunch and fruit length and girth, the effect of 12 to 16 functional leaves was very similar and on par with the controls. Kothavade et al. (1985) reported after their investigations on the effect of leaf area on the growth and yield of basarai banana that plant height rose as the number of leaves/plant increased. The yield also found to be increased. They also observed that the chemical quality of fruits increased with increase in the levels of functional leaves.

The studies conducted by Hegde (1986) on the growth and yield analysis of 'Robusta' banana in relation to soil water potential and nitrogen fertilization revealed that increasing N application from 100 to 200 g/plant significantly increased the fruit yield, this improvement being due to significant increase in LAI, LAD and CGR.

2.3 Effect of weather on plant characters and yield

2.3.1 Plant characters

Summerville (1944) reported after his studies on nutrition as qualified by development in Musa cavendishii L. conducted at Queensland that the time interval between emergence of successive leaves is reduced by low temperatures. The 'Dwarf Cavendish' produced leaves at a higher rate in the warm autumn weather (March) but much less rapidly in winter. He also reported that the time interval between the emergence of successive leaves in tropical climate is 7 days although extremes vary from as low as 6 to 20 days in subtropical climate. Leaf longivity varies from 71 to 281 days for plants in Southern Queensland, being closely related to the month of emergence. He recognised flowering as a function of the total expanded leaf area, the exposure of each leaf to sufficient hours of day light and the mean temperature during the functional life of each leaf. Boyriven et al. (1955) reported that winds cause the leaves to split, and hamper the assimilations of chlorophyl.

Nagpal et al. (1958) reported that the growth, flower bud differentiation and fruit development were adversely affected in months when the average temperature was below 75°F. Smirin (1960) opined that the low temperatures lengthen the period between shooting and maturity of the bunch. The difference in temperature between the various seasons causes the period between emergence and harvest to vary between 80 to 240 days.

Green et al. (1969) reported after their investigations on growth of banana plant in relation to winter air temperature fluctuations that the growth of banana was closely related to air temperature, the response to temperature fluctuations being exceedingly fast, so that a growth estimate could be made from temperature data alone. The studies conducted by Sanchez - Nieva (1970) on effect of zone and climate on yields, quality and ripening characteristics of montecristo banana at Puerto Rico revealed that any period of temperature below 20°c will slow down growth and the rate of fruit maturation. He also observed that in Honduras, the duration from flowering to harvest varies seasonally with temperatures from an average of 90 to 120 days. Fruit maturation times also increase with altitude mostly as a result of lower temperatures. Turner (1971) reported that the time interval between emergence of successive leaves is influenced by temperature, wind velocity and relative humidity.

Manshard (1974) reported that next to temperature, rainfall determines where most bananas and plantains are produced in the tropics. The studies conducted by Kuhne (1975) on seasonal variations in the development cycle of the dwarf cavendish banana at Burgershall revealed that the annual growth potentials of banana in South Africa is mainly predetermined by climate. Warner *et al.* (1976) reported after their investigations on effect of nitrogen and climatic factors on seasonality of banana production conducted at Hawaii that growth rates were lower from November to April when solar energy was 257 cal/cm^2 per day and maximum-minimum temperatures were 26°c and 18°c. Wardlaw (1979) observed that at high temperatures top growth is favoured. In many species, the root-shoot ratio decreases with increase in temperature. He also made a distinction between sub-optimum conditions for growth and and critical temperature, above or below which a plant will either die, or become dormant.

Ganry (1980) reported that the optimum temperature for foliar growth in banana is between 26 and 28°c and slightly higher at 29-30°c for fruit growth. Korovin (1981) observed that the plant response to a range of temperature differs during different periods of its life cycle. During the periods of adaptation and damage, the temperature had a marked effect on growth and development and yield of the plants. Lahav (1982) opined that plant dry weight was greatest at 25/18°c and leaf area was greatest at 33/26°c. Higher temperatures induced horizontal leaves.

Experiments conducted in growth chamber by Turner *et al.* (1983) revealed that leaf area production was greatest at 33°c day and 26°c night. Also, bunch size was best with a pseudostem temperature near the growing point of 21-24°c. Stover *et al.* (1987) opined that in Honduras temperature and radiation data are useful for predicting the rate of plant and fruit development. They also observed that strong winds (relative humidity 25-50%) with maximum temperatures of 38-42°c caused widespread damage to the lamina where it joins the main vein.

2.3.2 Yield characters

The studies conducted by Summerville (1944) on nutrition as qualified by development in *Musa Cavendishii* L. revealed that the fruit number was correlated with the climatic conditions that prevail during the period of development of the last three or four leaves. Boyriven *et al.* (1955) observed that the forming of the fruit is hindered by a lowering of temperature between December and March, in the Canary Islands. The development of the fruit in slightly cooler climate is less than that in a higher temperature. A mean temperature of 25.5°c during the harvest month increase the weight of the fruit. An increase in rainfall from the 10th to 5th month before picking increases the number of hands and the weight of the fruit. Rose (1986) reported that for fruit emerging in June, July, September, November and December, the time to reach maturity was related to the number of heat units received during the maturation period.

Obiefuna (1985) reported after his investigations on the effect of monthly planting on yield, yield patterns and and yield decline of plantains (Musa AAB) that plants established between July and December experienced minimum wind damage and produced significantly higher yields. Stover et al. (1987) opined that weather measurements are very important in banana plantations to provide historical base of data for predicting seasonal production trends. They also observed that bananas require between 25 to 50 mm of water weekly or 1.2-1.4 times class A pan evaporation for maximum production. Winds in excess of 40 km/hr are the single highest cause of losses in banana plantations of taller varieties and in excess of 70 km/hr for dwarf varieties.

2.4 Fruit quality

Fruit quality is influenced by time of planting. However, few attention have been made to study the effects of time of planting on the quality aspects of banana fruit. Teaotia *et al.* (1972) observed marked increase in the concentration of total soluble solids, total sugars, acidity and TSS/acid ratio in fruits produced on water-stressed plants. Krishnan and Shanmugavelu (1979) could also observe a similar trend in fruit quality under conditions of soil water deficits. They noticed substantial increase in the concentration of total soluble solids, reducing sugars, total sugars and acidity of fruits under stressed conditions.

Materials and Methods

MATERIALS AND METHODS

A field experiment designed to study the crop weather relationship of rainfed banana under different times of planting was conducted during December 1986 to July 1988, at the College of Horticulture, Kerala Agricultural University, Vellanikkara. The details of the materials used and the techniques adopted during the course of the investigation are briefly described below.

3.1 Materials

3.1.1 Site and climate

The site is situated at 10° 31'N latitude and 76° 13'E longitude at an altitude of 22 m above MSL. This area enjoys a typical humid tropical climate.

3.1.2 Season

The experiment was conducted during the period December, 1986 to July, 1988.

3.1.3 Cultivar

'Palayankodan' a popular cultivar of banana in Kerala which is mainly grown as a rainfed crop was selected for the study. It comes under the subgroup poovan with AAB genome. Three month old suckers were selected for planting.

3.1.4 Manures and fertilizers

Farm yard manure at the rate of 10 kg per plant was applied uniformly to all the pits as basal dose. Urea, mussouriphos, muriate of potash were applied as fertilizers to supply the required quantity of nitrogen (at the rate of 100 g per plant), phosphorus (at the rate of 200 g per plant) and potassium (at the rate of 400 g/plant) respectively. The fertilizers were applied in two equal split doses. First dose at 3 months after planting and the second at 5 months after planting.

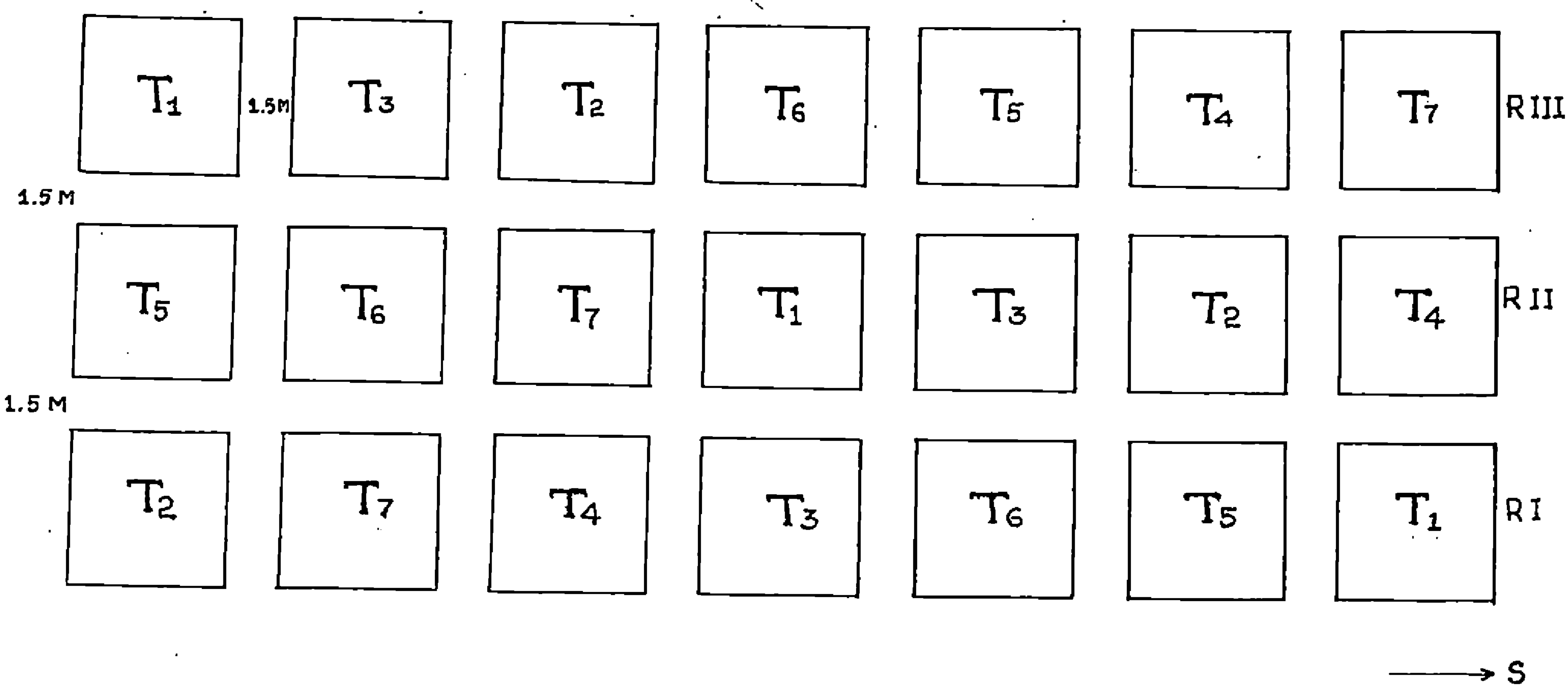
3.2 Methods

3.2.1 Layout

The experiment was laid out in randomised block design with three replications. The layout plan is given in fig.1. In each plot, there were 25 plants. The treatments consisted of 7 times of planting. The details of the different treatments and the notations used to represent the treatments are given below.

Treatment (Time of planting)		Notations
1st week of December	-	T_1
1st week of January	-	T_2
1st week of February	-	T_3
1st week of March	-	T_4
1st week of April	-	T_5
1st week of May	-	T_6
1st week of June	-	T_7

FIG. 1. LAYOUT



T1
1.5M
T3
T2
T6
T5
T4
T7
R III
1.5 M
T5
T6
T7
T1
T3
T2
T4
R II
1.5 M
T2
T7
T4
T3
T6
T5
T1
R I
S

3.2.2 Cultural operations

The land was ploughed and then levelled. Plots of 15 m x 15 m size were taken leaving 1.5 m gap between the plots. Area inside each plot was levelled properly and twenty five pits of 50 cm depth and 50 cm width were taken at a spacing of 2.13 m x 2.13 m.

The pits were filled partly with top soil and the recommended quantity of farm yard manure. The selected suckers were then planted in the centre of the pits.

At all the seven times of planting, few additional suckers were also planted at a plot nearby. These standby suckers were used for possible substitution in the experimental plots, when damages due to diseases or wild pig attack were noticed. The plots were kept weed free throughout the crop growth period. During the dry season, only life saving irrigation was provided. The plants were staked with bamboo poles just before shooting to avoid the wind damage. As a prophylactic measure thimet granules at the rate of 25 g per plant was applied in pits at the time of planting suckers. All other cultural and management practices were adopted uniformly for all the plantings.

3.2.3 Harvesting

The bunches were harvested as and when they matured. The harvesting was completed by 15 months after planting. It varied with the different times of planting.

3.3 Observations

3.3.1 Biometric characters

Observations on various morphological characters were recorded at monthly intervals from 30 days after planting to harvest adopting the method suggested by Yang and Pao (1962).

(a) Height of pseudostem

The height of the plant was measured from the base of the pseudostem to the axil of the youngest leaf and recorded in cm.

(b) Girth of pseudostem

The girth of the pseudostem was measured at 20 cm from the ground level.

(c) Total leaf area

The area of each functional leaf was calculated by the formula given by Murray (1960). The total leaf area per plant was found by adding all the functional leaves' area.

(d) Total number of leaves

The total number of fully opened functional leaves present at the time of observation was recorded.

(e) Sucker production

The number of suckers per plant was recorded.

(f) Days for shooting

The number of days taken from planting to shooting were recorded.

(g) Days taken from shooting to harvest

The number of days taken from shooting to harvest were recorded.

(h) Length of bunch

The length of the bunch was measured from the point of attachment of the first hand to that of the last hand and recorded in cm.

(i) Number of fingers per bunch

The number of fingers on the bunch was counted and recorded.

(j) Weight of bunch

Weight of the bunch including the peduncle was recorded.

(k) Number of hands

The number of hands on each bunch was counted and recorded.

(l) Weight of hand

The weight of the representative hand on the bunch was recorded in kg.

(m) Number of fingers per hand

The second hand from the base of the bunch was selected as the representative hand and the number of fingers present in it were counted and recorded.

(n) Length of finger

Length of the finger was measured from the point of attachment to the tip using a fine thread and a scale. The middle finger on the top row of the second hand (from the base of the bunch) was selected as the representative finger for recording the finger characters (Gottreich et al. 1964).

(o) Girth of finger

Girth of the finger was measured at the mid-portion using a fine thread and a scale and expressed in cm.

3.4 Qualitative analysis of fruits

The fruits collected from well ripe bunches were used for quality analysis. The middle fruit in the top row of the second hand was selected as the representative sample. Samples were taken from each fruit from three portions., viz. top, middle and bottom and these samples were then pooled and macerated in a waring blender. Triplicate samples from this were used for analysis of different constituents as detailed below.

(a) Total soluble solids

Total soluble solids was found out by a pocket refractometer and was expressed as percentage.

(b) Acidity

Ten g of the macerated sample was mixed with distilled water and made upto a known volume. An aliquat of the filtered solution was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid (A.O.A.C., 1960).

(c) Reducing sugars

The reducing sugars of the sample were determined as per the method described by A.O.A.C. (1960).

To a known quantity of macerated pulp, a small quantity of distilled water was added. The solution after thorough mixing was clarified with neutral lead acetate and deleaded with sodium oxalate and made upto a known volume. The solution was titrated against a mixture of Fehling's A and B solutions using methylene blue as indicator. The content of reducing sugars was expressed as percentage.

(d) Total sugars

Total sugars were determined as per the method described by A.O.A.C. (1960). Five ml. of concentrated hydrochloric acid was added to a known volume of clarified solution and the content was kept overnight. The solution was then neutralized by adding sodium hydroxide and titrated against a mixture of Fehling's A and B solutions.

(e) Non-reducing sugars

This was computed by working out the difference between the total and reducing sugars.

(f) Sugar acid ratio

This was arrived at by dividing the total sugars with titrable acidity.

3-5 Meteorological data during the period of plant growth

The daily values of the following meteorological parameters were recorded.

a) Maximum temperature
b) Minimum temperature
c) Rainfall
d) Relative humidity
e) Bright sunshine hours
f) Windspeed and
g) Pan evaporation

The monthly meteorological data from December 1986 to July 1988 are presented in the Appendix I. Soil temperature observations at 5,10 and 20 cm depths twice daily were also recorded.

3.6 Statistical analysis

The data recorded were subjected to statistical analysis by applying the analysis of variance technique for randomised block design (Panse and Sukhatme, 1985).

3.7 Crop weather relationship

Simple linear correlation between the various growth and yield characters, and the weekly weather parameters for the overlapping periods from 1 to 13 months after planting were worked out. Correlations were also worked out between yield and important morphological characters.

The crop growth characters selected are :

1. Height of pseudostem at 6 months after planting.
2. Girth of pseudostem of 6 months after planting.

3. Number of days taken from shooting to harvest.
4. Monthwise change in height of pseudostem.
5. Monthwise change in girth of pseudostem.
6. Number of leaves at 9 months after planting and shooting.
7. Leaf area at 9 months after planting and shooting.

The yield characters selected are :

1. Weight of the bunch
2. Weight of the hand

The monthly values of mean temperature, rainfall, relative humidity, windspeed, bright sunshine hours and evaporation are considered as the important weather elements. Multiple linear regression equations were developed between weather elements and bunch weight.

A comparison between the yields estimated from these regression equations and the actuals is also made.

Results

RESULTS

During the course of investigation to study the crop weather relationship of rainfed banana under different times of planting at Vellanikkara, observations on the various biometric and bunch characters, and weather were recorded. The data collected were subjected to statistical analyses and the results are presented below.

4.1 Weather conditions

The total crop growth period for all the treatments was about twenty months. The first planting was done in the 1st week of December 1986 and the last planting was harvested in July 1988. The data on the weather conditions during this period are presented in Fig.2 and Fig.3 and Appendix I.

4.2 Microclimate - Soil temperatures

Information on soil temperatures is basic to studies on soil climate which inturn influences the phytoclimate. Hence, the soil temperatures at 5 cm, 10 cm and 20 cm

FIG. 2. WEATHER CONDITIONS DURING THE CROP PERIOD

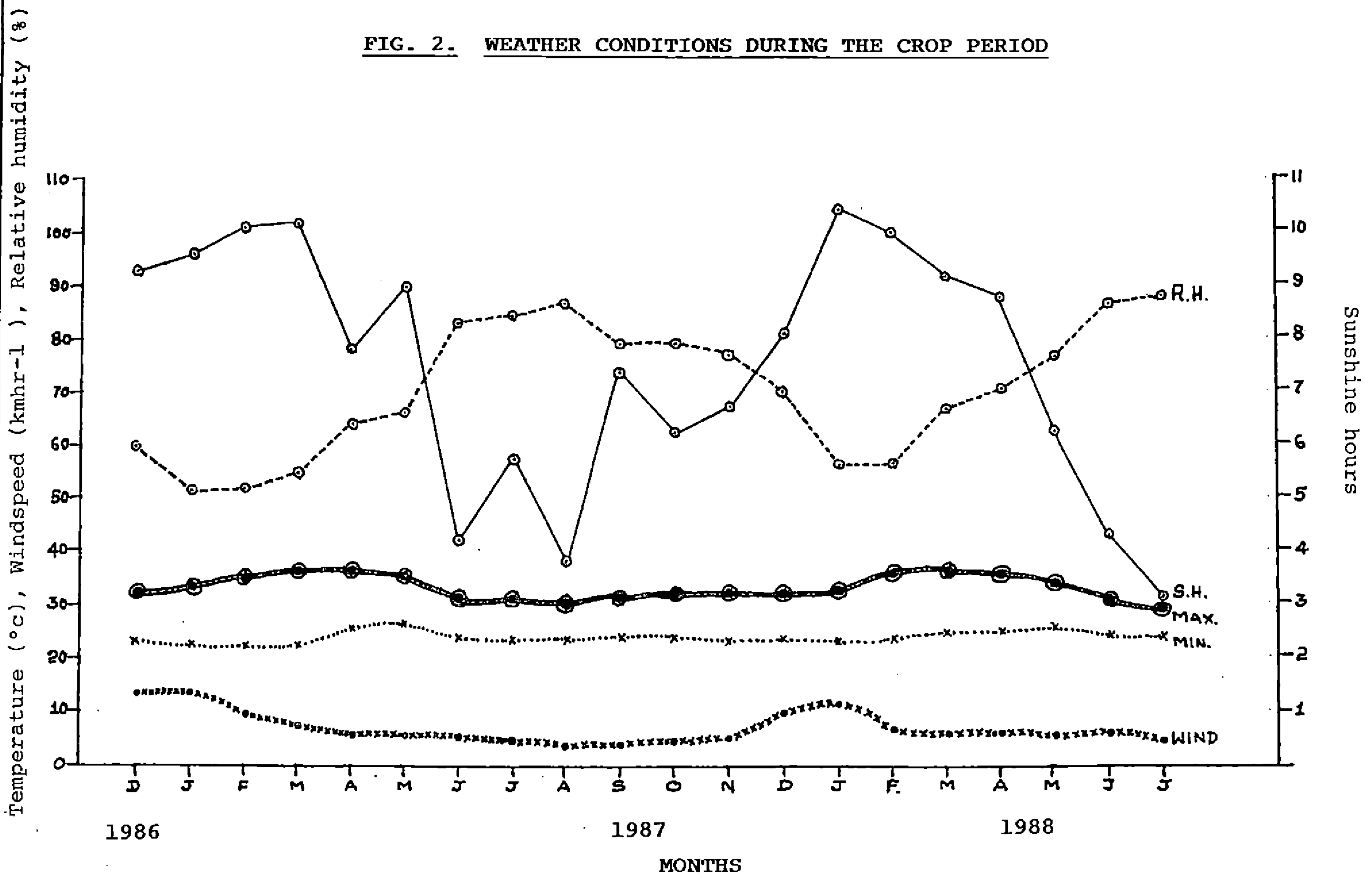
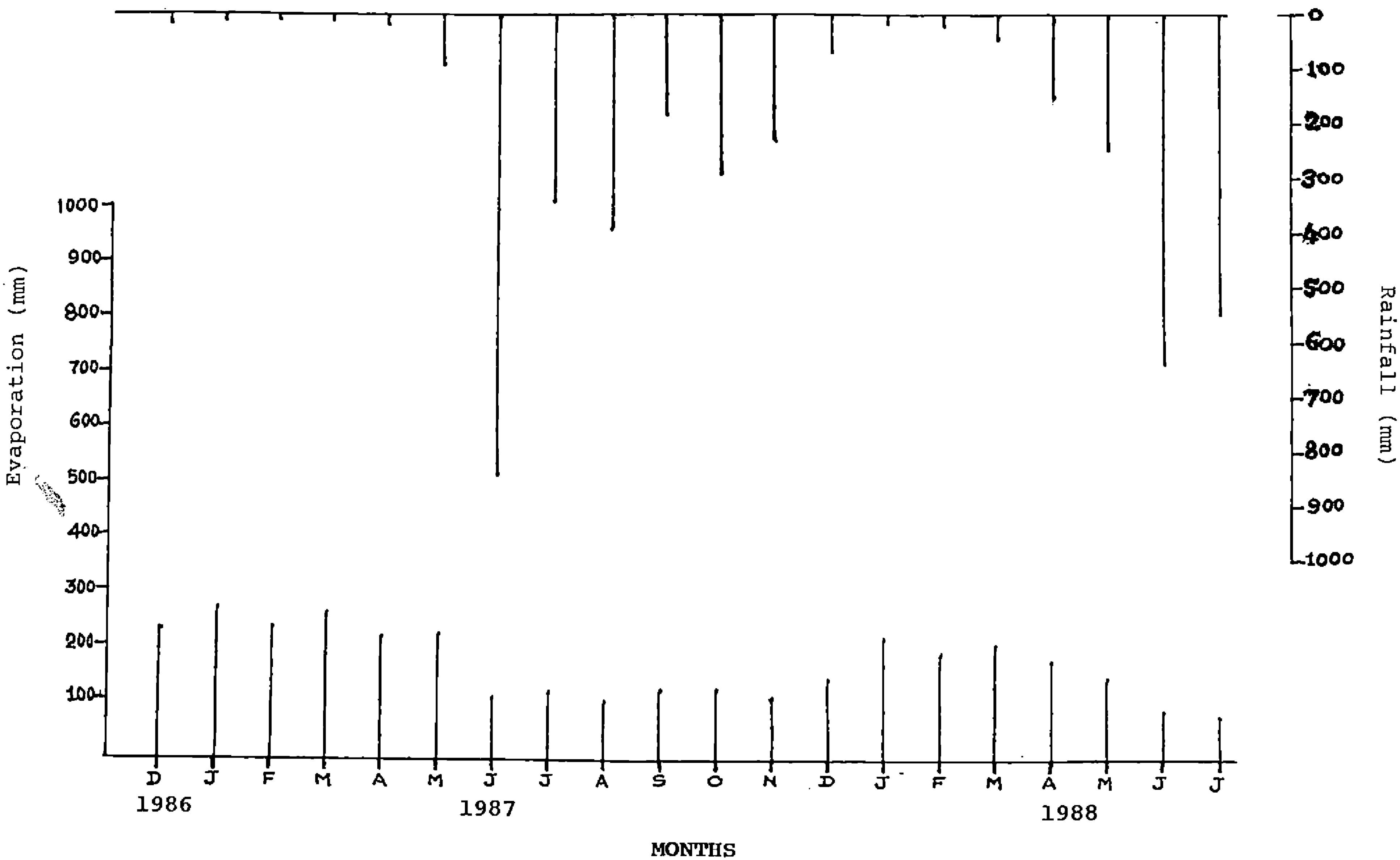


FIG. 3 RAINFALL AND EVAPORATION DURING THE CROP GROWTH PERIOD



depths recorded two times a day i.e., 0700 Hrs LMT and 1400 Hrs LMT were collected. Monthly averages were worked out for the three depths at both the times and shown in the figures 4A amd 4B.

4.3 Growth parameters

4.3.1 Height of pseudostem

The mean values of the height of pseudostem recorded at various stages of growth are presented in Table 1. and illustrated in Fig.5. The analysis of variance is given in the Appendix II.

Height of the pseudostem was significantly influenced by the time of planting at almost all the stages of growth except at shooting and later stages. At 3 months after planting, T_7 recorded the highest value and T_1 recorded the lowest value which was on par with T_2, T_3 and T_4. At 6 months after planting, T_7 recorded the highest value which was on par with T_5 and T_6. The lowest value was recorded by T_1 which was on par with T_2. T_6 recorded the highest

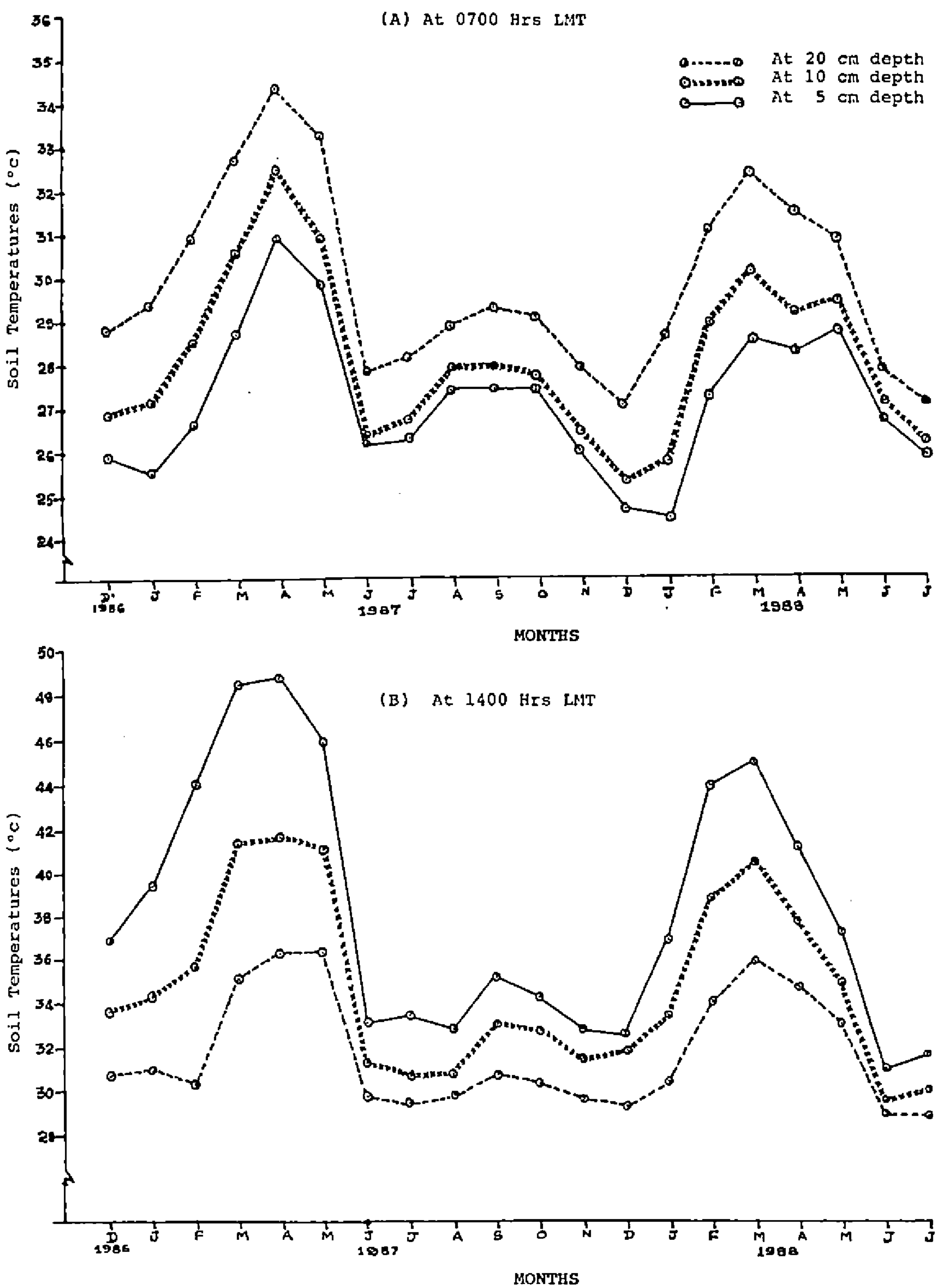
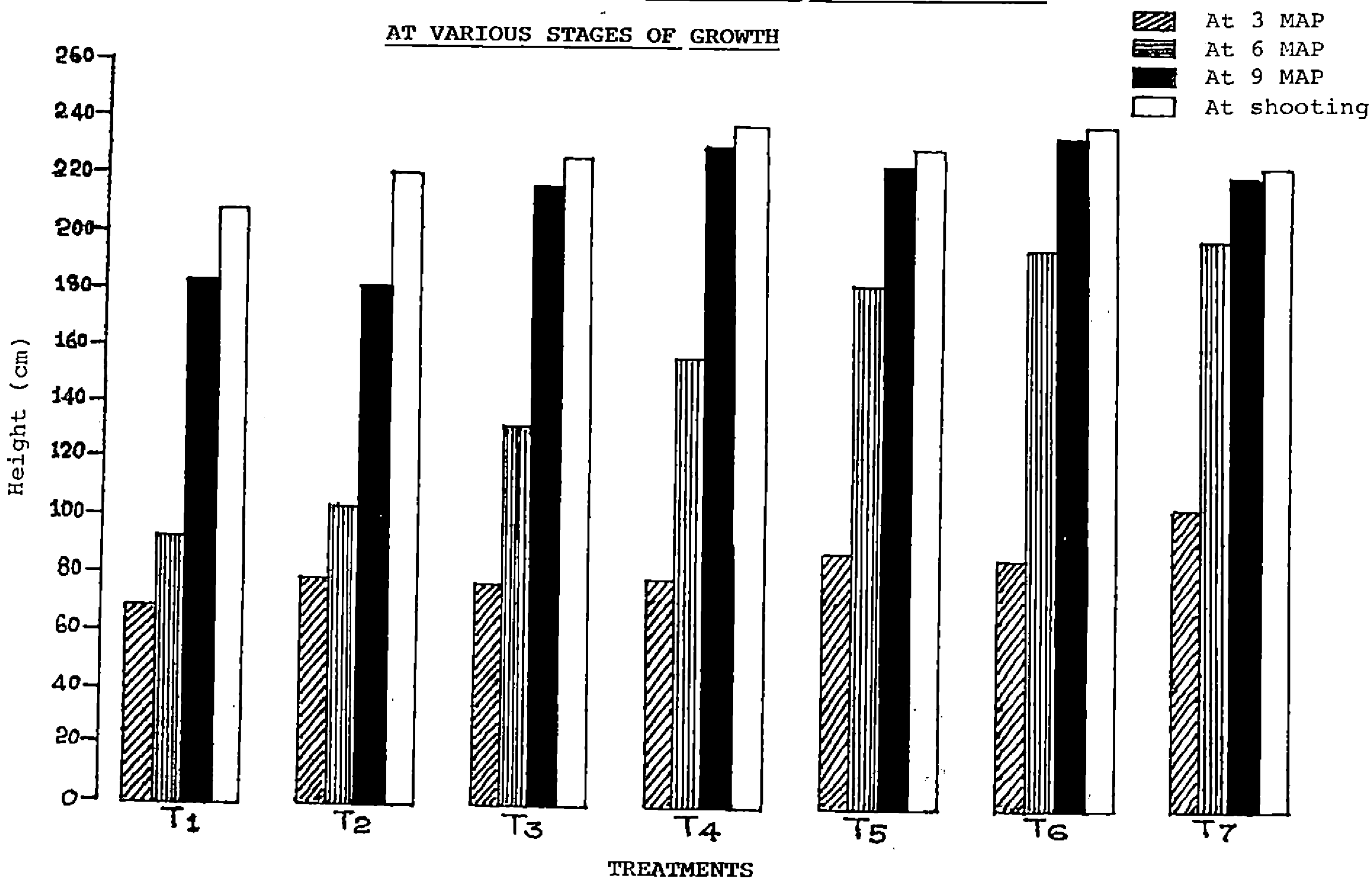


FIG. 4. SOIL TEMPERATURES (°C)

Table 1. Effect of time of planting on the height of pseudostem (cm) at various stages of growth

Treatments	3 months after planting	6 months after planting	9 months after planting	At shooting
T_1	69.53	93.20	183.73	208.67
T_2	78.60	103.53	180.13	221.07
T_3	76.67	130.27	216.20	226.93
T_4	78.67	157.53	231.53	239.07
T_5	88.80	183.67	224.73	231.27
T_6	86.60	195.20	234.13	237.87
T_7	103.80	198.00	220.53	222.53
$SE_m \pm$	3.03	7.90	11.39	9.14
CD (0.05)	9.33	24.34	35.09	NS

FIG. 5. EFFECT OF TIME OF PLANTING ON THE HIGHT OF PSEUDOSTEM AT VARIOUS STAGES OF GROWTH



value at 9 months after planting which was on par with T_3, T_4, T_5, and T_7. The lowest value was recorded by T_2 which was on par with T_1. There was no significant difference in height of pseudostem at shooting.

The correlation coefficients between weather and the height at 6 months after planting are presented in the Table 2. Rainfall and relative humidity during the first five months correlated positively whereas sunshine during the same period correlated negatively with the height of pseudostem. Temperature during 2-6 months after planting, and windspeed and evaporation during the first 6 months after planting are negatively correlated with height.

4.3.2 Girth of pseudostem

Table 3 and Fig.6 shows mean values of the girth of pseudostem recorded at various stages of growth. The analysis of variance is given in the Appendix III.

Girth of the pseudostem was significantly influenced by the time of planting at almost all stages of growth except at shooting and later stages. At 3 months after

Table 2. Correlation coefficients between weather and crop growth characters at 6 months after planting

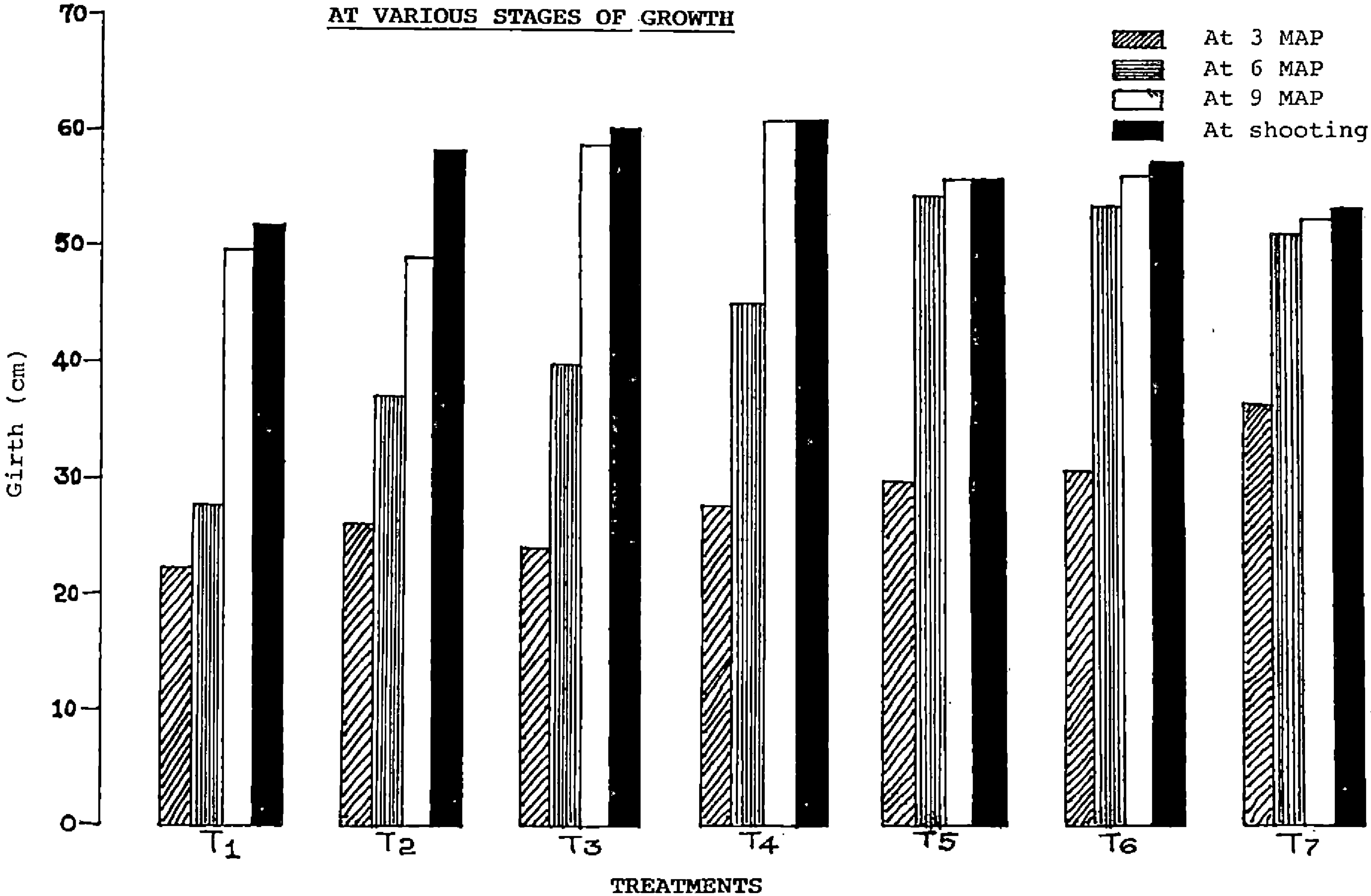
Weather element	Significant period (months after planting)	*Correlation coefficient	
		Height of pseudostem	Girth of pseudostem
Rainfall	1-5	+0.952	+0.936
Relative humidity	1-5	+0.967	+0.936
Sunshine hours	1-5	-0.936	-0.937
Mean temperature	2-6	-0.978	-0.906
Wind speed	1-6	-0.929	-0.951
Evaporation	1-6	-0.955	-0.933

* Significant at 1% level

Table 3. Effect of time of planting on the girth of pseudostem (cm) at various stages of growth

Treatments	3 months after planting	6 months after planting	9 months after planting	At shooting
T_1	22.30	27.10	49.20	51.13
T_2	25.63	36.47	48.67	57.93
T_3	23.43	39.20	58.33	59.40
T_4	27.43	44.33	60.33	60.33
T_5	29.33	53.93	55.07	55.07
T_6	30.00	52.87	55.47	56.13
T_7	35.60	50.40	51.47	52.20
SEm ±	1.12	2.41	2.41	2.42
CD (0.05)	3.44	7.41	7.43	NS

FIG. 6. EFFECT OF TIME OF PLANTING ON THE GIRTH OF PSEUDOSTEM AT VARIOUS STAGES OF GROWTH



planting, T_7 recorded the highest value and T_1 recorded the lowest value which was on par with T_2 and T_3. At 6 months after planting, T_5 recorded the highest value which was on par with T_6 and T_7. The lowest value was recorded by T_1. T_4 recorded the highest value at 9 months after planting which was on par with T_3, T_5 and T_6. The lowest value was recorded by T_2 which was on par with T_1, T_5, T_6 and T_7. There was no significant difference in girth of pseudostem at shooting.

Table 2 shows the correlation coefficients between weather and the girth of pseudostem at 6 months after planting. The values indicate that at 6 months after planting, both the height and girth of pseudostem responded similarly to the prevailing weather conditions.

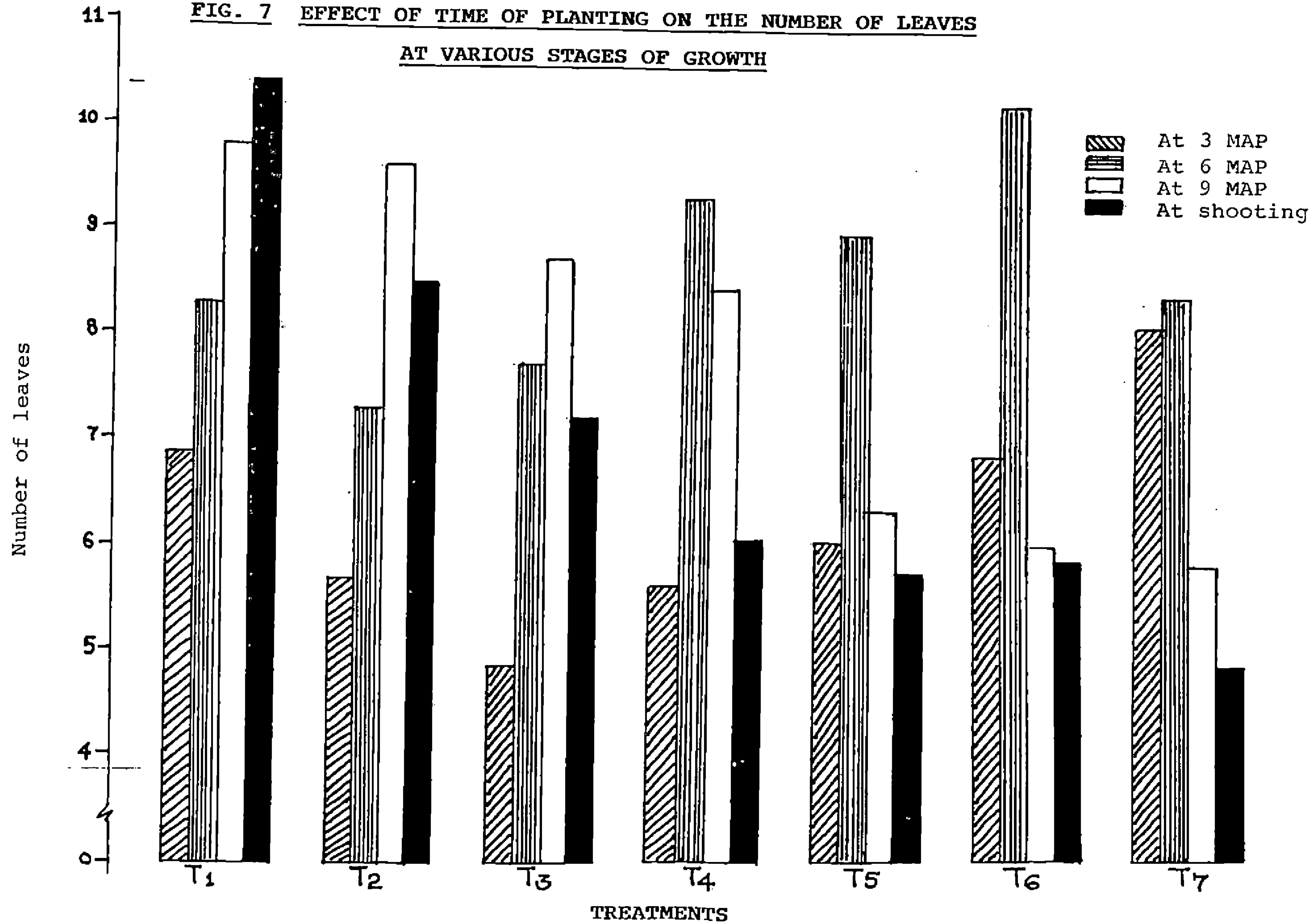
4.3.3 Number of leaves

The mean values of the number of leaves at various stages of growth are presented in Table 4 and Fig. 7. The analysis of variance is given in the Appendix IV.

Table 4. Effect of time of planting on number of leaves at various stages of growth

Treatments	3 months after planting	6 months after planting	9 months after planting	At shooting
T_1	6.93	8.33	9.80	10.40
T_2	5.67	7.33	9.60	8.53
T_3	4.87	7.73	8.67	7.20
T_4	5.60	9.27	8.40	6.07
T_5	6.03	8.93	6.33	5.73
T_6	6.80	10.13	5.93	5.80
T_7	8.00	8.27	5.73	4.80
SEm ±	0.54	0.47	0.32	0.36
CD (0.05)	1.68	1.44	0.98	1.12

FIG. 7 EFFECT OF TIME OF PLANTING ON THE NUMBER OF LEAVES AT VARIOUS STAGES OF GROWTH



Number of leaves was significantly influenced by the time of planting at all the stages of growth. At 3 months after planting, T_7 recorded the highest value which was on par with T_1 and T_6. The lowest value was recorded by T_3 which was on par with T_2, T_4 and T_5. At 6 months after planting, T_6 recorded the highest value which was on par with T_4 and T_5. T_2 recorded the lowest value which was on par with T_1, T_3 and T_7. At 9 months after planting, T_1 recorded the highest value which was on par with T_2. The lowest value was recorded by T_7 which was on par with T_5 and T_6. At shooting also, T_1 recorded the highest value and the lowest was recorded by T_7 which was on par with T_5 and T_6.

4.3.4 Leaf area

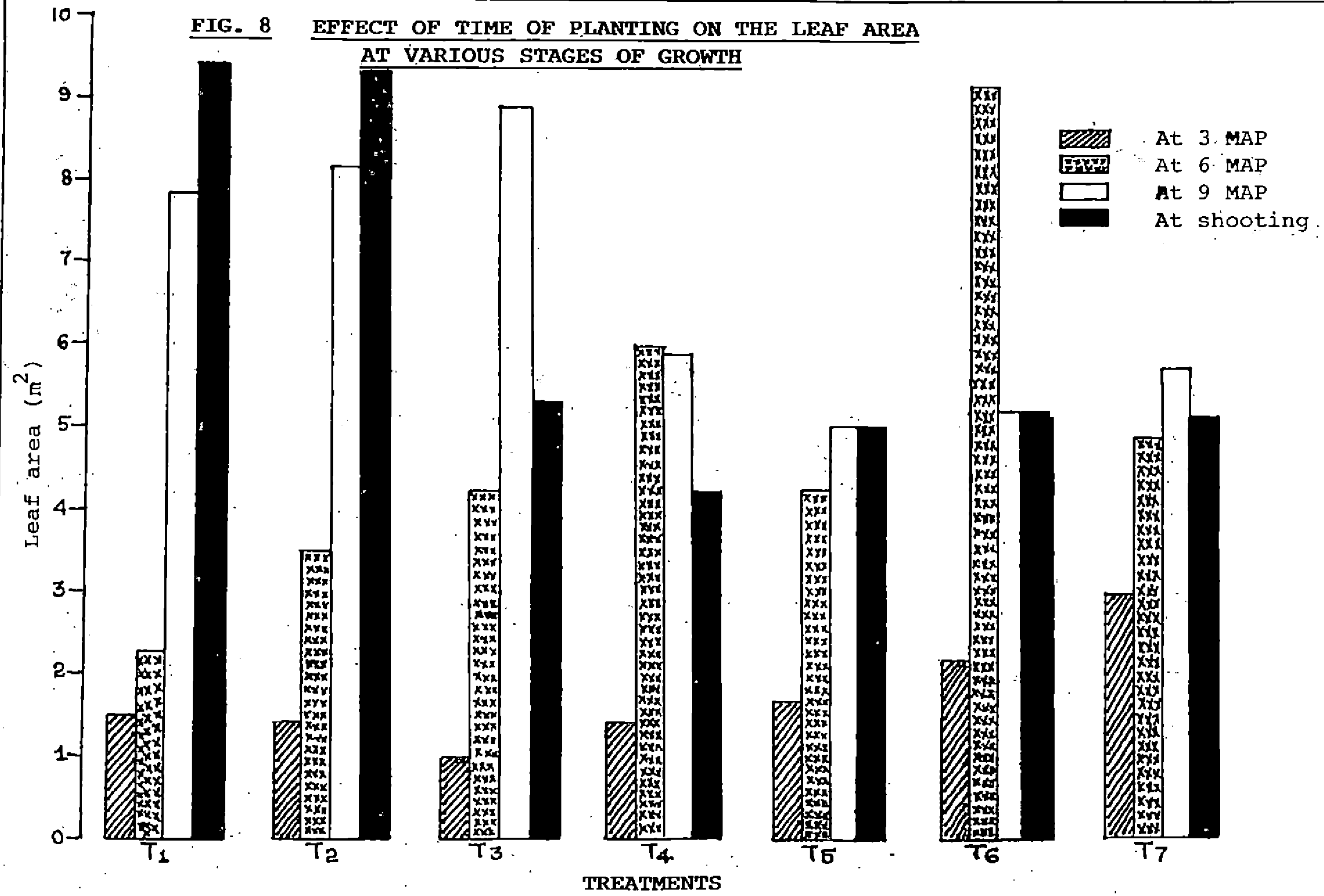
The mean values of the leaf area at various stages of growth are presented in Table 5 and Fig. 8. The analysis of variance is given in the Appendix V.

Leaf area was significantly influenced by the time of planting at the various stages of growth. At 3 months

Table 5. Effect of time of planting on leaf area (m^2) at various stages of growth

Treatments	3 months after planting	6 months after planting	9 months after planting	At shooting
T_1	1.46	2.26	7.87	9.46
T_2	1.40	3.54	8.18	9.39
T_3	1.00	4.24	8.97	5.38
T_4	1.41	6.03	5.92	4.24
T_5	1.61	4.36	5.05	5.02
T_6	2.18	9.20	5.22	5.23
T_7	3.00	4.90	5.75	5.18
SEm ±	0.25	0.38	0.64	0.63
CD (0.05)	0.77	1.17	1.99	1.95

FIG. 8 EFFECT OF TIME OF PLANTING ON THE LEAF AREA AT VARIOUS STAGES OF GROWTH



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after planting, T_7 recorded the highest value which was on par with T_6. T_3 recorded the lowest value which was on par with T_1, T_2, T_4 and T_5. At 6 months after planting, T_6 recorded the highest value. The lowest value was recorded by T_1. T_3 recorded the highest value at 9 months after planting which was on par with T_1 and T_2. The lowest value was recorded by T_5 which was on par with T_4, T_6 and T_7. At shooting, T_1 recorded the highest value which was on par with T_2. T_4 recorded the lowest value which was on par with T_3, T_5, T_6 and T_7.

4.3.5 Sucker production

The mean values of sucker production at shooting and at harvest are presented in Table 6. The analysis of variance is given in the Appendix VI.

There was no significant difference in sucker production at shooting. Whereas, at harvest T_7 recorded the highest value which was on par with T_4 and T_6. The lowest value was recorded by T_1 which was on par with T_2, T_3, T_4 and T_5.

Table 6. Effect of time of planting on sucker production

Treatments	At shooting	At harvest
T_1	2.27	3.42
T_2	2.20	4.08
T_3	2.80	4.17
T_4	2.93	4.77
T_5	2.80	4.07
T_6	2.87	5.67
T_7	3.40	5.93
SEm ±	0.27	0.45
CD (0.05)	NS	1.38

4.3.6 Crop duration

The mean values of the crop duration (Days for shooting, Days from shooting to harvest and Days from planting to harvest) are presented in Table 7 and Fig. 9. The analysis of variance is given in the Appendix VII.

There was no significant difference in days for shooting. The duration from shooting to harvest was longest for T_7. T_3 took the least number of days which was on par with T_1, T_2, T_4 and T_5. The total duration from planting to harvest did not differ significantly among the treatments.

Studies on correlation between the days taken from shooting to harvest and weather during the same period indicated that rainfall, relative humidity and sunshine hours during the period 2-3 months after shooting had a strong influence on the duration. The correlation coefficients are presented in the Table 8. Rainfall and relative humidity correlated positively with duration, whereas, sunshine hours correlated negatively.

Table 7. Effect of time of planting on crop duration

Treatments	Days taken from		
	Planting to shooting	Shooting to harvest	Planting to harvest
T_1	356.93	97.27	454.00
T_2	343.20	97.87	441.33
T_3	323.07	95.53	419.67
T_4	308.40	98.93	407.00
T_5	313.07	97.07	410.00
T_6	313.00	104.27	417.33
T_7	289.00	111.07	400.00
SEm $\pm$	16.32	1.60	14.58
CD (0.05)	NS	4.92	NS

FIG. 9 EFFECT OF TIME OF PLANTING ON CROP DURATION

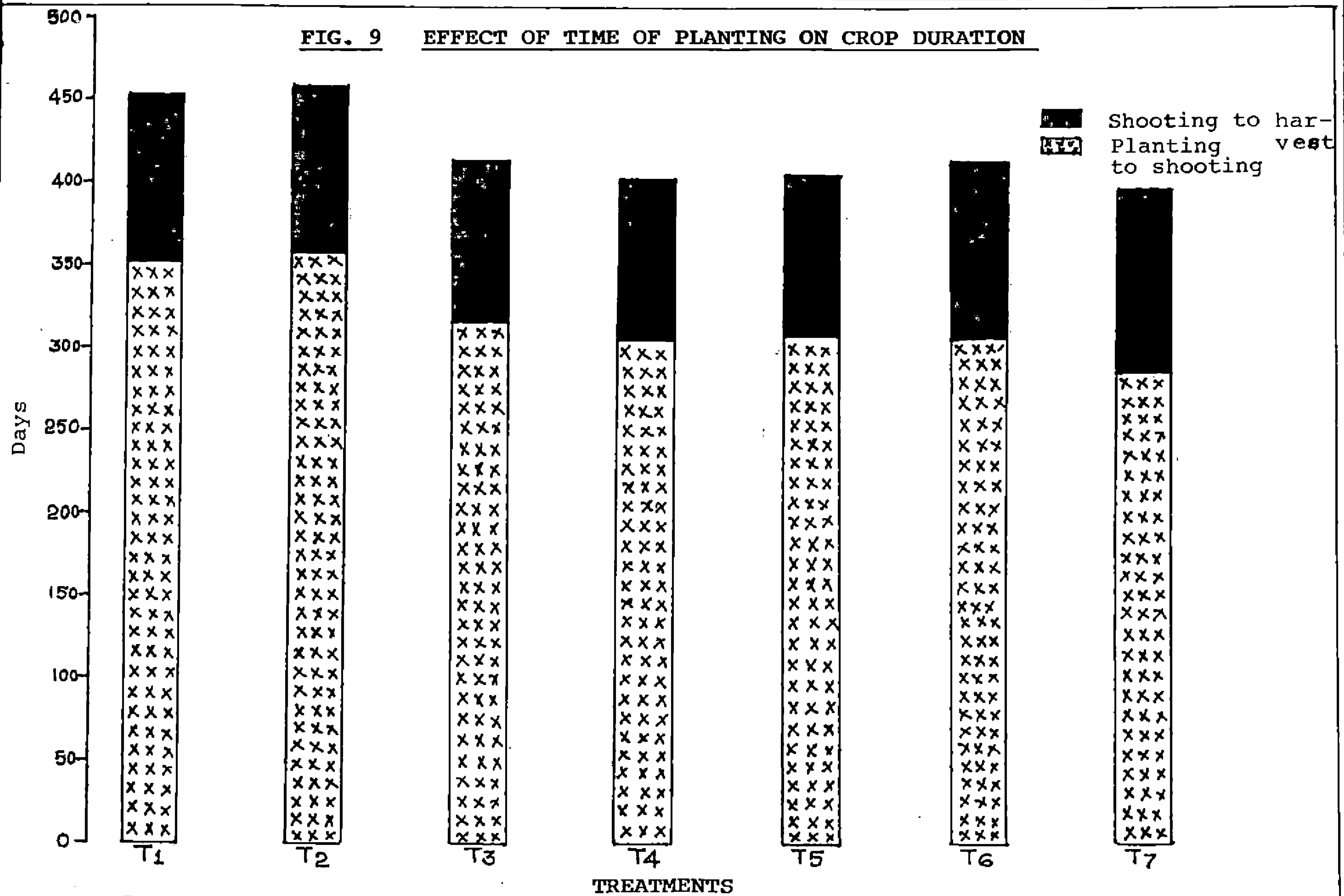

Table 8. Correlation coefficients between weather and days from shooting to harvest

Weather element	Significant period	Correlation coefficient
Rainfall	2-3 months after shooting	+0.928**
Relative humidity	" " "	+0.783*
Sunshine hours	" " "	-0.869**

* Significant at 5% level

** Significant at 1% level

4.4 Yield characters

4.4.1 Bunch weight

The mean values of the bunch weight are presented in Table 9 and Fig. 10. The analysis of variance is given in the Appendix VIII.

Bunch weight was significantly influenced by the time of planting. T_1 recorded the highest bunch weight of 12.4 kg which was on par with T_2 and T_3. The lowest bunch weight of 8.09 kg was recorded by T_5 which was on par with T_6 and T_7.

(a) Effect of weather on bunch weight

Simple linear correlations were worked out between the bunch weight and planting to harvest overlapping periods of monthwise weather elements like mean temperature, rainfall, relative humidity, sunshine hours, windspeed and evaporation to identify the critical periods. The correlation coefficients are presented in the Table 10. The analysis indicated that

Table 9. Effect of time of planting on the various bunch characters

Treatments	Bunch weight (kg)	Length of bunch (cm)	Weight of hand (kg)	Number of hands
T_1	12.40	58.80	1.24	9.67
T_2	12.13	58.53	1.24	9.53
T_3	12.03	58.40	1.19	9.47
T_4	9.79	56.07	1.14	8.80
T_5	8.09	51.27	0.89	8.73
T_6	8.32	48.53	0.89	9.13
T_7	8.38	47.20	0.90	9.07
SEm ±	0.32	0.61	0.03	0.22
CD (0.05)	0.99	1.89	0.08	NS

FIG. 10. EFFECT OF TIME OF PLANTING ON BUNCH CHARACTERS

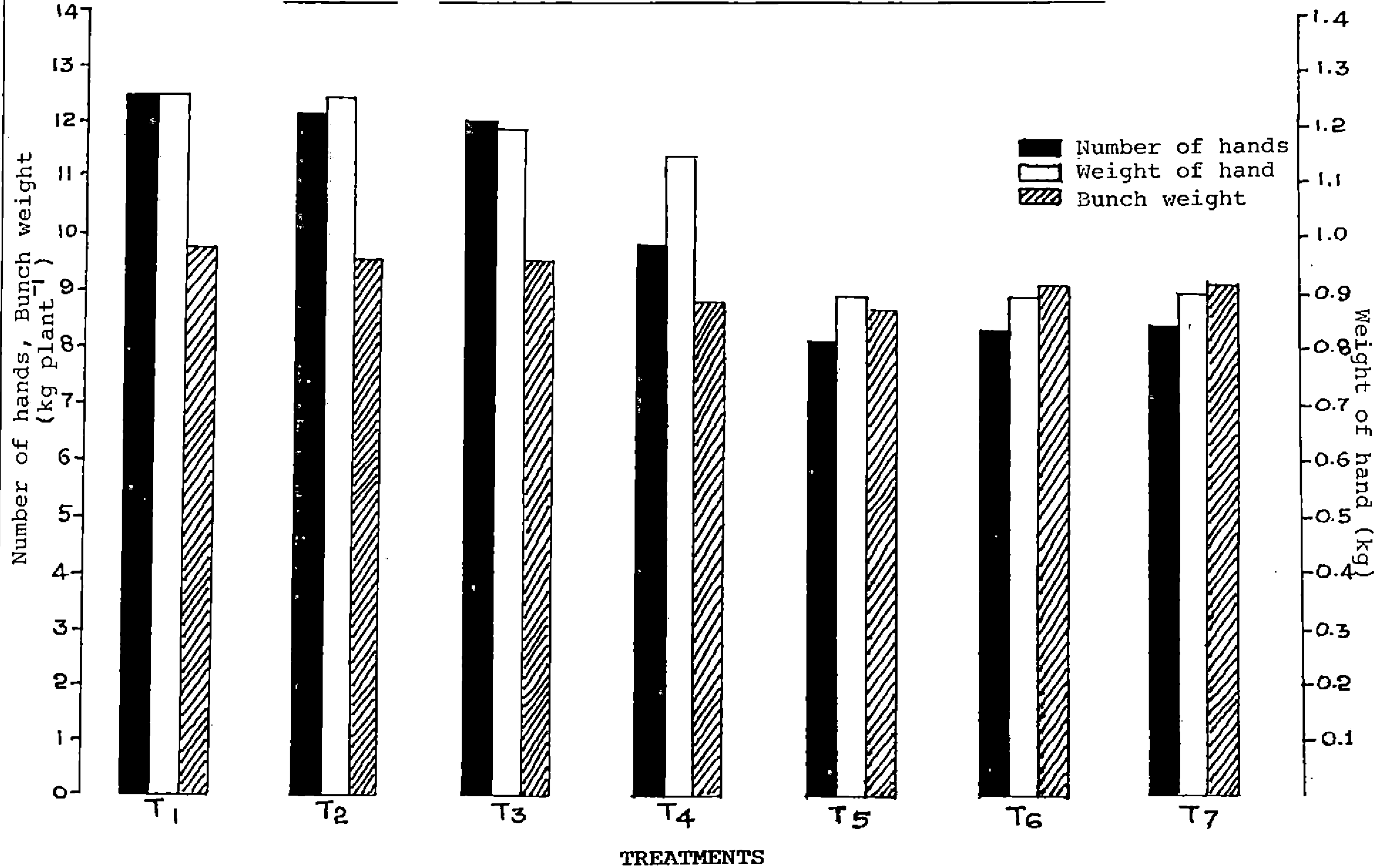

Table 10. Correlation coefficient between weather and bunch weight and weight of hand

Weather element	Significant period (months after planting)	Correlation coefficient*	
		Bunch weight	Weight of hand
Sunshine hours	1-5 months	+0.966	+0.962
Rainfall	8-10 months	+0.937	+0.965
Windspeed	8-10 months	-0.973	-0.977
Relative humidity	7-11 months	+0.976	+0.958
Evaporation	9-11 months	-0.977	-0.973
Mean temperature	10-12 months	-0.926	-0.952

* All are significant at 1% level

1. During the first five months after planting, sunshine had a positive correlation with bunch weight.

2. During the period eight months after planting to shooting, rainfall had a positive correlation, whereas, windspeed during this period had a negative correlation.

3. During the period seven months after planting to one month after shooting, relative humidity had a positive correlation.

4. During the shooting period and also one month before and after shooting, evaporation had a negative correlation.

5. During the shooting period and two months after shooting, temperature had negative correlation with bunch weight.

Because of the multicolinearity of variables, only three weather elements i.e., sunshine hours (SH), rainfall (RF) and mean temperature (MT) were selected while working out the multiple regression equation. The regression equation is

$$Y = 1.84\ SH - 0.01\ RF - 1.20\ MT + 33.89$$

The multiple correlation coefficient was 0.980 and about 96 percent of total variation in bunch weight could be explained by the regression. Actual bunch weight and the bunch weight estimated from the regression equation are presented in the Table 11 and Fig. 11.

(b) Effect of plant characters on bunch weight

With a view to understand the relation between the morphological characters and bunch weight, simple linear correlations were worked out between the bunch weight and the important plant growth characters. Whenever a significant correlation is observed simple linear regression equations were developed for prediction purpose. The correlation coefficients along with the regression equations are provided in the Table 12. The table indicates that a strong positive correlation exists between the yield and change in the height and girth of pseudostem

Table 11. Actual and estimated yield (Kg bunch $^{-1}$)

Treatments	Yield in kg per plant	
	Actual	Estimated
T_1	12.40	12.10
T_2	12.13	12.41
T_3	12.03	11.80
T_4	9.79	9.93
T_5	8.09	8.47
T_6	8.32	8.68
T_7	8.38	7.75

FIG. 11. ACTUAL AND ESTIMATED BUNCH WEIGHT FOR DIFFERENT TREATMENTS

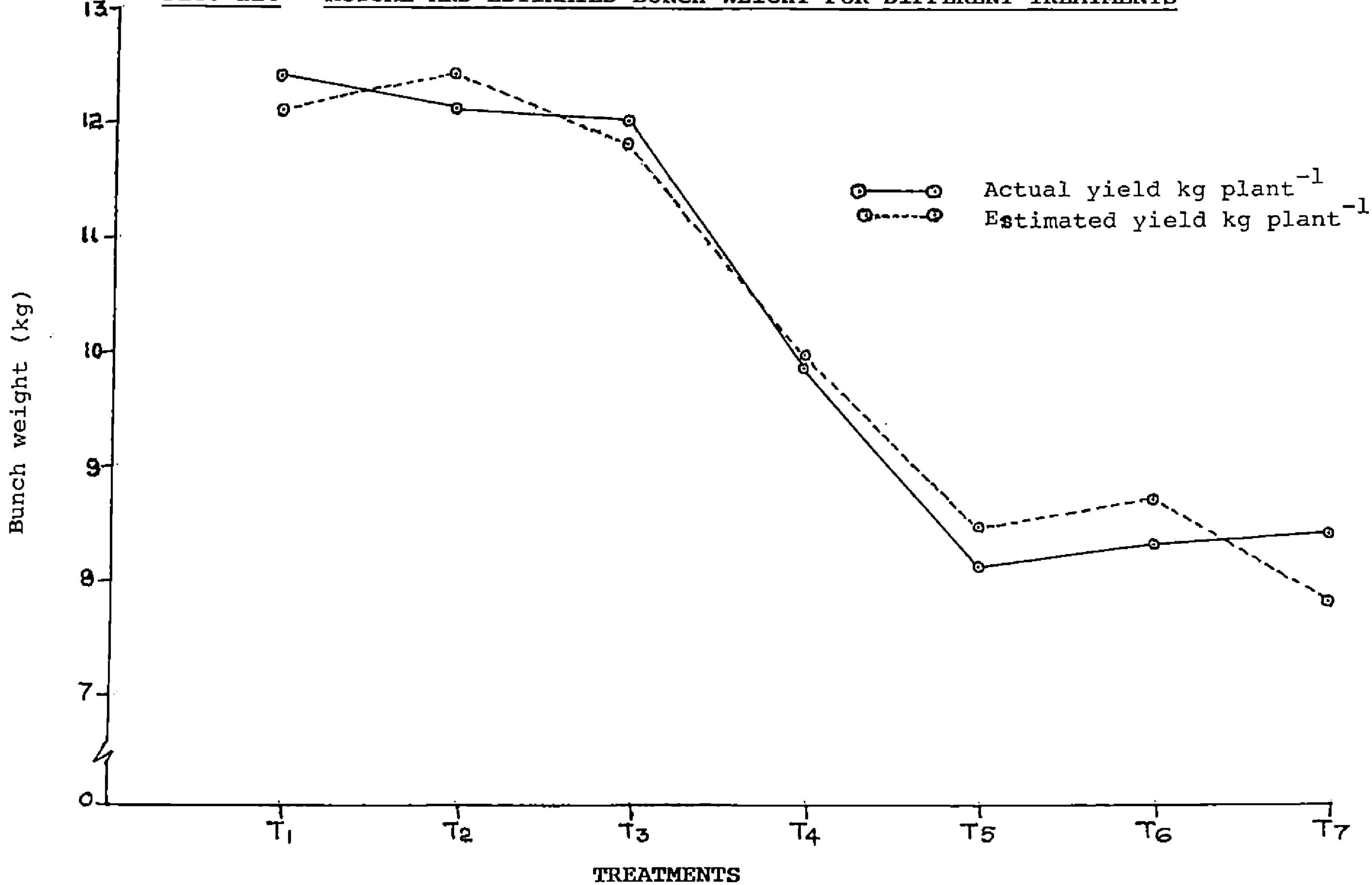

Table 12. Correlation coefficients between bunch weight and morphological characters

Character	Period	Correlation coefficient	Regression equation
Change in height of pseudostem	7-9 MAP	+0.900**	Y = 6.294 + 0.059x
Change in girth of pseudostem	7-9 MAP	+0.944**	Y = 7.891 + 0.185x
Number of leaves	9 MAP	+0.948**	Y = 1.829 + 1.071x
Leaf area	9 MAP	+0.952**	Y = 2.229 + 1.183x
Number of leaves	shooting	+0.873*	Y = 4.014 + 0.887x
Leaf area	shooting	+0.727	

* Significant at 5% level

** Significant at 1% level

between 7 and 9 months after planting. Number of leaves and leaf area at 9 months after planting, and number of leaves at shooting had a strong positive correlation with bunch weight.

4.4.2 Length of the bunch

Table 9 shows the mean values of the length of bunch. The analysis of variance is given in the Appendix VIII.

Length of bunch was significantly influenced by the time of planting. The highest value was recorded by T_1 which was on par with T_2 and T_3. T_7 recorded the lowest value which was on par with T_6.

4.4.3 Weight of the hand

The mean values of the weight of hand are presented in Table 9 and Fig. 10. The analysis of variance is given in the Appendix VIII.

Weight of the hand was significantly influenced by the time of planting. T_1 recorded the highest value which was on par with T_2 and T_3. The lowest value was recorded by T_5 and T_6 which was on par with T_7.

The correlation coefficient between weather and the weight of hand are presented in the Table 10. It can be seen from the table that the weight of hand responded to the weather in a similar way as that of the bunch weight.

4.4.4 Number of hands

Number of hands was not significantly influenced by the time of planting.

4.4.5 Other bunch characters

The mean values of the other bunch characters viz. number of fingers per bunch, number of fingers per hand, length of finger and girth of finger are presented in Table 13. The analysis of variance is given in the Appendix IX.

4.4.5.1 Number of fingers per bunch

Number of fingers per bunch was not significantly influenced by the time of planting.

Table 13. Effect of time of planting on other bunch characters

Treatments	Number of fingers per bunch	Number of fingers per hand	Length of finger (cm)	Girth of finger (cm)
T_1	130.27	13.13	10.57	10.78
T_2	135.33	13.80	10.40	10.03
T_3	141.07	14.80	10.10	10.54
T_4	126.47	13.80	9.97	10.42
T_5	122.00	13.53	9.43	9.86
T_6	129.47	14.07	9.70	10.17
T_7	132.13	14.60	10.00	10.05
SEm ±	3.86	0.24	0.28	0.27
CD (0.05)	NS	0.73	NS	NS

4.4.5.2 Number of fingers per hand

Number of fingers per hand was significantly influenced by the time of planting. T_3 recorded the highest value which was on par with T_6 and T_7. The lowest value was recorded by T_1 which was on par with T_2, T_4 and T_5.

4.4.5.3 Length of finger

Length of finger was not significantly influenced by the time of planting.

4.4.5.4 Girth of finger

Time of planting had no significant influence on the girth of finger.

4.5 Fruit quality

The data on the various quality aspects of fruit are presented in Table 14 and the analysis of variance in Appendix X.

Table 14. Effect of time of planting on fruit quality (%)

Treatments	Fruit quality					
	Total soluble solids	Reducing sugars	Non-reducing sugar	Total sugar	Acidity	Sugar acid ratio
T_1	20.3	14.70	1.70	16.40	0.33	49.7
T_2	20.0	14.75	2.20	16.95	0.33	51.4
T_3	20.0	14.90	2.03	16.93	0.50	33.9
T_4	20.0	15.30	2.63	17.93	0.50	36.0
T_5	20.0	15.17	2.20	17.37	0.33	53.0
T_6	20.0	15.10	2.30	17.40	0.30	58.0
T_7	20.0	15.13	2.20	17.33	0.30	57.7
SEm ±	0.13	0.09	0.05	0.08	0.02	2.4
CD (0.05)	NS	0.28	0.15	0.25	0.05	7.4

4.5.1 Total soluble solids

Time of planting did not influence the total soluble solids.

4.5.2 Reducing sugars

Reducing sugars was significantly influenced by the time of planting. T_4 recorded the highest value which was on par with T_5, T_6 and T_7 and T_1 recorded the lowest value which was on par with T_2 and T_3.

4.5.3 Non-reducing sugars

Time of planting significantly influenced the non-reducing sugars. T_4 recorded the highest value. The lowest value was recorded by T_1.

4.5.4 Total sugars

Total sugars was significantly influenced by the time of planting. T_4 recorded the highest value. The lowest value was recorded by T_1.

4.5.5 Acidity

Acidity was significantly influenced by the time of planting. T_3 and T_4 recorded the highest value. The lowest value was recorded by T_6 and T_7 which was on par with T_1, T_2 and T_5.

4.5.6 Sugar acid ratio

Sugar acid ratio was significantly influenced by the time of planting. T_6 recorded the highest value which was on par with T_2, T_5 and T_7. The lowest value was recorded by T_3 which was on par with T_4.

Discussion

DISCUSSION

The present investigation was taken up to study the crop weather relationship of rainfed banana under different times of planting at Vellanikkara. The results are discussed below.

5.1 Weather conditions

The total crop growth period for all the treatment was about twenty months from December 1986 to July 1988. At Vellanikkara, the period from December to April is normally considered as dry season as it receives little rainfall. The total crop growth period included two such dry seasons during 1986-'87 and 1987-'88. The general pattern of weather during the 1987-'88 dry season was better compared to that of 1986-'87. The rainfall during the 1986-'87 dry season was extremely low (24.1 mm) compared to that of 1987-'88 (255.7 mm). Monthwise relative humidity was also consistently low during the dry season of 1986-'87. Moderate to high temperatures of 36-37°c were recorded in the hottest months of this season. The highest maximum temperature of 40°c was recorded on 17th April 1987.

Monthly minimum temperatures were not very low and varied between 22-25°c. The lowest minimum of 17.8°c was recorded on 1st Feb. 1987. Skies were clear and on an average more than 9 hours of bright sunshine per day was recorded during this season. Winds were very high, particularly during December and January with windspeeds sometimes exceeding 30 km/hr. Evaporative demand was very high during this season and the record highest pan evaporation of 12.8 mm was recorded on 12th February 1987.

The Southwest monsoon was good during the year 1987 with a total rainfall of 1737 mm. Highest daily rainfall of 217.2 mm was recorded on 23rd June 1987. During this year, the Northeast monsoon was also favourable with a total rainfall of 289 mm. Moderate temperatures prevailed during this season with high relative humidity and low evaporation. Due to continuous rains and cloudiness the number of bright sunshine hours was low.

5.2 Microclimate - Soil temperature

Microclimate - the climate of a smaller area - is caused by the effect of terrain relief, the subjascent surface, and other factors which determine the disparity between air and soil temperature conditions, humidification etc. A phytoclimate - the meteorological condition produced amongst plants - is a modified microclimate. The features of a microclimate are most notably manifested in the near-soil air layers. Soil climate effects the microclimate of the near-earth air layer as well as ,soil processes, and also determines, to a considerable extent, the productive capacity of growing plants. Information on soil temeratures is basic to studies on soil climate which inturn influences the phytoclimate.

It can be seen from the figures 4A and 4B that highest soil temperatures at any depth and time were observed in April during 1987 and in March during 1988. There is a sharp decrease in soil temperatures in June due to the onset of Southwest monsoon. Then onwards soil temperatures did not vary much with time till November. Generally, December recorded the lowest soil temperatures and later they increased sharply till March-April. Soil temperatures always increased with depth in the morning and vice versa in the afternoon. The difference between the 5 cm and

20 cm depth soil temperatures was highest in the afternoon, particularly during the dry season. The lowest soil temperature (21.5°c) at 5 cm depth was recorded on 2nd January 1988 at 0700 Hrs LMT. The highest soil temperature (55.6°c) at 5 cm depth was recorded on 16th April 1987 at 1400 Hrs LMT.

5.3 Effect of time of planting and weather on growth and yield of banana

5.3.1 Growth characters

(a) Height of pseudostem

The results indicated a significant variation in height of pseudostem among the treatments. This is in agreement with the findings of Chattopadhyay et al. (1980). The plant height showed an increasing trend with delay in planting upto 9 months after planting, but did not differ significantly at shooting and at later stages. Correlation studies indicated a strong influence of weather particularly temperature on the height of pseudostem. Similar results were reported by Green et al. (1969). High rainfall and relative humidity during the first five months contributed positively to the height at 6 months after planting and sunshine during the same period correlated negatively. The plant height decreased with increase in temperature, windspeed and evaporation upto 6 months after planting. Similar trends were observed in the later stages.

(b) Girth of pseudostem

A significant variation was observed in girth of pseudostem among the treatments. This is in agreement with the findings of Chattopadhyay et al. (1980) and Chakrabarthy and Rao (1980). The girth of pseudostem showed an increasing trend with delay in planting upto 9 months after planting. But did not differ significantly at shooting and at later stages. Correlation studies indicated a strong influence of weather, particularly temperature on the girth of pseudostem. Similar results were reported by Green et al. (1969). The correlation studies indicated that the girth of pseudostem responded to the weather in a way similar as that of height of pseudostem.

(c) Number of leaves

The results indicated that the number of leaves produced was significantly influenced by the time of planting. Chattopadhyay *et al.* (1980) reported similar results. At 3 and 6 months after planting, the late (summer) plantings, in general, produced more number of leaves compared to the early (winter) plantings. This is in agreement with Chakrabarthy and Rao (1980). At 9 months after planting and at shooting, the number of leaves varied significantly with time of planting. Turner (1970) reported similar results. The results also indicated that of various stages of crop growth, the treatments experiencing the dry weather conditions always produced fewer leaves. This result is in confirmation with Flores *et al.* (1982).

(d) Leaf area

The results showed a significant variation in leaf area among the treatments. This is in agreement with the findings of Chakrabarthy and Rao (1980) and Chattopadhyay *et al.* (1980). The effect of time of planting on leaf area and number at various growth stages were similar.

(e) Sucker production

The results indicated a significant variation in sucker production at harvest among the treatments. The number of sucker production at harvest showed an increasing trend with delay in planting.

(f) Crop duration

The results indicated that among the various phenological phases, only the period from shooting to harvest was significantly influenced by the time of planting. Duration from shooting to harvest showed a slight increasing trend with delay in planting. Dec.-Feb plantings took more number of days for harvesting compared to the March-June plantings. Reddy et al. (1984) reported similar results. Correlation studies indicated a strong influence of weather, particularly rainfall on the duration from shooting to harvest. High rainfall combined with relative humidity increased the days from shooting to harvest. Whereas, sunshine combined with temperature reduced the duration. Similar results were reported by Smirin (1960) and Stover et al. (1987)

5.3.2 Yield characters

(a) Bunch weight

The results indicated a significant variation in bunch weight among the treatments. Similar results were reported by Wills and Berril (1953), Nagpal et al. (1958), Gowder et al. (1960), Bhaktavatsalu et al. (1973), Chattopadhyay et al. (1980), Turner (1983), Chundawat et al. (1984), Haque (1984), Obiefuna (1985) and Robinson et al. (1986). The bunch weight showed a decreasing trend with delay in planting. Among the plantings T_1 recorded the highest bunch weight of 12.4 kg which was on par with T_2 and T_3. For these three treatments, bunch emergence was observed just after the rainy season and all the three treatments were harvested in the month of March 1988, which might be the reason for the similar and higher bunch weights. T_5 experienced very dry conditions one month prior to bunch emergence. The windspeeds were also very high during this one month period. Obiefuna (1985) and Stover et al. (1987) reported that high windspeeds can damage the plantations and also significantly reduce the yields. T_5 also took comparitively less number of days to maturity. The above two might be the reasons for the lowest bunch weight of 8.09 kg recorded by T_5.

Multiple regression equation developed between the bunch weight and the weather elements during the various critical periods could explain about 96 per cent of the total variation in the bunch weight. Fig. 11 shows that the estimated bunch weights from the multiple regression equation are in general agreement with the actual values.

Correlation coefficients presented in the Table 14 indicated a strong relationship between the important morphological characters and the bunch weight. Higher growth rates in the height and girth of pseudostem during the period 2-3 months before shooting increased the final bunch weight. Similar results were reported by Lossois (1964), Krishnan et al. (1983) and Hegde (1986). Number of leaves and leaf area at 9 months after planting and at shooting also had a positive influence on the final weight of the bunch. This is in confirmation with the findings of Krishnan et al. (1983), Kothovade et al. (1985), and Hegde (1986).

(b) Length of the bunch

The results indicated a significant variation in length of bunch among the treatments. Delay in planting decreased the length of the bunch. The effect of time of planting on the length of bunch was similar to that of bunch weight.

(c) Weight of the hand

The results showed a significant variation in weight of hand among the treatments. The effect of time of planting on the weight of hand was similar to that of bunch weight and bunch length. Correlation studies indicated a strong influence of weather on the weight of hand. The correlation coefficients indicated that both the bunch weight and weight of hand responded similarly to the prevailing weather conditions.

(d) Number of hands

The results indicated no significant variation in number of hands among the treatments.

(e) Other bunch characters

(i) The results indicated that the number of fingers per hand showed a significant variation among the treatments. T_3 recorded the highest value and the lowest by T_1. However, no significant trend was observed.

(ii) The results indicated that the remaining bunch characters viz. number of fingers per bunch, length of finger and girth of finger showed no significant variation among the treatments.

5.4 Fruit quality

The results indicated a significant variation among the treatments in the various fruit quality aspects viz. reducing sugars, non-reducing sugars, total sugars, acidity and sugar acid ratio. The highest value for reducing sugars, non-reducing sugars, total sugars and acidity was recorded by T_4. This may be due to the severe water stress experienced by the treatment during the fruit development period. Similar results were reported by Teaotia et al. (1972), and Krishnan and Shanmugavelu (1979).

Summary

SUMMARY

An experiment was conducted to study the crop weather relationship of rainfed banana under different times of planting during December 1986 to July 1988 at the College of Horticulture, Vellanikkara. In this experiment, the first planting was done in the 1st week of December 1986 and the last in the 1st week of June 1987. The results of the experiment are summarised below.

1. The total experimental period for all the seven treatments was twenty months which included two dry seasons and one rainy season. The general pattern of weather during the 1987-'88 dry season was better compared to that of 1986-'87. The Southwest monsoon was good during the year 1987 with a total rainfall of 1737 mm.

2. Soil temperature observations indicated that highest soil temperature at any depth and time were observed in April during 1987 and in March during 1988. Soil temperatures decreased from June onwards due to the onset of Southwest monsoon. Generally, December recorded the lowest soil temperatures.

3. The various growth characters like height of pseudostem, girth of pseudostem, number of leaves and leaf area at various stages of growth were significantly influenced by time of planting.

4. In early stages, the mean height of pseudostem showed an increasing trend with delay in planting. Time of planting did not affect the height of pseudostem at shooting and later stages.

5. Correlation studies indicated that height of pseudostem at 6 months after planting was very strongly influenced by weather parameters. Rainfall and relative humidity during the first five months after planting correlated positively and sunshine during the same period correlated negatively with height of pseudostem. Windspeed and evaporation during the first 6 months after planting and temperature during 2-6 months after planting correlated negatively with height at 6 months after planting.

6. The mean girth of pseudostem showed an increasing trend with delay in planting, markedly in the earlier stages

of growth. Time of planting did not effect the girth at shooting and later stages.

7. Correlation studies indicated that girth of pseudostem at 6 months after planting was strongly influenced by weather parameters. At 6 months after planting, both the height of pseudostem and girth responded in a similar way to the prevailing weather conditions.

8. Early plantings poduced maximum number of leaves in the later stages of growth and vice versa in the later plantings.

9. Late plantings produced more leaf area in the early stages of growth and early plantings produced highest leaf area in the later stages of growth. The results indicated a direct influence of rainfall on the leaf number and area.

10. The time of planting did not influence significantly the sucker production at shooting, but at harvest it was significant. June plantings produced the highest number of suckers at harvest.

11. The time of planting did not effect significantly the duration from planting to shooting and planting to harvest. The duration from shooting to harvest was significantly influenced by the time of planting and a slight increase in duration is observed with delay in planting, particularly in the last two plantings.

12. Studies on correlation between the various weather elements and days taken from shooting to harvest indicated that rainfall and relative humidity during 2-3 months after shooting had strong positive correlation and the sunshine hours during this period correlated negatively.

13. The various bunch characters like bunch weight, length of bunch, weight of hand and number of fingers per hand were significantly influenced by time of planting.

14. The time of planting greatly influenced the bunch weight. December 1st week planting recorded the highest bunch weight followed by January and February plantings and the lowest bunch weight was recorded by the April planting.

15. Correlation studies between various weather parameters and bunch weight indicated the following.

a) During the first 5 months after planting, sunshine (SH) had a positive correlation with bunch weight.

b) During the period 8 months after planting to shooting, rainfall (RF) had a positive correlation. Whereas, windspeed during this period had a negative correlation.

c) During the period 7 months after planting to one month after shooting, relative humidity had a positive correlation.

d) During the shooting period and also one month before and after shooting, evaporation had a negative correlation.

e) During the shooting period and two months after shooting, temperature (MT) had a negative correlation with bunch weight.

Multiple regression equation developed between various weather parameters and bunch weight could explain about 96 percent of the total variation in the bunch weight .

16. Planting during the 1st week of December recorded the highest length of bunch which was on par with 1st week of January and February plantings.

17. Weight of hand was influenced by time of planting and the highest and lowest values were recorded by the 1st week of December and 1st week of April plantings respectively.

18. Number of fingers/hand was influenced by time of planting. 1st week of February planting recorded the highest value and the lowest by 1st week of December planting.

19. Time of planting significantly influenced the fruit quality. The results indicated that waterstress during the fruit development stage can increase the reducing sugars, non-reducing sugars, total sugars and acidity.

The results of the experiment indicated that the time of planting had a very significant influence on the growth, yield and quality of rainfed banana cv. palayankodan. It was also found that planting in the 1st week of December gave higher yield. The rainfall during the period 1-2 months before bunch emergence will increase the yield of banana.

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Appendices

Appendix I Mean monthly weather parameters for the crop growth period

Year	Month	Maximum temperature (°c)	Minimum temperature (°c)	Sunshine hours	Relative humidity (%)	Windspeed (km/hr)	Total evaporation (mm)	Total rainfall (mm)
1986	December	32.5	23.5	9.3	60	14.0	223.4	10.8
1987	January	33.2	22.7	9.6	52	14.1	266.8	0
"	February	35.0	22.4	10.1	52	9.5	230.0	0
"	March	36.4	22.2	10.2	55	7.1	257.6	0
"	April	36.2	25.3	7.8	64	5.5	214.9	13.3
"	May	36.1	24.7	9.0	66	5.6	218.6	95.0
"	June	30.7	23.7	4.2	83	5.0	106.5	837.7
"	July	30.3	23.5	5.7	84	4.3	117.4	336.5
"	August	29.6	23.5	3.7	87	3.8	100.0	388.4
"	September	31.5	23.9	7.4	79	4.0	120.0	174.0

Appendix I continued

Year	Month	Maximum temperature (°c)	Minimum temperature (°c)	Sunshine hours	Relative humidity (%)	Windspeed (km/hr)	Total evaporation (mm)	Total rainfall (mm)
1987	October	31.9	23.9	6.2	79	4.2	118.2	280.4
"	November	31.6	22.8	6.7	77	4.4	103.8	224.4
"	December	31.6	23.3	8.1	70	9.1	143.8	64.6
1988	January	32.4	22.0	10.4	56	11.7	217.4	0
"	February	35.8	23.1	10.0	56	6.7	191.2	7.8
"	March	35.7	24.4	9.1	67	5.1	202.5	37.9
"	April	35.1	24.3	8.8	70	5.2	172.9	145.4
"	May	33.7	25.4	6.2	76	4.7	144.9	242.6
"	June	30.0	23.7	4.2	86	5.2	86.3	632.1
"	July	29.0	23.2	3.0	88	4.0	78.7	545.0

Appendix II Analysis of variance for the height of pseudostem (cm) at various stages of growth

Source	Degrees of freedom	Mean squares									
		2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP	11 MAP
Block	2	9.20	3.06	5.33	6.14	28.05	75.97	113.44	69.98	34.94	70.69
Treatment	6	354.85**	369.22**	698.12**	3113.13**	5646.73**	3470.48**	2530.51**	1465.77*	336.40	109.56
Error	12	17.55	27.50	71.03	145.79	187.21	404.39	372.23	389.04	250.75	95.57

* Significant at 5% level

** Significant at 1% level

Appendix III Analysis of variance for the girth of pseudostem (cm) at various stages of growth

Source	Degrees of freedom	Mean squares									
		2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP	11 MAP
Block	2	3.60	0.98	3.86	2.47	3.13	2.54	4.49	6.65	2.30	3.48
Treatment	6	76.36**	61.04**	111.04**	200.73**	290.90**	106.22**	84.40**	60.02*	36.54	19.57
Error	12	2.50	3.74	8.35	10.81	17.36	14.02	14.90	17.44	17.59	14.18

* Significant at 5% level

** Significant at 1% level

Appendix IV Analysis of variance for the number of leaves at various stages of growth

Source	Degrees of freedom	Mean squares									
		2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP	8 MAP	9 MAP	10 MAP	11 MAP
Block	2	0.25	1.39	0.03	0.01	0.02	0.05	0.20	0.03	0.33	0.69
Treatment	6	1.06*	3.28*	2.79*	3.64**	2.72*	2.99*	5.88**	9.13**	11.34**	5.66**
Error	12	0.27	0.89	0.63	0.42	0.66	0.64	0.37	0.31	0.40	0.67

* Significant at 5% level

** Significant at 1% level

Appendix V Analysis of variance for the leaf area at various stages of growth

Source	Degrees of freedom	Mean squares			
		3 MAP	6 MAP	9 MAP	At shootig
Block	2	0.03	0.09	0.37	0.62
Treatment	6	1.32**	14.66**	7.58**	14.35**
Error	12	1.88	0.43	1.25	1.20

** Significant at 1% level

Appendix VI Analysis of variance for sucker production

Source	Degrees of freedom	Mean squares	
		At shooting	At harvest
Block	2	0.32	0.02
Treatment	6	0.51	2.54*
Error	12	0.21	0.60

* Significant at 5% level

Appendix VII Analysis of variance for crop duration

Source	Degrees of freedom	Mean squares		
		Days for shooting	Days taken from shooting to harvest	Days taken from planting to harvest
Block	2	47.75	13.65	4.63
Treatment	6	2165.46	90.91**	1708.88
Error	12	798.54	7.63	637.73

** Significant at 1% level

Appendix VIII Analysis of variance of bunch characters

Source	Degrees of freedom	Mean squares			
		Bunch weight	Length of bunch	Weight of hand	Number of hands
Block	2	0.04	1.51	0.002	0.15
Treatment	6	11.71**	75.36**	0.088**	0.40
Error	12	0.31	1.13	0.002	0.14

** Significant at 1% level

Appendix IX Analysis of variance for other bunch characters

Source	Degrees of freedom	Mean squares			
		Number of fingers/ hand	Number of fingers/ bunch	Length of finger	Girth of finger
Block	2	0.27	78.42	0.06	0.04
Treatment	6	1.02**	112.91	0.45	0.32
Error	12	0.17	44.68	0.23	0.22

** Significant at 1% level

Appendix X Analysis of variance for fruit quality

Source	Degrees of freedom	Mean squares Fruit quality					
		Total soluble solids	Reducing sugars	Non-reducing sugars	Total sugars	Acidity	Sugar acid ratio
Block	2	0.05	0.05	0.01	0.07	0.004	90.43
Treatment	6	0.05	0.68**	0.24**	1.25**	0.02**	312.76**
Error	12	0.05	0.02	0.007	0.02	0.001	17.26

** Significant at 1% level

CROP WEATHER RELATIONSHIP OF RAINFED BANANA UNDER DIFFERENT TIMES OF PLANTING

By

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ABSTRACT OF THE THESIS

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the requirement for the degree

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1990

ABSTRACT

An experiment was conducted at the College of Horticulture, Vellanikkara, Kerala Agricultural University during December 1986 to July 1988 to study the crop weather relationship of rainfed banana under different times of planting.

The experiment was conducted in randomised block design with seven times of planting (1st week of December, 1st week of January, 1st week of February, 1st week of March, 1st week of April, 1st week of May, and 1st week of June) and the treatments were replicated three times.

Observations on all weather parameters and soil temperatures were recorded daily. Crop growth characters like height of pseudostem, girth of pseudostem, number of leaves and leaf area at various stages of growth, sucker production at shooting and harvest, and the days taken from planting to shooting, shooting to harvest and planting to harvest were recorded. Yield characters like bunch weight,

length of bunch, weight of hand, number of hands, number of fingers per bunch, number of fingers per hand, length of finger and girth of finger were recorded. The various fruit quality characters like total soluble solids, reducing sugars, non-reducing sugars, total sugars, acidity and sugar acid ratio were recorded.

The total crop growth period for all the treatments included two dry seasons. The general pattern of weather during the 1987-'88 dry season was better compared to that of 1986-'87. The highest soil temperature at any depth and time were observed in April during 1987 and in March during 1988. Generally, December recorded the lowest soil temperatures.

The time of planting greatly influenced all the growth, yield and quality characters. At early stages, late plantings generally recorded taller plants with more girth, number of leaves and leaf area. The time of planting had a significant influence on the sucker production at harvest. The duration from shooting to harvest was significantly influenced by time of planting and the last two plantings took comparatively more time for fruit development.

Time of planting significantly influenced bunch weight. Highest bunch weight, was obtained in the 1st week of December planting followed by 1st week of January and 1st week of February plantings. Correlation studies between bunch weight and various weather elements indicated that

a) during the first 5 months after planting sunshine had a positive correlation with bunch weight.

b) during the period 8 months after planting to shooting, rainfall had a positive correlation. Whereas, windspeed during this period had a negative correlation.

c) during the period 7 months after planting to one month after shooting, relative humidity had a positive correlation.

d) during the shooting period and also one month before and after shooting, evaporation had a negative correlation.

e) during the shooting period and two months after shooting, temperature had a negative correlation with bunch weight.

Multiple regression equation was developed between bunch weight and three weather elements i.e., sunshine hours (SH) during the first five months after planting, rainfall (RF) during the period 8 months after planting to shooting and mean temperature (MT) during the shooting period and two months after shooting. The regression equation is,

$$Y = 1.84 \ SH - 0.01 \ RF - 1.20 \ MT + 33.89$$

The multiple correlation coefficient was 0.980 and about 96 percent of total variation in the bunch weight could be explained by the regression.

Time of planting significantly influenced the length of bunch, weight of hand and the number of fingers per hand. Fruit quality aspects like reducing sugars, non-reducing sugars, total sugars and acidity were also influenced by time of planting. Water stress during the fruit development stage increased the reducing sugars, non-reducing sugars, total sugars and acidity.

The results of the experiment indicated that the time of planting had a very significant influence on the growth, yield and quality of rainfed banana cv. Palayankodan. Planting during the 1st week of December gave higher yield. The rainfall during the period 1-2 months before bunch emergence will increase the yield of banana.