EFFECT OF PLANTING DATE, WEIGHT OF RHIZOME AND SPACING ON THE GROWTH, YIELD AND QUALITY CONSTITUENTS ON TURMERIC (*Curcuma longa* L.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of planting date, weight of rhizome and spacing on the growth, yield and quality constituents on turmeric (Curcuma longa L.)" is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
10th February, 1983

R.K. Chatterjee

CERTIFICATE

Certified that this thesis entitled "Effect of planting date, weight of rhizome and spacing on the growth, yield and quality constituents on turmeric (Curcuma longa L.)" is a record of research work done independently by Shri. R.K. Chatterjee 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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CERTIFICATE

We, the undersigned members of the Advisory Committee of Shri. R.K. Chatterjee, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Effect of planting date, weight of rhizome and spacing on the growth, yield and quality constituents on Turmeric (Curcuma longa L.)" may be submitted by Shri. R.K. Chatterjee in partial fulfilment of the requirements for the degree.

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To My Wife and Children

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Introduction

1. INTRODUCTION

The turmeric of commerce is mainly the dried rhizomes of Curcuma longa L. To a small extent, it also includes the rhizomes of Curcuma aromatica Salisb. In India, it is mainly valued for its use as a spice and as an ingredient in medicinal preparations. Smaller quantities of turmeric are being used for the preparation of cosmetics. In foreign countries, the demand of turmeric is mainly for curcumin which is used as colouring material for food, wool, silk and cotton. Curcumin is also in demand in the Middle East, Japan, U.S.A., England and other European countries.

The estimated world production of turmeric is around 1.6 lakh tonnes of which, the contribution of India is about 1.5 lakh tonnes (93.7 per cent). In India, turmeric occupies about 77,400 hectares. Andhra Pradesh, Tamil Nadu, Bihar, Orissa and Kerala are the important turmeric producing states of India.

Planting of turmeric in India commences from April and continues upto the end of June. Different seed size and spacings are being adopted by the cultivators of this crop. The factors like planting time, spacing and weight of planting material have exhibited profound influence on the morphological and yield characters in crops like ginger (Khan, 1959; Thomas, 1960; Loknath and Das, 1964; Kannan and Nair, 1965;

Aiyadurai, 1966; Nair and Varma, 1970; Randhawa and Nandpuri, 1970; Randhawa et al., 1972; Kingra and Gupta, 1977; Sivan, 1979 and Whiley, 1981) and Costus (Sarin et al., 1977; Pandey et al., 1980; and Sharma et al., 1980) which are related to turmeric.

A few attempts have been made to understand the influence of these factors on the productivity of turmeric. In a spacing trial conducted at Vellanikkara, planting turmeric at 25 x 25 cm gave maximum yield. However, the trial did not yield conclusive results (Anon., 1980). In another trial, large mother rhizomes (35-44 g) gave significantly superior yield over the other treatments (Anon., 1980). These trials pointed to the need for detailed systematic studies on the influence of these factors as well as their interactions on the growth and production parameters. The present studies were, therefore, initiated at the College of Horticulture, Vellanikkara with the objective of finding out the optimum spacing, weight of planting material and time of planting for commercial cultivation of turmeric in Kerala.

Review of Literature

2. REVIEW OF LITERATURE

Though the importance of turmeric as a spice and medicinal plant is well known, no systematic research seems to have been done on ascertaining the optimum time of planting, seed size and spacing for turmeric cultivation. The yield and quality of turmeric are influenced by the cultural practices and the climatic conditions under which the crop is grown (Nair, 1980). In this chapter, an attempt has been made to trace the available research information on these lines of work. Review of relevant literature on related crops has also been presented.

2.1. Turmeric

2.1.1. Time of planting

Sarma and Krishnamurthy (1965) reported that delayed planting produced comparatively lesser number of leaves. They also observed variation in the performance of the plants under different seasons. While they observed greater variation in leaf size, tiller production, plant height and yield for every fortnight's delay in planting of finger rhizomes, no such effects were observed when mother rhizomes were planted. Sarma and Krishnamurthy (1965) felt that turmeric can be planted from June to August under Andhra Pradesh conditions. They reported that plant height was very much influenced by the planting time and nature of the planting material.

Aiyadurai (1966) reported that the second fortnight of June was the optimum period for planting 'short' and 'medium' duration varieties under Andhra Pradesh conditions, while for 'long' duration varieties it was between 15th June and 15th July. Randhawa and Misra (1970) reported that planting from the end of April to the first fortnight of May of large sized seeds (weighing about 100 g) at 22 x 22 cm spacing gave the best results. In an experiment conducted at the Tamil Nadu Agricultural University, Coimbatore it was found that first week of May to 3rd week of June was the best time for planting turmeric (Ratinam and Sankaran, 1977). Planting during July and August gave poor yields. Hari _et al_. (1978) observed that planting from May first to tenth was significantly superior to the other planting dates, for getting better growth and yield of the rhizomes. While Rao (1979) preferred May to August, Anjaneyulu and Krishnamurthy (1979) found July as the best planting time in the Duggirala region of Andhra Pradesh. According to Nair (1980), yield in turmeric will be influenced by the planting time. The optimum time would vary depending upon the varieties, planting material and the agro-climatic conditions. In Kerala, the period of one month between 15th April to 15th May was found to be the best time of planting (Nair, 1980).

2.1.2. Spacing

Said and Hussain (1964) reported that highest yields were obtained with 30 cm (12") inter-row and 15 cm (6") inter-plant spacings and sowing on flat beds rather than on ridges. A spacing of 25 x 25 cm for "flat bed" method and 45-60 cm between rows and 25 cm between plants for "ridge and furrow" method was found to be the optimum (Aiyadurai, 1966). Lower plant spacings gave better results as compared to higher ones (Said and Altaf, 1963; Randhawa and Nandpuri, 1966). Rao et al. (1975) recommended a spacing of 46 x 23 cm in black clay loams and 30 x 15 cm in light loams. According to Sundararaj and Thulasidas (1976), 15-20 cm spacing was the optimum. Under Kerala conditions, a spacing of 30 x 15 cm has been recommended under "flat bed" system (Anon., 1981). Rao (1979) felt that the spacing of 30 x 20 cm was better. Anjaneyulu and Krishnamurthy (1979) observed that yields were highest from the plots with whole mother rhizomes spaced at 22.5 cm with 30 cm between the rows. Rajput et al. (1980) reported that spacing of 30 x 45 cm produced significantly more yield than the other spacing treatments in turmeric. Ponnuswamy and Muthuswamy (1981) observed that the spacing 45 cm x 20 cm recorded the highest number of tillers per plant, number of primary and secondary rhizomes and yield per plot when compared to other spacings. When the spacing was less, it affected the growth and development of plants due to competition for nutrients and other resources. Increasing the spacing to more than what is required, reduced the percentage utilization of land and thereby, the yield.

2.1.3. Weight of rhizome

Hussain and Said (1965) reported that the use of rhizomes having 3.81 cm (1½") diameter resulted in significantly higher germination percentage and fresh yields than those obtained from the use of smaller sized rhizomes or whole or divided central rhizomes. Based on a critical analysis of the morphological and yield data in different cultivars of *C. longa* and *C. aromatica*, Nambiar (1979) concluded that the final yield would be influenced by the weight of the seed material, since a progressive increase in yield was observed with the increase in the weight of the seed rhizomes. Population studies as well as studies on the effect of planting date and weight of rhizome on the growth, yield and quality constituents in turmeric are few. Hence, the following review traces the work on these and related aspects in ginger.

2.2. Ginger

2.2.1. Time of planting

Khan (1959) observed that the yield could often be doubled by early planting. Thomas (1960) reported that planting by 15th April gave significantly higher yields. He observed that even smaller delays in planting reduced the yield appreciably. It was found that the date of planting of seed rhizomes influenced the yield very much and that the earliest planting by the 1st April gave the highest yield. Planting seed rhizomes of ginger early by first April gave significantly higher yield than the traditional way of undertaking planting of seed rhizomes during the month of June. Kannan and Nair (1965), Aiyadurai (1966), and Nair and Varma (1970) reported that early planting of ginger (by the first week of April) was the best under Ambalavayal conditions in Kerala. A reduction in yield with delayed planting has been observed by these workers also. Randhawa et al. (1972) reported that the early planted (1st, 10th and 20th May) ginger had better growth and yield than ginger planted on 30th May and 10th June.

2.2.2. Spacing

Loknath and Das (1964) found the spacing of 15 x 15 cm as the best for obtaining higher yields in ginger. Trials at Ambalavayal conducted by Kannan and Nair (1965) showed that the closer spacings of 22.9 x 15.2 cm and 22.9 x 22.9 cm were better than the wider spacings like 30.5 x 15.2 cm and 30.5 x 30.5 cm. Aiyadurai (1966) found that, under Thodupuzha conditions, a closer spacing of 15 x 15 cm gave substantially higher yield. Randhawa and Nandpuri (1970) found 25 cm between rows and 15 to 20 cm between plants as the optimum spacing under Himachal Pradesh conditions. Randhawa et al. (1972) reported highest yields from 20 x 20 cm and 20 x 30 cm spacings.

Kingra and Gupta (1977) recommended a spacing of 30 x 50 cm under Himachal Pradesh conditions. Sivan (1979) reported that highest total yield/ha as well as net yield/ha were obtained at the closest spacing (60 x 10 cm). Average yield/plant, however, was highest at the widest spacing (60 x 30 cm). Whiley (1981) reported that increased plant density reduced the "time to first harvest" and increased the yield.

2.2.3. Weight of planting material

A seed rate of 1200-1400 kg/ha was recommended, based on trials conducted at Ambalavayal (Nair and Varma, 1970). A marked and progressive increase in yield was noted as the size of the seed bit was increased. The highest yield was obtained when the seed bit was 28 g. Randhawa and Nandpuri (1970) found 1250 kg seed/ha as the optimum seed rate, with each seed bit being about one ounce (28 g) in weight. Thankamma Pillai (1973) reported that a seed rate of 1800 kg/ha was the best for better tillering, height of plant and weight of rhizomes.

2.3. Other relevent crops

2.3.1. *Costus* sp.

According to Sarin *et al*. (1977), the optimum sprouting (above 95%) occurred when the rhizomes were planted during April and May. The rhizomes planted during June and July recorded 85 per cent sprouting within 60 days. Those planted afterwards showed a sharp decline in the percentage germination and the plants were unable to complete their full annual cycle of growth.

As regards spacing, Sarin and his co-workers reported in 1977 that the spacing could be reduced in the case of crops to be harvested six to nine months after planting. Pandey et al. (1980) found that nine plants per square metre gave higher yields than three, four or six plants per square metre.

Pandey et al. (1980) worked on the weight of planting material to be used to realise maximum yield. They obtained annual yields of 1.24 kg per plant by planting rhizomes weighing about 75 g. Sharma et al. (1980) concluded that the germination percentage, number of shoots per plant, number of leaves per shoot, number of leaves per plant, and yield of rhizome and diosgenin were significantly increased with an increase in the weight of planting material upto 125 g.

2.3.2. Yam

A comparison of dry-season and rainy-season plantings of yam was made by Onwueme (1977a). The dry-season planting was found to have the advantage of giving an earlier harvest; but this advantage was small if the rainy-season planting was done early enough. On the other hand, rainy-season planting required a much shorter time from planting to harvesting than the dry season planting. In the northern forest zone of Nigeria, February or early March plantings have been recommended, even though the rains do not become regular until late March or April. It has been reported that the lator the plantings, the lower were the yield obtainable (Chinwuba, 1971; Lal and Hahn, 1973).

As regards spacing, the bigger the sett the wider the spacing (Onwueme, 1978). It has also been suggested (U.S.D.A., 1972) that wider spacing should be used in heavy soils and if staking is not intended.

As regards the weight of the planting material, the greater the weight of the sett used, the greater would be the weight of the tuber produced by that plant. This relationship between sett weight and yield has been repeatedly confirmed in various experiments (Miege, 1957; Onwueme, 1972; Lyonga et al., 1973; Nwoke et al., 1973). It was also observed that large setts gave rise to a more vigorous plant than small setts even if both sprouted and emerged at the same time (Onwueme, 1972; Enyi, 1973; Nwoke et al., 1973). The vine diameter, number of leaves per stand, and leaf area per stand were found to be greater for the large-sett planting than for the small-sett planting. According to Nwoke et al. (1973), the main effect of large sett size was to produce a vigorous initial growth of root, vine and leaves which gave the plant an advantage that lasted throughout the growing season. It has also been observed that large setts had more food material which could be translocated directly to the new tuber (Onwueme, 1975b). In addition, plants from large setts produced a greater number of tubers per stand than plants from small setts (Onwueme, 1972). Large sett weights ranging upto 4.5 kg have been used for planting (Coursey, 1967). Even though yam plants can grow from sprouted pieces as little as 5.0 g (Onwueme, 1978), commercial production of yams utilised setts in the 150 g range and heavier.

Materials and Methods

3. MATERIALS AND METHODS

The investigations were carried out at the College of Horticulture, Vellanikkara during 1981-82.

The area selected for the experiment was fairly level and uniform, with good drainage. The soil was red loam. Kasturi Tanuka was the test variety.

3.1. Experimental details

The trial was laid out in split-split plot design with three replications.

3.1.1. Treatments

Main plot: Date of planting (T)

T_1 - Beginning of May (1-5-81)

T_2 - Middle of May (15-5-81)

T_3 - Beginning of June (1-6-81)

Sub plot : Spacing (S)

S_1 - 10 x 20 cm to accommodate 150 plants/plot

S_2 - 15 x 20 cm to accommodate 100 plants/plot

S_3 - 20 x 20 cm to accommodate 75 plants/plot

Sub-sub plot: Weight of rhizome (W)

W_1 - 20 g

W_2 - 40 g

W_3 - 60 g

Replications - Three

Plot size (net) - 3 m x 1 m

Total number of plots - 108

3.1.2. Cultivation

The land was ploughed well and raised beds of size 3 m x 1 m and height 25 cm were formed with 30 cm wide channels around each plot. A fertilizer dose of 30:30:60 kg/ha of N, P_2O_5 and K_2O was applied in addition to 30 tonnes of cattle manure as per the package of practices recommended by the Kerala Agricultural University (Anon., 1981). Nitrogen was applied in two split doses, at 30 days and 60 days after planting. The whole of P_2O_5 and K_2O was applied as basal dose at the time of planting. The rhizomes were treated with Dimecron (Phosphamidon) at the rate of 0.5 ml/litre and Aretan 6 (6 per cent mercury as methoxy ethyl mercury chloride) at the rate of 3 g per kg of seed material before sowing. Dimecron (0.5 ml/litre) and Dithane Z-78 (75% zinc ethylenebis-dithio carbamate) at the rate of 2 g/litre were mixed and sprayed 60 days and 120 days after planting. After planting, the beds were uniformly mulched with leaves of the Eupatorium odoratum.

3.2. Sampling techniques

The entire population in the plot was taken for recording the germination percentage and the yield of green rhizomes per bed. Ten plants in each bed were marked at random for recording the leaf characters, tiller characters, height of the plant and number of rhizomes.

Harvesting was done on the 270th day after planting (Philip et al., 1980) when the leaves had dried in most of the plants. The ten plants marked from each plot were lifted individually for recording the various observations. The remaining plants were harvested and the weight of rhizomes recorded after proper cleaning. For chemical analysis, the dried samples of the rhizomes were ground in a Multiplex grinder, passed through a 60 mesh sieve and utilized for subsequent analysis.

3.3. Observations

3.3.1. Germination

The number of rhizomes germinated out of the rhizome bits planted in each plot were recorded.

3.3.2. Height of the plants

The height of the plant was measured at two months interval after planting. The main plant in the clump was taken for recording the height and leaf characters. The measurement was taken from the ground level to the tip of the topmost leaf of all observational plants, averaged and expressed in centimetres.

3.3.3. Number of tillers/plant

The number of tillers per plant was recorded in the observational plants in each plot at two months interval and averaged.

3.3.4. Number of leaves/plant

For each plot, the total number of leaves in the observational plants was counted and the average number recorded at two months' interval.

3.3.5. Number of leaves/tiller

Average number of leaves/plant was divided by the average number of tillers/plant to give the average number of leaves per tiller.

3.3.6. Average length, width and leaf area

The length of leaf was measured in centimeters from the proximal to the distal end of the lamina and the width was measured at the middle of the leaves. In order to work out the relationship between geometrical (maximum length x maximum breadth) and graphical leaf area, 100 leaves were collected at random from different plants and their leaf area was measured by both these methods. The value of correlation co-efficient (r) between the graphical and geometrical leaf area was 0.99 and K value was 0.70, as per the method suggested by Randhawa et al. (1982). The length and breadth of all the leaves in each observational plant were recorded. The area of each leaf was then calculated by multiplying the product of maximum length and maximum breadth of leaf with the K value obtained. From the leaf area values so obtained, average leaf area was worked out.

3.3.7. Total leaf area per plant

For each observational plant, the total leaf area was calculated by multiplying the average leaf area by the number of leaves per plant. These values were averaged to give total leaf area per plant.

3.3.8. Mother rhizome characters

The number of mother rhizomes was recorded in respect of the observational plants. The length of the rhizomes was measured in centimetres using a non-elastic twine and the mean worked out.

3.3.9. Characters of primary and secondary fingers

3.3.9.1. Number of primary and secondary fingers

The number of primary and secondary fingers were counted in respect of the observational plants and the mean worked out.

3.3.9.2. Number of nodes per finger, length, girth and internodal length

The number of nodes, length, girth and internodal length of the primary and secondary fingers were recorded and the means worked out.

3.3.10. Yield of green rhizome

The total yield (kg per 3.0 m^2 plot) was obtained by weighing the entire produce of the plot.

3.3.11. Per cent recovery of dry rhizomes

For arriving at the percentage recovery, five kg of fresh rhizome were taken, cured as per the conventional method (Anon., 1981) and dried. Based on the fresh weight and dry weight, the percentage recovery was worked out.

3.3.12. Yield of dry rhizomes

The yield of cured, dry turmeric (kg per plot) was obtained by multiplying the yield of green turmeric with the percentage recovery.

3.4. Chemical analysis

3.4.1. Analysis of soil before and after the experiment

Soil samples were taken, both before and after the experiment, from 0 to 30 cm depth at five random spots in each block. These were pooled to get a representative sample for each block. The samples were air dried, ground to pass 2.0 mm sieve and stored in polythene bags.

Total nitrogen in the samples were determined by Kjeldahl digestion and distillation method (Jackson, 1973). Available phosphorus extracted by Bray No.1 reagent (0.03 N NH_4F in 0.025 N HCl) was determined by the chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1973). Available potassium extracted by 1 N neutral ammonium acetate was estimated flame photometrically (Jackson, 1973).

The pre-experimental nutrient status of the soil was recorded as 0.081 per cent nitrogen, 8.63 ppm available P_2O_5 and 224.6 ppm available K_2O, with a pH of 5.2.

3.4.2. Estimation of oleoresin

Oleoresin in turmeric was estimated by extracting with acetone (Anon., 1974). The percentage recovery of oleoresin was worked out on moisture free basis.

3.5. Meteorological data

The maximum and minimum temperatures, rainfall and relative humidity were recorded for the period from middle of April, 1981 to end of January, 1982 (Appendix XXIII).

3.6. Statistical analysis

The data were subjected to the analysis of variance in split-split plot design and the significance tested by 'F' test (Panse and Sukhatme, 1957). Correlation co-efficients among the different growth parameters and yield components were worked out and their significances tested.

Results

4. RESULTS

The influence of time of planting, spacing and weight of planting material on the growth, yield and quality constituents of turmeric has been investigated upon. The experiment was carried out in split-split plot design with the time of planting as main plots, spacing as sub plots and weight of planting material as sub-sub plots. The results are presented in this chapter.

4.1. Germination

The data on germination of the rhizomes planted in the different treatments are presented in Table 1 and the ANOVA in Appendix I. The results have been depicted in Fig.1.

The results showed that the time of planting and weight of the planting material significantly influenced the germination. Spacing did not exhibit significant influence on the germination of rhizomes. The rhizomes planted during early June (T_3) gave 89.44 per cent germination which is significantly higher than the germination of rhizomes (9.48 per cent) planted in early May (T_1). The difference between middle May (T_2) planting which gave 76.18 per cent germination and T_3 was not significant. With regard to the weight of planting material, 60 g (W_3) gave the highest germination of 61.07 per cent showing significant difference with 20 g (W_1) which gave

Table 1.- Effect of time of planting, spacing and weight of planting material on germination (%)

Treatments@	T_1	T_2	T_3
S_1W_1	9.00@@	61.66	92.66
S_1W_2	11.33	72.00	93.66
S_1W_3	18.00	67.33	93.33
S_2W_1	4.66	72.66	90.66
S_2W_2	8.00	76.33	93.33
S_2W_3	10.66	81.33	87.66
S_3W_1	5.66	78.66	97.00
S_3W_2	8.00	90.66	96.33
S_3W_3	10.00	85.00	93.00

Means

Main plot : T_1 = 9.48; T_2 = 76.18; T_3 = 89.44

Sub plot : S_1 = 57.66; S_2 = 54.74; S_3 = 62.70

Sub-sub plot : W_1 = 53.33; W_2 = 60.07; W_3 = 61.70

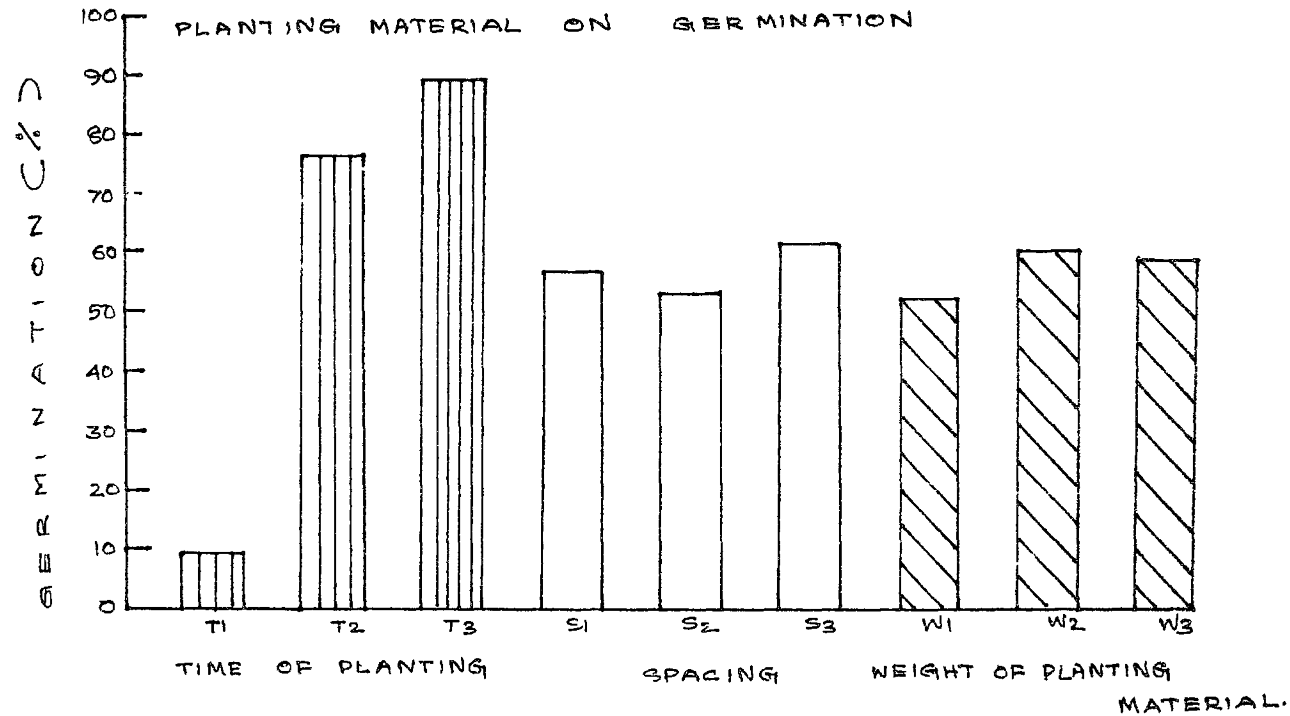
$CD_{(0.05)}$

Main plot = 9.22
Sub plot = 6.93
Sub-sub plot = 6.93

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g
T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g
T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG 1 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON GERMINATION



53.33 per cent germination. The difference between 60 g (W_3) and 40 g (W_2) giving 60.07 per cent germination was not significant.

The interaction between time of planting and spacing was significant at five per cent level. Maximum germination of 95.44 per cent was obtained from T_3S_3 (crop planted during early June at 20 x 20 cm spacing) which did not differ significantly with T_3S_1 (93.22) and T_2S_3 (84.77). Main plot x sub-plot as well as sub-plot x sub-sub plot interactions were not significant.

4.2. <u>Height of the plant</u>

The data relating to height of plant with respect to the treatments are presented in Table 2 and Fig.2, and the ANOVA in Appendix II.

The height of the plant was significantly influenced by the time of planting and weight of the planting material. However, spacings had no effect on this character. T_2 gave maximum height (86.41 cm) showing statistically significant difference with T_1 (65.45 cm). T_3 (82.91 cm) and T_2 were at par. Plant height progressively increased with the weight of planting material. W_3 gave the maximum height of 81.71 cm. W_1 with 73.31 cm was significantly lower than W_3, while W_2 and W_3 were at par. None of the interactions showed statistical significance.

Table 2.- Effect of time of planting, spacing and weight of planting material on height of plant (cm)

Treatments@	T_1	T_2	T_3
S_1W_1	62.26@@	90.97	88.28
S_1W_2	65.05	91.01	85.54
S_1W_3	69.12	90.44	81.48
S_2W_1	54.14	85.59	81.05
S_2W_2	73.23	85.25	84.22
S_2W_3	67.16	91.29	87.47
S_3W_1	65.36	81.97	80.19
S_3W_2	60.93	93.27	75.96
S_3W_3	71.81	94.63	82.01

Means

Main plot : T_1 = 65.45; T_2 = 86.41; T_3 = 82.91

Sub plot : S_1 = 77.50; S_2 = 78.82; S_3 = 78.46

Sub-sub plot : W_1 = 73.31; W_2 = 79.75; W_3 = 81.71

$CD_{(0.05)}$

Main plot = 13.51

Sub plot = 6.21

Sub-sub plot = 5.91

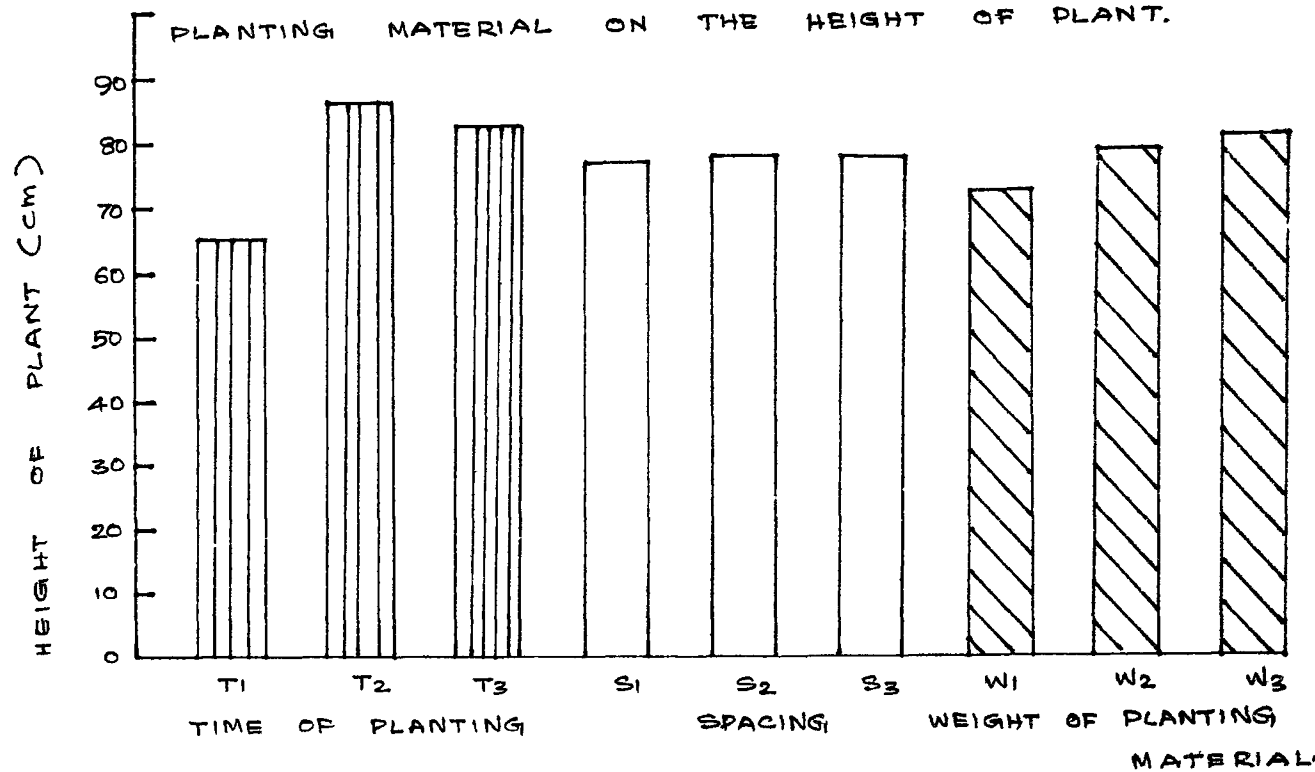
@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG. 2. EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON THE HEIGHT OF PLANT.



4.3. Number of tillers/plant

Mean values of the number of tillers produced per plant under each treatment have been presented in Table 3 and Fig.3. The ANOVA is presented in Appendix III.

Time of planting did not show significant influence on the number of tillers per plant. Number of tillers per plant increased with increase in spacing. At S_3, on an average, 2.15 tillers were produced. S_2 and S_1 produced 1.70 and 1.31 tillers/plant, respectively. The differences among the three spacings were statistically significant. The effect of weight of planting material was also significant on the tiller production. W_3 with an average of 1.97 tillers, differed significantly from W_2 and W_1 which produced 1.65 and 1.54 tillers, respectively. Difference between W_2 and W_1 was not significant.

The interaction between spacing and weight of planting material was significant. S_3W_3 gave the maximum number of tillers (2.59) while S_1W_2 gave the minimum (1.21). S_3W_3 differed significantly from the others.

4.4. Number of leaves/plant

The data on the mean number of leaves produced per plant are presented in Table 4, Fig.4 and the analysis of variance, in Appendix IV.

Time of planting, spacing as well as weight of planting material exhibited significant influence on this character.

Table 3.- Effect of time of planting, spacing and weight of planting material on number of tillers per plant

Treatments@	T_1	T_2	T_3
S_1W_1	1.16@@	1.30	1.23
S_1W_2	1.20	1.36	1.06
S_1W_3	1.20	1.80	1.53
S_2W_1	1.63	1.86	1.43
S_2W_2	1.60	1.93	1.40
S_2W_3	1.70	1.96	1.80
S_3W_1	1.36	2.10	1.80
S_3W_2	1.46	2.43	2.40
S_3W_3	2.26	3.06	2.46

Means

Main plot : T_1 = 1.51; T_2 = 1.98; T_3 = 1.68

Sub plot : S_1 = 1.31; S_2 = 1.70; S_3 = 2.15

Sub-sub plot : W_1 = 1.54; W_2 = 1.65; W_3 = 1.97

$CD_{(0.05)}$

Main plot = 0.55

Sub plot = 0.18

Sub-sub plot = 0.16

@ T_1 = Beginning of May; S_1 = 10 x 20 cm; W_1 = 20 g

T_2 = Middle of May; S_2 = 15 x 20 cm; W_2 = 40 g

T_3 = Beginning of June; S_3 = 20 x 20 cm; W_3 = 60 g

@@ Mean of three replications

Table 4.- Effect of time of planting, spacing and weight of planting material on number of leaves per plant

Treatments[@]	T_1	T_2	T_3
S_1W_1	6.19[@@]	8.39	7.90
S_1W_2	6.01	8.51	7.93
S_1W_3	5.68	8.67	8.24
S_2W_1	5.74	9.02	7.59
S_2W_2	6.05	8.59	7.99
S_2W_3	6.51	9.17	8.20
S_3W_1	6.18	8.85	8.26
S_3W_2	6.17	9.08	8.43
S_3W_3	6.24	9.71	9.18

Means

Main plot : T_1 = 6.08; T_2 = 8.89; T_3 = 8.19

Sub plot : S_1 = 7.50; S_2 = 7.65; S_3 = 8.01

Sub-sub plot : W_1 = 7.57; W_2 = 7.64; W_3 = 7.95

$CD_{(0.05)}$

Main plot = 0.60

Sub plot = 0.23

Sub-sub plot = 0.30

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

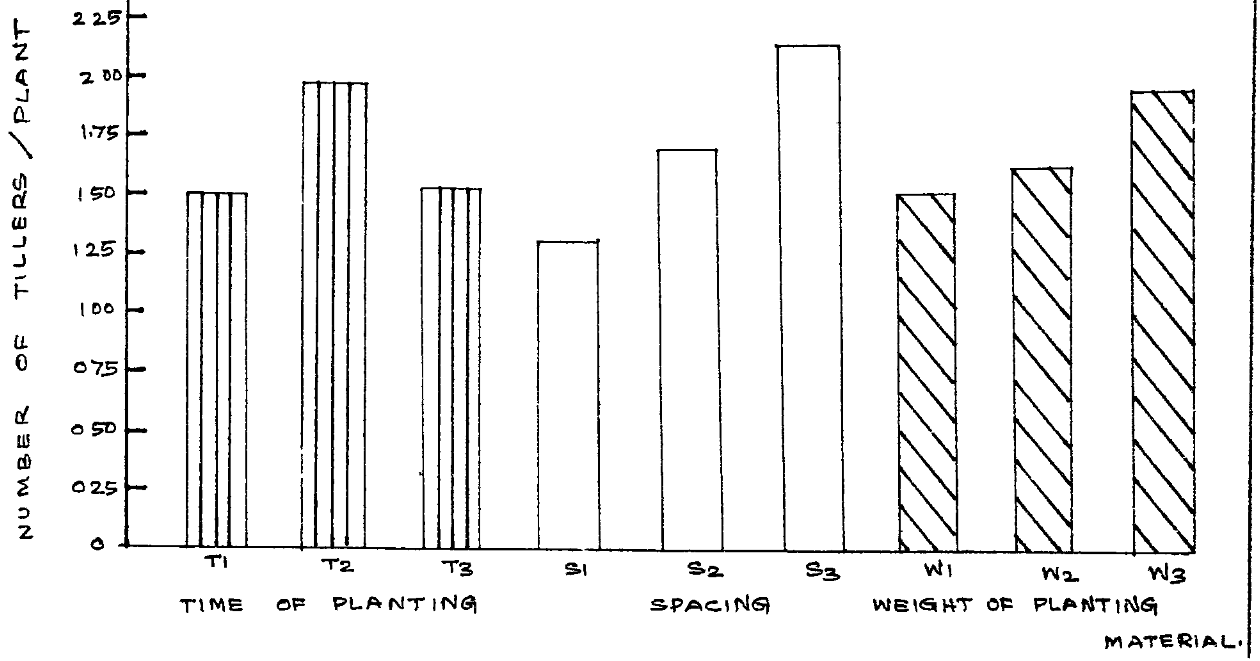
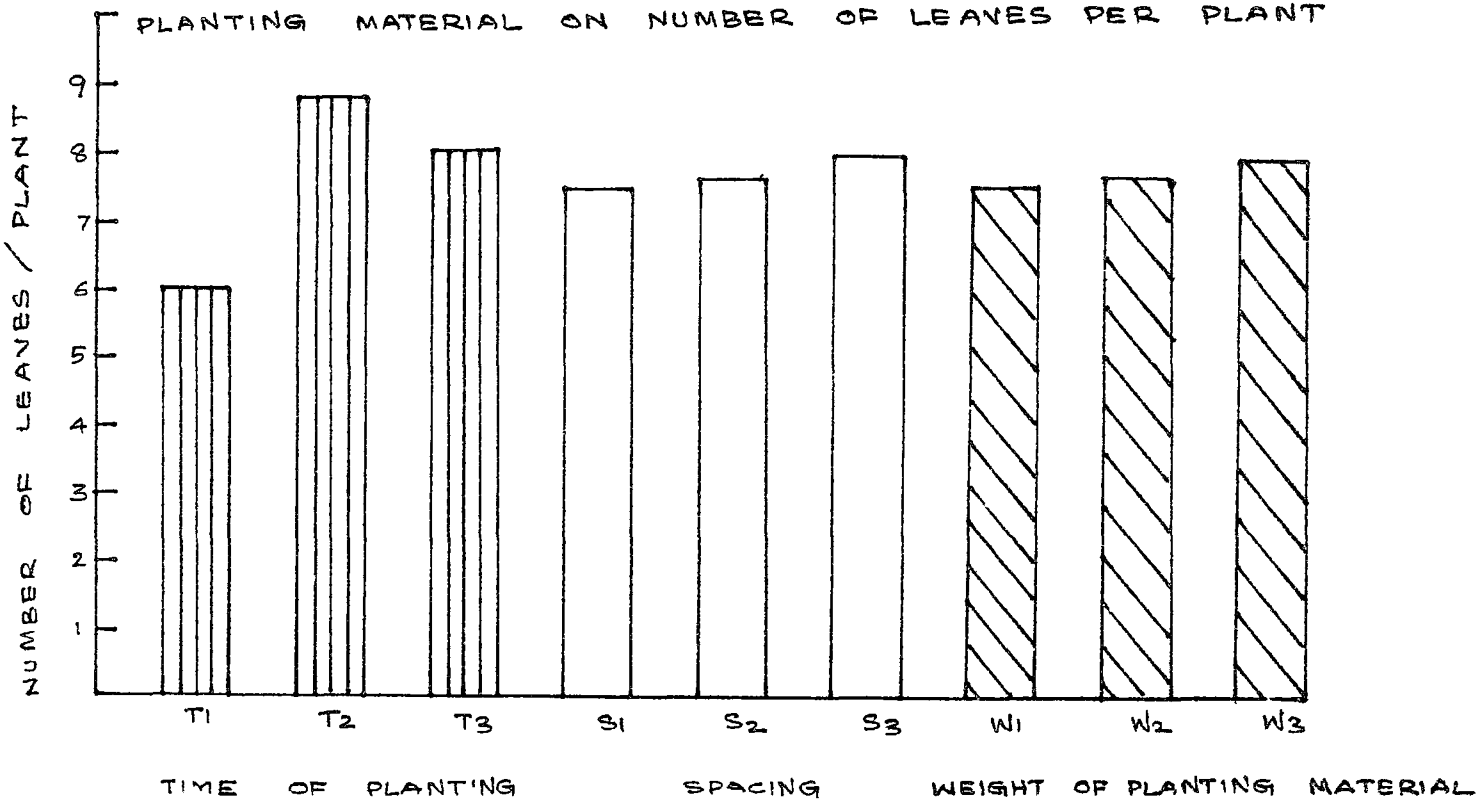


FIG 3 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF TILLERS PER PLANT.

FIG 4 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF LEAVES PER PLANT



A mean maximum of 8.89 leaves were produced in T_2 which differed significantly from T_3 (8.19) and T_1 (6.08). S_3, on an average, gave 8.01 leaves and differed significantly from S_1 (7.50) and S_2 (7.65). S_1 and S_2 were statistically on par.

The effect of weight of planting material on leaf production was also significant with 7.95 leaves in W_3 and 7.57 in W_1. W_3 was significantly superior to W_2 and W_1 which were statistically on par. An increase in the number of leaves was observed with increase in the weight of planting material used. The interactions between different factors were not significant.

4.5. Number of leaves/tiller

The mean number of leaves produced per tiller under the different treatments are shown in Table 5 with its graphical presentation appearing in Fig.5. The ANOVA has been presented in Appendix V.

The analysis indicated that the effect of time of planting alone was statistically significant. Number of leaves per tiller increased from 3.79 at T_1 to 4.95 at T_2. At T_3, the leaf production per tiller recorded a decrease. Significant differences were observed among the three treatments. The spacing, weight of planting material as well as the interactions between the various factors did not show any statistically significant influence on the leaf production per tiller.

Table 5.- Effect of time of planting, spacing and weight of planting material on number of leaves per tiller

Treatments[@]	T_1	T_2	T_3
S_1W_1	3.66[@@]	4.60	4.40
S_1W_2	3.83	5.26	4.53
S_1W_3	3.86	4.83	4.70
S_2W_1	3.70	4.86	4.60
S_2W_2	3.50	4.83	4.66
S_2W_3	3.86	4.66	4.50
S_3W_1	3.43	5.00	4.53
S_3W_2	4.06	4.90	4.73
S_3W_3	4.23	5.63	4.80

Means

Main plot : T_1 = 3.79; T_2 = 4.95; T_3 = 4.60

Sub plot : S_1 = 4.41; S_2 = 4.35; S_3 = 4.59

Sub-sub plot : W_1 = 4.31; W_2 = 4.48; W_3 = 4.56

$CD_{(0.05)}$

Main plot = 0.30

Sub plot = 0.33

Sub-sub plot= 0.28

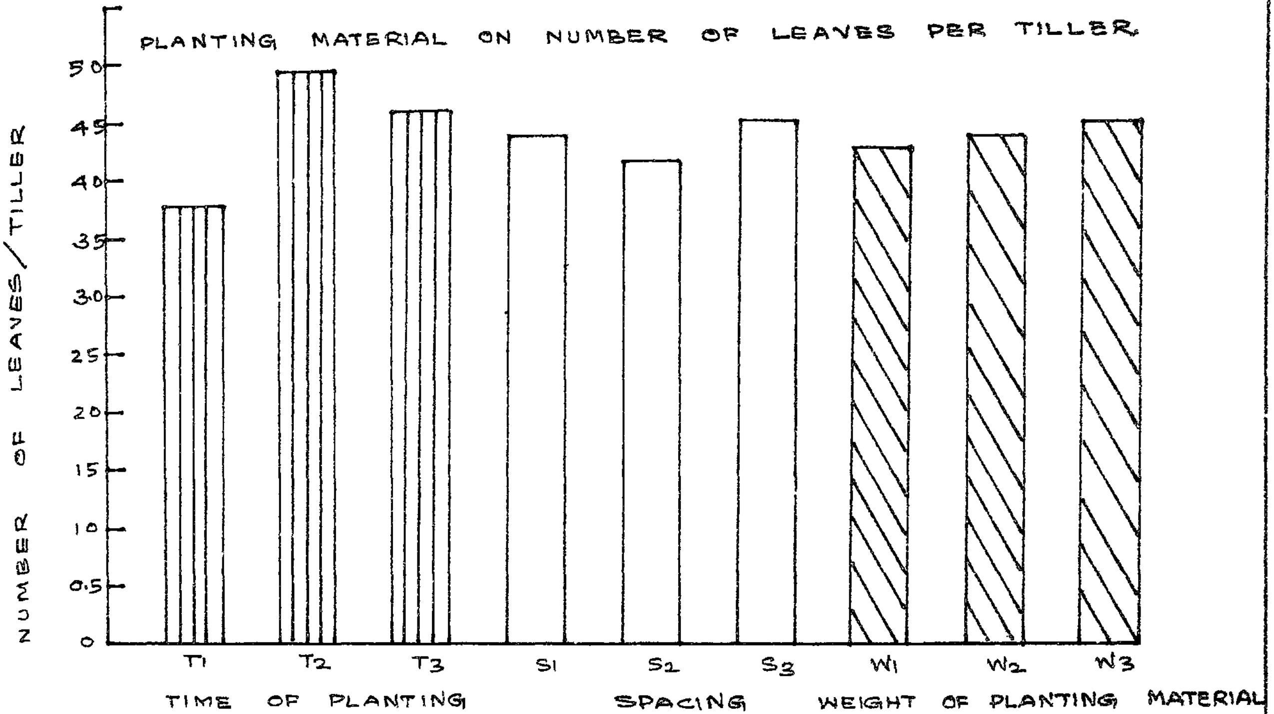
@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG 5 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF LEAVES PER TILLER



4.6. Average length, width and leaf area

Tables 6 to 8 and Figs. 6 to 8 show the average length, width and leaf area, respectively. The ANOVA have been presented in Appendices VI to VIII.

The effect of spacing and weight of planting material on the length of the leaves was significant. The mean leaf length varied from 35.97 cm at S_1 to 36.78 cm at S_2 and 36.66 cm at S_3. Statistically, S_2 and S_3 were on par; but differed significantly from S_1. The length of the leaf was significantly influenced by the weight of planting material. Use of heavier planting material (W_3) resulted in longer leaves (37.03 cm).

Interaction effects between time of planting and weight of planting material and between spacing and weight of planting material were found to be significant at five per cent level. T_3W_3 gave the maximum leaf length of 38.72 cm. S_3W_3 gave a maximum of 37.84 cm. The effects of time of planting as well as the interaction between time of planting and spacing were not significant.

Time of planting exhibited significant influence on the width of the leaves. A maximum width of 11.11 cm was observed in T_3. The difference between T_2 (10.94 cm) and T_3 was not statistically significant; but these differed significantly from T_1 (10.11 cm). With regard to the effects of spacing

Table 6.- Effect of time of planting, spacing and weight of planting material on the length of leaf (cm)

Treatments@	T_1	T_2	T_3
S_1W_1	35.23@@	37.14	36.61
S_1W_2	35.36	35.34	36.94
S_1W_3	33.34	35.89	37.95
S_2W_1	33.94	37.74	37.77
S_2W_2	34.36	37.56	37.05
S_2W_3	35.01	38.84	38.81
S_3W_1	34.51	37.20	37.00
S_3W_2	34.22	34.91	38.59
S_3W_3	35.46	38.66	39.41

Means

Main plot : T_1 = 34.60; T_2 = 37.03; T_3 = 37.79

Sub plot : S_1 = 35.97; S_2 = 36.78; S_3 = 36.66

Sub-sub plot : W_1 = 36.35; W_2 = 36.03; W_3 = 37.03

$CD_{(0.05)}$

Main plot = 2.83

Sub plot = 0.65

Sub-sub plot = 0.55

@ T_1 Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 7.- Effect of time of planting, spacing and weight of planting material on the width of leaf (cm)

Treatments[@]	T_1	T_2	T_3
S_1W_1	10.55[@@]	11.24	11.50
S_1W_2	9.70	10.60	11.05
S_1W_3	9.47	10.62	10.77
S_2W_1	10.13	9.72	10.97
S_2W_2	10.22	10.37	10.45
S_2W_3	10.01	11.77	11.59
S_3W_1	9.74	11.39	11.18
S_3W_2	10.66	10.75	11.11
S_3W_3	10.57	12.12	11.40

Means

Main plot : T_1 = 10.11; T_2 = 10.94; T_3 = 11.11

Sub plot : S_1 = 10.60; S_2 = 10.56; S_3 = 10.99

Sub-sub plot : W_1 = 10.71; W_2 = 10.54; W_3 = 10.92

$CD_{(0.05)}$

Main plot = 0.50

Sub plot = 0.42

Sub-sub plot = 0.36

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 8.- Effect of time of planting, spacing and weight of planting material on mean leaf area (cm^2)

Treatments[@]	T_1	T_2	T_3
S_1W_1	260.70[@@]	291.10	295.01
S_1W_2	240.36	262.47	285.82
S_1W_3	220.99	267.81	286.37
S_2W_1	241.03	256.12	290.17
S_2W_2	245.04	273.28	271.15
S_2W_3	245.27	320.00	314.85
S_3W_1	235.17	297.31	290.11
S_3W_2	254.74	262.73	300.20
S_3W_3	261.40	328.37	314.60

Means

Main plot : T_1 = 244.76; T_2 = 284.35; T_3 = 294.25

Sub plot : S_1 = 267.54; S_2 = 272.99; S_3 = 282.73

Sub-sub plot : W_1 = 266.20; W_2 = 272.96; W_3 = 284.40

$CD_{(0.05)}$

Main plot = 12.34

Sub plot = 11.78

Sub-sub plot = 11.36

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG 6 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON THE LENGTH OF LEAF.

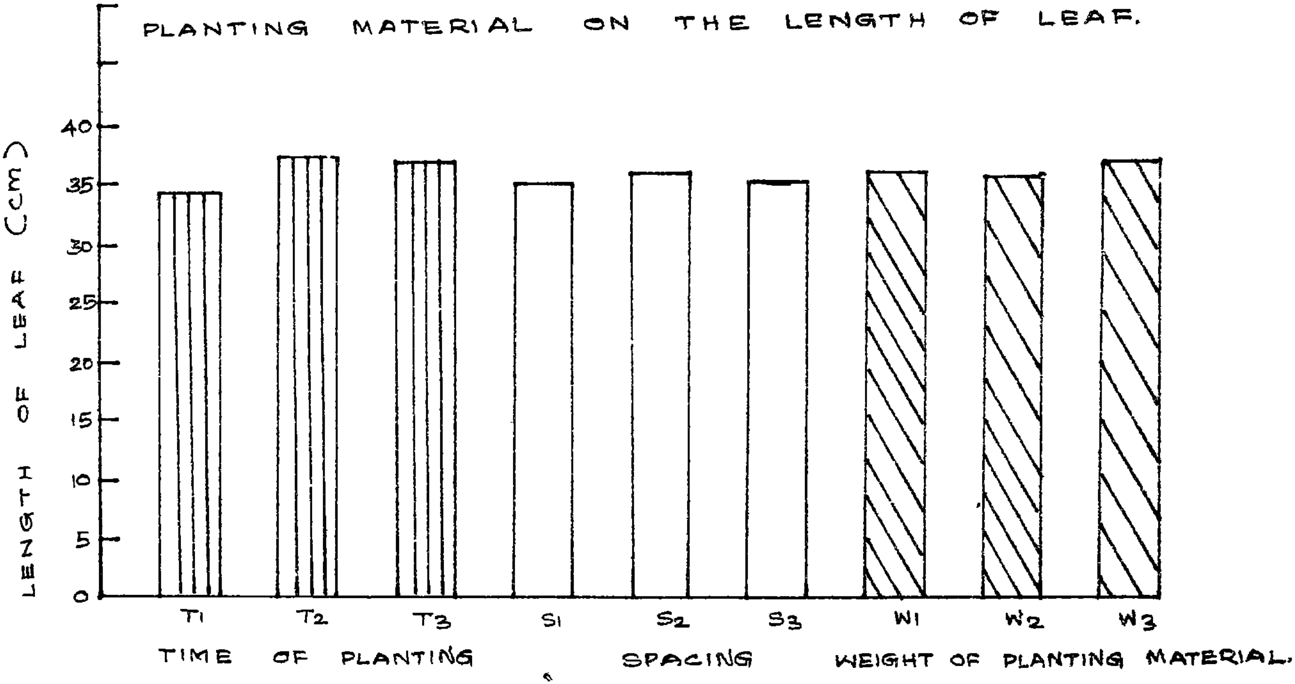


FIG 7 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON THE WIDTH OF LEAF.

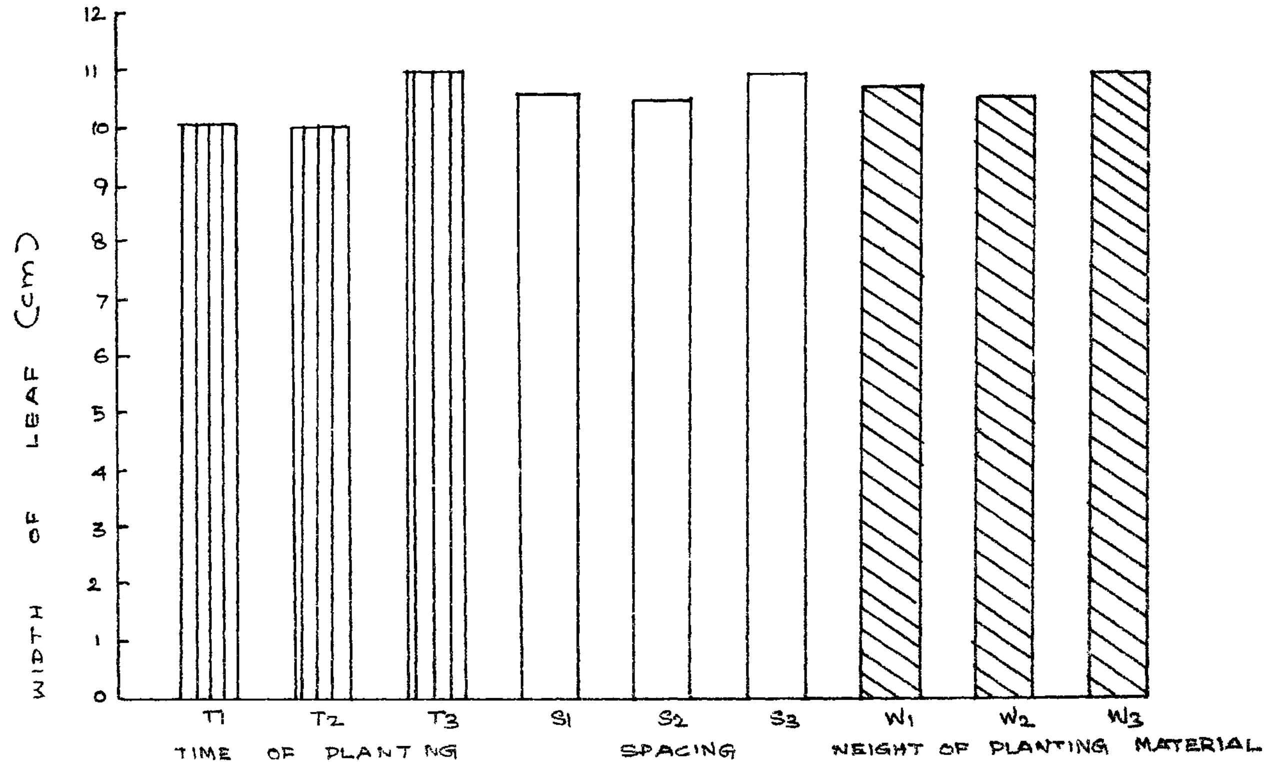
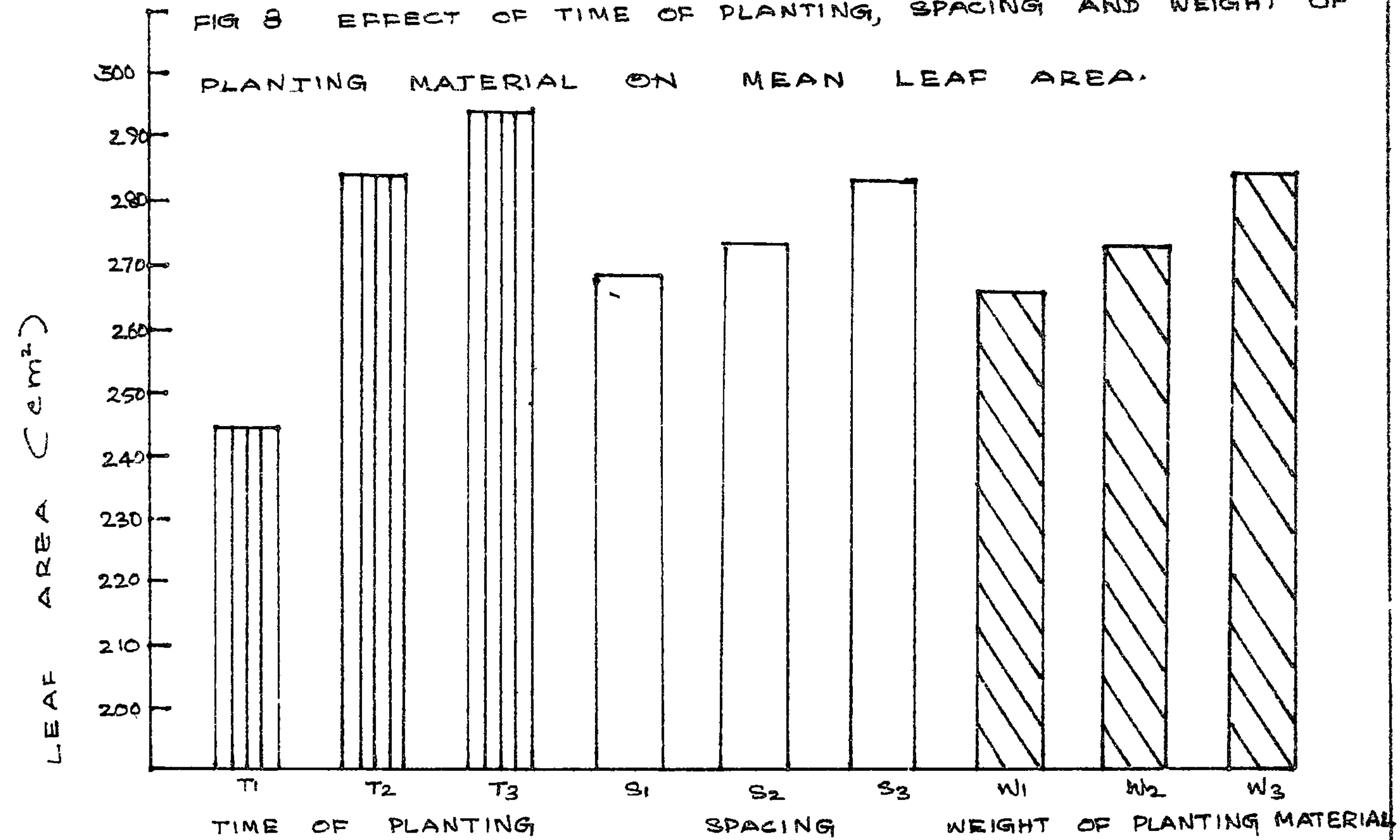


FIG 8 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON MEAN LEAF AREA.



and weight of planting material, no statistical significance could be established from the analysis.

Among the interactions, the spacing x weight of planting material interaction alone exhibited statistical significance. S_3W_3 produced the broadest leaves (11.36 cm). However, the differences between S_3W_3, S_2W_3 and S_1W_1 were not statistically significant.

All the three treatments under study exhibited significant influence on the area of the leaves. The average leaf area increased from 244.96 cm^2 at T_1 to 284.35 cm^2 at T_2 and 294.25 cm^2 at T_3. T_3 and T_2 were statistically on par. A progressive increase in leaf area with the increase in spacing was observed. Plants at S_3 produced the largest leaves (282.73 cm^2). The differences between S_3 and S_2 as well as between S_2 and S_1 were not significant. With regard to the weight of planting material, W_3 gave maximum leaf area of 284.40 cm^2 which is significantly higher than that obtained for W_2 and W_1 (272.96 cm^2 and 266.20 cm^2, respectively).

The interaction between spacing and weight of planting material also indicated statistical significance. S_3W_3 recorded the maximum value of 301.45 cm^2 and showed significant difference with all other combinations except S_2W_3 (293.37 cm^2).

4.7. <u>Total leaf area</u>

The values relating to total leaf area are presented in

Table 9.- Effect of time of planting, spacing and weight of planting material on total leaf area (cm^2)

Treatments[@]	T_1	T_2	T_3
S_1W_1	1619.18[@@]	2245.09	2084.84
S_1W_2	1442.79	1979.15	1757.37
S_1W_3	1256.34	2136.78	1953.33
S_2W_1	1392.08	1872.54	1856.63
S_2W_2	1483.80	1995.52	1813.77
S_2W_3	1597.21	2403.85	2237.88
S_3W_1	1458.75	2141.58	1997.16
S_3W_2	1574.90	2032.48	1884.23
S_3W_3	1639.51	2752.29	2313.25

Means

T_1 = 1496.07; T_2 = 2173.24; T_3 = 1988.72

S_1 = 1830.53; S_2 = 1850.36; S_3 = 1977.13

W_1 = 1773.73; W_2 = 1851.98; W_3 = 2032.27

$CD_{(0.05)}$

Main plot = 187.55

Sub plot = 150.37

Sub-sub plot = 93.80

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG. 9 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON TOTAL LEAF AREA

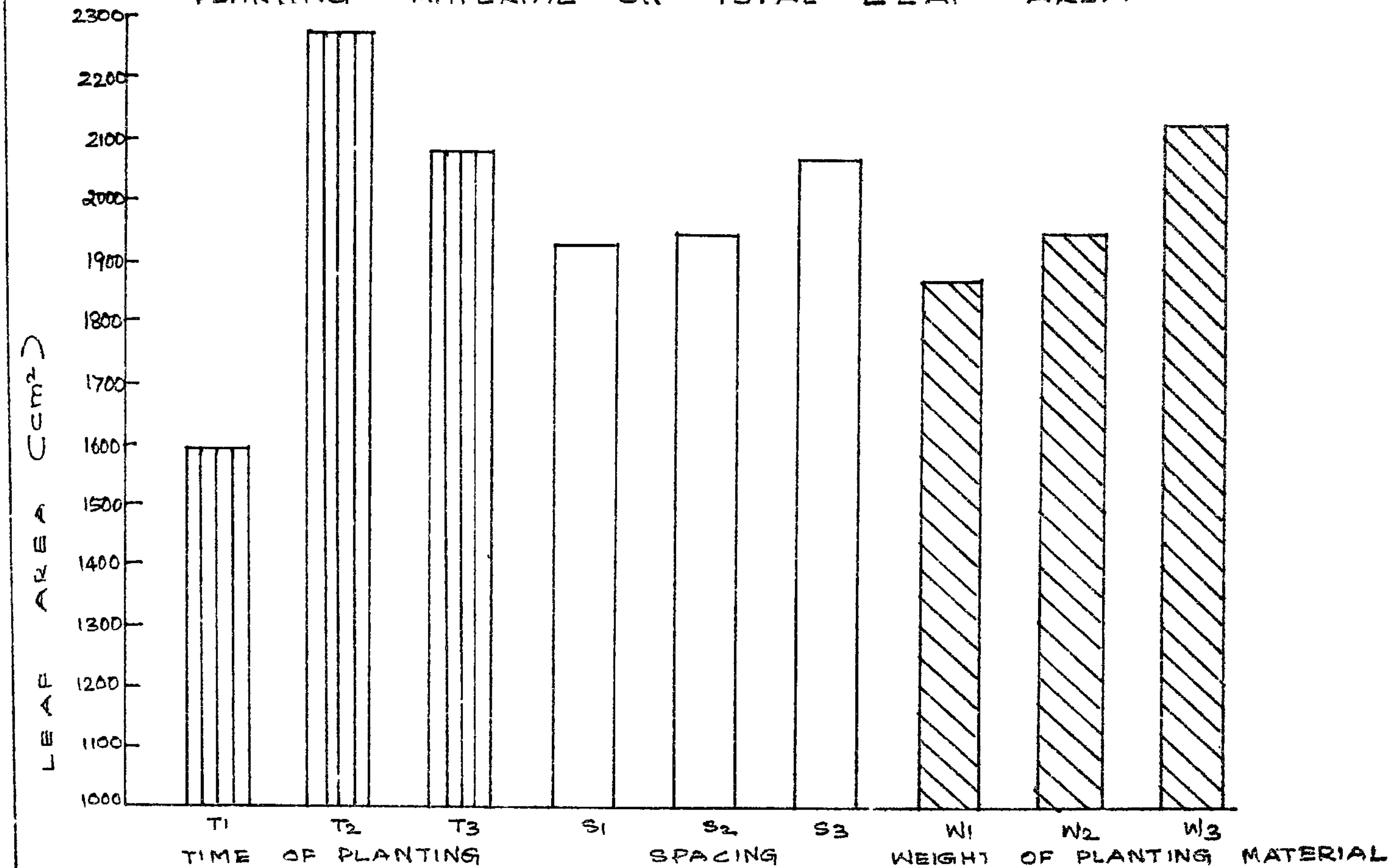


Table 9 and Fig.9. The results of the statistical analysis appears in Appendix IX.

The time of planting as well as the weight of planting material exhibited significant influence on the total leaf area per plant. T_2 gave a maximum area of 2173.24 cm^2 showing significant difference from T_1 (1496.07 cm^2). T_3 (1988.72 cm^2) and T_2 were on par. With respect to the effect of weight of planting material, W_3 gave a maximum area of 2032.27 cm^2 significantly different from W_1 and W_2 with 1773.73 cm^2 and 1851.98 cm^2, respectively.

The interaction effects between the time of planting and weight of planting material as well as that between spacing and weight of planting material appeared to be significant with the best combination of the former being T_2W_3 (2436.97 cm^2) and that of latter being S_3W_3 (2235.03 cm^2).

4.8. Length of the mother rhizomes

The observations on this parameter have been shown in Table 10 with Fig.10 supporting it diagramatically. The ANOVA appears in Appendix X.

The analysis has shown that the time of planting as well as the weight of planting material significantly influenced the length of the mother rhizomes. T_2 with a mean maximum of 12.67 cm was significantly superior to both T_1 (10.67 cm)

Table 10.- Effect of time of planting, spacing and weight of planting material on length of mother rhizome (cm)

Treatments@	T_1	T_2	T_3
S_1W_1	10.19@@	11.17	10.32
S_1W_2	12.04	11.47	11.29
S_1W_3	11.13	11.79	11.52
S_2W_1	10.93	11.55	10.96
S_2W_2	10.74	11.87	10.46
S_2W_3	11.37	13.84	12.63
S_3W_1	9.88	12.36	10.62
S_3W_2	9.77	14.47	12.17
S_3W_3	10.14	15.54	13.97

Means

Main plot : T_1 = 10.67; T_2 = 12.67; T_3 = 11.54

Sub plot : S_1 = 11.21; S_2 = 11.58; S_3 = 12.10

Sub-sub plot : W_1 = 10.88; W_2 = 11.58; W_3 = 12.42

$CD_{(0.05)}$

Main plot = 0.46

Sub plot = 0.01

Sub-sub plot = 0.78

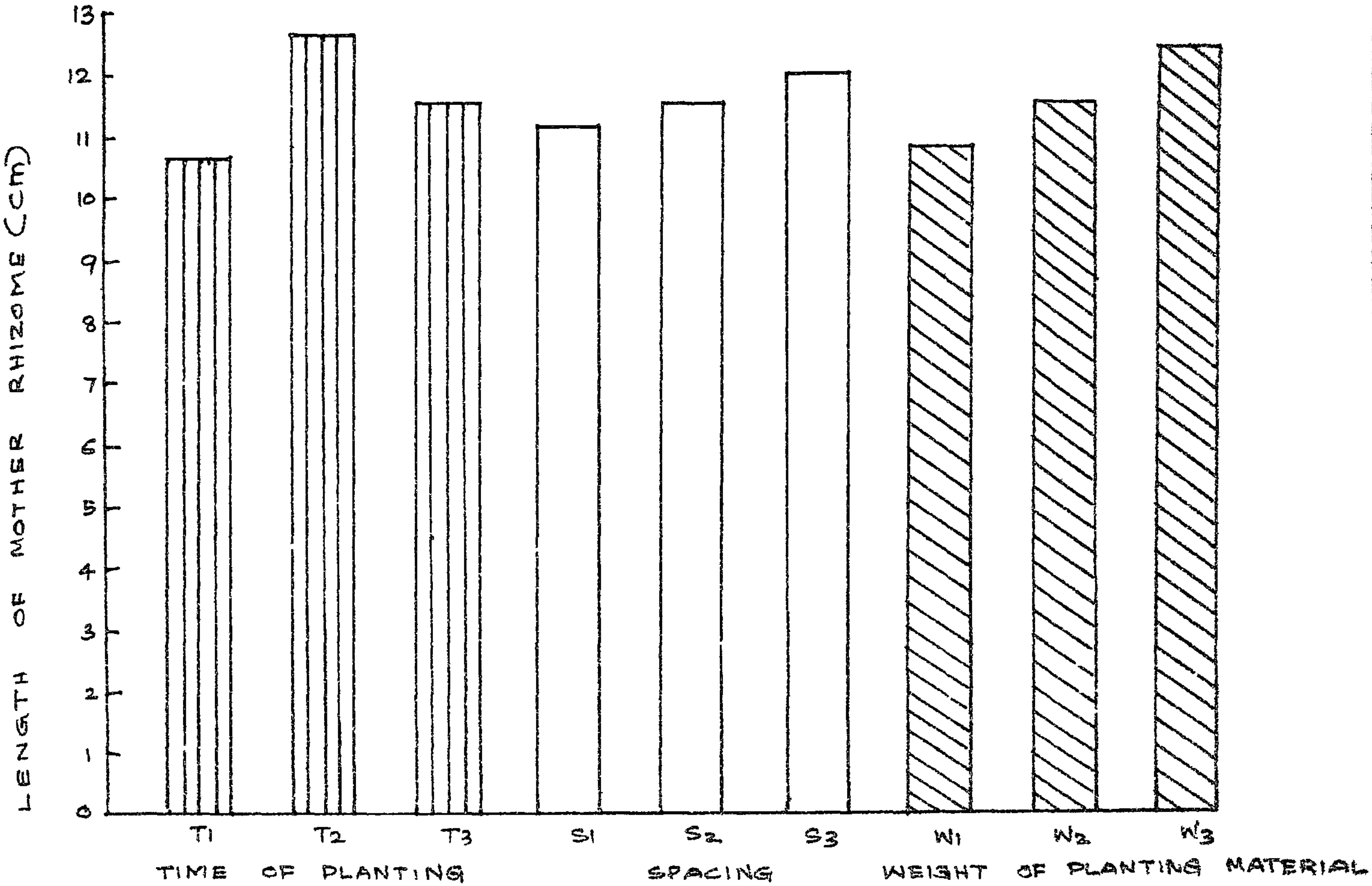
@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG. 10 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON LENGTH OF MOTHER RHIZOME.



and T_3 (11.54 cm). The length of mother rhizome progressively increased with the increase in the weight of planting material wherein W_1 recorded a mean length of 10.88 cm which was not statistically different from that recorded by W_2 (11.58 cm). W_3 was superior to W_1 and W_2 recorded the maximum length (12.42 cm). Spacing had no significant influence on this character. Significant differences could not be observed for the various interaction effects.

4.9. Number of primary and secondary fingers

Table 11 and Fig.11 show the data on the number of primary fingers with its ANOVA appearing at Appendix XI. Table 12, Fig.12 and Appendix XII pertain to the number of secondary fingers.

The analysis indicated that the number of primary fingers per plant was not influenced by the treatments under study. However, the number of secondary fingers per plant was significantly influenced by the time of planting. T_2 gave a maximum of 6.79 fingers per plant, differing significantly from T_1 with 5.99 fingers per plant. T_2 and T_3 (6.23 fingers per plant) were on par. The effects of spacing and weight of planting material were not found significant.

All the interaction effects except that between spacing x weight of planting material were non-significant. The maximum number of secondary fingers per plant was obtained

Table 11.- Effect of time of planting, spacing and weight of planting material on number of primary fingers

Treatments@	T_1	T_2	T_3
S_1W_1	5.93@@	6.27	5.83
S_1W_2	5.83	6.06	5.83
S_1W_3	5.73	6.16	5.87
S_2W_1	6.00	6.43	5.87
S_2W_2	5.80	6.63	5.98
S_2W_3	6.70	6.40	5.94
S_3W_1	6.10	6.05	5.70
S_3W_2	6.43	6.14	5.83
S_3W_3	6.13	7.08	6.13

Means

Main plot : T_1 = 6.07; T_2 = 6.33; T_3 = 5.88

Sub plot : S_1 = 5.94; S_2 = 6.17; S_3 = 6.17

Sub-sub plot : W_1 = 6.02; W_2 = 6.04; W_3 = 6.23

$CD_{(0.05)}$

Main plot = 0.49

Sub plot = 0.22

Sub-sub plot = 0.26

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 12.- Effect of time of planting, spacing and weight of planting material on number of secondary fingers

Treatments[@]	T_1	T_2	T_3
S_1W_1	5.4[@@]	6.47	5.80
S_1W_2	6.6	7.44	6.82
S_1W_3	6.03	5.80	5.43
S_2W_1	5.17	7.43	6.77
S_2W_2	5.60	6.63	6.31
S_2W_3	6.17	6.27	6.03
S_3W_1	5.63	6.53	6.20
S_3W_2	6.65	6.67	6.00
S_3W_3	6.67	7.93	6.77

Means

Main plot : T_1 = 5.99; T_2 = 6.79; T_3 = 6.23

Sub plot : S_1 = 6.19; S_2 = 6.26; S_3 = 6.56

Sub-sub plot : W_1 = 6.15; W_2 = 6.52; W_3 = 6.34

$CD_{(0.05)}$

Main plot = 0.61

Sub plot = 0.48

Sub-sub plot = 0.42

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

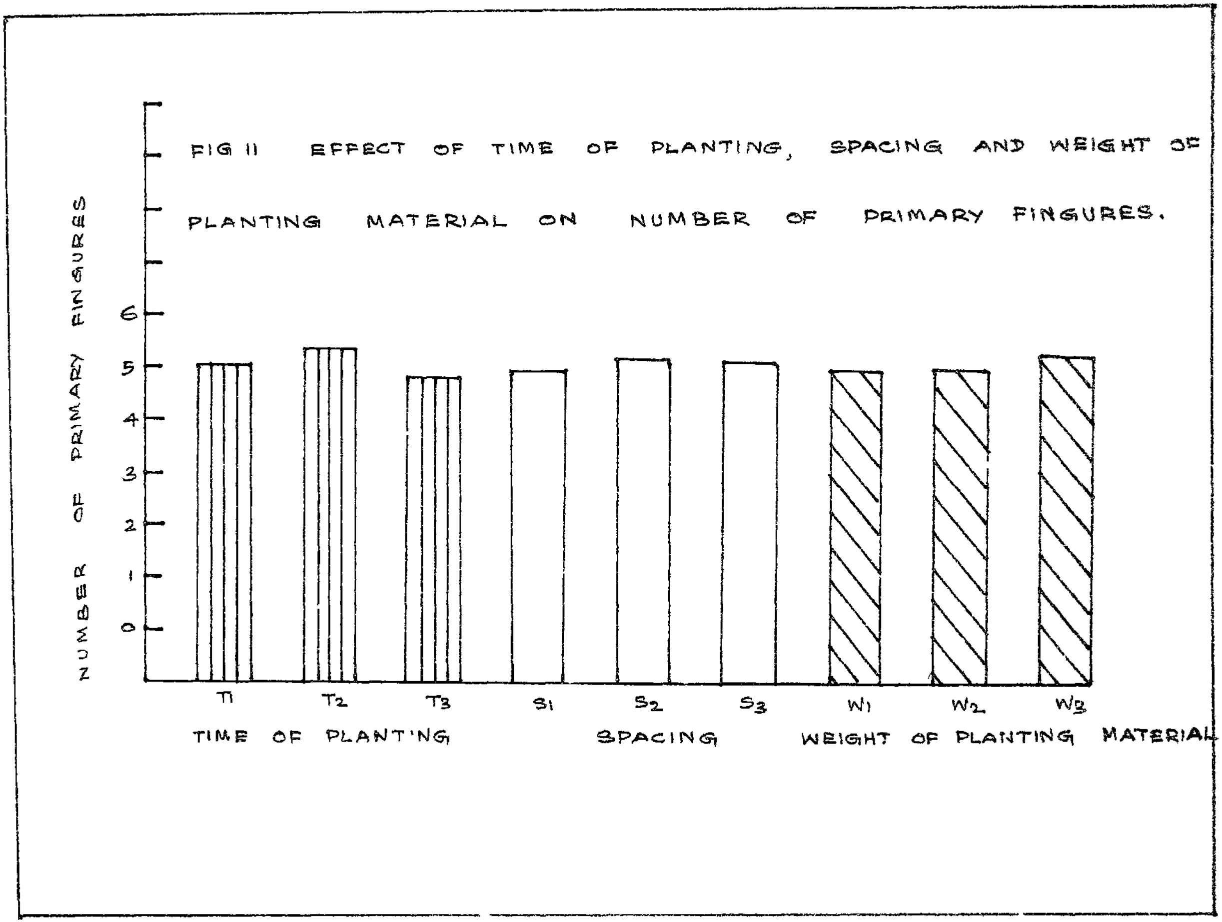
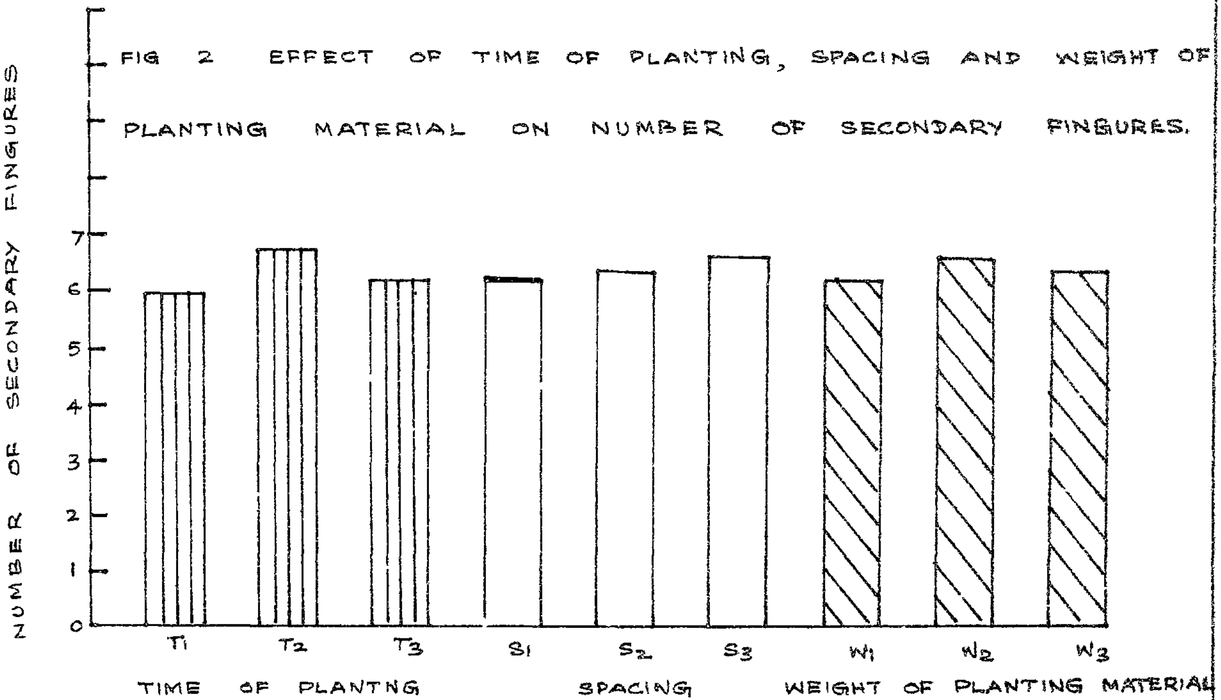


FIG II EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF PRIMARY FINGURES.
NUMBER OF PRIMARY FINGURES
0
1
2
3
4
5
6
T1
T2
T3
S1
S2
S3
W1
W2
W3
TIME OF PLANTING
SPACING
WEIGHT OF PLANTING MATERIAL

FIG 2 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF SECONDARY FINGURES.



under S_3W_3 (7.12). However, S_3W_3 and S_1W_2 (6.95) were statistically on par. S_1W_3 recorded the minimum number of secondary fingers (5.75).

4.10. Number of nodes, girth and internodal length of primary fingers

Data on these characters are presented in Tables 13 to 16 and Figures 13 to 16 with their ANOVA at Appendices XIII to XVI.

Regarding the number of nodes per primary finger, the analysis showed that the treatment effects were not significant. With respect to the length of primary fingers, only the weight of planting material showed statistically significant effects. There was a progressive increase in the length of the primary fingers with increase in the weight of the planting material from 5.81 cm at W_1, 6.10 cm at W_2 and 6.52 cm at W_3. The differences between W_1 and W_2 as well as that between W_2 and W_3 were not statistically significant.

The results presented in Table 15 indicate that the time of planting influenced the girth of the primary fingers at a significant level. Planting by the middle of May (T_2) produced primary fingers with 5.88 cm girth. T_2 was significantly different from T_3 (5.09 cm) and T_1 (4.96 cm). Effects of the other treatments as well as their interactions were not found significant.

Table 13.- Effect of time of planting, spacing and weight of planting material on number of nodes

Treatments[@]	T_1	T_2	T_3
S_1W_1	9.43[@@]	9.58	9.23
S_1W_2	9.53	8.93	9.37
S_1W_3	9.69	9.39	8.59
S_2W_1	9.47	9.07	9.91
S_2W_2	9.47	9.30	8.78
S_2W_3	8.97	9.31	9.13
S_3W_1	10.01	10.16	8.78
S_3W_2	9.50	9.23	9.46
S_3W_3	10.17	8.99	9.19

Means

Main plot : T_1 = 9.56; T_2 = 9.33; T_3 = 9.16

Sub plot : S_1 = 9.28; S_2 = 9.26; S_3 = 9.49

Sub-sub plot : W_1 = 9.49; W_2 = 9.28; W_3 = 9.27

CD (0.05)

Main plot = 0.31

Sub plot = 0.33

Sub-sub plot = 0.38

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 14.- Effect of time of planting, spacing and weight of planting material on length of primary finger (cm)

Treatments@	T_1	T_2	T_3
S_1W_1	5.05@@	6.05	5.81
S_1W_2	6.71	5.94	5.69
S_1W_3	5.62	6.78	6.24
S_2W_1	4.92	6.38	6.03
S_2W_2	5.41	6.73	6.18
S_2W_3	6.96	6.60	6.25
S_3W_1	5.94	6.44	5.73
S_3W_2	6.31	6.31	5.66
S_3W_3	6.56	7.31	6.37

Means

Main plot : T_1 = 5.94; T_2 = 6.50; T_3 = 5.99

Sub plot : S_1 = 5.98; S_2 = 6.16; S_3 = 6.29

Sub-sub plot : W_1 = 5.81; W_2 = 6.10; W_3 = 6.52

$CD_{(0.05)}$

Main plot = 0.72

Sub plot = 0.46

Sub-sub plot = 0.50

@ T_1 = Beginning of May, S_1 = 10 x 20 cm, W_1 = 20 g

T_2 = Middle of May, S_2 = 15 x 20 cm, W_2 = 40 g

T_3 = Beginning of June, S_3 = 20 x 20 cm, W_3 = 60 g

@@ Mean of three replications

Table 15.- Effect of time of planting, spacing and weight of planting material on girth of primary fingers (cm)

Treatments[@]	T_1	T_2	T_3
S_1W_1	5.00[@@]	5.14	4.81
S_1W_2	4.84	5.46	5.20
S_1W_3	5.02	5.46	5.37
S_2W_1	4.66	5.74	5.19
S_2W_2	4.71	5.51	5.04
S_2W_3	4.62	5.52	5.37
S_3W_1	4.87	5.10	5.29
S_3W_2	6.17	5.16	4.82
S_3W_3	4.83	5.54	4.78

Means

Main plot : T_1 = 4.96; T_2 = 5.88; T_3 = 5.09

Sub plot : S_1 = 5.14; S_2 = 5.13; S_3 = 5.17

Sub-sub plot : W_1 = 5.08; W_2 = 5.19; W_3 = 5.16

$CD_{(0.05)}$

Main plot = 0.20

Sub plot = 0.28

Sub-sub plot = 0.30

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 16.- Effect of time of planting, spacing and weight of planting material on internodal length of rhizome (cm)

Treatments[©]	T_1	T_2	T_3
S_1W_1	0.50[@@]	0.60	0.56
S_1W_2	0.51	0.55	0.51
S_1W_3	0.58	0.74	0.63
S_2W_1	0.45	0.67	0.58
S_2W_2	0.67	0.78	0.66
S_2W_3	0.52	0.74	0.75
S_3W_1	0.58	0.67	0.66
S_3W_2	0.57	0.66	0.59
S_3W_3	0.82	0.88	0.75

Means

Main plot : T_1 = 0.57; T_2 = 0.69; T_3 = 0.63

Sub plot : S_1 = 0.57; S_2 = 0.64; S_3 = 0.68

Sub-sub plot : W_1 = 0.58; W_2 = 0.60; W_3 = 0.71

$CD_{(0.05)}$

Main plot = 0.07

Sub plot = 0.05

Sub-sub plot = 0.04

© T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g
T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g
T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG. 13. EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON NUMBER OF NODES.

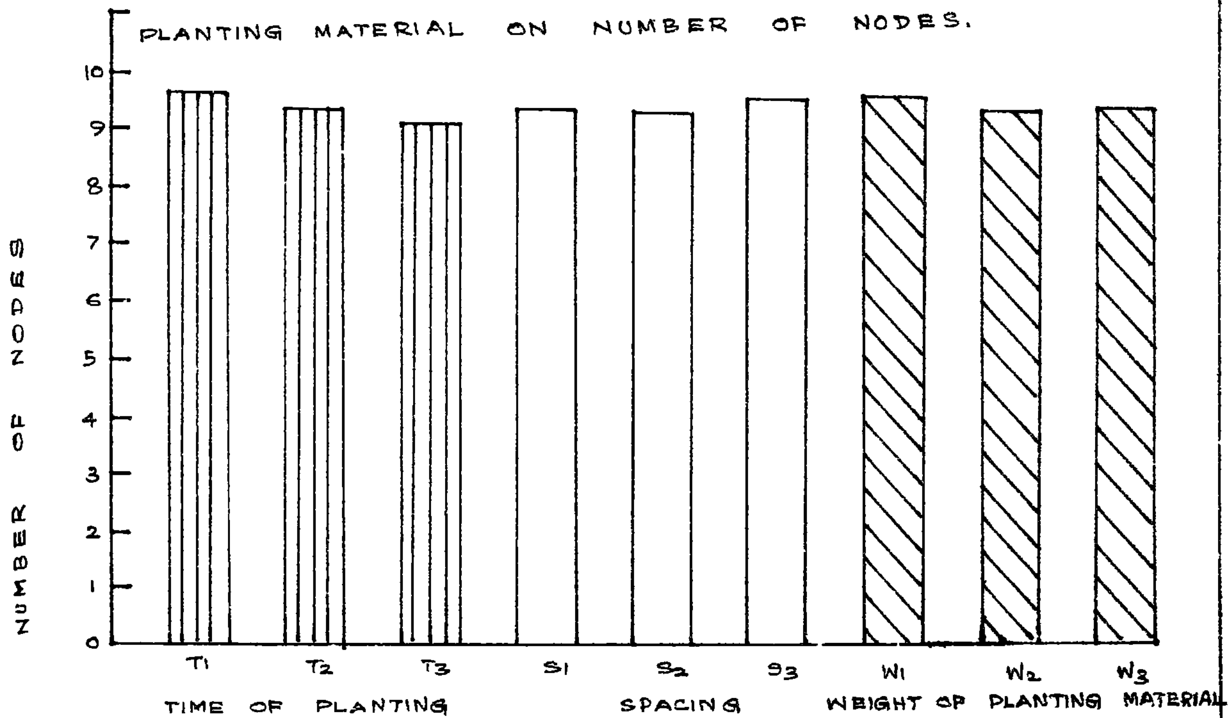


FIG 14. EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON LENGTH OF PRIMARY FINGURE

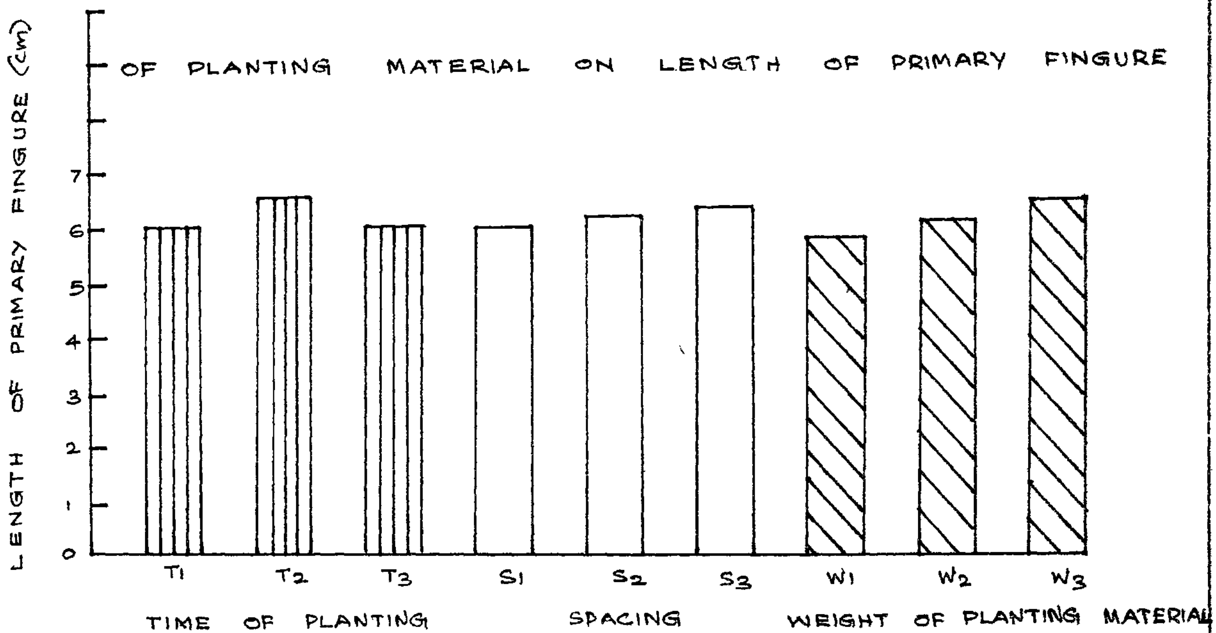
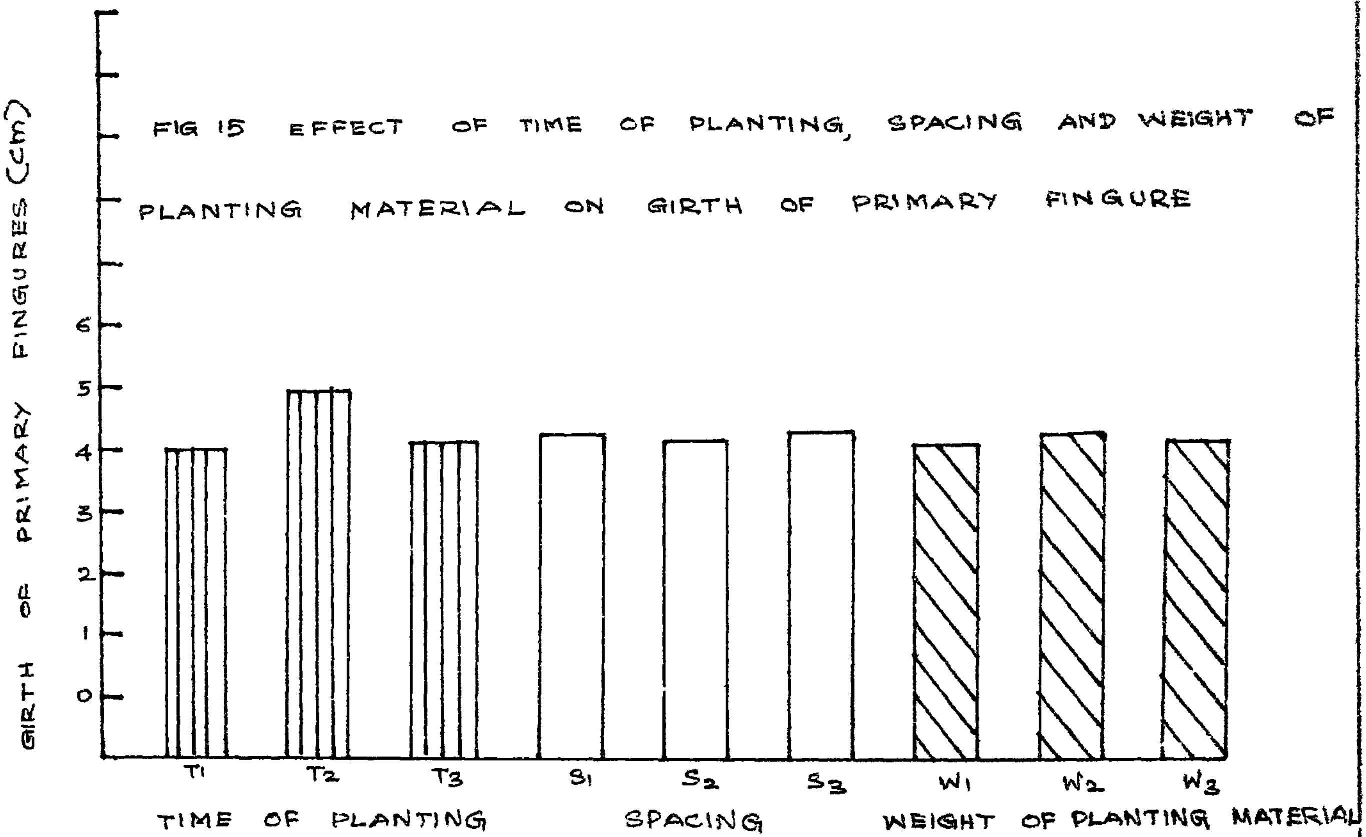


FIG 15 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON GIRTH OF PRIMARY FINGURE



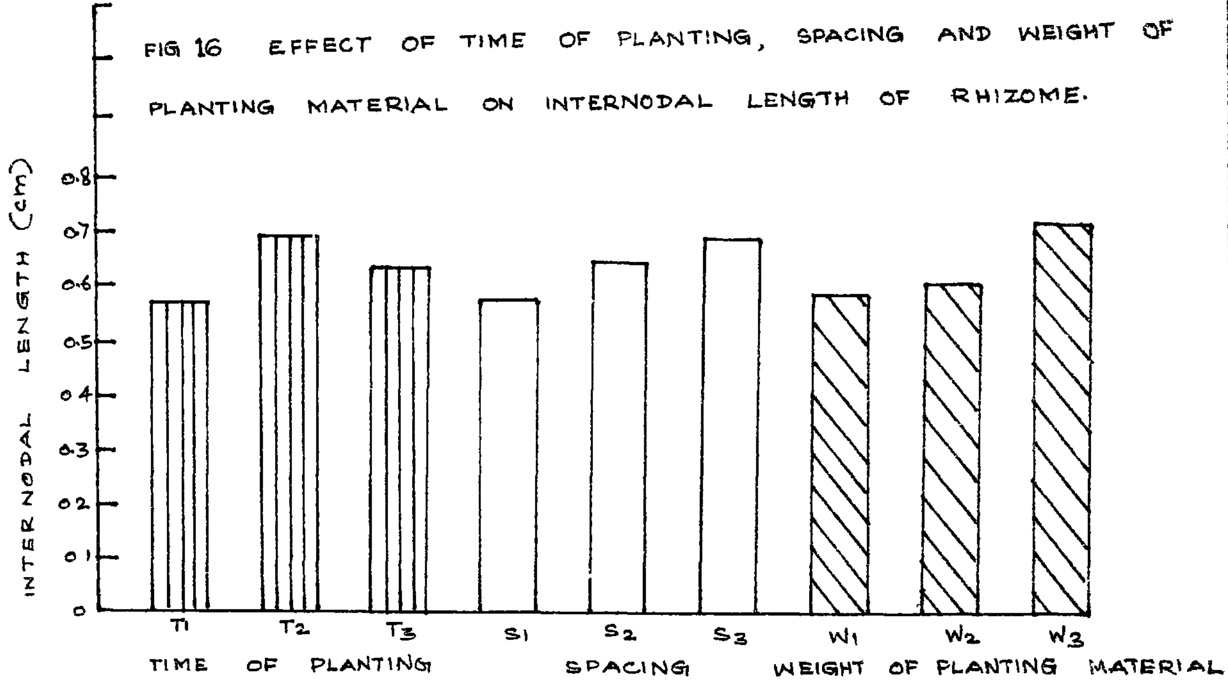


FIG 16 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON INTERNODAL LENGTH OF RHIZOME.

The internodal length was significantly influenced by all the three treatments under study. Among the different times of plantings tried, T_2 ranked first with a maximum internodal length of 0.69 cm, followed by T_3 (0.63 cm) and T_1 (0.57 cm). The differences between T_2 and T_3 as well as between T_3 and T_1 were not significant. With regard to the effect of spacings tried, S_3 recorded the highest mean length of 0.68 cm followed by S_2 (0.64 cm) and S_1 (0.57 cm). However, S_3 and S_2 was on par. With regard to the weight of planting material W_3 with average internodal length of 0.71 cm was significantly superior to W_2 and W_1 with 0.60 cm and 0.58 cm, respectively.

The data also indicated that the spacing x weight of planting material interaction had significant influence on the internodal length. The best combination was S_3W_3 with internodal length of 0.81 cm.

4.11. <u>Yield of green rhizomes</u>

The data on yield of green rhizomes per plot are given in Table 17 and Fig.17 with ANOVA in Appendix XVII.

The green rhizome yield exhibited highly significant variation with respect to the three treatments. The highest yield of 9.46 kg/plot (31.53 t/ha) was recorded when planting was done during middle of May (T_2) which differed significantly from the others. With regard to the effect of spacing, an

Table 17.- Effect of time of planting, spacing and weight of planting material on yield of fresh rhizome/plot (kg/3 m^2)

Treatments@	T_1	T_2	T_3
S_1W_1	1.60@@	10.37	8.73
S_1W_2	1.87	11.60	9.59
S_1W_3	2.65	12.45	10.33
S_2W_1	1.38	7.09	6.82
S_2W_2	1.67	9.05	8.35
S_2W_3	2.40	10.38	9.55
S_3W_1	1.40	7.08	6.28
S_3W_2	1.54	7.94	7.52
S_3W_3	2.22	9.20	8.59

Means

Main plot : T_1 = 1.85; T_2 = 9.46; T_3 = 8.41

Sub plot : S_1 = 7.69; S_2 = 6.29; S_3 = 5.75

Sub-sub plot : W_1 = 5.63; W_2 = 6.56; W_3 = 7.53

$CD_{(0.05)}$

Main plot = 0.85

Sub plot = 0.51

Sub-sub plot = 0.22

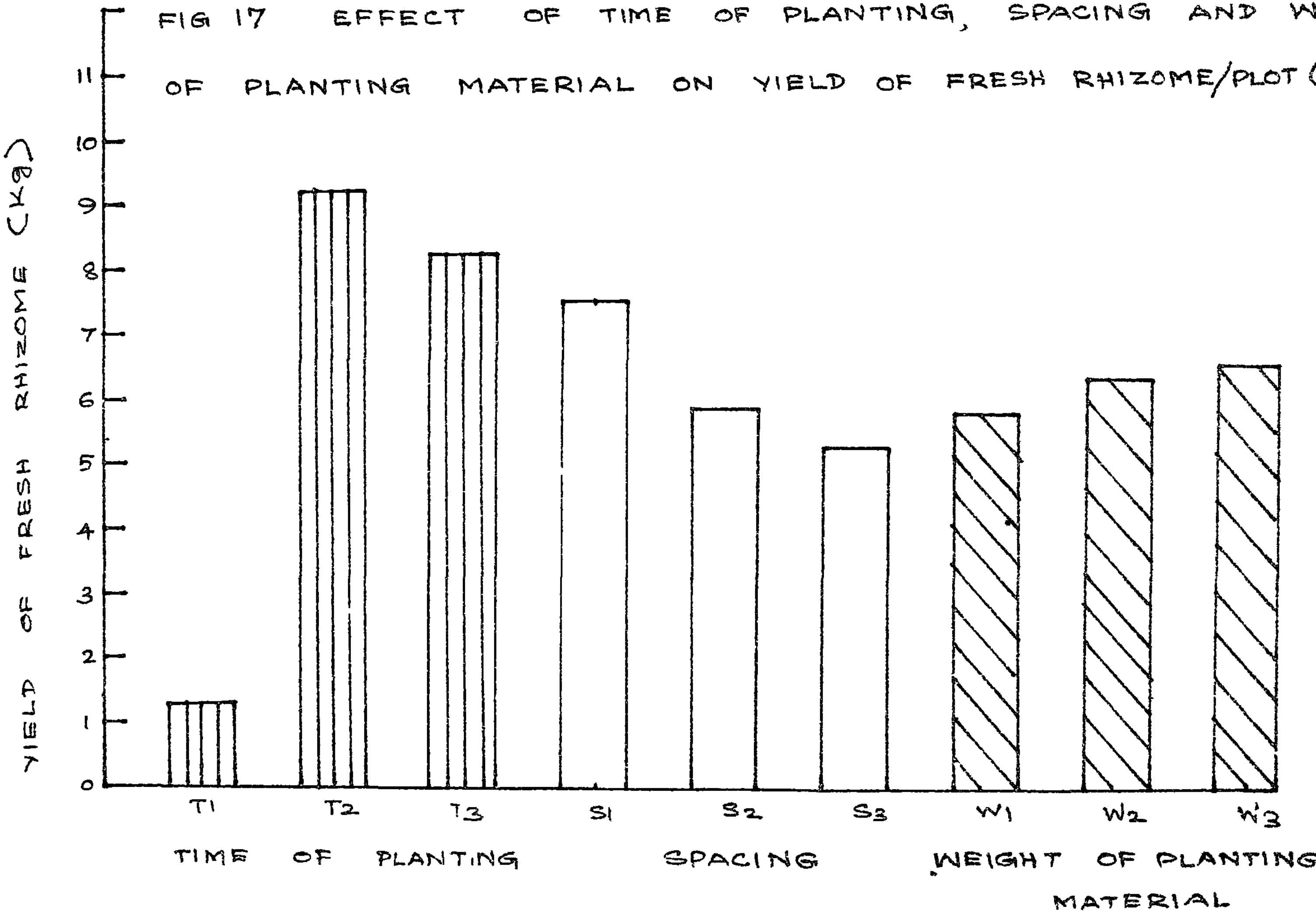
@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG 17 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON YIELD OF FRESH RHIZOME/PLOT (3 m²).



yield of 7.69 kg per plot (25.63 t/ha) was recorded when planting was done at 10 x 20 cm spacing (S_1). Highest yield of 7.53 kg per plot (25.1 t/ha) was recorded when planting material weighing 60 g (W_3) was used.

Among the interaction, time of planting x spacing and time of planting x weight of planting material interactions exhibited significance. T_2S_1 with 11.47 kg/plot (38.23 t/ha) and T_2W_3 with 10.67 kg per plot (35.56 t/ha) ranked first.

4.12. Curing percentage

The data on percentage recovery of rhizomes after curing and drying are presented in Table 18 and Fig.18 with ANOVA in Appendix XVIII.

The statistical analysis showed that none of the treatments except the weight of planting material had significant influence on the curing percentage. The curing percentage improved from 11.46 at W_1 to 12.09 at W_2 and 12.62 at W_3. The three levels differed significantly.

4.13. Yield of cured dry rhizomes

The data on cured, dry rhizome are presented in Table 19 and Fig.19 with ANOVA in Appendix XIX. The yield of cured, dry rhizomes showed highly significant variation among the treatments. All the treatments exhibited statistically significant influence. Planting during mid May (T_2) recorded

Table 18.- Effect of time of planting, spacing and weight of planting material on per cent recovery of dry weight

Treatments[@]	T_1	T_2	T_3
S_1W_1	11.78[@@]	11.40	11.08
S_1W_2	12.50	12.67	11.27
S_1W_3	13.20	12.87	12.60
S_2W_1	11.90	11.50	12.00
S_2W_2	12.07	11.87	12.00
S_2W_3	12.56	12.77	12.20
S_3W_1	11.73	10.63	11.13
S_3W_2	12.37	11.93	12.17
S_3W_3	12.88	12.33	12.20

Means

Main plot : T_1 = 12.33; T_2 = 11.99; T_3 = 11.85

Sub plot : S_1 = 12.15; S_2 = 12.09; S_3 = 11.93

Sub-sub plot : W_1 = 11.46; W_2 = 12.00; W_3 = 12.62

$CD_{(0.05)}$

Main plot = 0.64

Sub plot = 0.44

Sub-sub plot = 0.37

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 19.- Effect of time of planting, spacing and weight of planting material on yield of dry rhizome/plot (kg/3 m^2)

Treatments[@]	T_1	T_2	T_3
S_1W_1	0.19[@@]	1.17	0.97
S_1W_2	0.23	1.47	1.08
S_1W_3	0.35	1.63	1.31
S_2W_1	0.16	0.89	0.83
S_2W_2	0.20	1.12	1.03
S_2W_3	0.30	1.32	1.22
S_3W_1	0.17	0.84	0.69
S_3W_2	0.19	0.98	0.89
S_3W_3	0.29	1.18	1.06

Means

Main plot : T_1 = 0.23; T_2 = 1.17; T_3 = 1.00

Sub plot : S_1 = 0.93; S_2 = 0.78; S_3 = 0.69

Sub-sub plot : W_1 = 0.65; W_2 = 0.79; W_3 = 0.96

$CD_{(0.05)}$

Main plot = 0.10

Sub plot = 0.07

Sub-sub plot = 0.03

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

FIG 18. EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON PERCENT RECOVERY OF DRY WEIGHT.

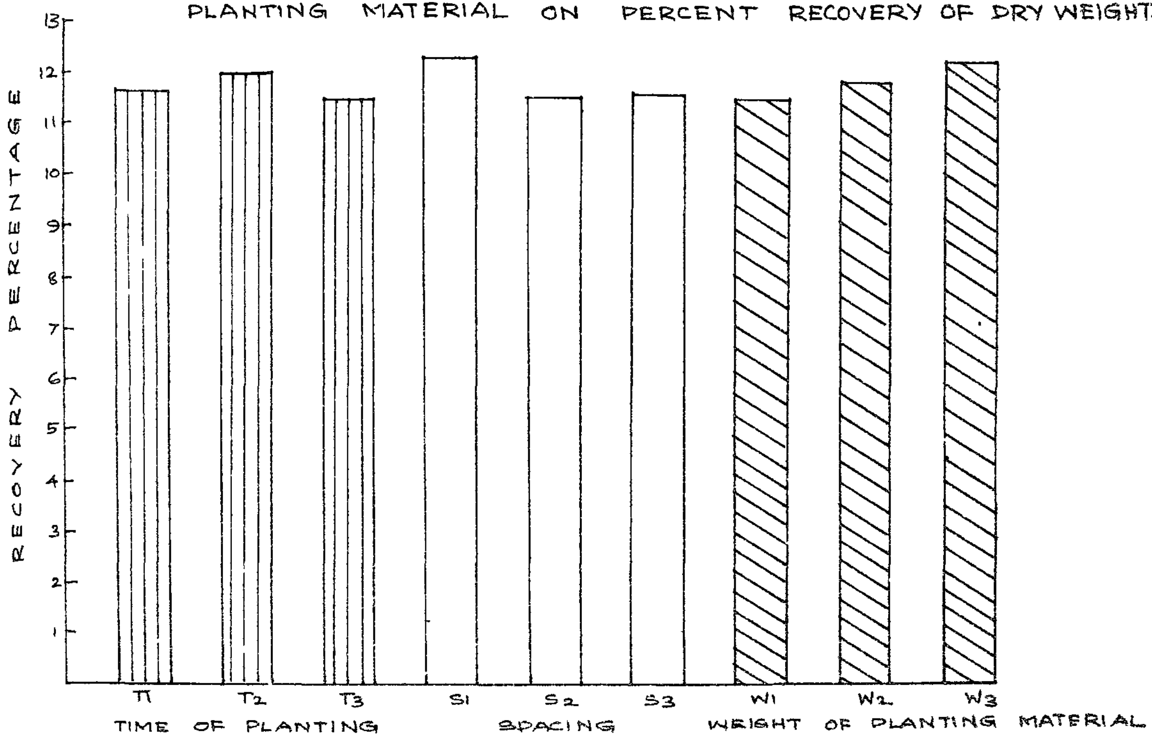
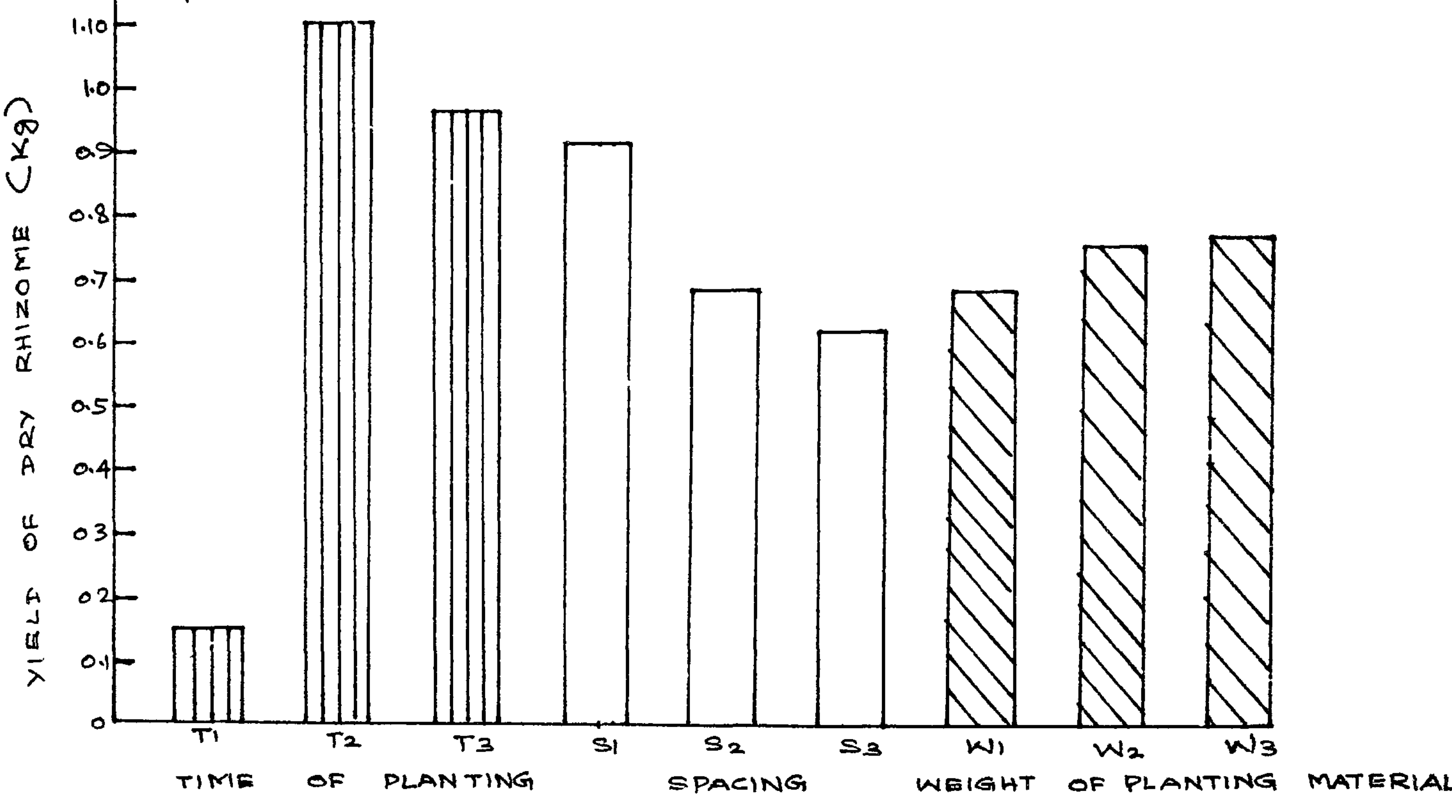


FIG 19 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON YIELD OF DRY RHIZOME / PLOT (3 m²).



the highest yield of 1.17 kg per plot (3.9 t/ha) among the different planting dates tried. As regards spacing, close planting at 10 x 20 cm (S_1) resulted in the highest dry rhizome yield of 0.93 kg/plot (3.1 t/ha). Planting material weighing 60 g (W_3) recorded the highest yield of 0.96 kg/plot (3.2 t/ha). In all the cases, the means showed significant differences. The time of planting x spacing as well as time of planting x weight of planting material interactions were statistically significant. T_2S_1 with a yield of 1.42 kg/plot (4.73 t/ha) and T_2W_3 with a yield of 1.37 kg/plot (4.56 t/ha) ranked first. The other two interactions were not significant.

4.14. Oleoresin content (%)

The effects of the treatments on the oleoresin content was analysed and the data have been presented in Table 20 and Fig.20 with ANOVA in Appendix XX.

The effect of time of planting, spacing as well as weight of the planting material showed no statistical significance with respect to the percentage oleoresin content.

4.15. Yield of oleoresin (kg/ha)

The analysis of the computed data on oleoresin yield per hectare (Table 21, Fig.21 and Appendix XXI) revealed that the effects of time of planting and weight of planting material were significant. Among the different planting dates tried, T_2 with a oleoresin yield of 513.38 kg/ha was the best. The

Table 20.- Effect of time of planting, spacing and weight of planting material on oleoresin content (%)

Treatments@	T_1	T_2	T_3
S_1W_1	10.16@@	16.66	12.83
S_1W_2	9.33	11.00	11.66
S_1W_3	13.66	14.00	11.16
S_2W_1	13.50	15.83	12.83
S_2W_2	14.83	11.00	11.83
S_2W_3	12.83	8.16	10.50
S_3W_1	12.33	11.33	11.00
S_3W_2	11.66	14.00	10.16
S_3W_3	13.00	15.33	11.50

Means

Main plot : T_1 = 12.37; T_2 = 13.03; T_3 = 11.50

Sub plot : S_1 = 12.27; S_2 = 12.37; S_3 = 12.25

Sub-sub plot : W_1 = 12.94; W_2 = 11.72; W_3 = 12.24

$CD_{(0.05)}$

Main plot = 5.95

Sub plot = 2.23

Sub-sub plot = 1.88

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Mean of three replications

Table 21.- Effect of time of planting, spacing and weight of planting material on yield of oleoresin (kg/ha)

Treatments@	T_1	T_2	T_3
S_1W_1	64.16@@	641.11	417.43
S_1W_2	71.91	549.56	417.01
S_1W_3	160.39	755.56	508.57
S_2W_1	70.68	479.56	352.62
S_2W_2	84.28	411.91	402.79
S_2W_3	127.77	403.81	430.90
S_3W_1	64.49	321.70	256.07
S_3W_2	66.85	450.70	307.77
S_3W_3	118.25	606.53	411.55

Means

Main plot: T_1 = 92.64; T_2 = 513.38; T_3 = 389.41

Sub plot : S_1 = 398.41; S_2 = 307.15; S_3 = 289.88

Sub-sub plot: W_1 = 296.98; W_2 = 306.97; W_3 = 391.44

$CD_{(0.05)}$

Main plot = 206.42

Sub plot = 96.27

Sub-sub plot = 70.84

@ T_1 = Beginning of May S_1 = 10 x 20 cm W_1 = 20 g

T_2 = Middle of May S_2 = 15 x 20 cm W_2 = 40 g

T_3 = Beginning of June S_3 = 20 x 20 cm W_3 = 60 g

@@ Means of three replications

Fig 20 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON OLEORESIN CONTENT

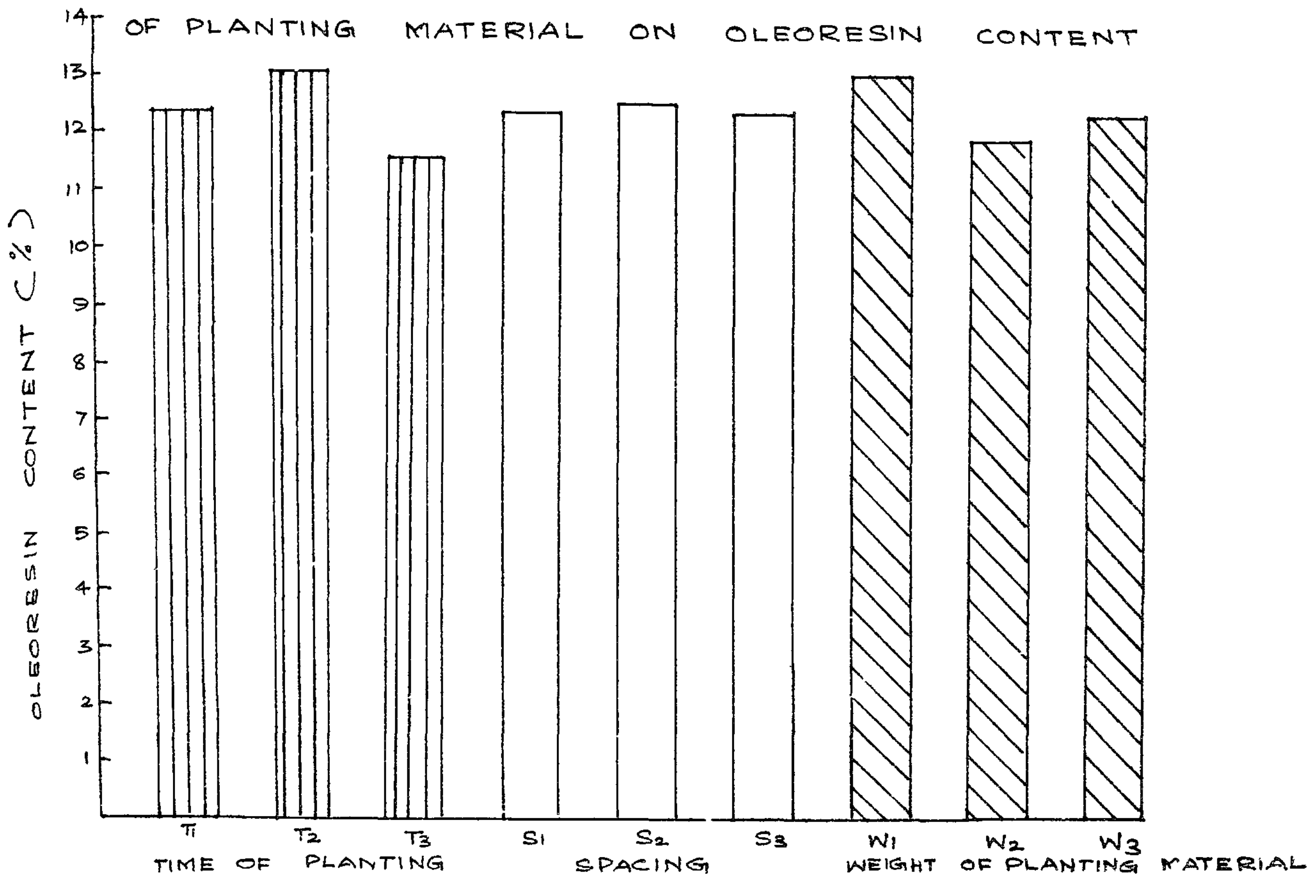
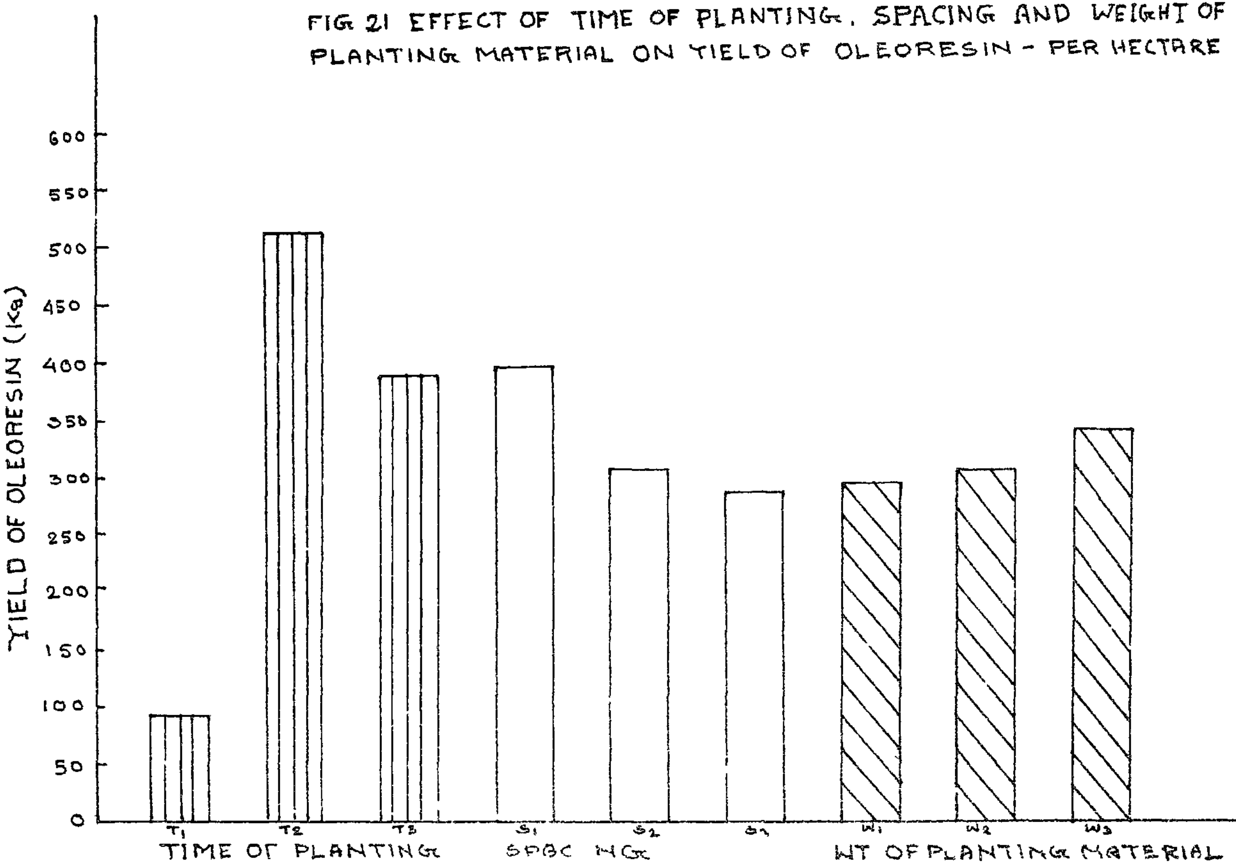


FIG 21 EFFECT OF TIME OF PLANTING, SPACING AND WEIGHT OF PLANTING MATERIAL ON YIELD OF OLEORESIN - PER HECTARE



difference between T_2 and T_3 (389.41 kg/ha) was not significant. The oleoresin yield showed an increasing trend with increase in weight of planting material. W_3 with 391.44 kg/ha of oleoresin ranked first and was superior to the other two. The difference between W_1 and W_2 was not significant. Spacing as well as the different interactions did not show any significant influence on the yield of oleoresin.

4.16. Correlation studies

Correlations between the different characteristics were examined and the correlation coefficients are presented in Table 22. Significant positive correlation was observed in 32 cases. Total leaf area exhibited highly significant positive correlation with all the components of yield.

4.17. Chemical characteristics of the soil

The chemical characteristics of the soil at the experimental site after the experiment are presented in Appendix XXII.

There was no marked difference in total nitrogen, available P_2O_5 and available K_2O in the soil compared to the pre-experimental nutrient status.

Table 22.- Correlation coefficient of characters

	Plant height	Number of tillers	Number of leaves	Total leaf area	Length of mother rhizome	Number of primary fingers	Number of secondary fingers	Fresh weight	Dry weight	Recovery per cent of dry weight	Oleoresin content %
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I. Plant height		0.28**	0.76**	0.55**	0.38**	0.16	0.33**	0.75**	0.71**	-0.082	0.073
II. Number of tillers			0.43**	0.38**	0.39**	0.20	0.21*	0.14	0.14	0.31**	0.22*
III. Number of leaves				0.63**	0.50**	0.10	0.36**	0.80**	0.77**	-0.093	-0.039
IV. Total leaf area					0.52**	0.31**	0.33**	0.58**	0.56**	-0.066	-0.048
V. Length of mother rhizome						0.28**	0.30**	0.28**	0.30**	0.15	0.034
VI. Number of primary fingers							0.36**	0.059	0.053	-0.005	0.002
VII. Number of secondary fingers								0.24**	0.24**	0.24**	0.037
VIII. Fresh weight									0.97**	-0.022	0.051
IX. Dry weight										0.12	0.051
X. Recovery percent of dry weight											0.12
XI. Oleoresin content per cent											

Discussion

5. DISCUSSION

Maximising the yield of oleoresin is the major objective of the turmeric growers of today. The genetical make-up of the material used, the quality of the seed material planted, the condition under which the crop is grown, the post-harvest handling of the produce, etc. influence the above. In the investigations reported in this thesis, the influence of the time of planting, spacing and weight of planting material on the production as well as on the quality of the produce (in terms of oleoresin yield) was studied. The results obtained in the studies have been presented in the previous chapter, characterwise. In this chapter, the results have been critically discussed in the light of available information on turmeric and other related crops to unravel the influence of the three factors studied on the establishment, growth of the crop, yield and quality constituents.

5.1. Germination

Establishment of a crop directly depends upon the germination percentage. The present study indicated that while spacing did not influence the germination of the planted rhizomes, the time of planting and weight of planting material exerted significant influence. Planting during early June was found to be better than early or mid-May plantings, in respect of percentage germination. The literature shows that the planting season of turmeric extends from the first week of May to the end of August in the turmeric belt of South India (Sarma and Krishnamurthy, 1965; Aiyadurai, 1966; Ratinam and Sankaran, 1977). Since turmeric is grown mainly as a rainfed crop, the deciding factor would be the timely receipt of the pre-monsoon showers facilitating operations connected with land preparation. Under Vellanikkara conditions, the pre-monsoon showers are normally received by mid-May and monsoon strengthens by the middle of June. As such, planting the rhizome at T_3(early June) would not only result in higher percentage of germination but also will give a start to the plants before the monsoon strengthens.

The present studies also indicated that the weight of the planting material influenced the germination of the planted rhizomes. It would be, therefore, advisable to use larger and heavier pieces of rhizomes to obtain a good crop stand. Hussain and Said (1965) obtained higher percentage germination by using larger rhizomes of turmeric. In a related crop Costus sp., Sharma et al. (1980) reported significant increases in germination percentage with increase in the weight of the planting material. In the present investigations, as the response was linear even at W_3 (60 g), the optimum weight of the planting material could not be worked out. However, the influence of weight of planting material on the percentage germination has been clearly brought out by the studies. Among the interactions, the time of planting x spacing interaction alone was significant. The best combination was T_3S_3.

5.2. Growth parameters

Subsequent growth of the crop would be influenced to an appreciable extent by the initial crop stand which, as stated earlier, would depend on the percentage germination. However, the time of planting (through the influence of the climatic factors), the spacing (through the competition effects) and the weight of planting material (through the initial advantage resulting from stored food material, intrinsic vigour, etc.) can substantially modify the growth of the crop. In order to gather information on these aspects, the growth of the plants was studied in relation to the time of planting, population density and weight of the planting material. The growth parameters studied in the present investigations were the height of the plant, number of tillers per plant, leaf production and total leaf area. These factors are normally taken to reflect the vigour of the plants.

The height of the plant was found to be significantly influenced by the time of planting. Planting during mid-May (T_2) gave the maximum height of 86.41 cm. In respect of number of tillers per plant, time of planting did not show significant influence. In the case of number of leaves per tiller as well as number of leaves per plant, the time of planting exhibited significant influence. The number of leaves per tiller increased from 3.79 at T_1 to 4.95 at T_2. At T_3, the leaf production per tiller recorded a decrease. A mean maximum of 8.89 leaves per plant were produced in T_2 which differed significantly from T_3 (8.19) and T_1 (6.08). As regards total leaf area, the time of planting exhibited significant influence. T_2 gave a maximum area of 2173.24 cm^2 showing significant difference from T_1 (1496.07 cm^2). T_3 (1988.72 cm^2) and T_2 were on par. Sarma and Krishnamurthy (1965) reported that the height of turmeric plants was greatly influenced by the planting time. They also reported that delayed planting of fingers produced less number of leaves in turmeric and there was wide variation in the size of the leaves. The present investigation clearly brought out the advantages of planting turmeric in mid-May with respect to the growth of the plants as indicated by the height of the plants, the leaf production and the leaf area. It can be concluded that the advantage mainly was due to the fact that the plants were well established by the time the monsoon strengthened.

Contrary to what is normally observed, spacing did not exhibit significant influence on the height of the plant. One would expect the high density plants to be taller due to competition for light. It is probable that the lowest spacing given in the present experiment (10 x 20 cm) was not low enough to make the plants compete for light. Further experiments with still lower spacing may throw light on this aspect. Spacing exhibited significant influence on the production of tillers. It was found that the number of tillers per plant increased with increase in spacing. Maximum number of tillers (2.15) were produced at S_3 (20 x 20 cm). It may be pointed out that Kasturi Tanuka is a normally shy tillering variety. Spacing exhibited significant influence on the number of leaves per tiller and per plant also. In the present investigation. S_3 (20 x 20 cm) gave the maximum number of leaves per plant (9.01 on an average). The effect of spacing on the length of the leaves was significant. The mean leaf length varied from 35.97 cm at S_1 to 36.78 cm at S_2 and 36.66 cm at S_3. Statistically, S_2 and S_3 were on par; but differed significantly from S_1. No statistical significance could be established with regard to the effect of spacing on the width of leaves. A progressive increase in the leaf area with increase in spacing was observed. Plants at S_3 produced the largest leaves (282.73 cm^2). The differences between S_3 and S_2 as well as between S_2 and S_1 were not significant. The studies thus revealed that wider spacing encouraged more tillering and production of more number of larger leaves. According to Said and Altaf (1963) and Randhawa and Nandpuri (1966), lower plant spacing compared to higher ones gave better results. Results of spacing trials conducted at Ambalavayal had also shown that closer spacings were better than wider spacing (Kannan and Nair, 1965).

With regard to the effect of weight of the planting material on the growth parameters, it was observed that W_3 (60 g) gave the maximum height of 81.71 cm. W_1 with 73.31 cm was significantly lower than W_3, while W_2 and W_1 were at par. Weight of planting material exerted significant influence on the tiller production also.

W_3 with an average of 1.97 tillers, differed significantly from W_2 and W_1 which produced 1.65 and 1.54 tillers, respectively. Difference between W_2 and W_1 was not significant. The effect of weight of planting material on leaf production was also significant with 7.95 leaves per plant in W_3. W_3 was significantly superior to W_2 and W_1 which were statistically on par. An increase in the number of leaves was observed with increase in the weight of planting material used. The weight of planting material indicated statistically significant influence on the length of leaves. Use of heavier planting material (W_3) resulted in larger leaves (37.03 cm). The effect of weight of planting material was found statistically significant on the average leaf area produced. W_3 gave maximum of 284.40 cm^2 which differed significantly from W_2 and W_1 (272.96 cm^2 and 266.20 cm^2, respectively). The total leaf area was significantly influenced by the weight of the planting material. W_3 gave a maximum area of 2032.27 cm^2 per plant, significantly different from W_1 and W_2 with 1773.73 cm^2 and 1851.98 cm^2, respectively.

In general, the studies have indicated that use of heavier planting material would lead to better growth of the plants. Though the relationship between weight of planting material and growth of the plants has not been established earlier in turmeric, Pillai (1973) observed beneficial effects on using heavier material in ginger. She reported better height, more tillering and better weight of rhizomes as the advantages of using heavier seed material. Sharma et al.(1980) concluded that the percentage germination, the number of shoots per plant, the number of leaves per shoot and the number of leaves per plant significantly increased with an increase in the weight of planting material, in Costus sp. In yam, it has been observed that larger setts give rise to more vigorous plants than the smaller ones (Onwueme, 1972). The vine diameter, number of leaves per stand and leaf area per stand were found to be greater for the larger sett planting than for the smaller sett-planting in yam (Onwueme, 1972; Enyi, 1973; Nwoke et al., 1973). The interaction between spacing and weight of planting material showed significance with respect to the number of tillers, average leaf area and total leaf area per plant. The combination S_3W_3 was identified as the best. The time of planting x weight of planting material interaction showed significance only with respect to total leaf area. In this case, T_2W_3 was the best combination.

5.3. Rhizome characters, yield and quality constituents

The results showed that the time of planting significantly influenced the length of the mother rhizomes. T_2 with a mean maximum of 12.67 cm was significantly superior to both T_1 (10.67 cm) and T_3 (11.54 cm). It was found that the number of primary fingers per plant was not influenced by the time of planting. However, the numoer of secondary fingers per plant was significantly influenced. T_2 gave a maximum of 6.79 fingers per plant, differing significantly from T_1 with 5.99 fingers per plant. T_2 and T_3 (6.23 fingers per plant) were on par.

The analysis indicated that the time of planting influenced the girth of the primary fingers at a significant level. Planting by the middle of May (T_2) produced primary fingers with 5.88 cm girth. T_2 was superior to T_3 (5.09 cm) and T_1 (4.96 cm). The internodal length was also significantly influenced by the time of planting. Among the different times of plantings tried, T_2 ranked first with a maximum internodal length of 0.69 cm, followed by T_3 (0.63 cm) and T_1 (0.57 cm). The differences between T_2 and T_3 as well as between T_3 and T_1 were not significant. The green rhizome yield exhibited highly significant variation with respect to time of planting. The highest yield of 9.46 kg/plot was recorded when planting was done during the middle of May (T_2) which was superior to the others.

Sarma and Krishnamurthy (1965) observed greater variation in the yield of turmeric for every fortnight's delay in planting. Randhawa and Misra (1974) reported that early planting from the end of April to the first fortnight of May gave the best results. Hari et al. (1978) indicated that planting on May first and tenth proved significantly superior than other planting dates for getting better growth and yield of rhizomes in turmeric. In ginger which is closely related to turmeric, Kannan and Nair (1965), Aiyadurai (1966) and Nair and Varma (1970) reported early planting to be the best under Ambalavayal conditions in Kerala. They also observed that there was a reduction in yield as the time of planting was delayed. Randhawa et al. (1972) reported that the early planted ginger crop (1st, 10th and 20th May) had better growth and yield than ginger planted on 30th May and 10th June. Though the time of planting did not exhibit significant influence on the curing percentage, the yield of cured, dry turmeric showed highly significant variation with respect to time of planting. Among the different planting dates tried, planting during mid-May (T_2) recorded the highest yield (1.17 kg per plot). As regards quality constituents, time of planting did not show any significant influence on the oleoresin content (per cent); but the per hectare yield of oleoresin was found to be influenced by the time of planting. Among the different planting dates tried, T_2 with an oleoresin yield of 513.38 kg/ha was the best. The difference between T_2 and T_3 (389.41 kg/ha) was not, however, significant.

The effects of spacing on the rhizome characters like length of mother rhizome and number of primary and secondary fingers were not found to be significant. But spacing had highly significant influence on the yield of green rhizomes. An yield of 7.69 kg/plot (25.63 t/ha) was recorded where planting was done at 10 x 20 cm spacing (S_1). Though spacing did not show significant influence on the recovery percentage, it showed highly significant influence on the yield of cured, dry rhizomes. Close planting at 10 x 20 cm (S_1) resulted in the highest dry rhizome yield of 0.93 kg/plot (3.1 t/ha). No statistically significant influence could be observed regarding the effect of spacing on the oleoresin content (%) and the yield of oleoresin per hectare.

It was reported by Said and Altaf (1963) and Randhawa and Nandpuri (1966) that lower plant spacing compared to higher ones gave better results. Randhawa and Misra (1974) reported that 22 x 22 cm plant spacing gave the best result. From the foregoing, it is evident that closer spacing (10 x 20 cm) resulted in higher yield of green as well as dry rhizomes, as compared to the wider spacings. It is generally known that though the yield per unit area may be higher at closer spacing, the yield per plant would be low as compared to that under wider spacings. In the present studies, an analysis of this kind could not be made because of the interlocking of primary and secondary rhizomes of neighbouring plants under the closest spacing tried. However, it is possible that yield per plant would be higher at wider spacings.

The weight of planting material significantly influenced the length of the mother rhizomes. It was found that the length of mother rhizome progressively increased with the increase in the weight of planting material wherein W_1 recorded a mean length of 10.88 cm which was significantly different from that recorded by W_2 (11.58 cm). W_3 was superior to W_1 and W_2 having recorded the maximum length (12.42 cm). It was found that the number of primary and secondary fingers was not significantly influenced by the weight of planting material. The yield of green rhizomes exhibited highly significant variation with respect to the weight of planting material. Highest yield of 7.53 kg per plot was recorded where planting material weighing 60 g (W_3) was used. In the case of curing percentage, highly significant influence was exhibited by the weight of the planting material. Curing percentage improved from 11.46 at W_1 to 12.09 at W_2 and 12.62 at W_3. The three levels differed significantly.

The data on cured, dry rhizomes showed highly significant variation with respect to the weight of planting material. Planting material weighing 60 g (W_3) recorded the highest yield of 0.96 kg/plot. The effect of weight of planting material was not statistically significant when the percentage oleoresin content was considered. However, it showed significant influence on the per hectare yield of oleoresin. The oleoresin yield showed an increasing trend with increase in weight of planting material. W_3 with 391.44 kg/ha of oleoresin ranked first and was superior to the other two.

Hussain and Said (1965) reported that use of large sized (3.81 cm) rhizomes of turmeric resulted in significantly higher fresh yields than those obtained from smaller sized rhizomes. Nambiar (1979) concluded that the final yield of turmeric is influenced by the weight of the seed material, since a progressive increase in yield was observed with the increase in the weight of the seed rhizomes. In ginger, Nair and Varma (1970) observed marked and progressive increase in yield as the size of the seed bit was increased. In Costus, Sharma et al. (1980) observed that the rhizome and diosgenin yields were significantly increased with an increase in the weight of planting material.

With respect to the yield of green rhizomes and the yield of cured, dry rhizomes, the time of planting x spacing and the time of planting x weight of planting material interactions were found to be significant. T_2S_1 and T_2W_3 were identified as the best combinations.

Summing up, the investigation clearly brought out the advantage of planting turmeric during mid-May. Though the percentage germination was better in early June planting, the growth characters, the yield of green as well as cured, dry rhizomes and the yield of oleoresin were significantly better in mid-May planting. Under Vellanikkara condition, the pre-monsoon showers are received by mid-May and planting at that time would give sufficient time for establishment of the crop before the monsoon strengthens. However, to assure good germination supplementary watering may become essential. With regard to spacing, the plant growth characters were better under wider spacing. The yield of green and cured dry rhizomes, however, was better at the closest spacing. Heavier planting material significantly improved the plant growth characters, curing percentage, yield of green as wall as cured, dry rhizomes and the yield of oleoresin. Taking the three factors and their interaction into consideration, the combination $T_2S_1W_3$ (middle May planting with 60 g planting material at 10 x 20 cm spacing) seemed to be the best for obtaining better growth and higher yields of cured, dry rhizomes and oleoresin.

Summary

6. SUMMARY

The present studies, with the objective of arriving at the optimum time of planting, spacing and weight of planting material to be adopted, were conducted at the College of Horticulture, Vellanikkara during 1981-82 using Kasturi Tanuka as the test variety. The salient results are summarised below:

6.1. The germination of the planted rhizomes was influenced by the time of planting and weight of planting material used. Best performance was observed with the crop planted during early June with 60 g planting material. The spacing adopted did not influence the percentage germination.

6.2. The morphological characters like height of the plant, number of tillers per plant, number of leaves per tiller, number of leaves per plant, length and width of leaves as well as mean leaf area and total leaf area per plant were influenced by the factors under study. The plant height was influenced by the time of planting and weight of planting material, while the spacing and weight of planting material influenced the production of tillers. All the three factors influenced the leaf production per plant; but when the number of leaves per tiller was considered, the only influencing factor was the time of planting. The analysis of the leaf characters indicated that the mean leaf area was significantly influenced by all the three factors. With regard to the total leaf area per plant, the time of planting as well as the weight of planting material were found to have significant influence.

6.3. The rhizome characters such as the length of the mother rhizome, the number of primary and secondary fingers and the number of nodes, length, girth and internodal length of the primary fingers were analysed to detect the effects of the treatments. The influence of time of planting as well as weight of planting material was found significant on the length of mother rhizome. None of the factors under study assumed importance with respect to the number of primary fingers, while the effect of time of planting was observed to be significant on the number of secondary fingers per plant. The length and girth of primary fingers were significantly influenced by the weight of planting material and time of planting, respectively. Whereas the number of nodes per finger was not influenced by any of the factors, the internodal length was found to have been influenced by the three characters.

6.4. With regard to the yield (both green and cured, dry rhizomes) it was observed that the effects of time of planting, spacing and weight of planting material were highly significant. The rate of recovery of dry rhizomes from the fresh ones was not a character which was influenced by the treatments.

6.5. The percentage oleoresin content between the rhizomes harvested from the different treatments was not influenced by any of the treatments under study.

6.6. The time of planting and weight of the planting material had significant influence on the yield of oleoresin per unit area. Spacing had no significant influence on this aspect.

6.7. Total leaf area exhibited highly significant positive correlation with all the components of yield.

6.8. The combination $T_2S_1W_3$ was identified as the best. It was concluded that middle of May planting using planting material weighing 60 g and at a spacing of 10 x 20 cm could realise best crop performance resulting in maximum yield of green and cured, dry rhizomes. Maximum oleoresin yield was also obtained under such conditions.

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* Originals not seen

Appendices

Appendix I

Abstract of ANOVA

Germination percentage

Source	df	MS
Replication	2	50.03
Main plot	2	49536.70**
Error (a)	4	148.96
Sub plot	2	438.03
Main x sub plot	4	502.62*
Error (b)	12	136.85
Sub-sub plot	2	514.70*
Main x sub-sub plot	4	55.18
Sub x sub-sub plot	4	114.85
Main x sub x sub-sub plot	8	147.99
Error (c)	36	146.64

* Significant at 0.05 level

** Significant at 0.01 level

Appendix II

Abstract of ANOVA

Height of plant

Source	df	MS
Replication	2	252.00
Main plot	2	3405.33*
Error (a)	4	319.84
Sub plot	2	12.66
Main x sub plot	4	119.93
Error (b)	12	109.70
Sub-sub plot	2	521.82*
Main x sub-sub plot	4	188.23
Sub x sub-sub plot	4	64.91
Main x sub x sub-sub plot	8	164.28
Error (c)	36	114.99

* Significant at 0.05 level

Appendix III

Abstract of ANOVA

Number of tillers

Source	df	MS
Replications	2	0.76
Main plot	2	1.53
Error (a)	4	0.53
Sub plot	2	4.69**
Main x sub plot	4	0.31
Error (b)	12	0.10
Sub-sub plot	2	1.37**
Main x sub-sub plot	4	0.021
Sub x sub-sub plot	4	0.29*
Main x sub x sub-sub plot	8	0.09
Error (c)	36	0.09

* Significant at 0.05 level

** Significant at 0.01 level

Appendix IV

Abstract of ANOVA

Number of leaves per plant

Source	df	MS
Replications	2	0.30
Main plot	2	57.44**
Error (a)	4	0.64
Sub plot	2	1.83**
Main x sub plot	4	0.32
Error (b)	12	0.15
Sub-sub plot	2	1.13*
Main x sub-sub plot	4	0.19
Sub x sub-sub plot	4	0.23
Main x sub x sub-sub plot	8	0.17
Error (c)	36	0.30

* Significant at 0.05 level

** Significant at 0.01 level

Appendix V

Abstract of ANOVA

Number of leaves per tiller

Source	df	MS
Replications	2	0.36
Main plot	2	9.55**
Error (a)	4	0.15
Sub plot	2	0.41
Main x sub plot	4	0.05
Error (b)	12	0.30
Sub-sub plot	2	0.45
Main x sub-sub plot	4	0.03
Sub x sub-sub plot	4	0.26
Main x sub x sub-sub plot	8	0.15
Error (c)	36	0.25

** Significant at 0.01 level

Appendix VI

Abstract of ANOVA

Length of leaf

Source	df	MS
Replications	2	12.04
Main plot	2	74.86
Error (a)	4	14.06
Sub plot	2	5.10*
Main x sub plot	4	3.30
Error (b)	12	1.22
Sub-sub plot	2	7.08**
Main x sub-sub plot	4	3.79*
Sub x sub-sub plot	4	3.70*
Main x sub x sub-sub plot	8	1.70
Error (c)	36	1.01

* Significant at 0.05 level

** Significant at 0.01 level

Appendix VII

Abstract of ANOVA

Width of leaf

Source	df	MS
Replication	2	0.62
Main plot	2	7.71*
Error (a)	4	0.43
Sub plot	2	1.42
Main x sub plot	4	0.32
Error (b)	12	0.60
Sub-sub plot	2	0.98
Main x sub-sub plot	4	0.83
Sub x sub-sub plot	4	1.77*
Main x sub x sub-sub plot	8	0.51
Error (c)	36	0.50

* Significant at 0.05 level

Appendix VIII

Abstract of ANOVA

Mean leaf area

Source	df	MS
Replications	2	2073.92*
Main plots	2	18353.32**
Error (a)	4	267.18
Sub plot	2	1543.95*
Main x sub plot	4	100.44
Error (b)	12	395.10
Sub-sub plot	2	2286.79**
Main x sub-sub plot	4	1087.43
Sub x sub-sub plot	4	2169.70**
Main x sub x sub-sub plot	8	534.68
Error (c)	36	423.88

* Significant at 0.05 level

** Significant at 0.01 level

Appendix IX

Abstract of ANOVA

Total leaf area

Source	df	MS
Replication	2	527405.27*
Main plot	2	3308936.42**
Error (a)	4	61297.99
Sub plot	2	170799.99
Main x sub plot	4	14588.60
Error (b)	12	64293.98
Sub-sub plot	2	474515.58**
Main x sub-sub plot	4	132861.30**
Sub x sub-sub plot	4	251725.63**
Main x sub x sub-sub plot	8	10636.79
Error (c)	36	28884.41

* Significant at 0.05 level

** Significant at 0.01 level

Appendix X

Abstract of ANOVA

Length of mother rhizome

Source	df	MS
Replication	2	1.97
Main plot	2	27.08**
Error (a)	4	0.38
Sub plot	2	5.36
Main x sub plot	4	9.08
Error (b)	12	2.94
Sub-sub plot	2	15.98**
Main x sub-sub plot	4	2.06
Sub x sub-sub plot	4	2.56
Main x sub x sub-sub plot	8	0.96
Error (c)	36	2.02

** Significant at 0.01 level

Appendix XI

Abstract of ANOVA

Number of primary finger

Source	df	MS
Replication	2	0.05
Main plot	2	1.38
Error (a)	4	0.43
Sub plot	2	0.47
Main x sub plot	4	0.047
Error (b)	12	0.16
Sub-sub plot	2	0.39
Main x sub-sub plot	4	0.03
Sub x sub-sub plot	4	0.20
Main x sub x sub-sub plot	8	0.27
Error (c)	36	0.23

Appendix XII

Abstract of ANOVA

Number of secondary finger

Sources	df	MS
Replication	2	2.73
Main plot	2	4.59*
Error (a)	4	0.65
Sub plot	2	1.00
Main x sub plot	4	0.42
Error (b)	12	0.67
Sub-sub plot	2	0.91
Main x sub -sub plot	4	0.89
Sub x sub-sub plot	4	2.78**
Main x sub x sub-sub plot	8	0.49
Error (c)	36	0.60

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XIII

Abstract of ANOVA

Number of nodes

Source	df	MS
Replication	2	1.45*
Main plot	2	1.11
Error (a)	4	0.17
Sub plot	2	0.43
Main x sub plot	4	0.30
Error (b)	12	0.31
Sub-sub plot	2	0.44
Main x sub-sub plot	4	0.19
Sub x sub-sub plot	4	0.04
Main x sub x sub-sub plot	8	0.81
Error (c)	36	0.48

* Significant at 0.05 level

Appendix XIV

Abstract of ANOVA

Length of primary finger

Source	df	MS
Replication	2	0.47
Main plot	2	2.60
Error (a)	4	0.92
Sub plot	2	0.63
Main x Sub plot	4	0,36
Error (b)	12	0.61
Sub-sub plot	2	3.38*
Main x sub-sub plot	4	0.54
Sub x sub-sub plot	4	0.21
Main x sub x sub-sub plot	8	0.80
Error (c)	36	0.83

* Significant at 0.05 level

Appendix XV

Abstract of ANOVA

Girth of primary finger

Source	df	MS
Replication	2	0.10
Main plot	2	1.19*
Error (a)	4	0.07
Sub plot	2	0.01
Main x sub plot	4	0.58
Error (b)	12	0.23
Sub-sub plot	2	0.07
Main x sub-sub plot	4	0.28
Sub x sub-sub plot	4	0.24
Main x sub x sub-sub plot	8	0.39
Error (c)	36	0.31

* Significant at 0.05 level

Appendix XVI

Abstract of ANOVA

Internodal length of rhizome

Source	df	MS
Replication	2	0.007
Main plot	2	0.098*
Error (a)	4	0.008
Sub plot	2	0.087**
Main x sub plot	4	0.009
Error (b)	12	0.007
Sub-sub plot	2	0.12**
Main x sub-sub plot	4	0.005
Sub x sub-sub plot	4	0.041**
Main x sub x sub-sub plot	8	0.007
Error (c)	36	0.007

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XVII

ABstract of ANOVA

Yield of fresh rhizome/plot

Source	df	MS
Replication	2	2.83
Main plot	2	458.75**
Error (a)	4	1.25
Sub plot	2	26.97**
Main x sub plot	4	6.00**
Error (b)	12	0.74
Sub-sub plot	2	24.15**
Main x sub-sub plot	4	1.62**
Sub x sub-sub plot	4	0.40
Main x sub x sub-sub plot	8	0.14
Error (c)	36	0.16

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XVIII

Abstract of ANOVA

Curing percentage

Source	df	MS
Replication	2	1.66
Main plot	2	1.65
Error (a)	4	0.72
Sub plot	2	0.35
Main x sub plot	4	0.65
Error (b)	12	0.70
Sub-sub plot	2	9.12**
Main x sub-sub plot	4	0.26
Sub x sub-sub plot	4	0.56
Main x sub x sub-sub plot	8	0.20
Error (c)	36	0.46

** Significant at 0.01 level

Appendix XIX

Abstract of ANOVA

Yield of dry rhizome

Source	df	MS
Replication	2	0.063*
Main plot	2	6.87**
Error (a)	4	0.02
Sub plot	2	0.37**
Main x sub plot	4	0.092**
Error (b)	12	0.014
Sub-sub plot	2	0.63**
Main x sub-sub plot	4	0.051**
Sub x sub-sub plot	4	0.001
Main x sub x sub-sub plot	8	0.003
Error (c)	36	0.004

* Significant at 0.05 level

** Significant at 0.01 level

Appendix XX

Abstract of ANOVA

Oleoresin content

Source	df	MS
Replication	2	14.08
Main plot	2	16.04 NS
Error (a)	4	62.10
Sub plot	2	0.08 NS
Main x sub plot	4	15.71
Error (b)	12	14.16
Sub-sub plot	2	10.16 NS
Main x sub-sub plot	4	7.49
Sub x sub-sub plot	4	21.77
Main x sub x sub-sub plot	8	10.22
Error (c)	36	11.69

NS = Not significant

Appendix XXI

Abstract of ANOVA

Yield of oleoresin

Source	df	MS
Replication	2	23029.10
Main plot	2	1262096.75*
Error (a)	4	74650.70
Sub plot	2	91829.21
Main x sub plot	4	34042.33
Error (b)	12	26351.90
Sub-sub plot	2	72773.06*
Main x sub-sub plot	4	2889.46
Sub x Sub-sub plot	4	15484.94
Main x sub x sub-sub plot	8	8570.20
Error (c)	36	16476.44

* Significant at 0.05 level

Appendix XXII

Cnemical characteristics of the soil in the experimental plot

Constituent	Content in soil		*Rating	Method used for estimation
	Before experi-ment	After experi-ment		
Total Nitrogen(%)	0.081	0.089	High	Microkjeldahl (Jackson, 1973)
Available P_2O_5 (ppm)	8.63	9.45	Low	In Bray-1 extract, Chlorostannous reduced molybdo-phosphoric blue colour method
Available K_2O (ppm)	224.6	241.7	High	In neutral normal ammonium acetate extract - Flame photometric.
pH	5.2	5.3		1:2.5 soil:water suspension using pH meter

* Muhr <u>et</u> <u>al</u>. (1965)

Appendix XXIII

Meteorological data averaged on weekly intervals during April 1981 to January 1982

Month	Week	Meteorological parameters				
		Maximum temperature (M_1)	Minimum temperature (M_2)	Total rainfall (M_3)	Number of rainy days (M_4)	Relative humidity (M_5)
1	2	3	4	5	6	7
April 1981	1	36.00	25.60	0.00	0	66.55
	2	36.90	25.70	1.90	2	66.80
	3	35.30	25.40	14.20	1	62.90
	4	34.30	26.00	13.00	2	77.60
May 1981	1	35.90	25.90	52.20	2	68.95
	2	34.30	24.70	48.40	1	78.10
	3	34.60	26.60	19.40	2	76.30
	4	32.30	24.50	105.80	4	81.85
June 1981	1	30.30	23.10	394.40	7	91.75
	2	28.20	22.50	283.30	7	92.15
	3	27.70	22.10	356.80	7	90.10
	4	28.80	22.10	143.80	5	86.75
July 1981	1	29.90	22.90	131.90	4	86.75
	2	29.00	22.00	170.60	7	87.75
	3	30.40	23.10	19.30	2	78.05
	4	28.30	22.80	191.10	8	90.10
August 1981	1	28.90	21.60	68.60	5	90.90
	2	28.40	22.40	50.00	4	86.85
	3	27.50	22.30	257.10	7	88.60
	4	29.20	21.90	32.20	4	82.85

(contd.)

Appendix XXIII continued

Month	Week	M_1	M_2	M_3	M_4	M_5
September 1981	1	30.70	23.60	48.10	3	79.15
	2	28.40	22.50	138.70	7	88.20
	3	28.50	22.90	252.60	7	88.75
	4	29.60	22.90	82.40	5	84.25
October 1981	1	30.80	22.80	11.00	1	81.45
	2	30.70	72.60	25.20	2	78.75
	3	31.50	23.00	10.20	1	77.55
	4	30.20	22.80	40.00	5	79.30
November 1981	1	30.20	22.50	50.60	2	81.90
	2	31.20	22.10	27.40	2	73.45
	3	32.30	22.60	0.00	0	68.10
	4	31.30	21.10	22.00	1	65.60
December 1981	1	32.20	22.00	0.00	0	60.75
	2	32.10	18.60	0.00	0	59.40
	3	30.70	23.50	0.00	0	65.45
	4	31.90	22.00	0.00	0	56.80
January 1982	1	31.50	21.50	0.00	0	55.15
	2	32.30	20.30	0.00	0	58.75
	3	32.70	20.70	0.00	0	57.20
	4	33.20	22.50	0.00	0	68.65

EFFECT OF PLANTING DATE, WEIGHT OF RHIZOME AND SPACING ON THE GROWTH, YIELD AND QUALITY CONSTITUENTS ON TURMERIC (*Curcuma longa* L.)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A split-split plot experiment was conducted during 1981-82 at the College of Horticulture, Vellanikkara using Kasturi Tanuka as the test variety with a view to arriving at the optimum time of planting, spacing and weight of planting material that can be advocated for commercial cultivation of turmeric. The treatments were early May, middle of May and early June planting, 10 x 20 cm, 15 x 20 cm and 20 x 20 cm spacing and 20 g, 40 g and 60 g weight of the planting material. The crop performance was analysed based on germination, growth and yield parameters. The percentage germination was higher for the early June planted crop with 20 x 20 cm spacing and 60 g planting material. It was observed that the plant growth characters like number of leaves per plant and mean leaf area were significantly influenced by all the three treatments. The height of the plant as well as the length of mother rhizomes were significantly influenced by time of planting and weight of planting material. The effects of spacing and weight of planting material were manifested significantly in the tiller production.

The effect of time of planting was significant on the number of secondary fingers and girth of the primary fingers. Length of primary fingers and number of nodes per primary fingers were not influenced by the treatments under study.

The highest yield (fresh as well as cured, dry turmeric) was obtained from the crop planted during the middle of May with 10 x 20 cm spacing, using 60 g planting material. Though the oleoresin content in the produce did not exhibit any significant change with respect to the treatments, the time of planting and weight of planting material significantly influenced the yield of oleoresin on per hectare basis.