# EFFECT OF SPACING, RHIZOME WEIGHT AND TIME OF HARVEST ON THE YIELD AND QUALITY CONSTITUENTS IN *Costus speciosus*


By

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**THESIS**

Submitted in partial fulfilment of the requirement for the degree of

## Master of Science in Horticulture


Faculty of Agriculture
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COLLEGE OF HORTICULTURE
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**1983**

## DECLARATION

I hereby declare that this thesis entitled "Effect of spacing, rhizome weight and time of harvest on the yield and quality constituents in *Costus speciosus*" 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.

JOSEPH, E.J.

Vellanikkara,
24-1-1983.

CERTIFICATE

Certified that this thesis entitled "Effect of spacing, rhizome weight and time of harvest on the yield and quality constituents in *Costus speciosus*" is a record of research work done independently by Shri. Joseph, E.J. 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. Joseph, E.J. a candidate for the degree of Master of Science in Horticulture agrees that the thesis entitled "Effect of spacing, rhizome weight and time of harvest on the yield and quality constituents in *Costus speciosus*" may be submitted by Shri. Joseph, E.J. in partial fulfilment of the requirement for the degree.

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JOSEPH, E.J.

Vellanikkara,

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*To my parents*

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# Introduction

# INTRODUCTION

*Costus speciosus* (Koening) Smith is a perennial herb with tuberous rhizomes. It belongs to the family *Zingiberaceae*. This species is widely distributed throughout India and other South Asian countries, upto an altitude of about 1200 m above the mean sea level.

The presence of diosgenin in the rhizome of *Costus speciosus* was first reported by Das Gupta and Pandey (1970). They reported the diosgenin content as 2.12 per cent in the alcoholic extract of the rhizome samples. However, chemical evaluation of a number of samples from different parts of the country revealed the existence of definite clonal variation in respect of diosgenin content (Gupta *et al*., 1980).

Diosgenin is the most important raw material required for the synthesis of a large number of steroidal drugs which include cortico-steroids, sex hormones and antifertility compounds. About 50 per cent of the steroid drug production in the world relies on diosgenin as the base material. Mexico contributes 75 per cent of the world's diosgenin output (Applezweig, quoted by Asolkar and Chadha, 1979). The other countries producing diosgenin are China, Guatemala, Costa Rica and India. The total world requirements of steroid drugs and diosgenin by 1985 have been estimated to be around 320 tonnes and 2607 tonnes, respectively (Asolkar and Chadha, 1979).

In India, the pharmaceutical industry has been meeting the requirements of diosgenin from the tubers of Dioscorea deltoidea. The demand for steroidal drugs especially those used as oral contraceptives, has increased very much in recent years and there is a fear of depletion of this natural raw material. There is thus, necessity to find out alternate sources of diosgenin. For this, two major approaches have been resorted to. One is the introduction of the exotic species such as Dioscorea floribunda and Dioscorea composita, which have been found to be promising. The other approach is to search for the presence of the alkaloid and its extraction from other locally available plant species. Hence it becomes necessary to develop and standardise methods for commercial cultivation of such diosgenin yielding plants.

Although there are several sources of diosgenin such as Dioscorea spp., Solanum khasianum, Tribulus terrestris and Kallstroemia pubescens; Costus speciosus has the advantage that it has a very wide geographical distribution extending from the sub-Himalayan tracts in the north to the hilly regions of the central India and the Western Ghats. The production of higher bio-mass in a short period and the comparative ease in the extraction of diosgenin are added advantages. Further, the diosgenin from Costus speciosus has been found to be purer than that obtained from other sources.

Realising the possibilities of grooming Costus speciosus as a commercial source of diosgenin, a series of research projects have been programmed by the Kerala Agricultural University. One study conducted at the College of Horticulture during 1979-81 indicated that the application of 45 kg N along with 30 kg each of $P_2O_5$ and $K_2O$ per ha resulted in the maximum yield of diosgenin (Sudhadevi, 1981). This dose was considered as the tentative optimum. While Singh et al. (1979) reported a net profit of only Rs.2250 per ha from a 21-month old crop, in Lucknow, the investigations conducted at the College of Horticulture indicated that a net profit of Rs.7500 per ha could be expected from a six-month old crop of Costus speciosus. In Jammu, Balyan et al. (1980) obtained a net profit of Rs.8980 per ha from an eight-month old crop. As such, further studies are required to determine the stage of harvest in relation to the yield of diosgenin and the net profit that can be expected from one hectare of Costus speciosus.

Closer spacings were found to be better than wider spacings for obtaining higher yields per ha in related crops such as ginger and turmeric (Loknath and Das, 1964; Said and Hussain, 1964; Aiyadurai, 1966; Randhawa and Misra, 1974). Large sized rhizomes gave higher yields than smaller ones when used as the planting material (Hussain and Said, 1965; Randhawa et al., 1972; Randhawa et al., 1974). These aspects were investigated upon in *Costus speciosus* by Sarin *et al*. (1977), Pandey *et al*. (1980) and Sharma *et al*. (1980), although their results were not conclusive. Further studies are required to make firm recommendations and to evolve a package of practices for the commercial cultivation of *Costus speciosus*.

The present study, the second in the series, was aimed to find out:

i) the optimum spacing and thereby the population density for the commercial cultivation of *Costus speciosus*,

ii) the optimum weight of rhizomes to be used for planting and

iii) the duration of the crop at which maximum yield of rhizomes and diosgenin could be obtained.

# Review of Literature

# 2. REVIEW OF LITERATURE

*Costus speciosus* (Koening) Smith has been recently designated as a medicinal plant of commercial value. Research work done on this crop is very scanty as compared to the work on other commercially important medicinal plants. The literature available on this crop as well as on other medicinal plants and zingiberaceous crops relevant to the present investigations is reviewed hereunder.

## 2.1. *Costus speciosus*

### 2.1.1. Variation in diosgenin content

The presence of the active principle, diosgenin, in the rhizomes of *Costus speciosus* was first reported by Das Gupta and Pandey (1970). They reported a diosgenin content of 2.12 per cent in the rhizomes. Chemical evaluation of a large number of samples collected from different geographical parts of the country indicated wide range of variability in diosgenin content (Sarin *et al.*, 1974). According to them, the variation appeared to be genetic rather than physiological, as no relationship could be established between the size and age of the rhizomes and the diosgenin content. The rhizomes of *Costus speciosus* were shown to contain upto 2.6 per cent diosgenin, the average being 1.5 per cent (Atal, 1975; Kapathi *et al.*, 1977).

Asolkar and Chadha (1979) reported diosgenin content varying from 0.32 to 3.37 per cent in rhizome samples collected from various parts of the country. According to them, the materials from the sub-Himalayan belt of Jammu, Himachal Pradesh, Uttar Pradesh and Bihar were better in quality with respect to diosgenin content than the samples from the Western Ghats and Orissa. Among the collections from Uttar Pradesh, Bihar, West Bengal, Manipur, Jammu & Kashmir, Himachal Pradesh, Karnataka, Maharashtra, Kerala and Andamans, Gupta et al. (1980) obtained a strain from Lucknow containing 6.1 per cent crude and 4.92 per cent pure diosgenin. Lubis and Sastrapradja (1980) analysed the rhizome samples of 12 species of Costus and found diosgenin content ranging from 0.46 per cent (Costus afer) to 2.91 per cent (Costus rumphianus).

Gupta et al. (1979) reported that the colour of the crude extracts of different samples had a significant bearing on the ratio of pure to crude diosgenin. Panda and Chatterjee (1980) from biochemical studies of Costus speciosus reported that a distinct correlation existed between the microscopic characters of the starch grains and the diosgenin content in the rhizomes. They found that the diosgenin content rose and the number of starch grains per cell diminished as the rhizomes aged from six months to two years. In young rhizomes, the grains were small and round; but in older rhizomes, they were large and oval and restricted to the area of vascular bundles.

### 2.1.2. Factors influencing the yield of rhizomes and diosgenin

Sarin et al. (1977) reported that highest diosgenin content was obtained in July when the plants were in active stage of growth, with flowering just started. They also reported that de-flowering had no effect in increasing the yield of diosgenin. Gupta et al. (1981) observed that from the dormant stage of the plants, the diosgenin content of the rhizomes increased reaching the maximum of 3.18 per cent when flower buds appeared on the plants in July. By the time the plants became dormant again, the diosgenin level came down to 1.88 per cent.

Several workers have studied the influence of the agronomic practices on the yield of rhizomes and diosgenin. Atal (1975) obtained an average yield of 1.57 kg rhizomes per plant after nine months of growth. In their studies, Sarin et al. (1977) obtained, rhizomes weighing 413 g, 655 g and 1773 g, respectively from six, nine and twenty-month old crops. However, the maximum yield was obtained from the six-month old crop planted in July. The crop was planted at 1 $m^2$ and 0.75 $m^2$; but the crop growth indicated that the spacing could be further reduced in the case of crops to be harvested six to nine months after planting. Sarin et al. (1977) did not find any marked differences in the yield of diosgenin between the plants grown on ridges and in flat beds. Singh et al. (1979) conducted studies to develop package of practices for the cultivation of Costus speciosus. They planted 50-60 g pieces on ridges. Harvesting was done at eight months, 18 months and 21 months after planting. Highest yield in terms of fresh weight, dry weight and diosgenin per unit area was obtained after 21 months of growth. Pandey et al. (1980) observed annual yield of 1.24 kg per plant by planting rhizomes weighing about 75 g. They also found that nine plants per square metre gave higher yields than three, four or six plants per square metre. The germination percentage, number of shoots per plant, number of leaves per shoot, number of leaves per plant, rhizome yield and diosgenin yield significantly increased with an increase in the weight of planted rhizomes upto 125 g (Sharma et al., 1980).

### 2.1.3. Improving diosgenin yield

Very little work has been done to improve the diosgenin yield. Sharma et al. (1980) reported that application of 150 kg N and 80 kg $K_2O$ per ha increased the rhizome yield. In a field study conducted at the Regional Research Laboratory, Jammu, maximum yield of rhizomes and crude diosgenin was obtained by a treatment consisting of 150 kg N, 100 kg $P_2O_5$ and 100 kg $K_2O$ per ha (Singh et al., 1980). In a nutritional trial conducted at the College of Horticulture, Vellanikkara, the tentative optimum dose for obtaining maximum yield of diosgenin was observed to be 45, 30, 30 kg/ha of N, $P_2O_5$ and $K_2O$, respectively (Sudhadevi, 1981).

Few reports are available on the attempts made in increasing the diosgenin yield using chemicals or radiation. Incubation of rhizome slices with water alone or in combination with growth regulators has given encouraging results. Seth et al. (1979) found that incubation of rhizome slices with 2,4-D at 100 ppm significantly increased the diosgenin yield by about 370 per cent, relative to the control taken as 100 per cent. Effect of gamma irradiation on the rhizomes of Costus speciosus was studied and some desirable plants with high rhizome yield and diosgenin content were detected from the irradiated population indicating the possibility of improving the crop through induced mutations (Laxmi et al.,1980).

2.1.4. Tissue culture

Rathore and Khanna (1978) observed a diosgenin content of 0.17 per cent and 0.76 per cent (on dwb) respectively in the undifferentiated callus of stem and rhizome. The diosgenin content was greatest after six weeks. Khanna et al. (1980) reported that suspension cultures of Costus speciosus grown in RT liquid medium supplemented with cholesterol, sugarcane juice, kinetin and 2,4-D gave the highest production of diosgenin with a level of 2.7 per cent. Gupta et al. (1981) found that by sprouting the rhizomes in a sealed polythene bag and leaving them as such for five to six weeks, 20 per cent more diosgenin could be obtained.

2.1.5. Cytological studies

In *Costus speciosus*, somatic chromosome numbers of 2n=18 and 2n=27 have been recorded by Sato and Simmonds, respectively (quoted by Fedorov, 1974). Raghavan and Venkatasubban, Chakravarti, Sharma and Bhattacharya (quoted by Fedorov, 1974) observed higher number (2n=36). Subrahmanyam (1978) also observed intraspecific chromosomal races of *Costus speciosus*, namely diploid (2n=18), triploid (2n=27) and tetraploid (2n=36). He reported that due to their small size, the chromosomes were not amenable to precise karyotypic analysis. However, in general, the karyotype was found to be symmetrical consisting of chromosomes ranging in size from 0.31 to 0.42 µ and with centromeres located at median or sub-median positions. Nagendra and Abraham (1981) attempted to throw more light on the ploidy level, geographic distribution and origin of *Costus speciosus*. They observed smaller leaves in the diploids, compared to the triploid and tetraploid plants. A higher seed set (63.6 per cent) was recorded in the tetraploid plants as compared to the diploids (30.7 per cent) and the triploids (5.9 per cent).

2.2. Other important medicinal plants

2.2.1. Spacing

Reports on the influence of spacing on the yield and quality constituents in the medicinal plants where the commercial part is the underground stem/root are scanty. Chatterjee (1977) observed a spacing of 22.5 x 10 cm to be optimum for obtaining higher yield of roots and total alkaloid content in ipecac. Rao _et al_. (1981) observed that 45 x 30 cm spacing for one-year crop and 60 x 45 cm spacing for two-year crop were the optima for obtaining higher tuber and diosgenin yield in _Dioscorea floribunda_.

A few experiments on spacing have been conducted in other medicinal plants where the economic part is the aerial portions. Closer spacings of 90 cm x 90 cm and 1 m x 0.75 m were recommended by Hazarika and Bora (1976), and Rane and Vidulaya (1976), respectively for getting maximum yield of berries per unit area in _Solanum khasianum_. In _Atropa belladonna_, Gulati _et al_. (1977) observed that wider spacings gave higher leaf yield per plant but a closer spacing of 60 cm x 60 cm produced better yield per unit area. Goren _et al_. (1980) reported that closer spacing (125 cm x 150 cm) resulted in better growth and quality of produce in hops. In the case of senna, while the total herbage yield per unit area was higher at 30 cm x 30 cm spacing, the sennoside content per plant and the total sennoside yield were found to be higher at the spacings of 90 cm x 60 cm and 60 cm x 60 cm, respectively (Nandi & Chatterjee, 1981). Turkhede _et al_. (1981) reported that the yield of alkaloids in opium poppy remained unaffected by plant densities.

### 2.2.2. Weight of planting material

In *Dioscorea floribunda* when the initial tuber weight was around 80 g, the average tuber yield was 1.710 kg per plant per year and the highest diosgenin percentage (on dwb) was 4.55 (Khanna *et al.*, 1976). Hedge *et al.* (1981) reported that in *Dioscorea* the diosgenin content and the sprouting of the tubers from the resultant crops were found to be unaffected by the type of planting material.

### 2.2.3. Time of harvest

Literature available on the crop duration studies on medicinal plants having underground stem/root as the commercial part is limited. Abrol and Kapoor (1962) reported that the diosgenin content in *Dioscorea deltoidea* tubers increased to a limited extent with the age of the plant. In the case of *Dioscorea caucasia* harvesting at the end of fourth growing season was found to produce highest yield of diosgenin per unit area (Kodash *et al.*, 1977). According to Hedge *et al.* (1981) harvesting of tubers earlier than February 15 reduced the tuber and diosgenin yield in *Dioscorea floribunda*. Banerjee (1974) found that in ipecac, the yield of alkaloid increased with the age of the plant which was due to an increase in total dry weight of roots and not due to an increase in percentage of alkaloid in the tissues. In *Catharanthus roseus* harvesting at 200 days after planting was found to give better yield of leaves, stems and roots (Pareek et al., 1981). Shah et al. (1981) recorded 3843 kg/ha of dry roots in two harvests (at 15 months and 27 months of planting) and 4545 kg/ha in a single harvest (at 27 months of planting) in Glycyrrhiza glabra.

Experiments on the proper stage of harvest were also conducted in other medicinal plants where the economic part is the above ground portions. In Datura metel, hyoscine usually predominated in the pre-flowering stages and the hyoscyamine increased in the later stages (Gupta et al., 1973). Shah et al. (1976) observed that the diosgenin content was lowest (0.34 per cent) in the leaves of Balanites roxburghii when the plants started flowering in February. Then it gradually increased reaching a maximum content of 0.8 per cent in December when the fruits matured on the plant. In senna, eventhough the highest concentration of sennosides was reached on the 50th day after planting, the maximum yield of leaflets as well as total sennosides were obtained when stripping was initiated on 70th day after planting (Shah et al., 1979). In Yucca filamentosa, Bedor & Elagmal, (1980) recorded the maximum concentration (0.35 per cent) of sarsasapogenin in the leaves during August. In Digitalis lanata, it was found that harvesting the crop from June to August gave the maximum glycoside concentration as well as foliage yield (Rajukkannu et al.,1981).

## 2.3. Zingiberaceous crops

### 2.3.1. Spacing

In turmeric, closer spacing has been found to give higher yields per unit area. Said and Hussain (1964) recommended a spacing of 30.48 x 15.24 cm (12 x 6"), as it gave higher yields. Aiyadurai (1966) recommended a spacing of 25 x 25 cm for flat bed system and a spacing of 45-60 cm between the rows and 25 cm between the plants for ridge and furrow system of planting. Randhawa and Misra, (1974) found a spacing of 22 x 22 cm to be optimum for best growth and yield. According to Sundararaj and Thulasidas (1976), spacing of 15-20 cm was optimum for turmeric. Rao (1979) observed the spacing of 30 x 20 cm as better. In the experiments conducted by Rajput et al. (1980), 30 x 45 cm spacing gave substantially higher yields than 45 x 45 cm or 45 x 60 cm spacings. The Kerala Agricultural University has recommended a spacing of 30 x 15 cm for turmeric, under flat bed system (Anon., 1981).

For ginger also, closer spacings have been found to be better than wider spacings. Lokmath and Das (1964) found 15 x 18 cm spacing as the best, compared to other spacings. Under Thodupuzha (Kerala) conditions, Aiyadurai (1966) obtained higher yields with spacing of 15 x 15 cm. In a spacing trial on ginger, Randhawa et al. (1972) obtained high yields from 20 x 20 cm and 20 x 30 cm spacings. Based on the results of a three-year trial in ginger, Anjaneyulu and Krishnamurthy (1979) recommended a spacing of 22.5 x 45 cm. Sivan (1979) obtained the highest total yield per ha at the closer spacing of 60 x 10 cm, eventhough the average yield per plant was the highest at the widest spacing of 60 x 30 cm.

2.3.2. Weight of planting material

In rhizomatous crops, the size of the original planting material has been demonstrated to have influence on the resultant crop. The use of large sized (3.8 cm) rhizomes resulted in significantly higher germination and fresh yields in turmeric (Hussain and Said, 1965). Randhawa and Misra (1974) obtained best growth and yield in turmeric when large rhizomes weighing about 100 g was used as the planting material. According to Randhawa et al. (1972), large rhizomes (150 g) of ginger gave higher yields than the small ones (60 g).

2.3.3. Time of harvest

Mehta et al. (1980) reported that in turmeric curcumin content of leaves decreased and that of rhizome increased with increased maturity. From a study on the quality variations in turmeric at different maturity periods, Philip et al. (1980) found the optimum stage of harvesting to be 270 days after planting at which stage maximum yield of turmeric, oleoresin and curcumin were obtained in four types of turmeric, viz., $VK_4$ (G.L. Puram II), $VK_5$ (Mannuthy Local), $VK_{11}$

(Vonti mitta) and $VK_{17}$ (Armoor C11-324). The drying percentage was observed to be steadily increasing with maturity of the crop. The oleoresin content was found to show a quadratic response as it decreased from the maximum value on 180th day to the minimum value on 240th day and thereafter it steadily increased and again reached the maximum value on 270th day.

Mathai (1975) sampled ginger rhizomes from three to seven months after planting to examine the variation in the oleoresin content. He found that the oleoresin content decreased rapidly from the fourth month onwards. Helmi <u>et al</u>. (1975) found that the oil and oleoresin yields in ginger increased with rhizome age when harvested at 8, 9.5, 11 and 12 months age. Studying the quality variation in ginger at different maturity levels, Nybe (1978) observed that the oleoresin and oil content were maximum at 165 days after planting and minimum at 270 days in four types of ginger. However, the types, viz., Rio-de-Janeiro, Maran, Kuruppampady and Wynad Local, recorded maximum yield per hectare of oleoresin, oil and also dry ginger at 270, 195, 225 and 225 days after planting respectively. The maximum yield of green ginger was obtained at 180 days after planting in all the types. But the drying percentage continued to increase with the maturity of the crop. Based on these results, Nybe (1978) recommended the above said periods as the optimum stage for harvest of different types at which the maximum yields of oleoresin, oil and dry ginger could be obtained. Sivan (1979) reported that the optimum time of lifting for early harvest was 24 to 26 weeks after planting. He found that delayed harvesting resulted in a marked increase in the fibre content. Jayachandran et al. (1980) stated that Rio-de-Janeiro variety of ginger could be harvested after seven months maturity for green ginger purpose and for the extraction of oleoresin and oil. However, harvesting after eight months yielded higher content of dry ginger and minimum crude fibre.

## 2.4. Economics of cultivation of diosgenin yielding plants

The economics of cultivation of *Dioscorea floribunda* has been worked out by many workers (Bammi and Randhawa, 1972; Bammi et al., quoted by Asolkar and Chadha, 1979; Tyagi et al., 1976). A net profit per ha of Rs.10,000 to Rs.12,500 from a one-year crop and Rs.25,000 to Rs.30,000 from a two-year crop have been recorded for the FB (C-1) strain. The Pusa-1 strain recorded a net profit of Rs.20,000 per ha for a two-year crop. Tajuddin et al. (1976) estimated a net profit of Rs.18,000 per ha for a three-year old crop of *Dioscorea deltoidea*. The net per ha profit from two-year old and three-year old crops of *Dioscorea composita* were recorded as Rs.9,850 and Rs.18,210 respectively (Rabha, quoted by Asolkar and Chadha, 1979).

The net profits substantially increase when the diosgenin is extracted and marketed rather than when sold as tubers. Annual net profits of Rs.43,000 to Rs.59,000 per ha for a one-year crop and Rs.62,000 to Rs.69,000 per ha for a two-year crop of Dioscorea floribunda have been recorded (Bammi and Randhawa, 1972; Bammi et al., quoted by Asolkar and Chadha, 1979). Tajuddin et al. (1976) estimated an annual profit of Rs.17,400 per ha for a three-year old crop of Dioscorea deltoidea. However, Rs.18,600 and Rs.21,170 were the annual profits per ha obtained by the extraction of diosgenin from two-year and three-year old crops of Dioscorea composita, respectively (Rabha, quoted by Asolkar and Chadha, 1979).

Regarding the scope of Costus speciosus as a commercial crop, the reports are conflicting. Economics of cultivation of Costus based on the actual cost incurred at Lucknow showed a net profit of Rs.2250 per ha from a 21-month old crop (Singh et al., 1979). Their conclusion was that at the 1979 price level of diosgenin (Rs.450/kg), the crop could not be recommended to the farmers for commercial cultivation as a raw material for diosgenin. A net profit of Rs.8980 per ha was obtained from an eight-month old crop of Costus speciosus in Jammu (Balyan et al., 1980). Sudhadevi (1981) obtained a net profit of Rs.7,500 per ha from a six-month crop of Costus at Vellanikkara.

# Materials and Methods

# 3. MATERIALS AND METHODS

The present investigations were carried out from May, 1981 to May, 1982 at the College of Horticulture, Vellanikkara to investigate the effects of spacing, rhizome weight and time of harvest on the yield and quality factors in *Costus speciosus*.

## 3.1. Land preparation

The soil at the experimental plot had a sandy clay loam texture. The land was uniform with moderate fertility and good drainage. The meteorological data during the cropping season are presented (Fig.1, Appendix I).

The soil was dug to a depth of 30 cm and the clods were broken so as to obtain a medium fine tilth. The area was then levelled. Raised beds of size 3 m x 3 m and height of 45 cm were taken giving a spacing of 50 cm between the sub-sub plots, 60 cm between the sub plots, and 70 cm between the main plots. Cattle manure was applied at the rate of 10 kg per plot (10 t/ha) and incorporated to the soil prior to planting.

## 3.2. Planting material and planting

Rhizomes collected from the border plants of a previous experiment were used as the planting material. The

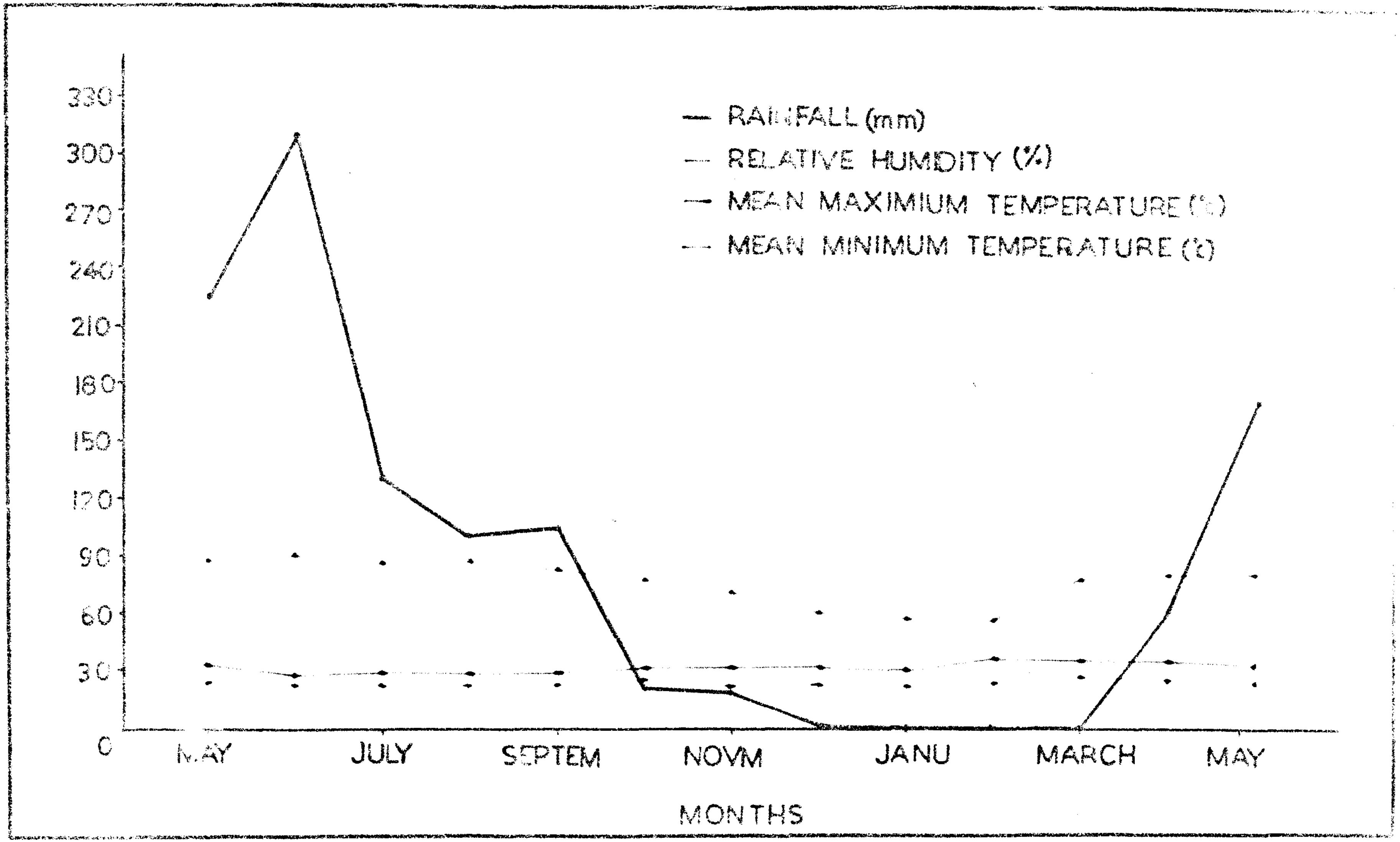



FIG-I. METEOROLOGICAL DATA FOR THE PERIOD, MAY 1981 TO MAY 1982.

rhizomes were cut into bits of three different grades, 50 g, 75 g and 100 g pieces. They were planted horizontally at a depth of seven to ten cm below the soil surface. Planting was done on 20-5-1981 according to the treatment allocations in the different plots. After planting, the soil surface was mulched with green leaves.

3.3. Lay out and treatment details

The experiment was laid out in split-split-plot design with three replications. The particulars of the treatments and their allocations were as given below:

Main plot (D - time of harvest)

$D_1$ - harvest at six months after planting

$D_2$ - harvest at nine months after planting

$D_3$ - harvest at twelve months after planting

Sub plot (S - Spacing)

$S_1$ - 50 cm x 50 cm

$S_2$ - 60 cm x 60 cm

$S_3$ - 75 cm x 75 cm

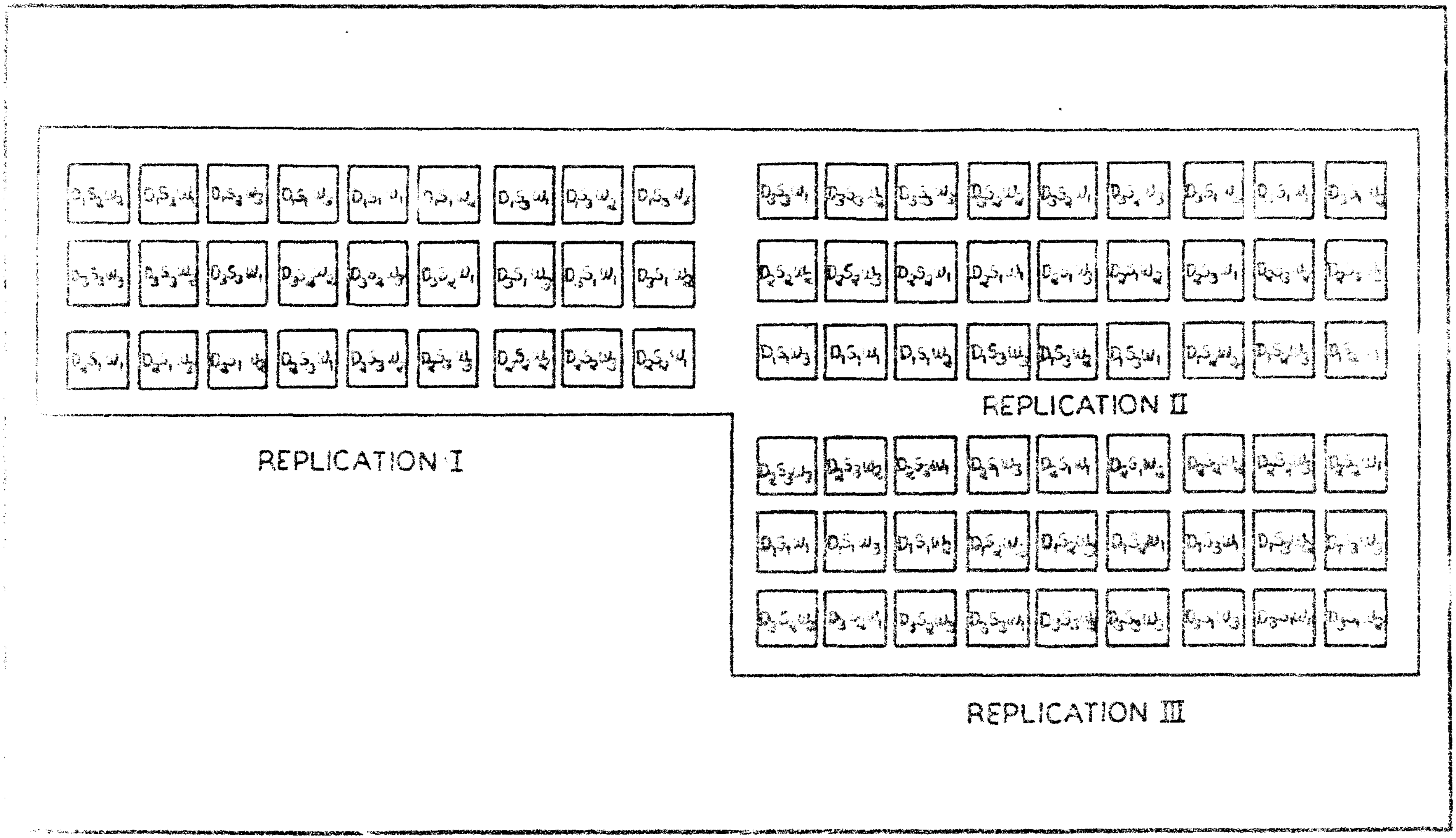
Sub-sub plot (W - weight of rhizome)

$W_1$ - 50 g

$W_2$ - 75 g

$W_3$ - 100 g

Each replication had 27 plots which gave a total of 81 plots. Detailed lay out of the experiment is given in Fig.2.




FIG—2. LAY OUT PLAN OF THE EXPERIMENT.

## 3.4. Fertilizer application

Nitrogen, phosphorus and potassium were applied at the rate of 75, 50, 50 kg/ha of N, $P_2O_5$ and $K_2O$, respectively. Nitrogen was applied in two split doses, two-third 20 days after planting and the remaining one-third 60 days after planting. $P_2O_5$ and $K_2O$ were applied in two equal splits, half as basal and the remaining 60 days after planting.

## 3.5. Intercultivation

Earthing up was done 60 days after planting. The plots were weeded thrice during the cropping season, at 60, 120 and 180 days after planting.

## 3.6. Observations on growth parameters

From each plot, four observational plants were marked at random after leaving the border plants. The following observations were recorded:

3.6.1. Plant height: Measurement was taken from the base of the stem to the tip of the topmost leaf of the highest tiller in each observational plant. The average of the four observational plants was worked out to get the mean height of the plants per plot.

3.6.2. Number of tillers per plant: The number of tillers were determined by counting the number of aerial

PLATE - I *Costus speciosus*: habit

shoots that had arisen from the rhizome. The mean number of tillers per plant was then calculated.

3.6.3. Number of leaves per tiller: The number of leaves on each tiller was recorded and the mean number of leaves per tiller was then computed.

3.6.4. Number of leaves per plant: The number of leaves of all the tillers in a plant was added upto get the number of leaves per plant. The mean number of leaves per plant in a plot was then worked out.

3.6.5. Length and width of leaves: The length and width of two leaves from each tiller were recorded. The distance between the point of attachment of the leaf blade to the pseudostem and the tip of the blade was taken as the length. Width was measured at three points, namely, at the point of maximum width and one each on either side of it corresponding to the points of inclination of the lamina towards the tip and base of the leaf. From these, the mean width of a leaf was arrived at. Average length and width of leaves per plot were then computed.

3.6.6. Total leaf area per plant: The methodology suggested by Sudhadevi (1981) was employed for the estimation of leaf area. The mathematical equation, $y=0.6341x + 4.008$ (where $y$ = the leaf area and $x$ = the product of length and breadth) was made use of. The total leaf area per plant was then arrived at by multiplying the average leaf area with the number of leaves per plant.

### 3.7. Harvesting

Harvesting was done at three stages, viz., at six months (20th November 1981), nine months (20th February 1982) and 12 months (20th May 1982) after planting. The rhizomes were dug out, roots were pruned and cleaned with tap water to remove the adhering soil particles. Finally, the cleaned rhizomes were rinsed with distilled water.

### 3.8. Post-harvest observations

3.8.1. Number of main rhizomes per plant: The number of main rhizomes produced by the observational plants in the plots was recorded separately and their mean calculated.

3.8.2. Length of main rhizome: The length of the rhizomes was measured separately for each observational plant and the mean worked out for each plot.

3.8.3. Internodal length of main rhizomes: The length of each internode of the main rhizomes of each observational plant was recorded separately and their mean worked out.

3.8.4. Number of primary and secondary fingers: The primary fingers are those originating from the main rhizome and the secondary fingers are those originating from the primary fingers (Plate II). The number of primary and secondary

PLATE - II *Costus speciosus*: rhizome

fingers were counted separately for the four observational plants and the mean per plot calculated.

3.8.5. Length and girth of primary and secondary fingers: Ten primary and ten secondary fingers were taken at random from each plot for the observations. Length of the primary and secondary fingers were recorded separately and the mean computed for each type. Their girth at the proximal, middle and distal portions was also measured to work out the mean girth for each type of finger.

3.8.6. Number of nodes per primary and secondary finger: The number of nodes of the ten primary and secondary fingers were recorded separately and the means computed for each type.

3.8.7. Total rhizome yield: The rhizomes of all the plants in the net plot were weighed and the mean worked out. The total yield of green rhizomes per ha was arrived at taking into consideration the net area of the plots.

Half a kilogram of the green rhizomes from each plot was chipped and dried in the sun for one day. The samples were later transferred to a hot air oven kept at 60-70°C and were dried to constant weight on test weighing. On completion of drying, the samples were weighed separately. The dry matter percentage was calculated on the basis of fresh weight and dry weight. The total dry rhizome yield per plot was then arrived at.

3.9. Soil sampling

Soil samples were taken before and after the experiment. Samples were taken from 0 to 30 cm depth at five random spots in each block and these were pooled to get a representative sample for each block. The samples were air dried, ground to pass 2 mm sieve and stored in polyethylene bags until analysis.

3.10. Sampling of rhizomes

Rhizome samples collected for the estimation of dry matter were powdered and used for the extraction of diosgenin.

3.11. Analytical methods

3.11.1. Soils: Total nitrogen in the samples was determined by Kjeldahl digestion - distillation method (Jackson, 1959). 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, 1959). Available potassium extracted by 1 N neutral ammonium acetate was estimated using a flame photometer (Jackson, 1959). The soil pH was determined in a 1:2.5 soil-water suspension.

3.11.2. **Estimation of diosgenin in rhizome:** For the extraction of diosgenin, the method of Selvaraj (1971) was adopted.

The powdered rhizome samples were used for the analysis. Ten grams of the material were blended thoroughly in a mixer with 50 ml of water for five minutes. The slurry was transferred to a 500 ml flask containing 100 ml of water and a calculated amount of 11.45 N HCl added to maintain the required acid concentration of 2.5 N. The flask, fitted with a condenser was placed on a boiling water bath for two hours to complete the hydrolysis. The slurry, after hydrolysis, was cooled to room temperature and filtered through a Buchner funnel under vacuum. The residue was then washed with distilled water till the filtrate became free of acid. The residue along with the filter paper was then transferred to a petri-dish and dried in an oven at 100°C for six hours. It was then extracted with petroleum ether (b.p. 40-60°C) in a soxhlet apparatus for eight hours. The extracted solvent containing diosgenin was concentrated to 25 ml, chilled in ice and filtered. The mother liquor obtained after filtering was concentrated, chilled in ice and the second crop of diosgenin, if any, was added to the first crop. The whole diosgenin was weighed after drying in an oven at 100°C for two hours and expressed as percentage.

3.11.3. **Statistical analysis**: The data obtained were statistically analysed in a microcomputer using the standard procedures (Snedecor and Cochran, 1967).

Statistical analysis of the morphological characters was done in split-plot design as observations in this regard could be taken only once at the first stage of harvest during November after which there was total defoliation. As the duration of the crop did not become a treatment in this analysis, spacing and rhizome weight were considered as the main plot and sub plot treatments, respectively. Rhizome characters and the yield parameters were analysed in split-split-plot design with the duration of the crop, spacing and weight of planting material alloted to the main plots, sub plots and sub-sub plots, respectively. With regard to the effect of crop duration on the yield parameters, quadratic response functions were fitted (wherever parabolic effects were noticed) to find out the optima.

3.12. <u>Cytological examination</u>

Root tip squash technique was used for the study of the karyotype. Root tips collected were pre-treated in a saturated solution of alpha-bromo naphthalene for 30 minutes. They were then washed in distilled water and fixed in Carnoy's fixative for 18-24 hours. Afterwards, they were hydrolysed in 1 N HCl at 70°C for 5 to 10 minutes. The root tips were then stained, squashed in iron acetocarmine and examined. Camera lucida drawings were made from well-spread somatic metaphase plates.

# Results

# 4. RESULTS

The effects of spacing, weight of planting material and duration of the crop on the yield and quality constituents in *Costus speciosus* were investigated upon in a field trial (split-split-plot experiment with three replications) conducted at the College of Horticulture, Vellanikkara during 1981-'82. The results of the investigations are presented in this chapter. The ANOVA tables for the different characters are appended (Appendices II to V).

## 4.1. Morphological characters

### 4.1.1. Growth characters:

The data pertaining to the morphological characters of the plants as influenced by spacing and weight of planted rhizomes were analysed as split-plot design. The results are presented in Table 1 and and the analysis of variance in Appendix II.

Statistical analysis of the data on plant height revealed that the height of the plant was significantly influenced by both spacing and rhizome weight. The plant height increased with decrease in spacing from 90.97 cm at $S_3$ (75×75cm) to 95.52 cm at $S_2$ (60×60cm) and 101.16 cm at $S_1$ (50×50cm). $S_1$ differed significantly from $S_2$ and $S_3$; but the difference between $S_2$ and $S_3$ was not significant. There was a progressive increase in the height of the plants with

Table 1.- Effect of spacing and weight of planting material on the growth characters of *Costus speciosus*

| Treatments | Plant height (cm) | Number of tillers per plant | Number of leaves per tiller | Number of leaves per plant | Length of leaves (cm) | Width of leaves (cm) | Area per leaf ($cm^2$) | Leaf area per plant ($cm^2$) |
|---|---|---|---|---|---|---|---|---|
| **Spacing** | | | | | | | | |
| $S_1$ - 50x50cm | 101.16 | 7.01 | 14.11 | 101.22 | 20.54 | 6.60 | 98.10 | 9390.71 |
| $S_2$ - 60x60cm | 95.52 | 8.50 | 14.60 | 121.91 | 20.55 | 6.77 | 100.20 | 11740.45 |
| $S_3$ - 75x75cm | 90.97 | 9.35 | 15.35 | 143.35 | 20.28 | 6.80 | 99.80 | 13251.58 |
| $CD_{0.05}$ | 5.39 | 0.99 | NS | 27.55 | NS | NS | NS | 1952.37 |
| **Weight of planting material** | | | | | | | | |
| $W_1$ - 50 g | 91.23 | 7.82 | 14.75 | 114.94 | 20.14 | 6.64 | 95.85 | 10152.82 |
| $W_2$ - 75 g | 95.88 | 8.17 | 14.71 | 121.84 | 20.58 | 6.75 | 100.48 | 11722.25 |
| $W_3$ - 100 g | 100.55 | 8.88 | 14.60 | 129.70 | 20.66 | 6.77 | 101.84 | 12507.67 |
| $CD_{0.05}$ | 4.00 | 1.03 | NS | 14.70 | NS | NS | NS | 990.73 |

NS = Not significant

increase in the rhizome weight. The height increased from 91.23 cm at $W_1$ (50 g) to 95.88 cm at $W_2$ (75 g) and 100.55 cm at $W_3$ (100 g). Significant differences were observed in all the cases. Interactions were not found to be significant.

The number of tillers per plant was found to increase with increase in spacing. The number of tillers was 7.01 at $S_1$, 8.5 at $S_2$ and 9.35 at $S_3$. $S_2$ and $S_3$ produced significantly more number of tillers than $S_1$; but between $S_2$ and $S_3$ significant difference was not seen. The effect of weight of rhizomes on production of tillers was found to be linear. Increased weight of rhizomes resulted in proportionately increased number of tillers. No significant differences were observed in the case of interactions.

While the number of leaves per tiller was not found to be influenced by spacing or rhizome weight, the number of leaves per plant was profoundly influenced by both the factors. The number of leaves per plant increased from 101.22 at $S_1$ to 121.91 at $S_2$ and 143.35 at $S_3$. Significant difference was observed between $S_1$ and $S_3$ only. The effect of weight of rhizomes on leaf production was found to be linear. Increase in weight of rhizomes proportionately increased the number of leaves per plant. Interactions were found to be not significant.

The spacing and weight of rhizomes showed no significant effect on the length, width and area of leaves. However, there was a substantial increase in the total leaf area per plant at wider spacings. The leaf area per plant increased from 9370.71 $cm^2$ at $S_1$ to 11740.45 $cm^2$ at $S_2$ and 13251.58 $cm^2$ at $S_3$. $S_2$ and $S_3$ did not differ significantly. The leaf area per plant was influenced by the weight of rhizomes also. The leaf area increased from 10152.82 $cm^2$ at $W_1$ to 11722.25 $cm^2$ at $W_2$ and 12507.67 $cm^2$ at $W_3$. $W_2$ and $W_3$ were at par; but significantly different from $W_1$. None of the interactions was found to be significant.

4.1.2. <u>Rhizome characters</u>: The data relating to the rhizome characters as influenced by spacing, weight of planting material and duration of the crop have been analysed as split-split-plot design with duration of the crop in main plot, spacing in sub plot and weight of planting material in sub-sub plot. The results are presented in Table 2 and the analysis of variance, in Appendix III.

Spacing did not influence the number of rhizomes. The weight of planting material significantly influenced the number of rhizomes. The number of rhizomes at $W_1$, $W_2$ and $W_3$ were 1.76, 1.90 and 2.02, respectively. Significant differences were observed between $W_1$ and $W_2$ as well as between $W_1$ and $W_3$; but not between $W_2$ and $W_3$. Stage of harvest did not have any marked effect on the number of rhizomes. The interactions were not found to be significant. The length of rhizomes was not markedly influenced by spacing. However,

Table 2.- Effect of spacing, weight of planting material and stage of harvest on the rhizome characters of *Costus speciosus*

| Treatments | Number of rhizomes per plant | Length of rhizomes (cm) | Internodal length (cm) |
|---|---|---|---|
| **Spacing** | | | |
| $S_1$ - 50 cm x 50 cm | 1.86 | 32.39 | 3.07 |
| $S_2$ - 60 cm x 60 cm | 1.87 | 34.00 | 3.14 |
| $S_3$ - 75 cm x 75 cm | 1.95 | 34.88 | 3.26 |
| $CD_{0.05}$ | NS | NS | NS |
| **Weight of planting material** | | | |
| $W_1$ - 50 g | 1.76 | 31.76 | 3.09 |
| $W_2$ - 75 g | 1.90 | 33.98 | 3.09 |
| $W_3$ - 100 g | 2.02 | 35.53 | 3.28 |
| $CD_{0.05}$ | 0.13 | 2.48 | 0.16 |
| **Stage of harvest** | | | |
| $D_1$ - 6 months | 1.88 | 32.92 | 2.98 |
| $D_2$ - 9 months | 1.89 | 33.03 | 3.16 |
| $D_3$ - 12 months | 1.91 | 35.32 | 3.30 |
| $CD_{0.05}$ | NS | 1.70 | NS |

NS = Not significant

the weight of the planting materials influenced the length of rhizomes significantly. Rhizome length increased from 31.76 cm at $W_1$ to 33.98 cm at $W_2$ and 35.53 cm at $W_3$. Significant difference was observed only between $W_1$ and $W_3$. As the crop duration increased from six months ($D_1$) to nine ($D_2$) and twelve ($D_3$) months, the length of rhizomes was found to increase. The rhizomes were 32.92 cm, 33.03 cm and 35.32 cm long at $D_1$, $D_2$ and $D_3$, respectively. $D_3$ differed significantly from $D_1$ and $D_2$. None of the interactions was found to be significant.

Spacing had no marked effect on the internodal length of the rhizomes. Weight of the planting materials significantly influenced the internodal length. The internodes were 3.09 cm, 3.09 cm and 3.28 cm long at $W_1$, $W_2$ and $W_3$, respectively. $W_3$ was significantly different from $W_1$ and $W_2$. Duration of the crop also had no significant effect on the internodal length of rhizomes. The interactions were not found to be significant.

4.1.3. <u>Characters of the primary and secondary fingers</u>:
Data on the effects of the three treatments on the characters of the primary and secondary fingers are presented in Table 3. The analysis of variance is given in Appendix IV.

Spacing had no effect on the number of primary fingers. Increase in the weight of planting materials brought about a progressive increase in the number of primary fingers from 5.28 at $W_1$ to 5.55 at $W_2$ and 5.80 at $W_3$. However, significant difference was observed only between $W_1$ and $W_3$. Statistical analysis of the data showed that number of primary fingers increased as the harvest was delayed. While $D_2$ and $D_3$ differed significantly from $D_1$ they showed no marked difference between them. The number of primary fingers at $D_1$, $D_2$ and $D_3$ were 5.14, 5.69 and 5.81, respectively. None of the interactions was found to be significant.

Length of the primary fingers corresponding to $S_1$, $S_2$ and $S_3$ were 11.61 cm, 13.14 cm and 13.50 cm, respectively. Significant differences were observed except between $S_2$ and $S_3$. Weight of the planting materials had significant effect on the length of primary fingers at $W_3$ level (13.88 cm). $W_1$ (11.92 cm) and $W_2$ (12.44 cm) did not vary significantly in this respect. Length of the primary fingers was very much influenced by the main plot treatment at $D_3$ level. The length of primary fingers was 14.44 cm at $D_3$. Both at $D_1$ and $D_2$, the primary fingers were only 11.91 cm long. The interactions showed no statistical difference.

Increasing the spacing as well as planting heavier material brought about positive effects on the girth of primary fingers. The girth increased from 3.89 cm at $S_1$ to 4.67 cm at $S_2$ and 5.88 cm at $S_3$. The girths were 4.33 cm,

Table 3. - Effect of spacing, weight of planting material and stage of harvest on the characters of primary and secondary fingers of <u>Costus speciosus</u>

| Treatments | Number of primary fingers | Length of primary fingers (cm) | Girth of primary fingers (cm) | Number of nodes per primary finger | Number of secondary fingers | Length of secondary fingers (cm) | Girth of secondary fingers (cm) | Number of nodes per secondary finger |
|---|---|---|---|---|---|---|---|---|
| <u>Spacing</u> | | | | | | | | |
| $S_1$ - 50×50cm | 5.48 | 11.61 | 3.89 | 5.48 | 4.37 | 3.92 | 2.91 | 3.72 |
| $S_2$ - 60×60cm | 5.67 | 13.14 | 4.67 | 6.35 | 4.39 | 4.23 | 3.05 | 3.71 |
| $S_3$ - 75×75cm | 5.49 | 13.50 | 5.88 | 6.42 | 4.60 | 4.82 | 3.32 | 3.77 |
| $CD_{0.05}$ | NS | 0.84 | 0.41 | 0.46 | NS | 0.36 | 0.24 | NS |
| <u>Weight of planting material</u> | | | | | | | | |
| $W_1$ - 50 g | 5.28 | 11.92 | 4.33 | 5.84 | 4.20 | 4.13 | 2.94 | 3.48 |
| $W_2$ - 75 g | 5.55 | 12.44 | 4.79 | 6.07 | 4.59 | 4.35 | 3.05 | 3.79 |
| $W_3$ - 100 g | 5.80 | 13.88 | 5.33 | 6.34 | 4.57 | 4.50 | 3.29 | 3.93 |
| $CD_{0.05}$ | 0.37 | 1.22 | 0.24 | 0.47 | NS | 0.34 | 0.20 | 0.22 |
| <u>Stage of harvest</u> | | | | | | | | |
| $D_1$ - 6 months | 5.14 | 11.91 | 4.56 | 5.93 | 3.34 | 3.63 | 2.92 | 3.35 |
| $D_2$ - 9 months | 5.69 | 11.91 | 4.88 | 5.95 | 4.61 | 4.45 | 3.22 | 3.69 |
| $D_3$ - 12 months | 5.81 | 14.44 | 5.01 | 6.37 | 5.44 | 4.89 | 3.14 | 4.17 |
| $CD_{0.05}$ | 0.23 | 1.17 | NS | NS | 0.47 | 0.43 | 0.19 | 0.38 |

NS = Not significant

4.79 cm and 5.33 cm at $W_1$, $W_2$ and $W_3$, respectively. Significant differences were observed in both the treatments. Delaying the harvest did not bring about any marked change in the girth of primary fingers. The interactions showed no statistical significance.

Increase in spacing increased the number of nodes from 5.48 at $S_1$ to 6.35 at $S_2$ and 6.42 at $S_3$. Significant differences were observed between $S_1$ and $S_2$ as well as between $S_1$ and $S_3$; but not between $S_2$ and $S_3$. As far as the weight of the planting material was concerned, significant variation in the number of nodes was observed only between $W_1$ (5.84) and $W_3$ (6.34), although there was a steady increase in the number of nodes with increase in the weight of rhizomes planted. Increasing the crop duration brought about a marginal increase in the number of nodes per primary finger which was not statistically significant. All interactions except that between spacing and weight of planting material were found to be not significant.

Increasing the spacing increased the length of secondary fingers from 3.92 cm at $S_1$ to 4.23 cm at $S_2$ and 4.82 cm at $S_3$. Significant differences were observed except between $S_1$ and $S_2$. Increase in the weight of planting material also contributed to the increase in length of the secondary fingers. The secondary fingers were 4.13 cm, 4.35 cm and 4.50 cm at $W_1$, $W_2$ and $W_3$, respectively. Significant difference was observed only between $W_1$ and $W_3$. Length of the secondary fingers increased by delaying the harvest. Length of the secondary fingers at different dates of harvest were 3.63 cm at $D_1$, 4.45 cm at $D_2$ and 4.89 cm at $D_3$. The effects were observed to be significant in all the cases. Interactions did not show significant effects.

Girth of the secondary fingers increased from 2.91 cm at $S_1$ to 3.05 cm at $S_2$ and 3.32 cm at $S_3$. $S_3$ had significant effect over $S_1$ and $S_2$. There was a progressive increase in the girth of secondary fingers as the weight of planted rhizomes increased. It increased from 2.94 cm at $W_1$ to 3.05 cm at $W_2$ and 3.29 cm at $W_3$. The effect of $W_3$ was found to be significant over that of $W_1$ and $W_2$. Girth of the secondary fingers was found to increase from 2.92 cm at $D_1$ to 3.22 cm at $D_2$ and decrease to 3.14 cm at $D_3$. $D_1$ differed significantly from both $D_2$ and $D_3$; but the difference between $D_2$ and $D_3$ was not statistically significant. Interactions showed no significant differences.

The three spacings were found to be statistically on par with respect to the number of nodes per secondary finger. There was a steady increase in the number of nodes as weight of the planting material increased. The number of nodes were 3.48 at $W_1$, 3.79 at $W_2$ and 3.93 at $W_3$. $W_2$ and $W_3$ did not differ significantly while $W_1$ and $W_2$ as well as $W_1$ and

$W_3$ showed significant differences. With increase in crop duration, the number of nodes per secondary finger increased from 3.35 at $D_1$ to 3.69 at $D_2$ and 4.17 at $D_3$. Significant differences were observed between $D_1$ and $D_3$ as well as between $D_2$ and $D_3$; but not between $D_1$ and $D_2$. None of the interactions showed statistical significance.

4.2. Yield of rhizomes and diosgenin

The data on the yield of rhizomes and diosgenin as influenced by the duration of the crop, spacing and weight of planting material are presented in Table 4 and the analysis of variance, in Appendix V.

With respect to spacing, higher yields of green rhizomes per ha were obtained at closer spacings. There was a steady increase in the yield by decreasing the spacing, $S_1$, $S_2$ and $S_3$ giving average yields of 43.12, 36.16 and 34.84 tonnes per ha, respectively. The effect of weight of planted rhizome on the yield was seen to be linear. Increased rhizome weight proportionately increased the yields. The yield increased from 35.11 tonnes/ha at $W_1$ to 37.7 tonnes/ha at $W_2$ and 41.31 tonnes/ha at $W_3$. With respect to the duration of the crop, the per hectare yield of green rhizomes significantly differed. There was a linear decrease in the yield as the harvest was delayed. The yield of green rhizomes at $D_1$, $D_2$ and $D_3$ were 45.31, 36.91 and 31.91 tonnes per ha, respectively. $D_1$ was significantly different from $D_2$ and $D_3$. The interactions were found to have no significant effect.

Spacing and weight of planting material had no effect on the dry matter. The stages of harvest exhibited significant influence on the dry matter percentage. The dry matter increased from 12.4 per cent at $D_1$ to 18.67 per cent at $D_2$ and decreased to 17.2 per cent at $D_3$. Significant differences were observed between $D_1$ and $D_3$ as well as between $D_1$ and $D_2$; but not between $D_2$ and $D_3$. Quadratic response function showed that the optimum maturity for obtaining high dry matter percentage was ten months.

At the closest spacing $S_1$, the dry rhizome yield per ha was found to be significantly higher as compared to the yields at $S_2$ and $S_3$. The yield was 6.90 tonnes/ha at $S_1$, 5.82 tonnes/ha at $S_2$ and 5.33 tonnes/ha at $S_3$. The effect of weight of the planting material on the yield of dry rhizomes was found to be linear. Increase in the weight of rhizome resulted in a proportionate increase in yield. The effect of duration of the crop on the yield of dry rhizomes was found to be quadratic. The dry rhizome yield increased from 5.62 tonnes/ha at $D_1$ to 6.96 tonnes/ha at $D_2$ and decreased to 5.48 tonnes/ha at $D_3$. By fitting the quadratic response function the optimum stage for obtaining high dry rhizome yield was found to be nine months. Significant differences were not observed in the case of interactions.

Table 4.- Effect of spacing, weight of planting material and stage of harvest on the yield parameters of *Costus speciosus*

| Treatments | Yield of green rhizomes (t/ha) | Dry matter (%) | Yield of dry rhizomes (t/ha) | Diosgenin content (%) | Yield of diosgenin (kg/ha) |
|---|---|---|---|---|---|
| **Spacing** | | | | | |
| $S_1$ - 50 cm x50cm | 43.12 | 16.32 | 6.90 | 1.79 | 123.65 |
| $S_2$ - 60 cm x60cm | 36.16 | 16.33 | 5.82 | 1.64 | 99.21 |
| $S_3$ - 75 cm x75cm | 34.84 | 15.68 | 5.33 | 1.63 | 88.74 |
| $CD_{0.05}$ | 5.80 | NS | 0.91 | NS | 21.42 |
| **Weight of planting material** | | | | | |
| $W_1$ - 50 g | 35.11 | 16.32 | 5.61 | 1.62 | 93.95 |
| $W_2$ - 75 g | 37.70 | 15.95 | 5.88 | 1.75 | 105.77 |
| $W_3$ - 100 g | 41.31 | 16.08 | 6.56 | 1.69 | 111.88 |
| $CD_{0.05}$ | 4.55 | NS | 0.82 | 0.11 | 15.63 |
| **Stage of harvest** | | | | | |
| $D_1$ - 6 months | 45.31 | 12.40 | 5.62 | 2.01 | 112.80 |
| $D_2$ - 9 months | 36.91 | 18.67 | 6.96 | 1.79 | 129.86 |
| $D_3$ - 12 months | 31.91 | 17.27 | 5.48 | 1.26 | 68.95 |
| $CD_{0.05}$ | 5.12 | 1.84 | 1.24 | 0.21 | 36.57 |

NS = Not significant

The effect of spacing on the diosgenin content was not significant. Weight of planting material exhibited significant effect on diosgenin content. The diosgenin content was 1.62 per cent at $W_1$, 1.75 per cent at $W_2$ and 1.69 per cent at $W_3$. Significant difference was observed only between $W_1$ and $W_2$. The data on diosgenin content showed a steady decline as the harvest was delayed. The diosgenin content was 2.01 per cent at $D_1$, 1.79 per cent at $D_2$ and 1.26 per cent at $D_3$. Significant differences were observed among all the stages. The interactions indicated no marked differences.

An yield of 123.65 kg per ha of diosgenin was obtained at the closest spacing, $S_1$. The yield decreased to 99.21 kg and 88.74 kg per ha at $S_2$ and $S_3$, respectively. $S_1$ was significantly superior to $S_2$ and $S_3$. The weight of planted rhizomes was observed to have a linear effect in the yield of diosgenin. There was a proportionate increase in the diosgenin yield as the weight of planting material increased. The data on per ha yield of diosgenin revealed that it inincreased from 112.8 kg at $D_1$ to 129.86 kg at $D_2$ and decreased to 68.95 kg at $D_3$. Both $D_1$ and $D_2$ were significantly superior to $D_3$; but between $D_1$ and $D_2$ there was no significant difference. From the quadratic response function the optimum stage of harvest for maximum yield of diosgenin per ha was found to be eight months. The interactions did not exhibit significant differences.

## 4.3. Optimum combination of factors

The expected yield of each treatment combination was deduced from the linear model of the experiment as follows:

$$Y_{ijk} = \mu + D_i + S_j + W_k$$

where $Y_{ijk}$ is the value to be expected (apart from experimental error) from a plot in which $i^{th}$ level of the duration of the crop, $j^{th}$ level of spacing and $k^{th}$ level of weight of planting material are applied and $D_i$, $S_j$ and $W_k$ are the effects of the duration of the crop, spacing and weight of planting material, respectively. The interactions were not considered in this model because of the absence of statistical significance. It was found that a maximum yield of 157.65 kg/ha of diosgenin could be expected from the treatment combination $D_2S_1W_3$, i.e., 100 g rhizome pieces planted at 50x50cm spacing and the harvest done at nine months of planting (Table 5).

## 4.4. Correlation studies

Correlations between the morphological characters of the plant and the rhizome characters on the one hand, and the yield of diosgenin per plant on the other were worked out. The correlation coefficients for different characters are furnished in Table 6.

Table 5.- Observed and expected yields of diosgenin under different treatment combinations (Mean of three replications)

| Treatments | Observed yield (kg/ha) | Expected yield (kg/ha) |
|---|---|---|
| $D_1S_1W_1$ | 127.30 | 122.66 |
| $D_1S_1W_2$ | 136.76 | 134.48 |
| $D_1S_1W_3$ | 147.38 | 140.59 |
| $D_1S_2W_1$ | 90.79 | 98.22 |
| $D_1S_2W_2$ | 104.88 | 110.04 |
| $D_1S_2W_3$ | 115.39 | 116.15 |
| $D_1S_3W_1$ | 98.55 | 87.75 |
| $D_1S_3W_2$ | 96.23 | 99.57 |
| $D_1S_3W_3$ | 97.90 | 105.68 |
| $D_2S_1W_1$ | 142.18 | 139.72 |
| $D_2S_1W_2$ | 152.59 | 151.54 |
| *$D_2S_1W_3$ | 159.90 | 157.65 |
| $D_2S_2W_1$ | 97.45 | 115 28 |
| $D_2S_2W_2$ | 120.05 | 127.10 |
| $D_2S_2W_3$ | 136.12 | 133.21 |
| $D_2S_3W_1$ | 89.57 | 104.81 |
| $D_2S_3W_2$ | 96.76 | 116.63 |
| $D_2S_3W_3$ | 136.08 | 122.74 |
| $D_3S_1W_1$ | 68.63 | 78.81 |
| $D_3S_1W_2$ | 102.50 | 90.63 |
| $D_3S_1W_3$ | 85.83 | 96.74 |
| $D_3S_2W_1$ | 50.72 | 54.37 |
| $D_3S_2W_2$ | 79.16 | 66.19 |
| $D_3S_2W_3$ | 48.34 | 72.30 |
| $D_3S_3W_1$ | 51.95 | 43.90 |
| $D_3S_3W_2$ | 51.62 | 55.72 |
| $D_3S_3W_3$ | 79.98 | 61.83 |

* Treatment combination which gave the maximum yield

Table 6.- Correlation coefficients for different variables

| y | x | Correlation coefficients (r) |
| --- | --- | --- |
| Yield of diosgenin per plant | Height of the plant | + 0.198[NS] |
| " | Number of tillers per plant | + 0.386** |
| " | Number of leaves per plant | + 0.275* |
| " | Leaf area per plant | + 0.361** |
| " | Number of rhizomes per plant | + 0.436** |
| " | Length of rhizomes | + 0.293** |
| " | Number of primary fingers | + 0.357** |
| " | Length of primary fingers | + 0.254* |
| " | Girth of primary fingers | + 0.227* |
| " | Number of secondary fingers | + 0.308** |
| " | Length of secondary fingers | + 0.215[NS] |
| " | Girth of secondary fingers | + 0.203[NS] |
| " | Dry matter (%) | + 0.499** |
| " | Diosgenin content (%) | + 0.526** |

n=81 df = 79

NS = Not significant
* = Significant at five per cent level
** = Significant at one per cent level

Number of tillers per plant, leaf area per plant, number of rhizomes per plant, length of rhizomes, number of primary fingers per plant, number of secondary fingers per plant, dry matter percentage and diosgenin content showed highly significant positive correlations with the yield of diosgenin per plant. Positive correlations significant at five per cent level was observed in the case of yield of diosgenin per plant with number of leaves per plant, and length and girth of primary fingers. Significant correlations were not observed between the characters such as height of the plant, length and girth of the secondary fingers, and the yield of diosgenin per plant.

4.5. Economics of cultivation

Economics of cultivation and the net profit which could be expected from six, nine and twelve-month old crops of *Costus speciosus* were computed based on the expected yields of 140.59 kg, 157.65 kg and 96.74 kg crude diosgenin of 60 per cent purity per ha, respectively (Table 7, Appendix VI). The price of diosgenin was taken as Rs.525/- per kg (Anon., 1982) for the calculation of the net profit. It was seen that a net profit of Rs.4840/- and Rs.6270/- could be obtained from six-month and nine-month old crops, respectively. The twelve-month old crop resulted in a loss of Rs.130 per ha.

Table 7.- Economics of *Costus* cultivation and extraction of diosgenin from one hectare*

| Items | $D_1S_1W_3$ | $D_2S_1W_3$ | $D_3S_1W_3$ |
|---|---|---|---|
| 1. Cost of cultivation | Rs. 9922.75 | Rs.10287.75 | Rs.10287.75 |
| 2. Cost of extraction and purification of diosgenin | Rs.29523.90 | Rs.33106.50 | Rs.20315.40 |
| 3. Total expenditure for cultivation, extraction and purification | Rs.39446.65 | Rs.43394.25 | Rs.30603.15 |
| 4. Crude diosgenin recovered | 140.59 kg | 157.65 kg | 96.75 kg |
| 5. Purity | 60% | 60% | 60% |
| 6. Quantity of pure diosgenin | 84.35 kg | 94.59 kg | 58.04 kg |
| 7. Sale value of diosgenin (@Rs.525/-per kg) | Rs.44283.75 | Rs.49659.75 | Rs.30471.00 |
| 8. Net profit/loss | +Rs. 4837.10 | +Rs. 6265.50 | -Rs.132.15 |

* Based on the expenditure incurred at the experimental plot - details worked out in Appendix VI

## 4.6. Cytological examination

The cytological examination revealed that the race of Costus speciosus used in the studies had a somatic chromosome number of 2n=36 (Plate III, Fig. 9).

## 4.7. Chemical characteristics of the soil

The soil at the experimental site was high in N and K and low with respect to P, based on the conventional soil test rating (Table 8).

PLATE - III Somatic cell at metaphase

Table 8.- Chemical characteristics of the soil in the experimental plot

| Constituent | Content in soil | | Rating* | Method used for estimation |
|---|---|---|---|---|
| | Before experiment | After experiment | | |
| Total nitrogen (%) | 0.072 | 0.072 | high | Microkjeldahl |
| Available $P_2O_5$ (ppm) | 8.85 | 9.46 | low | In Bray-1 extract, chlorostanous reduced molybdophosphoric blue colour method |
| Available $K_2O$ (ppm) | 224.8 | 182.8 | high | In neutral normal ammonium acetate extract - Flame Photometric |
| pH | 5.15 | 5.23 | - | 1:2.5 soil:water suspension using pH meter |

* Muhr *et al.* (1965)

# Discussion

# 5. DISCUSSION

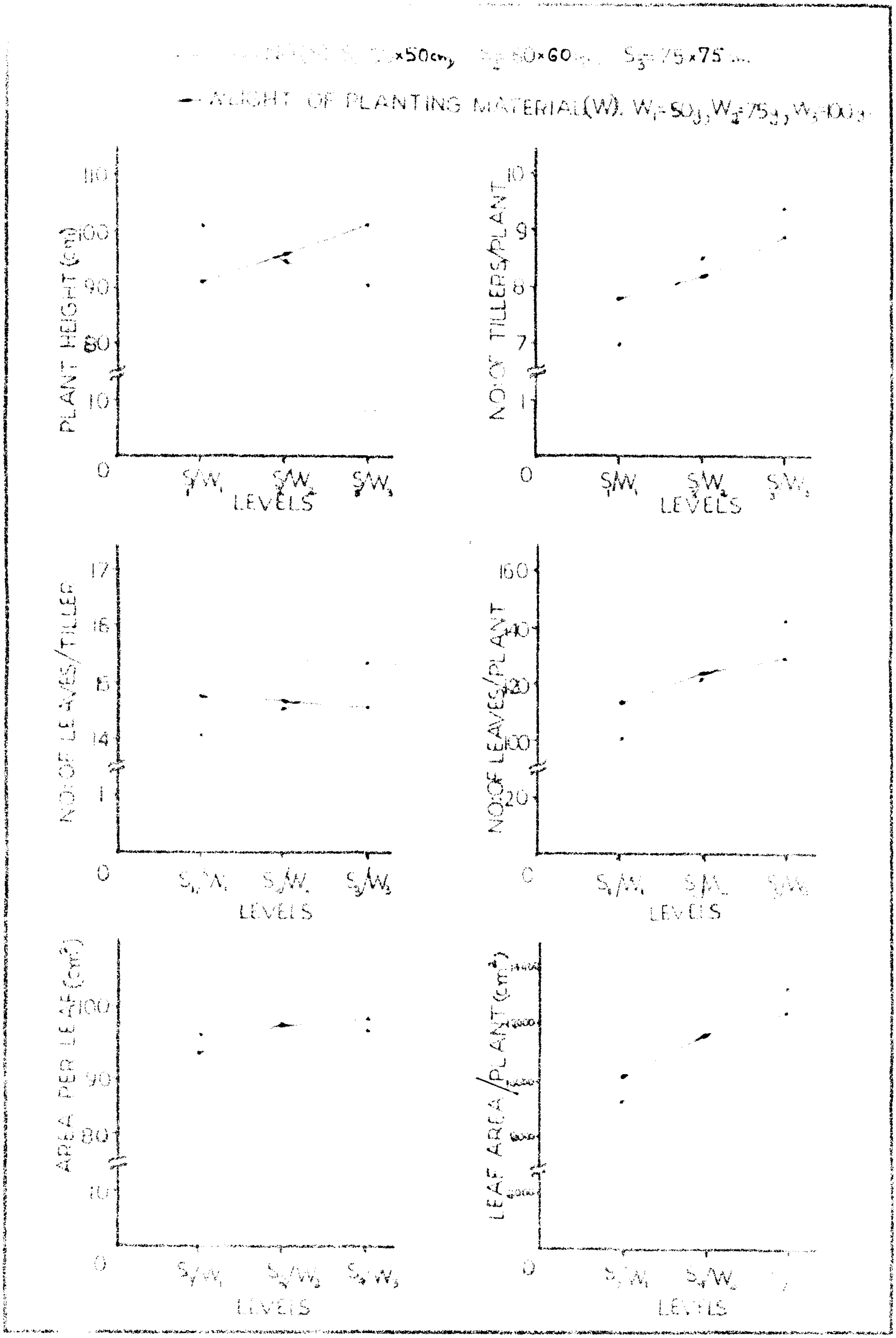
The investigations reported in this thesis were undertaken at the College of Horticulture, Vellanikkara during 1981-'82 to study the effects of spacing, weight of the planting material and duration of the crop on the yield and quality factors in Costus speciosus.

## 5.1. Morphological characters

5.1.1. Growth characters: The observations on morphological characters were taken only once, i.e., at the time of first harvest in November. Beyond this stage, defoliation set in and no leaves were retained by the plant. The statistical analysis was done as split-plot with spacing as main plot treatment and weight of planting material as sub plot treatment.

Among the morphological characters studied, the number of tillers per plant, number of leaves per plant and leaf area per plant increased progressively with spacing (Table 1, Fig. 3, Appendix II). Though significant differences were not observed in the number of leaves per tiller (and hence in the number of nodes) at the different spacings, the plant height was observed to be higher at closer spacings. This suggested that the increase in the plant height at high density planting was mainly due to internodal elongation. The increase observed in the number of leaves per plant at wider spacings without marked changes in the number of leaves per tiller suggested that the additional tillers contributed to the increased leaf production per plant at wider spacings. The length, width and area of leaves were not influenced by the spacing. But the leaf area per plant was found to be significantly higher at wider spacings. This can be attributed to the increased number of leaves per plant. The results thus indicate that planting Costus speciosus at wider spacing (75x75 cm) enhances the vegetative growth. Increased vegetative growth at wider spacings has been reported in a few medicinal plants. Gulati et al. (1977) observed better vegetative growth of Atropa belladonna at wider spacings. In senna, the plants at low density planting exhibited increased vegetative growth and herbage yield per plant (Nandi and Chatterjee, 1981), though the herbage yield per unit area was higher at closer spacings. A critical examination of these observations and the results of the present studies indicate that widely spaced plants fared better than closely spaced plants with regard to vegetative growth characters.

The weight of the planting material was observed to have significant influence on the plant height, number of tillers and leaf production per plant (Table 1, Fig. 3, Appendix II). The number of leaves per tiller was found unaffected by the weight of planted rhizomes. However, an



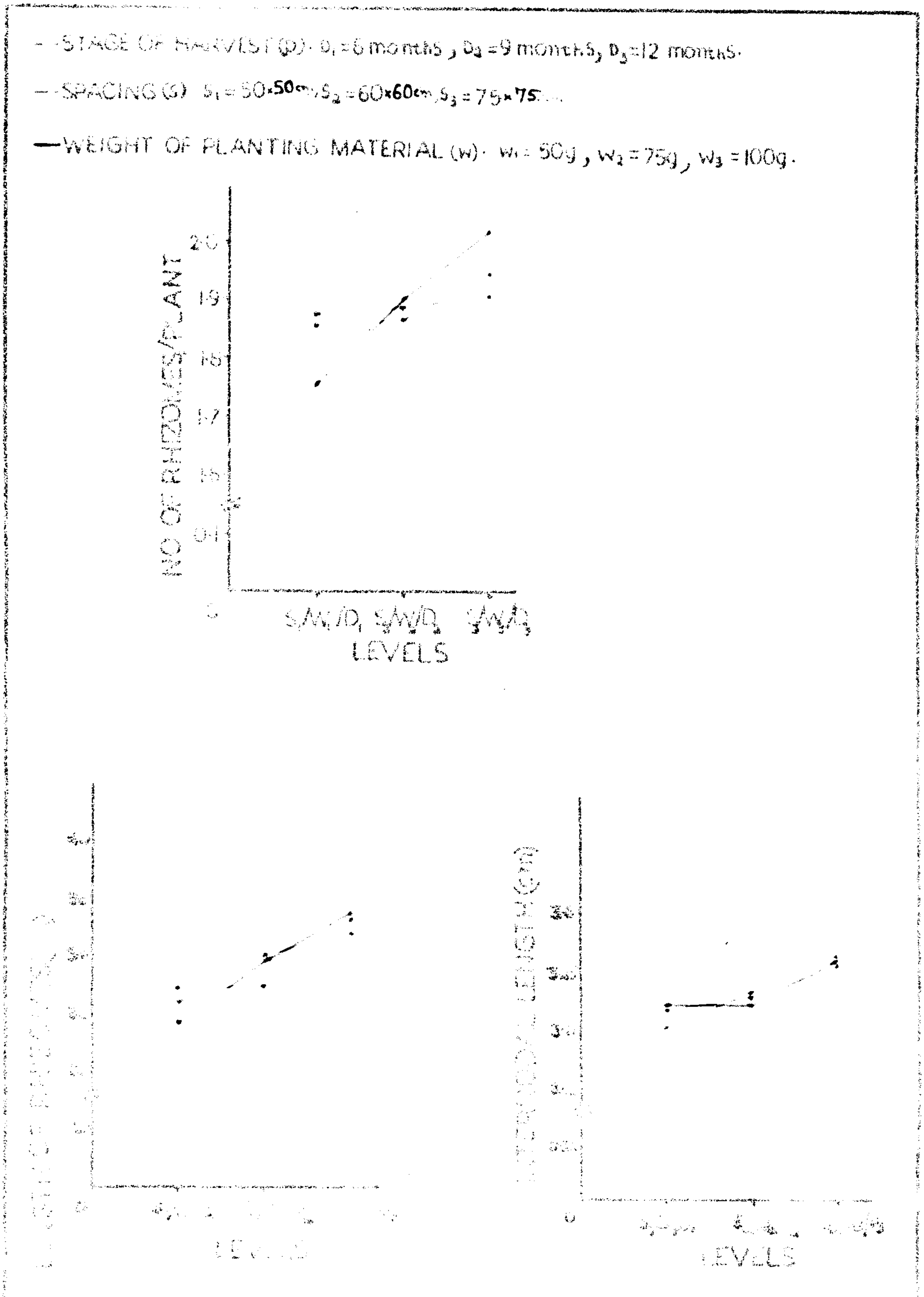

FIG—3· EFFECT OF SPACING AND WEIGHT OF PLANTING MATERIAL ON GROWTH CHARACTERS·

increase in the number of leaves per plant was observed with the increase in the weight of planting material, which is mainly due to the contribution of increased number of tillers. The length, width and leaf area were not markedly influenced by the weight of planting material; but the leaf area per plant steadily increased with increase in weight of the planted rhizomes (Table 1, Fig.3). This indicated that higher leaf area per plant resulted from higher leaf production which in turn resulted from higher tiller production.

The results of the present investigations are in conformity with the findings of Sharma et al. (1980) in Costus speciosus and Randhawa and Misra (1974) in turmeric. In general, planting of large sized rhizomes resulted in better vegetative growth.

5.1.2. Rhizome characters: The observations on rhizome characters were analysed in split-split-plot design with the duration of the crop in main plot, spacing in sub plot and weight of the planting material in sub-sub plot.

Spacing did not impart significant influence on any of the rhizome characters (Table 2, Fig. 4, Appendix III). The weight of planting material significantly influenced all the rhizome characters. The number, length and internodal length of rhizomes increased as the weight of planting material increased (Table 2, Fig. 4). Among the rhizome characters, the length of rhizome alone was influenced by the stage of




FIG—4 : EFFECT OF SPACING, WEIGHT OF PLANTING MATE-
RIAL AND STAGE OF HARVEST ON
RHIZOME CHARACTERS

harvest. The length increased significantly with the increase in crop duration (Table 2).

5.1.3. Characters of primary and secondary fingers: Wider spacing brought about a significant increase in the length and number of nodes of the primary fingers; but their number and girth were not markedly influenced by the different spacings (Table 3, Fig. 5, Appendix IV). The more the weight of planted rhizomes, the more was the number of primary fingers, their length, girth and number of nodes. The number of primary fingers and their length were significantly increased by delaying the harvest. However, delaying the harvest did not bring about any marked change in the girth and the number of nodes of the primary fingers (Table 3, Fig. 5, Appendix IV).

The length of the secondary fingers and their girth were significantly higher at wider spacings; but the number of secondary fingers and the number of nodes in them were not influenced by spacing. All the secondary finger characters, except their number, increased significantly with the increase in the weight of planted rhizomes. Increasing the crop duration brought about a progressive increase in the secondary finger characters such as their number, length and number of nodes. The girth of the secondary fingers first increased and then showed a decrease, with the age of the plant (Table 3, Fig. 5, Appendix IV).

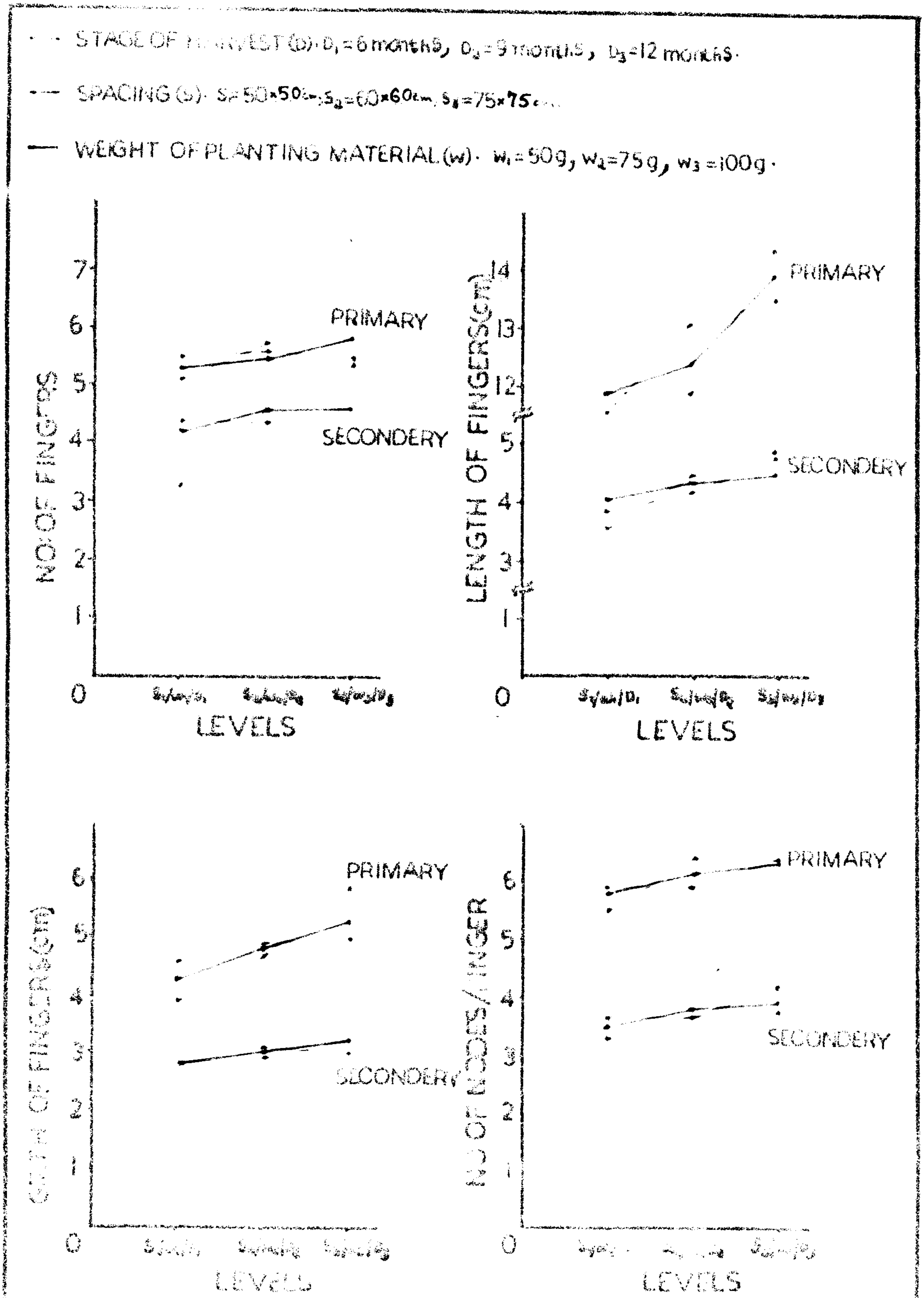



FIG-5-EFFECT OF SPACING, WEIGHT OF PLANTING MAT[illegible] AL AND STAGE OF HARVEST ON THE [illegible]ARACTERS OF PRIMARY AND SECONDERY FINGERS.

## 5.2. Yield of rhizome and diosgenin

In dense planting, the yield of green rhizomes, dry rhizomes and diosgenin per ha were found to be higher (Fig 6). Out of the three spacings (50×50cm, 60×60cm and 75×75cm) tried, the closest spacing of 50×50cm was found to be significantly superior to the others. Spacing had no significant effect on the dry matter percentage and diosgenin content (Table 4, Appendix V).

The role of high density planting in enhancing the yield per unit area in rhizomatous crops is well established. The results of the present investigations agree with the findings of Sarin et al. (1977), Pandey et al. (1980) in Costus and Rao et al. (1981) in Dioscorea floribunda. Said and Hussain (1964), Randhawa and Misra (1974), Sundararaj and Thulasidas (1976), Rao (1979) and Rajput et al. (1980) in turmeric; and Loknath and Das (1964), Aiyadurai (1966), and Randhawa et al. (1972) in ginger, also found closer spacings to give higher yields per unit area.

Weight of the planting material did not influence the dry matter percentage; but the diosgenin content was found to be higher when heavier materials were planted. The yield of rhizomes and diosgenin proportionately increased with the increase in the weight of planting material (Table 4, Fig. 7, Appendix V). Planting material weighing 100 g each was found

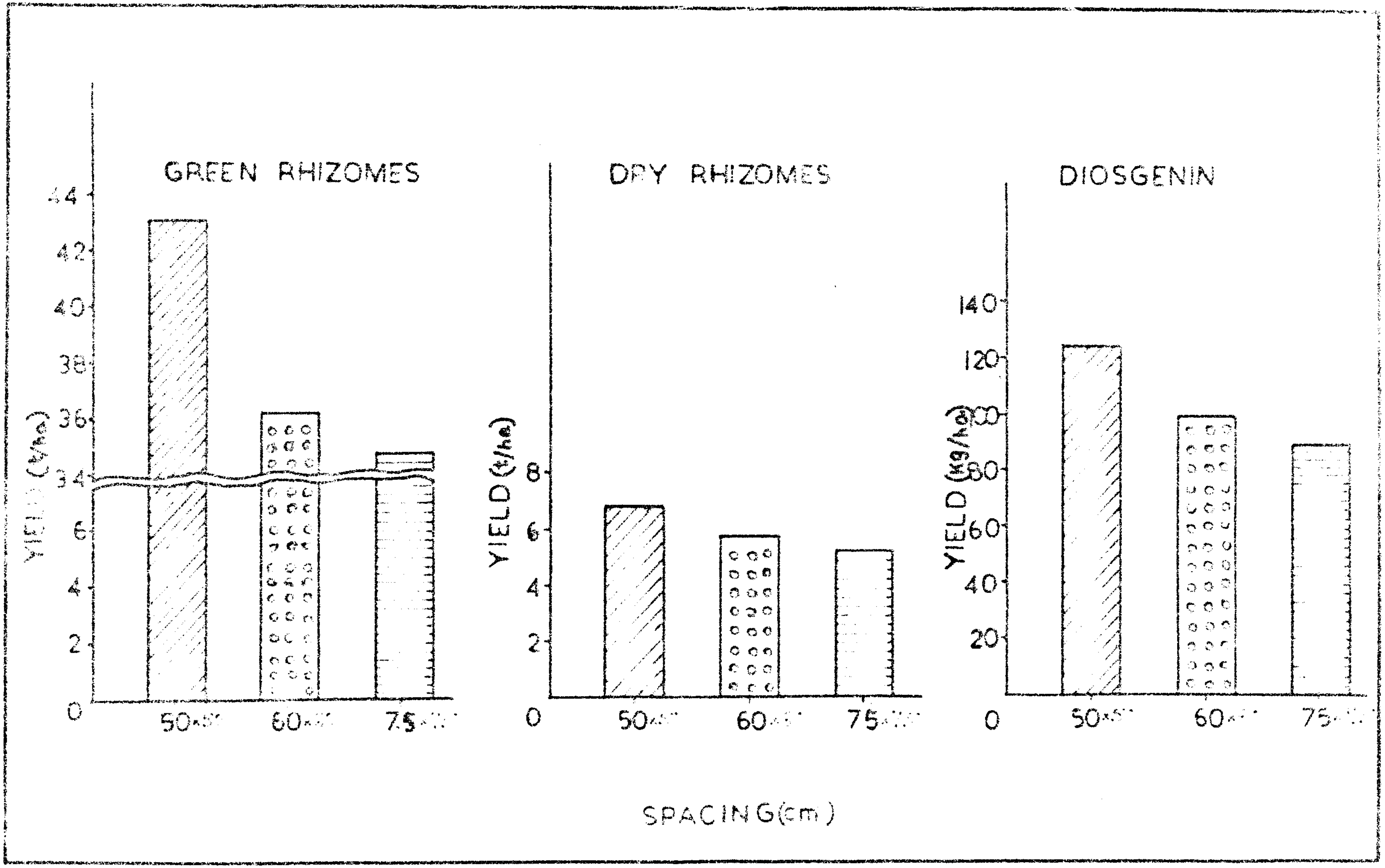



FIG-6. EFFECT OF SPACING ON THE YIELD OF RHIZOMES AND DIOSGENIN.

to be significantly superior to the others (50 g and 75 g) with respect to the yield of rhizomes and diosgenin.

Higher yields have been reported by several workers using heavier planting materials in Costus speciosus (Pandey et al., 1980; Sharma et al., 1980), in Dioscorea floribunda (Khanna et al., 1976), in turmeric (Hussain and Said, 1965; Randhawa and Misra, 1974) and in ginger (Randhawa et al., 1972).

Eventhough the yield of green rhizomes was highest at six months after planting, the highest yield of dry rhizomes was obtained at nine months after planting. While the yield of green rhizomes showed a linear decrease with the age of the plant, the yield of dry rhizomes showed a quadratic response. The yield of dry rhizomes increased from the sixth to the nineth month and decreased by the 12th month after planting. The dry matter percentage also showed a quadratic response with the crop duration. The dry matter content was highest when the crop was harvested at nine months after planting (Table 4, Fig. 8).

Sarin et al. (1977) obtained the maximum yield of green rhizomes from a six-month old crop of Costus. However, Singh et al. (1979) reported that harvesting Costus at 21 months duration gave higher yields of fresh weight and dry weight of rhizomes per unit area, compared to the harvest at eight months and nine months duration. Nybe (1978) obtained

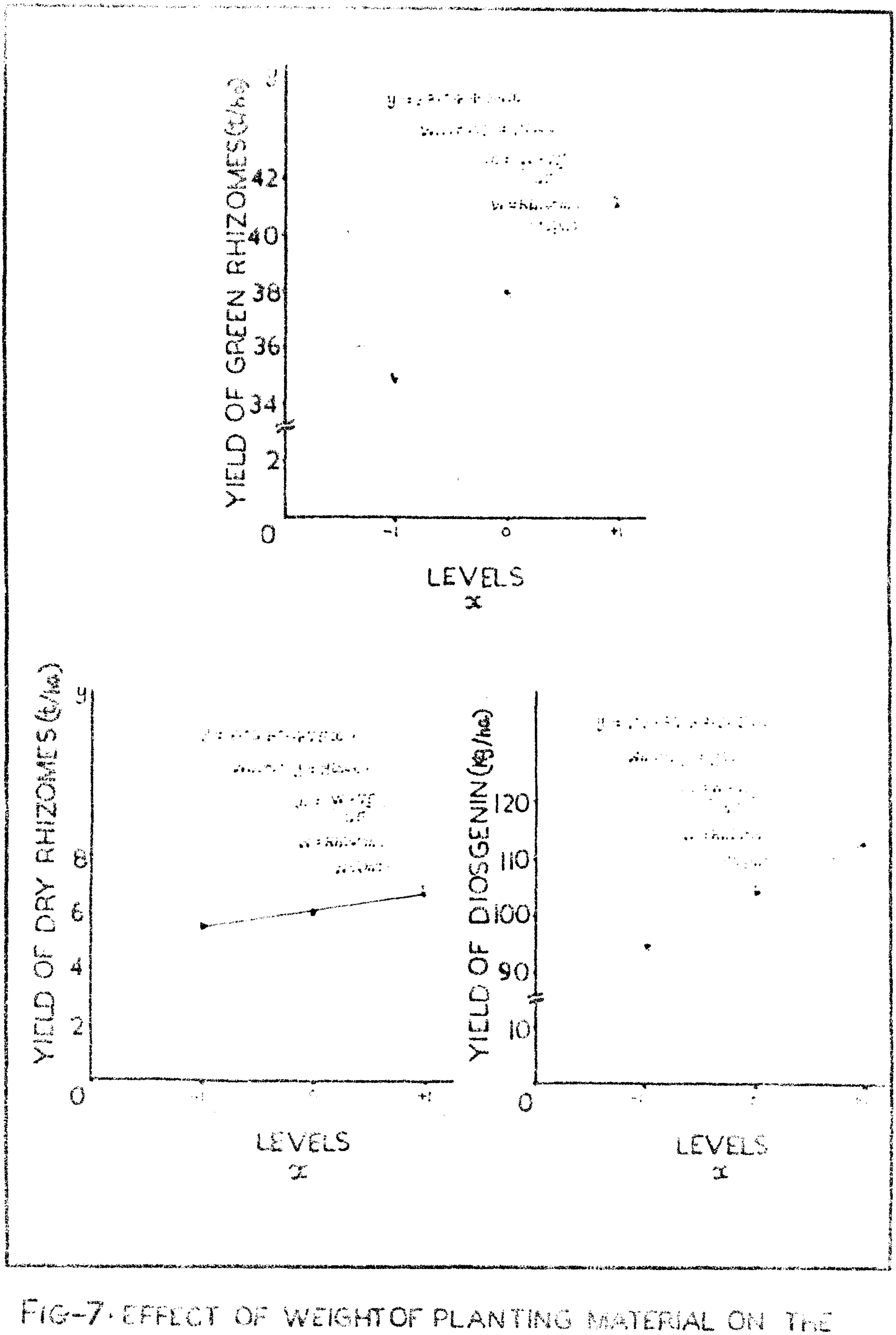



FIG-7· EFFECT OF WEIGHT OF PLANTING MATERIAL ON THE YIELD OF RHIZOMES AND DIOSGENIN·

the maximum yield of green ginger 180 days after planting; but the maximum yield of dry ginger was obtained during the period between 210 and 225 days after planting. He observed that the drying percentage continued to increase with the maturity of the crop. In turmeric, Philip et al. (1980) reported that the maximum yield of both fresh and dry rhizomes were obtained 270 days after planting. They observed that the dry matter percentage increased with the duration of the crop.

The percentage of diosgenin showed a steady decrease with the delay in harvest, the maximum being during the sixth month (November) and minimum, during the 12th month (May). However, the maximum yield of diosgenin per unit area was obtained at nine months after planting. The yield of diosgenin showed a steep decline from the ninth month onwards (Table 4, Fig. 8, Appendix V).

Sarin et al. (1977) obtained the highest diosgenin content in Costus with the onset of flowering in July. Gupta et al. (1981) also observed that the diosgenin content increased from the dormant stage of the plant to a maximum with the onset of flowering in July. The diosgenin content then declined till the plants became dormant again. Under Vellanikkara conditions, planting is possible only during May-June. As such, the crop would be only two or three months old in July of the year of planting when the plants would flower for the first time. Though the diosgenin content is likely to be high as observed by Sarin et al. (1977) and Gupta et al. (1981), the biomass would be small and hence the diosgenin yield would also be low. In order to obtain large quantity of biomass with high diosgenin content, one would have to harvest the crop during July of the second year when the plants would be in flower again. In fact, such were the observation of Singh et al. (1979) who obtained increasing yield of diosgenin when the crop duration was increased from eight to eighteen and twentyone months. However, further studies are required to ascertain whether such very long crop durations would yield economic results or not.

In ginger, Nybe (1978) observed that the oil and oleoresin content decreased with the maturity of the crop. However, the yield per hectare of oil and oleoresin were maximum at later maturity stages in the different types. Philip et al. (1980) reported a steady decrease in the curcumin and oleoresin content in turmeric from the maximum on the 180th day to a minimum on the 240th day. The maximum was again reached by the 270th day after planting. The per ha yield of curcumin and oleoresin were found to be highest at 270 days after planting.

Quadratic response functions were fitted to find out the optimum crop duration in relation to the different yield parameters (Fig. 8). Although the yield of green rhizomes

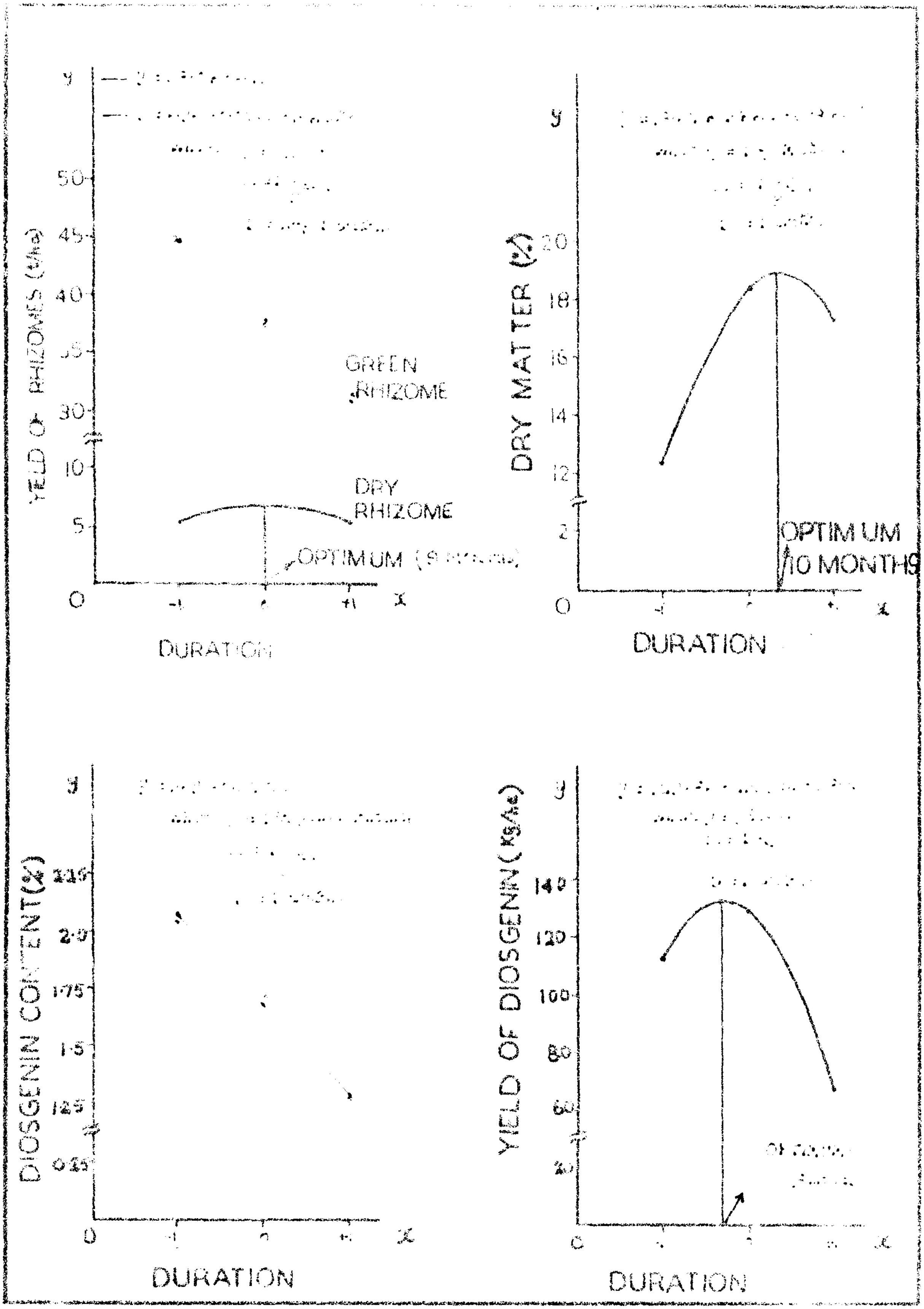



FIG-8 EFFECT OF STAGE OF HARVEST ON THE YIELD PARAMETERS was the highest at the first stage of harvest (six months after planting), the dry matter percentage was so low that the yield of dry rhizomes was low at that stage. The dry matter content was found to be highest at the tenth month after planting. However, the quadratic response functions showed that the ninth month after planting is the optimum stage of harvest for getting maximum yield of dry rhizomes in Costus. The diosgenin content was found to be maximum at six months after planting. However, because of the very low dry matter percentage and consequent poor dry rhizome yield, the diosgenin yield was poor at this stage. The optimum stage of harvest for getting the maximum yield of diosgenin per hectare was found to be eight months after planting.

## 5.3. Optimum combination of factors

The expected yield for each treatment combination was arrived at using the linear model of the experiment. The results showed the treatment combination $D_2S_1W_3$ as the economic optimum (Table 5). A maximum yield of 157.65 kg/ha of diosgenin could be expected by planting 100 g rhizome pieces ($W_3$) at 50x50cm spacing ($S_1$) and harvesting the crop at nine months after planting ($D_2$).

## 5.4. Correlation studies

In order to assess the nature and degree of association of the plant morphological characters and rhizome characters with the yield of diosgenin per plant, correlations were worked out with reference to 14 characters selected from among the 23 included in the studies. Out of these, highly significant or significant positive correlations were observed between 11 characters and diosgenin yield per plant (Table 6). The studies, thus, indicated that these characters (Number per plant of tillers, leaves, rhizomes, primary fingers and secondary fingers, leaf area per plant, dry matter content, diosgenin content, length of rhizomes, and length and girth of primary fingers) could be useful in selecting material which would give high diosgenin yield.

5.5. Economics of cultivation

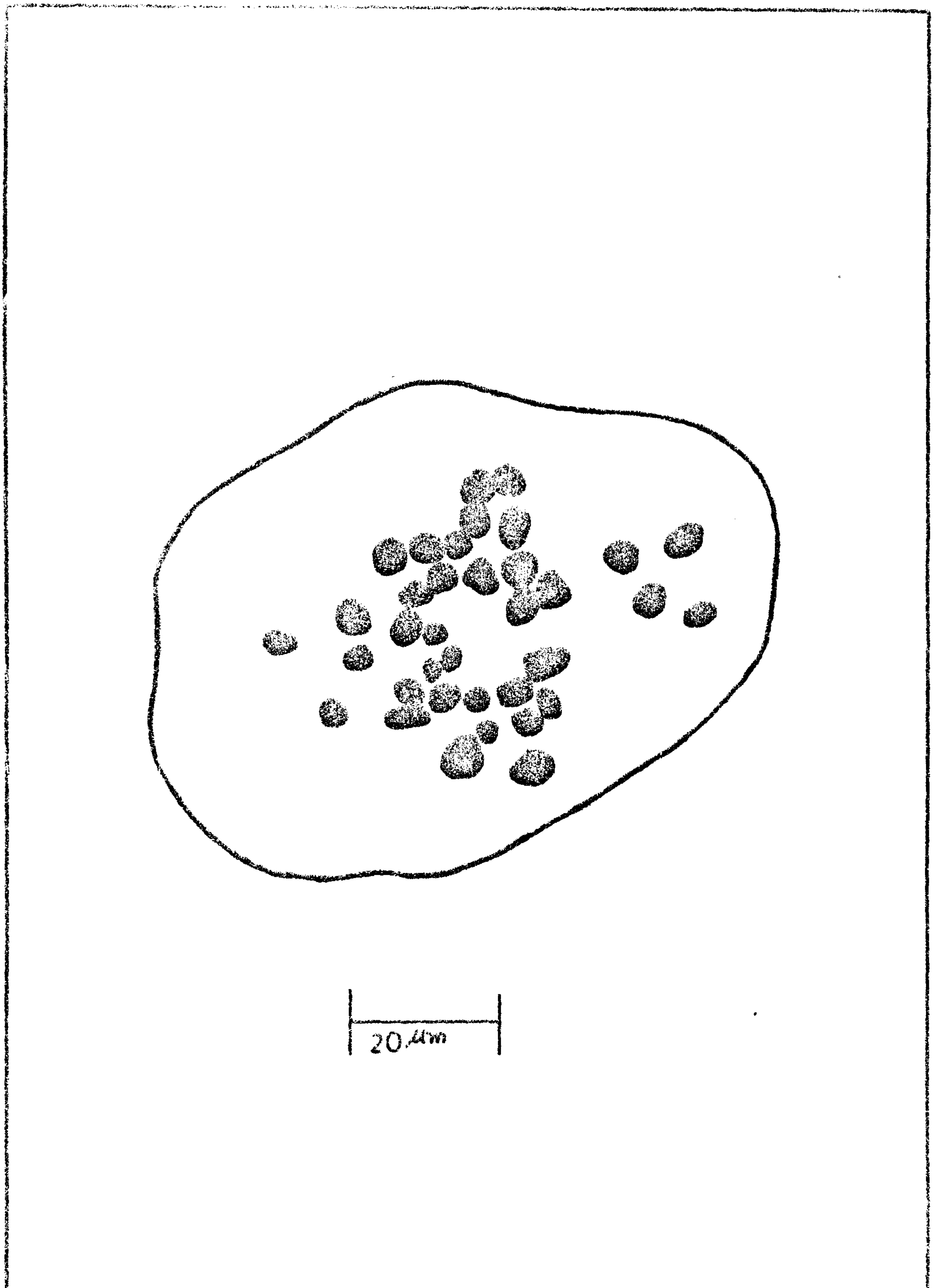
The expected yields of crude diosgenin from six-month, nine-month and twelve-month old crops of Costus worked out to 140.59 kg, 157.65 kg and 96.74 kg per ha, respectively. Considering the present market price of diosgenin (Rs.525 per kg), the net profit per ha worked out to Rs.4840 and Rs.6270 for the six-month and nine-month old crops, respectively. The twelve-month old crop showed a loss of Rs.130 per ha (Table 7, Appendix VI).

With regard to the profits obtainable from the commercial cultivation of Costus, the available reports show considerable variation. A net profit of Rs.2250 per ha was recorded by Singh et al. (1979) from a 21-month old crop.

According to them, at the 1979 price levels of diosgenin (Rs.450 per kg), Costus was not profitable for commercial cultivation. Balyan et al. (1980) obtained a net profit of Rs.8980 per ha from an eight-month old crop. Under Vellanikkara conditions, Sudhadevi (1981) reported a net profit of Rs.7500 per ha from a six-month old crop supplied with 45:30:30 kg/ha of $N:P_2O_5:K_2O$ (identified as the optimum in her studies). Sudhadevi's recommendation was not available at the time of starting the present investigations in which the plots were uniformly under 75:50:50 kg/ha of $N:P_2O_5:K_2O$. The shortfall in the net profit observed in the present investigations can be explained as due to decreased diosgenin yields at higher nitrogen levels as observed by Sudhadevi (1981). Further, Sudhadevi (1981) computed the per hectare figures from a net experimental area of 360 $m^2$. The net area in the present studies was 729 $m^2$ and the per hectare figures worked out on the basis, though more reliable, are likely to be lower. The third factor that lowered the net profit in the present investigation is the increase with wages of labour and cost of fertilizers.

5.6. Cytological examination

The race of Costus speciosus used in the studies was observed to be a tetraploid with 2n=36 (Plate III, Fig. 9). Somatic chromosome numbers of 2n=18 and 2n=27 have been




FIG–9. CAMERA LUCIDA DRAWING OF THE SOMATIC CELL AT METAPHASE recorded by Sato and Simmonds, respectively (quoted by Fedorov, 1974). Raghavan and Venkatasubban, Chakravarti, Sharma and Bhattacharya (quoted by Fedorov, 1974) observed tetraploids in <u>Costus speciosus</u>. Intraspecific chromosomal races (diploid, triploid and tetraploid) were also observed by Subrahmanyam (1978).

Summing up, the low density plants exhibited better growth and yield per plant. However, planting at the closer spacing (50cm x 50cm) gave significantly higher yield per unit area. In the case of weight of planting material, 100 g weight of planted rhizomes was found to be significantly superior to the other two lower rhizome weights (50 g and 75 g) with respect to growth and yield. Although the yield of green rhizomes as well as diosgenin content were higher at six months after planting, the dry matter content was very low. Therefore, the yield of dry rhizomes and diosgenin were poor at that stage. Quadratic response functions showed that the optimum stage of harvest for getting the maximum yield of diosgenin per ha is eight months after planting. A maximum yield of 157.65 kg/ha of diosgenin could be expected by planting 100 g rhizome pieces at 50 x 50cm spacing and harvesting the crop at nine months after planting. This treatment combination gave a net profit of Rs.6270/- per ha.

The present investigations clearly indicated that <u>Costus speciosus</u> could be groomed as a commercial crop in Kerala.

# Summary

# 6. SUMMARY

An experiment in split-split-plot design was conducted at the College of Horticulture, Vellanikkara during 1981-'82 to study the influence of spacing, weight of planting material and duration of the crop on the yield and quality factors in Costus speciosus. The salient results are summarised below:

6.1. Planting at low density (75×75cm) enhanced the vegetative growth of the plants in terms of number of tillers, number of leaves and leaf area per plant. Most of the primary and secondary finger characters also were significantly higher at wider spacings. The yield of rhizomes and diosgenin per plant were found to be higher.

6.2. Planting Costus speciosus at high density (50×50cm) was found to be beneficial for obtaining higher per ha yield of rhizomes and diosgenin as compared to planting it either at 60×60cm or 75×75cm

6.3. The plant height, number of tillers, number of leaves and leaf area per plant were found to be significantly higher when heavier planting materials were used. Planting of such rhizomes also resulted in better growth of the rhizomes. The yield of rhizomes, diosgenin content and yield of diosgenin were substantially higher when heavier rhizomes were planted. The studies indicated that planting of 100 g rhizome pieces was significantly superior to planting lighter rhizomes (50 g and 75 g).

6.4. Harvesting the crop at six months duration gave higher yields of green rhizomes with increased diosgenin content. However, the dry matter percentage was very low at this stage. As such, the yield of dry rhizomes and diosgenin were poor.

6.5. Eventhough the yield of green rhizomes and diosgenin content decreased with the duration of the crop, the dry matter percentage increased by the second stage of harvest, nine months after planting. This resulted in higher yields of dry rhizomes and diosgenin at this stage.

6.6. By delaying the harvest to 12 months after planting, the dry matter percentage decreased, which together with the low rhizome yield and diosgenin content resulted in poor yields of diosgenin.

6.7. Quadratic response functions were fitted to find out the optimum in relation to different yield parameters. The optimum stage of harvest for obtaining maximum dry rhizome yield was found to be nine months after planting.

However, the optimum stage of harvest for getting maximum yield of diosgenin was found to be eighth month after planting.

6.8. The treatment combination $D_2S_1W_3$ was identified as the economic optimum. A maximum yield of 157.65 kg/ha of diosgenin could be expected by planting 100 g rhizome pieces ($W_3$) at 50x50cm spacing ($S_1$) and harvesting the crop at nine months after planting ($D_2$). A net profit of Rs.6270 per ha could be expected from a nine month-old crop.

6.9. The characters such as number per plant of tillers, leaves, rhizomes, primary fingers and secondary fingers, leaf area per plant, dry matter content, diosgenin content, length of rhizomes, and length and girth of primary fingers exhibited highly significant or significant positive correlation with the yield of diosgenin per plant.

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* Originals not seen

# Appendices

## Appendix I

Weather data (monthly averages) from 1st May 1981 to 30th May, 1982

| Month | Temperature (°C) | | Relative humidity (%) | Total rainfall (mm) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| May | 33.10 | 24.70 | 88.70 | 225.80 |
| June | 28.53 | 22.50 | 90.50 | 303.23 |
| July | 29.26 | 22.68 | 87.00 | 128.23 |
| August | 28.65 | 21.95 | 87.75 | 101.23 |
| September | 29.45 | 22.94 | 84.60 | 104.56 |
| October | 30.78 | 22.85 | 78.50 | 21.60 |
| November | 31.50 | 21.85 | 72.25 | 19.50 |
| December | 31.54 | 21.54 | 62.40 | 0.44 |
| January | 32.43 | 21.25 | 58.75 | - |
| February | 36.90 | 21.30 | 57.70 | - |
| March | 35.40 | 27.20 | 78.20 | - |
| April | 34.70 | 25.40 | 81.70 | 61.40 |
| May | 33.80 | 24.50 | 79.90 | 172.60 |

Appendix II

Analysis of variance for the effect of spacing and weight of planting material on the growth characteristics of *Costus speciosus*

| Sources of variation | df | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Plant height | Number of tillers per plant | Number of leaves per tiller | Number of leaves per plant | Leaf length | Leaf width | Area per leaf | Total leaf area |
| Total | 26 | | | | | | | | |
| Replication | 2 | 682.90** | 1.84 | 4.42 | 1392.46 | 4.19 | 2.08** | 136.50 | 8010301.72 |
| Spacing (M) | 2 | 234.25* | 12.67** | 3.52 | 3993.83* | 0.21 | 0.11 | 11.64 | 34066685.40* |
| Error (a) | 4 | 16.96 | 0.57 | 0.85 | 443.07 | 0.77 | 0.09 | 31.65 | 2225865.32 |
| Rhizome weight (S) | 2 | 195.53** | 2.67 | 0.05 | 491.30 | 0.69 | 0.04 | 88.88 | 12938001.80** |
| Linear | 1 | 390.89** | 5.06* | - | 980.36* | - | - | - | 24953931.00** |
| Quadratic | 1 | 0.28 | 0.28 | - | 2.25 | - | - | - | 922072.00 |
| M x S | 4 | 21.08 | 0.93 | 0.39 | 310.22 | 0.85 | 0.04 | 28.13 | 2318959.94 |
| Error (b) | 12 | 15.17 | 1.00 | 0.50 | 204.82 | 0.45 | 0.10 | 54.42 | 930270.17 |

* Significant at 0.05 level

** Significant at 0.01 level

## Appendix III

**Analysis of variance for the effect of spacing, weight of planting material and stage of harvest on the rhizome characters of <u>Costus speciosus</u>**

| Source of variation | df | Mean squares | | |
|---|---|---|---|---|
| | | Number of rhizomes per plant | Length of rhizomes | Internodal length |
| Total | 80 | | | |
| Replication | 2 | 0.10 | 5.59 | 0.40 |
| Stage of harvest (M) | 2 | 0.007 | 49.95* | 0.71 |
| Error (a) | 4 | 0.03 | 5.09 | 0.21 |
| Spacing (S) | 2 | 0.06 | 43.13 | 0.25 |
| M x S | 4 | 0.01 | 23.27 | 0.07 |
| Error (b) | 12 | 0.03 | 30.16 | 0.10 |
| Rhizome weight (SS) | 2 | 0.47** | 97.12* | 0.30* |
| M x SS | 4 | 0.08 | 2.57 | 0.04 |
| S x SS | 4 | 0.01 | 13.80 | 0.05 |
| M x S x SS | 8 | 0.03 | 17.78 | 0.10 |
| Error (c) | 36 | 0.06 | 20.19 | 0.08 |

* Significant at 0.05 level

** Significant at 0.01 level

## Appendix IV

**Analysis of variance for the effect of spacing, weight of planting material and stage of harvest on the characters of primary and secondary fingers of *Costus speciosus***

| Source of variation | df | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number of primary fingers | Length of primary fingers | Girth of primary fingers | Number of nodes per primary finger | Number of secondary fingers | Length of secondary fingers | Girth of secondary fingers | Number of nodes per secondary finger |
| Total | 80 | | | | | | | | |
| Replication | 2 | 3.58** | 10.80 | 0.27 | 2.34 | 5.56* | 2.63* | 0.71* | 0.93 |
| Time of harvest (M) | 2 | 3.47** | 57.84** | 1.46 | 1.64 | 29.41** | 11.02** | 0.66* | 4.53** |
| Error (a) | 4 | 0.09 | 2.41 | 1.09 | 2.49 | 0.39 | 0.32 | 0.06 | 0.25 |
| Spacing (S) | 2 | 0.33 | 27.24** | 27.05** | 7.33** | 0.44 | 5.58** | 1.20** | 0.03 |
| M x S | 4 | 0.51 | 0.49 | 0.39 | 0.33 | 1.60 | 0.57 | 0.18 | 0.35 |
| Error (b) | 12 | 0.40 | 2.03 | 0.47 | 0.60 | 0.89 | 0.37 | 0.16 | 0.18 |
| Rhizome weight (SS) | 2 | 1.83* | 27.76** | 6.74** | 1.67 | 1.30 | 0.95 | 0.89* | 1.41** |
| M x SS | 4 | 0.52 | 10.63 | 0.15 | 0.47 | 0.08 | 0.42 | 0.14 | 0.07 |
| S x SS | 4 | 0.60 | 7.98 | 0.32 | 2.16* | 0.30 | 0.10 | 0.09 | 0.002 |
| M x S x SS | 8 | 0.28 | 4.69 | 0.34 | 0.57 | 0.25 | 0.29 | 0.10 | 0.10 |
| Error (e) | 36 | 0.44 | 4.86 | 0.18 | 0.72 | 0.50 | 0.38 | 0.13 | 0.16 |

* Significant at 0.05 level

** Significant at 0.01 level

Appendix V

Analysis of variance for the effect of spacing, weight of planting material and stage of harvest on the yield of rhizome and diosgenin of *Costus speciosus*

| Source of variation | | df | Mean squares | | | | |
|---|---|---|---|---|---|---|---|
| | | | Yield of green rhizomes | Dry matter content | Yield of dry rhizomes | Diosgenin content | Yield of diosgenin |
| Total | | 80 | | | | | |
| Replication | | 2 | 1077.29** | 4.07 | 22.14* | 0.11 | 11701.38 |
| Time of harvest (M) | | 2 | 1238.04** | 292.78** | 18.04 | 4.00** | 26657.88* |
| Linear | 1 | | 2424.06** | 320.18** | 0.27 | 7.59** | 25958.10* |
| Quadratic | 1 | | 52.03 | 265.39** | 35.80* | 0.41 | 27357.66* |
| Error (a) | | 4 | 45.83 | 5.94 | 2.69 | 0.08 | 2342.25 |
| Spacing (S) | | 2 | 535.04* | 3.77 | 17.58** | 0.23 | 8666.46* |
| M x S | | 4 | 77.65 | 1.43 | 1.48 | 0.04 | 605.78 |
| Error (b) | | 12 | 95.44 | 2.33 | 2.35 | 0.08 | 1304.12 |
| Rhizome weight (SS) | | 2 | 261.62* | 0.95 | 6.50 | 0.18* | 2242.34 |
| Linear | 1 | 1 | 518.94** | 0.78 | 12.18* | 0.022 | 4340.05* |
| Quadratic | 1 | | 4.30 | 1.13 | 0.83 | 0.338* | 144.64 |
| M x SS | | 4 | 51.47 | 3.27 | 0.81 | 0.05 | 350.25 |
| S x SS | | 4 | 80.91 | 2.14 | 2.79 | 0.10 | 1143.07 |
| M x S x SS | | 8 | 41.49 | 3.13 | 2.84 | 0.12 | 1276.48 |
| Error (c) | | 36 | 67.88 | 1.46 | 2.21 | 0.04 | 800.23 |

* Significant at 0.05 level
** Significant at 0.01 level

# EFFECT OF SPACING, RHIZOME WEIGHT AND TIME OF HARVEST ON THE YIELD AND QUALITY CONSTITUENTS IN *Costus speciosus*


By

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## ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

## Master of Science in Horticulture


Faculty of Agriculture
Kerala Agricultural University

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1983

## ABSTRACT

An experiment conducted at the College of Horticulture, Vellanikkara, during 1981-'82 to study the influence of spacing, weight of planting material and duration of the crop on the yield and quality factors in Costus speciosus revealed that low density planting (75x75cm) enhanced the overall vegetative growth. However, the per hectare yield of rhizomes and diosgenin were found to be significantly higher at the closest spacing (50x50cm).

The higher the weight of the planting material, the better was the vegetative and rhizomatous growth. The yield of rhizomes and diosgenin were proportionately higher when heavier planting materials were used. Planting of 100 g rhizome pieces was found to be significantly superior to planting of rhizomes weighing 50 g and 75 g.

Increasing the crop duration significantly increased some of the rhizome and finger characters. Though the yield of green rhizome and diosgenin content were higher at six months after planting, the dry matter content was low at that stage. The yield of dry rhizomes and diosgenin were higher at nine months after planting, due to the high dry matter content. Quadratic response functions showed the eighth month to be the optimum stage of harvest for obtaining maximum yield of diosgenin per unit area.

The treatment combination $D_2S_1W_3$ was found to be the economic optimum. A maximum yield of 157.65 kg/ha of diosgenin, giving a net profit of Rs.6270 per ha, could be expected by planting 100 g rhizome pieces ($W_3$) at 50 x 50cm spacing ($S_1$) and harvesting the crop at nine months after planting ($D_2$). The studies indicated that <u>Costus speciosus</u> could be groomed as a commercial crop under Kerala conditions.