STANDARDISATION OF PROPAGATION METHOD, TIME OF PLANTING, TIME OF HARVEST AND PHYTOCHEMICAL ANALYSIS OF *Kaempferia galanga* L.

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Standardisation of propagation method, time of planting, time of harvest and phytochemical analysis of *Kaempferia galanga* L." is a bonafide record of research work done by me during the course of research work and that this 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 Universsity or Society.

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CERTIFICATE

Certified that this thesis entitled "Standardisation of propagation method, time of planting, time of harvest and phytochemical analysis of *Kaempferia galanga* L." is a record of research work done independently by Shri.Rajagopalan, A. 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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to

the memory

of

my beloved father

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Introduction

INTRODUCTION

Medicines and perfumes had been in great demand in the international trade for a long time and are expected to better their positions in the coming years. As the right realisation of this reflection, medicinal and aromatic plants have attracted the attention of agriculturists, industrialists and economists of the world over in the recent past.

India, being blessed with the agroclimatic suitability for the cultivation of a variety of medicinal and aromatic plants, had been widely recognised as a prospective tract. The wealth of India in this connection is so great that it possesses many useful and economic species still remaining unutilised. In brief, to cope up with the present world trend, India should exploit its untapped medicinal plant wealth to the economic and export advantages. In this connection, genus Kaempferia appears to play a promising role.

Kaempferia, a genus of rhizomatous herbs belonging to the family Zingiberaceae, widely distributed in the tropics and subtropics of Asia and Africa (Synge, 1956). Of the ten species occuring in India, K.galanga L. and K.rotunda are of commercial significance.

The economic part of K.galanga L. is the underground stem, the rhizome. Rhizome of Kaempferia finds an important place in indegenous medicine as stimulant, expectorant, diuretic and carminative. Powdered rhizome mixed with honey is administered against coughs and pectoral infections. Decoction of rhizome is prescribed against dyspepsia, headache and malaria.

Steam distillation of the rhizome yields an essential oil. The oil is utilised in the manufacture of perfumes and curry flavourings (Guenther, 1975). Antifungal property of the essential oil had been demonstrated by Dayal and Purohit (1971).

At present, the cultivation of this crop is restricted to localised tracts of Kerala. It is grown under the agro-climatic conditions similar to the related crops like ginger and turmeric. Rhizomes of these crops contain an essential oil used mainly for flavouring food. In addition to the essential oil, rhizomes yield oleoresin, the total flavour extract comprising the volatile oil, non-volatile pungent principles, colours and fats. Oleoresin, a sterile product provides a solution to the unhygenic nature of spice utilisation. The strength or flavour of oleoresin can be adjusted to the required standard thereby providing uniformity of flavour. The tonnage can also be reduced; a desirable attribute from the export point of view.

Informations on the agronomic, propagational and quality attributes of K.galanga L. are meagre. Research on ginger and turmeric have shown that type of planting material, planting time and harvesting time have considerable influence on rhizome yield and quality constituents. (Aiyadurai, 1966). In view of these findings the present investigation was undertaken with the following objectives:

1. Finding out the best planting material.
2. Optimisation of planting time and harvesting time.
3. Evaluation of the quality in terms of dryage, essential oil and oleoresin.
4. To work out the economics of cultivation.

Review of Literature

REVIEW OF LITERATURE

Kaempferia galanga L. renowned as a medicinal plant, has not attracted any systematic research work except for the reports on the chemical analysis of rhizomes. Panicker et al. (1926) analysed the dried and powdered rhizomes which gave 2.4 - 3.88% of a volatile oil. Pillai and Wariyar (1962) investigated the non-essential oil constituents of the rhizomes but could not arrive at any conclusions.

The Aromatic and Medicinal Plants Research Station, Odakkali, Kerala has undertaken a study to find out the response of Kaempferia galanga L. to different spacing and levels of farm yard manure. Preliminary trials have shown that a spacing of 20x 15 cm and farm yard manure at the rate of 30 tonnes per hectare give maximum rhizome yield (Annual Progress Report, 1982).

Since the literature on the above crop is scanty, works carried out on the related crops, viz.ginger, turmeric and Costus sp. pertineht to the present investigation are reviewed in this section.

1. Ginger

1.1. Propagation Method

Aiyadurai (1966) reviewing research on spices and cashewnut in India reported that planting of large sized

seed rhizome (1½" to 2½") gave significantly increased yield than planting of small sized seed material (½" to 1"). According to Randhawa et al.(1972), large rhizomes (150 g with 4-6 buds) gave higher yields than small ones (60 g with 2 buds).

1.2. Time of Planting

Planting seed rhizome by first week of April gave significantly higher yield than other plantings (Thomas, 1961). Randhawa et al.(1972) reported that the early planted ginger (planted on Ist, 10th and 20th May) had better growth and yield than ginger planted on 30th May and 10th June.

1.3. Time of Harvest

Nair and Varma (1970) found that the optimum time of harvest was 260 days after planting. The crop was harvested 215 days after planting and subsequently at 15 days interval upto 275 days. A steady increase in the per cent of volatile oil was noted upto 260 days of planting and further delay in harvest decreased the per cent of oil and increased the fibre content. Jogi et al.(1972) recommended to harvest ginger 6.5 months after planting when the crude fibre content was low. Nybe (1978) obtained maximum yield of green ginger at 180 days after planting, but the drying per cent continued to increase with maturity. According to Jayachandran et al.(1980) Rio-de-Janeiro variety of ginger gave maximum fresh yield of

rhizome, oil and oleoresin yield at seven months after planting.

1.4. Chemical Analysis

At CFTRI, Mysore Natarajan et al.(1970) conducted qualitative studies on raw ginger samples and showed that the volatile oil varied from 1.25 to 2.81 per cent, crude fibre 1.4 to 9.5 per cent, cold water extract 1.12 to 3.9 per cent and acetone extract 5.11 to 11.71 per cent. Muralidharan (1972) reported highest oleoresin content of 7.1 per cent in Kuruppampady followed by Wynad Local, Assam, Mysore, Valluvanad and Narasapattom. According to Nybe (1978) the per cent of oleoresin and ginger oil were maximum at 165 days of planting whereas the maximum yield per hectare of the same were found to be 270, 195, 225 and 225 days after planting in Rio-de-Janeiro, Maran, Kuruppampady and Wynad Local respectively.

2. Turmeric

2.1. Propagation Method

Large sized (3.8 cm) rhizomes gave significantly higher germination and fresh rhizome yields in turmeric (Hussain and Said, 1965). Sarma and Murthy (1965) found that mother rhizomes were suitable for delayed planting whereas finger rhizomes showed decreased in yield with delayed planting. Randhawa and Misra (1974) obtained best

growth and yield when rhizomes weighing about 100 g were used as planting material. Nambiar (1979), based on a critical analysis of morphological and yield data in different cultivars of Curcuma longa and C.aromatica, concluded that the final yield was influenced by the weight of seed material.

From a spacing-cum-type of seed material trial, Anjaneyulu and Krishnamurthy (1979) reported that highest yield was obtained from plots with whole mother rhizomes spaced to 22.5 cm with 30 cm between the rows. According to Patil and Borse (1981) planting whole mother rhizomes gave the highest average yield (469.33 q.ha^{-1}) followed closely by transplanting cut rhizome seedlings at 30 days of age (457.29 g ha^{-1}). Chatterjee (1983) reported that rhizomes weighing 60 g when used as planting material gave maximum yield of green and cured rhizomes.

2.2. Time of Planting

Randhawa and Misra (1974) recommended early planting from the end of April to the first fortnight of May using large sized (weighing about 100g) rhizomes. Second fortnight of June was the optimum period for planting of 'short' and 'medium' duration varieties under Andhra conditions, while for 'long' duration varieties it was between 15th June and 15th July (Rao et al., 1975). Hari et al.(1978) compared six

dates of planting, i.e. Ist May, 10th May, 20th May, Ist June, 10th June and 20th June. He obtained maximum fresh yield (205.53 q ha^{-1}) in 10th May planting and least (171.30 q ha^{-1}) in Ist May planting. At Kerala Agricultural University, Chatterjee (1983) obtained highest rhizome yield from the crop planted during middle of May.

2.3. Time of Harvest

Turmeric when harvested 8 months and 15 days after planting gave highest yield of cured turmeric under Maharashtra conditions. The curing per cent increased as the period of harvesting was enhanced (Patil and Borse, 1979). Philip and Nair (1978) conducted qualitative studies on four turmeric cultivars, viz. G.L.Puram-II, Mannuthy L$_o$cal, Vontimitta and Armoor. They found that the yield of dry produce increased steadily as the period of maturity was increased from 165 days to 270 days. They recommended harvesting of turmeric 270 days after planting to get maximum yield of rhizome, oleoresin and curcumin per unit area.

2.4. Chemical Analysis

From a morphological and quality evaluation study, Philip (1978) reported that the oleoresin and curcumin content decreased during the period from 180 to 240 days after planting. Maximum yield of dry produce, oleoresin and curcumin per hectare were noticed on 270th day after planting.

Among the cultivars studied, VK-5 (Mannuthy Local) gave the maximum yield of dry produce, oleoresin and curcumin.

3. Costus speciosus

Sharma et al.(1980) from the results of two field trials concluded that the germination percentage, number of shoots per plant, yield of rhizome and diosgenin significantly increased by increasing the weight of planting material upto 125 g. At Kerala Agricultural University, Joseph (1983) found that rhizome pieces weighing 100 g were significantly superior to rhizomes weighing 50 g and 75 g.

Sarin et al.(1977) observed that optimum sprouting (above 95%) occured when the rhizomes were planted during April and May. The rhizome planted during June and July recorded 85 per cent sprouting within 60 days.

The effect of phenological condition on the crop was studied by Sarin et al.(1977). The highest yield was obtained in July when the plants were in the active stage of growth, with flowering just started. In another study, Sarin et al.(1977) obtained maximum yield from a six-month old crop planted in July. Joseph (1983) found that a crop of 9 months duration gave highest yield of rhizome and diosgenin.

Materials and Methods

MATERIALS AND METHODS

The present investigation was carried out from May 1982 to March 1983 at the College of Horticulture, Vellanikkara with a view to find out the best propagation method, time of planting and time of harvest to get maximum rhizome yield, volatile oil and oleoresin.

The seed material required for the above experiment was collected from the cultivators of Thodupuzha (Kerala State).

The area selected was fairly level, with good drainage. The soil type was a deep laterite with clay loam texture. The results of chemical analysis are presented in Table 13.

1. Land preparation

The land was dug to 30 cm depth and the soil was brought to a fine tilth. Raised beds of 3 x 1 m size and 25 cm height with 30 cm wide channels in between the beds were prepared. Cattle manure was applied at the rate of 9 kg per bed and incorporated by shallow digging.

2. Planting material and planting

The rhizomes were sorted out for uniform sized mother and finger rhizomes. Samples consisting of 100 numbers of mother and finger rhizomes were weighed separately

to determine the weight of planting materials. A spacing of 20 x 15 cm was adopted for planting rhizomes (Annual Progress Report of Aromatic & Medicinal Plants Research Station, Odakkali for the year 1982). The seed rate per plot was 288 g (960 kg ha^{-1}) for mother rhizomes and 130 g (432 kg ha^{-1}) for finger rhizomes. A plant population of 72 (4 rows with 18 plants per row) per plot was given.

3. Experimental details and layout

Design	: Split-plot
Main plot treatments	: 9 (combination of time of planting and time of harvest).
i) Time of planting	: 3
	P_1 - third week of May
	P_2 - first week of June
	P_3 - second week of June
ii) Time of harvest	: 3
	h_1 - 6 months after planting
	h_2 - 7 months after planting
	h_3 - 8 months after planting
Sub plot treatments	: 2 (method of propagation)
	m_1 - mother rhizomes
	m_2 - finger rhizomes

Total number of treatments	:	18
Number of replications	:	3
Total number of plots	:	54
Net plot size	:	3 m x 1 m
Gross plot size	:	3.6 m x 1.6 m = 5.76 m^2 inclusive of 30 cm channel all round.
Total experimental area	:	311.04 m^2

4. Crop management

Mulching was done immediately after planting with glyricidia leaves. Fertilizers were applied at the rate of 75:50:50 kg NPK ha^{-1} as per the package of practices recommended by Kerala Agricultural University for ginger (KAU, 1981). Weeding and Earthing up was done twice, i.e.60 days after planting and 90 days after planting. During heavy rainy season incidence of leaf spot caused by Phytophthora sp.was noticed. Spraying one per cent Bordeaux mixture gave good control. Minor attacks by root knot nematode (Meliodogyne incognita) was controlled by the application of carbofuran (5 g per bed).

5. Sampling technique

Random sampling technique was adopted to select the sample plants for recording various morphological characters. Ten plants were selected at random from each plot eliminating

the border rows for recording the above data. For the chemical analysis (volatile oil and oleoresin), rhizomes from these ten sample plants were bulked together to get a representative sample for each plot.

6. Pre-harvest studies

6.1. Sprouting

The number of rhizomes sprouted per plot were recorded and the sprouting per cent was worked out.

6.2. Number of leaves

Number of leaves produced per plant were recorded from 10 sample plants and the average was worked out for each plot.

6.3. Length, width and total leaf area

Three, top most fully opened leaves were selected at random from each of the sample plant for recording the length and width of leaves. The length was measured as the distance between the point of emergence of the leaf and the tip of the leaf blade. Width was determined as the mean of the three measurements, namely one at the point of maximum width and one each on either side of it corresponding to the point of inclination of the lamina towards the tip and base of the leaf. From these measurements, the average length and width of the leaves were computed.

For the estimation of leaf area a preliminary study was conducted to develop a quick method. For this purpose, 100 leaves were collected at random covering all the treatments, the length and mean width recorded and area was found out graphically. A mathematical equation derived from the data based on the leaf length and mean width measurements was used in further estimation of leaf area. The mean leaf area was thus calculated using the mean values of length and width. The total leaf area was then calculated by multiplying the average leaf area with number of leaves per plant.

6.4. Per cent of flowering

The flowers were produced successively from the same plant (Plate I). The number of plants flowered per plot was recorded to get an idea about season of flowering.

6.5. Season of flowering and duration

In all the plots, flowering commenced 40-50 days after planting. The flowering process continued for 1-1½ months starting from middle of July to last week of August (peak season of flowering). Flowers remained open for 1 to 2 days, later withered off; new flowers were produced successfully from the same plant.

6.6. Seed set

No seed set was observed.

6.7. Diseases and Pests

During July-August, leaf spot caused by Phytophthora sp. was observed. Spraying one per cent Bordeaux mixture gave good control. Minor infection by root knot nematode (Meloidogyne incognita) was also noticed, which was controlled by applying carbofuran (5 g per bed).

7. Post-harvest studies

7.1. Number and length of roots per plant

The number of roots attached to the rhizomes of each sample plant was recorded and the average worked out. Five roots were selected at random from each plant for recording the length and the average worked out.

7.2. Number of main and secondary rhizomes per plant

The number of main and secondary rhizomes produced per plant was recorded from the ten sample plants and their mean worked out.

7.3. Length of main rhizomes

The length of each main rhizome produced by the ten observational plants was recorded separately and the mean calculated for each plot.

7.4. Girth of main rhizomes

The girth at the middle was recorded using a twine.

7.5. Number of nodes and internodal length of main rhizomes

The number of nodes in each main rhizome of the sample plants was recorded. The internodal length was found out by dividing the total length of the main rhizome by the number of nodes.

7.6. Length of secondary rhizomes

Five secondary rhizomes were selected at random from each observational plant per plot for recording length of secondary rhizomes and their mean worked out.

7.7. Girth of secondary rhizomes

The maximum girth of the five secondary rhizomes per observational plant was recorded and the mean worked out for each plot.

7.8. Number of nodes and internodal length of secondary rhizomes

The number of nodes in the five secondary rhizomes was recorded. The internodal length was found out by dividing the total length of the secondary rhizome by the number of nodes.

7.9. Fresh rhizome yield

The weight of the entire rhizome harvested from individual plots was taken to record the fresh rhizome yield. Yield per hectare was calculated by converting the gross yield per plot (5.76 m^2) into hectare basis and expressed as fresh rhizome yield per hectare.

7.10. Dry rhizome yield

7.10.a Per cent recovery of dry rhizome

Immediately after harvest, 500 g of green rhizome from each plot was removed and dried in the sun. Drying was continued to get a constant weight and from the final weight, the per cent of dry rhizome was worked out.

7.10.b Dry rhizome production per hectare

It was calculated on the basis of the per cent of dry rhizome obtained by drying 500 g sample of fresh rhizome and multiplying the gross yield of fresh rhizome by the ratio and expressed as dry rhizome yield per hectare.

7.11. Chemical analysis

7.11.a Analysis of rhizomes for volatile oil and oleoresin

i) Sample preparation

Samples of 150 g of dried rhizome were taken and ground in a grinding mill to obtain particles of about 500 micron size. Undue heating of the mill was avoided during grinding. It was mixed carefully and transferred to a polythene bag and closed tightly.

ii) Volatile oil

Volatile oil was estimated by water distillation adopting Clevenger trap method as per ASTA (American Spice Trade Association, 1960) and expressed in per cent. The yield per hectare of oil was calculated by multiplying the

dry rhizome production per hectare with the per cent recovery of oil.

iii. Oleoresin

The oleoresin content was estimated by the Official Analytical Methods of the American Spice Trade Association (1960) using the Soxhlet extraction. The oleoresin production per hectare was calculated based on the dry rhizome production per hectare and the oleoresin content.

7.11.2 Analysis of plant sample for uptake studies

The total nitrogen content of the plant material was determined by the microkjeldhal method (Jackson, 1958). For the determination of phosphorus and potassium the plant material was digested in a mixture of perchloric, sulphuric and nitric acids (1:2:9). The phosphorus in the tripple acid extract was determined by the vanadomolybdate yellow colour method. Potassium was determined using flame photometer (Jackson, 1958).

7.11.3 Analysis of soil

The total nitrogen content in the soil was estimated by the kjeldhal digestion-distillation method. Available phosphorus extracted by Bray No.1 reagent (0.03 N NH_4F in 0.025 N HCl) was estimated by the chlorostannous reduced molybdophosphoric blue colour method. Available potassium

extracted by 1N neutral ammonium acetate was determined flame photometrically (Jackson, 1958).

7.12. Statistical analysis

The data were statistically analysed using the analysis of variance technique for the factorial cum split-plot design. The morphological characters were analysed in a split-plot design without factorial arrangement, treating the plot to plot variation between harvests within the same planting as main plot error and using a modified sub-plot error (Nigam and Gupta, 1979).

The data related to the uptake of plant nutrients were analysed by employing the correlation and multiple regression technique outlined by Snedecor and Cochran (1967).

Results

RESULTS

Experimental findings of the present investigation carried out to standardise the propagation method, time of planting and time of harvest in Kaempferia galanga L. are presented in this chapter.

1. Sprouting

The data on the per cent of sprouting of rhizomes are furnished in Table 1. The analysis of variance is given in Appendix I.

It may be seen from the table that time of planting and method of propagation had significant influence on the per cent of sprouting. Planting of rhizomes during the first week of June (P_2) was significantly superior to other planting treatments (P_1 and P_3). Sprouting in P_2 was 95.59 per cent, while that in P_1 and P_3 were 60.76 per cent and 87.56 per cent respectively. Of the planting materials, mother rhizome (m_1) was superior to finger rhizome (m_2). Mother rhizome recorded 82.5 per cent sprouting compared to 80.08 per cent in finger rhizome.

The interaction between time of planting and method of propagation was found to be significant. Maximum sprouting of 97.91 per cent was observed with the mother rhizomes planted during the first week of June (P_2m_1). It differed

Table 1. Effect of planting time and propagation method on percentage of sprouting.

Treatment	Percentage of sprouting
P_1m_1	59.91 (50.75)
P_1m_2	61.61 (51.79)
P_2m_1	97.91 (82.23)
P_2m_2	93.28 (76.06)
P_3m_1	89.72 (71.41)
P_3m_2	85.40 (67.80)
CD 0.05	(3.55)
Planting time	
P_1	60.76 (51.26)
P_2	95.59 (79.22)
P_3	87.56 (69.61)
CD 0.05	(3.40)
Propagation method	
m_1	82.51 (68.16)
m_2	80.08 (65.23)
CD 0.05	(2.04)

P_1 - Third week of May m_1 - Mother rhizome
P_2 - First week of June m_2 - Finger rhizome
P_3 - Second week of June

NB: Values in brackets are angular transformed ones

significantly from the remaining treatment combinations.

2. Morphological characters

Observations pertaining to the effect of time of planting and method of propagation on leaf characteristics, viz. length, width, mean leaf area and total leaf area are portrayed in Table 2 and the analysis of variance, in Appendix II. The growth habit is shown in Plate I.

2.1. Number of leaves per plant

A persual of the data presented in Table 2 revealed that the time of planting significantly influenced the number of leaves per plant. Planting during the third week of May (P_1) had definite advantage over the planting during the second week of June (P_3). However P_1 and P_2 did not exhibit significant difference. A maximum number of 30.25 leaves was recorded in P_1.

Influence of method of propagation on the number of leaves per plant was found to be not significant.

2.2. Leaf length

Time of planting and method of propagation had no significant influence on the leaf length.

2.3. Leaf width

Time of planting had significant effect on the leaf width (Table 2). The crop planted during the third week of May (P_1) significantly differed from other two plantings.

Plate 1 - Growth habit of Kaempferia galanga L.

Plate 2 - Rhizomes of Kaempferia galanga L.

Table 2. Effect of planting time and propagation method on morphological characters.

Treatment	Number of leaves	Leaf length (cm)	Leaf width (cm)	Mean leaf area (cm^2)	Total leaf area (cm^2)
P_1m_1	30.79	12.64	4.38	49.83	1534.27
P_1m_2	29.70	12.91	4.70	54.61	1621.92
P_2m_1	30.70	11.51	4.23	43.82	1345.27
P_2m_2	28.63	11.00	4.10	40.59	1162.09
P_3m_1	18.05	12.47	4.23	47.47	878.19
P_3m_2	21.92	11.99	4.02	43.38	950.89
CD 0.05	NS	NS	NS	NS	NS
Planting time					
P_1	30.25	12.78	4.54	52.22	1578.10
P_2	29.67	11.26	4.17	42.25	1253.68
P_3	20.21	12.23	4.13	45.43	914.54
CD 0.05	3.34	NS	0.46	NS	304.28
Propagation method					
m_1	26.67	12.21	4.28	47.04	1244.96
m_2	26.71	11.96	4.27	46.19	1252.57
CD 0.05	NS	NS	NS	NS	NS

NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
m_1 - Mother rhizome
m_2 - Finger rhizome

The difference between P_2 and P_3 was not significant. In P_1, the leaf width was 4.54 cm, whereas that in P_2 and P_3 were 4.17 cm and 4.13 cm respectively.

Planting materials did not vary significantly in respect of leaf width.

2.4. Mean leaf area

The treatments did not influence the mean leaf area significantly (Table 2). Maximum mean leaf area was recorded in P_1 (52.22 cm^2) followed by P_3 (45.43 cm^2) and P_2 (42.25 cm^2). The mean leaf area observed with mother rhizome (47.04 cm^2) was larger than that in finger rhizome (46.19 cm^2).

2.5 Total leaf area (TLA)

Time of planting was found to have significant influence on TLA. The method of propagation did not show any significant influence in this respect (Table 2).

Planting during the third week of May (P_1) showed significantly higher TLA compared to other plantings; the values being 1578.10 cm^2 for P_1, 1253.68 cm^2 for P_2 and 914.54 cm^2 for P_3. Method of propagation had no significant effect on the TLA.

Correlations among length, breadth and leaf area were worked out and the details are given in Table 3. Highly significant correlations existed between leaf length and leaf area ($r = 0.85^{**}$) and also between the breadth and the

Table 3. Relationship among the morphological characters of leaves (matrix of 'r' values).

Morphological characters	Leaf length (l)	Leaf width (b)	l x b	Leaf area
Leaf length (l)	...	0.75**	0.88**	0.85**
Leaf width (b)	...	...	0.97**	0.93**
l x b	...	...	...	0.98**
Leaf area	...	...	...	...

leaf area ($r = 0.93^{**}$). Leaf area of Kaempferia galanga L. was worked out from the length and breadth measurements of the leaf. The linear regression equation for estimating leaf area is $Y = 0.21 + 0.89x$ (where x = the product of length and breadth and Y = the leaf area). The above equation accounted for a variation (R^2) of 96.04 per cent.

3. Number and length of roots

Data presented in Table 4 and Appendix III revealed that the time of planting had significant influence on the number and length of roots. However, the time of harvest and method of propagation exerted no significant influence on number and length of roots.

Crop planted during the third week of May (P_1) was significantly superior to the crops planted during the first week of June (P_2) and second week of June (P_3). The difference between P_2 and P_3 was not significant. P_1 recorded an average number of 49.5 roots per plant while the corresponding figures in P_2 and P_3 were 41.12 and 37.71 respectively. With regard to the root length P_1 recorded a mean maximum of 12.99 cm. The root lengths in P_2 and P_3 were 11.63 cm and 10.86 cm respectively.

4. Characteristics of main rhizomes

Data on the number of main rhizomes per plant, length, girth, number of nodes and internodal length of main rhizomes are presented in Table 5 and the analysis of variance, in

Table 4. Effect of planting time, harvesting time, and propagation method on the number and length of roots.

Treatment	Number of roots per plant	Length of roots (cm)
$P_1h_1m_1$	57.58	13.94
$P_1h_1m_2$	46.68	12.59
$P_1h_2m_1$	55.20	13.27
$P_1h_2m_2$	48.13	13.04
$P_1h_3m_1$	46.08	12.79
$P_1h_3m_2$	43.33	11.96
$P_2h_1m_1$	43.13	12.31
$P_2h_1m_2$	39.03	11.76
$P_2h_2m_1$	46.53	11.92
$P_2h_2m_2$	37.63	11.12
$P_2h_3m_1$	37.94	11.13
$P_2h_3m_2$	42.47	11.55
$P_3h_1m_1$	39.73	11.18
$P_3h_1m_2$	36.67	10.83
$P_3h_2m_1$	42.32	11.87
$P_3h_2m_2$	37.49	10.73
$P_3h_3m_1$	36.50	10.22
$P_3h_3m_2$	33.53	10.34
CD 0.05	NS	NS

(Contd...)

Table 4 continued

Treatment	Number of roots per plant	Length of roots (cm)
Planting time		
P_1	49.50	12.99
P_2	41.12	11.63
P_3	37.71	10.86
CD 0.05	6.76	1.34
Harvesting time		
h_1	43.80	12.10
h_2	44.55	11.99
h_3	39.98	11.44
CD 0.05	NS	NS
Propagation method		
m_1	45.00	12.07
m_2	40.55	11.55
CD 0.05	NS	NS

S - Significant
NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
h_1 - 6 months after planting
h_2 - 7 months after planting
h_3 - 8 months after planting
m_1 - Mother rhizome
m_2 - Finger rhizome

Appendix IV. The rhizomes of Kaempferia galanga L. are displayed in Plate 2.

4.1. Number of main rhizomes per plant

Time of planting had significant influence on the number of main rhizomes per plant. Crop planted during the third week of May (P_1) differed significantly from other two plantings. P_1 recorded 2.46 main rhizomes; those in P_2 and P_3 were 2.20 and 2.01 respectively. The difference between P_2 and P_3 was not significant. The effect of time of harvest and method of propagation were not significant.

4.2. Length of main rhizomes

Time of planting and time of harvest had no significant influence on the length of main rhizomes. The method of propagation showed significant influence; mother rhizomes (m_1) being superior to finger rhizomes (m_2). The length of main rhizomes in m_1 was 3.32 cm and that in m_2 was 3.19 cm.

4.3. Girth of main rhizomes

Time of planting varied significantly with respect to the girth of main rhizomes. P_1 (6.37 cm) was superior to P_2 (5.75 cm) and P_3 (5.84 cm). The difference between P_2 and P_3 was not significant. Time of harvest and method propagation had no significant influence on the girth of main rhizomes.

4.4. Number of nodes

None of the treatments exhibited significant influence on the number of nodes.

Table 5. Effect of planting time, harvesting time and propagation method on the morphological characters of main rhizomes.

Treatment	Number of main rhizomes per plant	Length (cm)	Girth (cm)	Number of nodes	Internodal length (cm)
$P_1h_1m_1$	2.62	3.33	6.73	3.81	0.87
$P_1h_1m_2$	2.54	3.22	6.69	4.02	0.81
$P_1h_2m_1$	2.60	3.37	6.45	3.50	0.97
$P_1h_2m_2$	2.44	3.18	6.21	3.57	0.90
$P_1h_3m_1$	2.43	3.26	6.24	3.34	0.98
$P_1h_3m_2$	2.11	3.27	5.91	3.65	0.90
$P_2h_1m_1$	2.30	3.19	6.19	3.66	0.87
$P_2h_1m_2$	2.13	3.06	5.88	3.52	0.87
$P_2h_2m_1$	2.22	3.28	6.27	3.15	1.03
$P_2h_2m_2$	2.07	3.33	5.40	3.43	0.96
$P_2h_3m_1$	2.03	3.32	5.43	3.37	0.91
$P_2h_3m_2$	2.42	3.32	5.31	3.59	0.93
$P_3h_1m_1$	2.09	3.26	5.24	3.09	1.05
$P_3h_1m_2$	2.10	3.10	5.90	3.25	0.96
$P_3h_2m_1$	2.10	3.52	6.22	3.97	0.89
$P_3h_2m_2$	2.20	3.35	6.26	3.50	0.96
$P_3h_3m_1$	1.79	3.40	5.56	3.31	1.04
$P_3h_3m_2$	1.84	2.88	5.83	3.34	0.86
CD 0,05	NS	NS	NS	NS	NS

(Contd..)

Table 5 continued

Treatment	Number of main rhizomes per plant	Length (cm)	Girth (cm)	Number of nodes	Internodal length (cm)
Planting time					
P_1	2.46	3.27	6.37	3.65	0.91
P_2	2.20	3.25	5.75	3.45	0.93
P_3	2.01	3.25	5.84	3.41	0.96
CD 0.05	0.21	NS	0.47	NS	NS
Harvesting time					
h_1	2.30	3.19	6.11	3.56	0.91
h_2	2.27	3.38	6.14	3.52	0.95
h_3	2.10	3.23	5.71	3.43	0.94
CD 0.05	NS	NS	NS	NS	NS
Propagation method					
m_1	2.60	3.32	6.04	3.47	0.96
m_2	1.95	3.19	5.93	3.54	0.90
CD 0.05	NS	0.09	NS	NS	0.03

S - Significant
NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
h_1 - 6 months after planting
h_2 - 7 months after planting
h_3 - 8 months after planting
m_1 - Mother rhizomes
m_2 - Finger rhizomes

4.5. Internodal length

Method of propagation showed significant effect on the internodal length; mother rhizomes being superior (0.96 cm) to finger rhizomes (0.90 cm). The effect of other treatments were not significant.

5. Characteristics of secondary rhizomes

Observations on the number of secondary rhizomes, length, girth, number of nodes and internodal length of secondary rhizomes are presented in Table 6. The analysis of variance is given in Appendix V.

5.1. Number of secondary rhizomes

Time of planting had significant influence on the number of secondary rhizomes per plant. Crop planted during the third week of May (P_1) was significantly superior (12.18) to the crops planted during the first week of June (P_2 - 10.15) and second week of June (P_3 - 9.96). The difference between P_2 and P_3 was not significant. Time of harvest and method of propagation had no significant influence on the number of secondary rhizomes per plant.

5.2. Length of secondary rhizomes

Influence of time of planting and method of propagation on length of secondary rhizomes was not significant; but time of harvest exhibited significant effect. Crop harvested six months after planting (h_1) was significantly superior (3.08 cm) to the crops harvested

Table 6. Effect of planting time, harvesting time and propagation method on the morphological characters of secondary rhizomes.

Treatment	Number of secondary rhizomes per plant	Length (cm)	Girth (cm)	Number of nodes	Internodal length (cm)
$P_1h_1m_1$	13.73	3.29	4.92	4.24	0.66
$P_1h_1m_2$	12.58	3.16	4.87	4.19	0.69
$P_1h_2m_1$	12.17	3.01	4.93	4.00	0.69
$P_1h_2m_2$	11.02	3.05	4.70	3.95	0.68
$P_1h_3m_1$	12.13	2.98	4.81	3.70	0.77
$P_1h_3m_2$	11.49	2.93	4.78	3.75	0.79
$P_2h_1m_1$	10.39	3.05	4.69	3.92	0.76
$P_2h_1m_2$	10.87	3.20	4.54	4.03	0.75
$P_2h_2m_1$	9.81	2.84	4.62	4.05	0.69
$P_2h_2m_2$	10.80	2.78	4.65	3.94	0.70
$P_2h_3m_1$	9.07	2.72	4.66	3.95	0.73
$P_2h_3m_2$	9.96	2.75	4.36	3.68	0.74
$P_3h_1m_1$	10.74	2.85	4.49	4.40	0.73
$P_3h_1m_2$	9.30	2.93	4.09	4.05	0.74
$P_3h_2m_1$	9.85	2.71	3.96	4.23	0.75
$P_3h_2m_2$	9.71	2.74	3.58	4.13	0.73
$P_3h_3m_1$	8.94	2.65	4.47	3.95	0.79
$P_3h_3m_2$	9.43	2.70	3.62	3.75	0.76
CD 0.05	NS	NS	NS	NS	NS

(Contd..)

Table 6 continued

Treatment	Number of secondary rhizomes per plant	Length (cm)	Girth (cm)	Number of nodes	Internodal length (cm)
Planting time					
P_1	12.18	3.07	4.84	3.97	0.71
P_2	10.15	2.89	4.59	3.93	0.73
P_3	9.96	2.76	4.04	4.08	0.75
CD 0.05	1.57	NS	0.22	NS	NS
Harvesting time					
h_1	11.27	3.08	4.60	4.14	0.72
h_2	10.56	2.85	4.41	4.05	0.71
h_3	10.17	2.79	4.45	3.79	0.76
CD 0.05	NS	0.23	NS	NS	NS
Propagation method					
m_1	10.76	2.90	4.62	4.05	0.73
m_2	10.57	2.92	4.35	3.94	0.73
CD 0.05	NS	NS	NS	NS	NS

S - Significant
NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
h_1 - 6 months after planting
h_2 - 7 months after planting
h_3 - 8 months after planting
m_1 - Mother rhizomes
m_2 - Finger rhizomes

seven (h_2 - 2.85 cm) and eight (h_3 - 2.79 cm) months after planting respectively.

5.3. Girth of secondary rhizomes

Time of planting significantly influenced the girth of secondary rhizomes, while the effect of time of harvest and method of propagation was not significant. The girth of secondary rhizomes in P_1 was 4.84 cm; those in P_2 and P_3 were 4.59 cm and 4.04 cm respectively.

5.4. Number of nodes

The effect of treatments on the number of nodes was not significant.

5.5. Internodal length

Time of planting, time of harvest and method of propagation had no significant impact on the internodal length as shown in Table 6.

6. Yield characters

Table 7 represents the data on rhizome yield (fresh and dry) per plot, drying per cent and projected fresh and dry yields per hectare. The analysis of variance is given in Appendix VI.

6.1. Fresh rhizome yield per plot

All the treatments under consideration significantly influenced the fresh rhizome yield per plot.

Table 7. Effect of planting time, harvesting time and propagation method on the yield characteristics.

Treatment	Fresh rhizome yield per plot (kg)	Dry rhizome yield per plot (kg)	Drying percentage.	Projected gross yield	
				Fresh yield (Q/ha)	Dry yield (Q/ha)
$P_1h_1m_1$	3.210	0.771	23.97	55.73	13.39
$P_1h_1m_2$	2.530	0.561	22.11	43.92	9.74
$P_1h_2m_1$	2.612	0.702	27.07	45.31	12.19
$P_1h_2m_2$	2.530	0.671	26.06	43.92	11.65
$P_1h_3m_1$	2.685	0.689	25.83	46.53	11.96
$P_1h_3m_2$	2.281	0.563	24.78	39.58	9.78
$P_2h_1m_1$	2.510	0.642	25.44	43.58	11.15
$P_2h_1m_2$	2.153	0.514	23.69	37.33	8.92
$P_2h_2m_1$	2.641	0.786	29.78	45.83	13.65
$P_2h_2m_2$	1.945	0.545	28.19	33.68	9.46
$P_2h_3m_1$	1.982	0.513	25.97	34.38	8.91
$P_2h_3m_2$	2.250	0.628	27.83	39.06	10.90
$P_3h_1m_1$	2.133	0.566	26.55	36.98	9.83
$P_3h_1m_2$	1.852	0.482	26.11	32.12	8.37
$P_3h_2m_1$	2.360	0.660	27.94	40.97	11.46
$P_3h_2m_2$	1.885	0.478	25.28	32.46	8.29
$P_3h_3m_1$	1.370	0.407	29.78	23.78	7.07
$P_3h_3m_2$	1.190	0.344	28.85	20.66	5.97
CD 0.05	NS	NS	NS	NS	NS

(Contd..)

Table 7 continued

Treatment	Fresh rhizome yield per plot (kg)	Dry rhizome yield per plot (kg)	Drying percentage.	Projected gross yield	
				Fresh yield (Q/ha)	Dry yield (Q/ha)
Planting time					
P_1	2.642	0.659	25.06	45.83	11.45
P_2	2.245	0.605	26.87	38.98	10.50
P_3	1.793	0.489	27.42	31.19	8.49
CD 0.05	0.31	0.08	0.97	6.34	1.79
Harvesting time					
h_1	2.421	0.589	24.69	41.61	10.23
h_2	2.323	0.640	27.47	40.39	11.12
h_3	1.965	0.524	27.17	33.99	9.09
CD 0.05	0.31	0.08	0.97	6.34	NS
Propagation method					
m_1	2.392	0.637	26.96	41.45	11.06
m_2	2.074	0.532	25.94	35.88	9.23
CD 0.05	0.19	0.06	0.99	4.17	1.26

S - Significant
NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
h_1 - 6 months after planting
h_2 - 7 months after planting
h_3 - 8 months after planting
m_1 - Mother rhizome
m_2 - Finger rhizome

Early planting (P_1) recorded a mean yield of 2.642 kg, while those in mid (P_2) and late (P_3) plantings were 2.245 kg and 1.793 kg respectively; the difference was significant. Early harvest (h_1) was superior (2.421 kg) to mid (h_2 - 2.323 kg) and late (h_3 - 1.965 kg) harvests; the difference between h_1 and h_2 was not significant. Mother rhizomes varied significantly from finger rhizomes with respect to fresh yield; the yields being 2.392 kg and 2.074 kg respectively. The treatment combinations were not significantly different with respect to fresh yield. However, the treatment combination $P_1h_1m_1$ (Crop planted during the third week of May using mother rhizomes and harvested six months after planting) gave maximum mean yield of 3.210 kg per plot.

6.2. Dry rhizome yield per plot

Time of planting, time of harvest and method of propagation showed significant influence on dry rhizome yield per plot.

Early planting by third week of May (P_1) was significantly superior (0.659 kg) to mid (0.605 kg) and late (0.489 kg) plantings. Of the time of harvests, h_2 was superior to h_1 and h_3. h_2 recorded a dry rhizome yield of 0.640 kg, those in h_1 and h_3 were 0.589 kg and 0.524 kg respectively. In respect of the method of

propagation, mother rhizomes differed significantly (0.637 kg) from finger rhizomes (0.532 kg). The treatment combinations were not significantly different, but the treatment combinations $P_2h_2m_1$ (Crop planted during the first week of June using mother rhizomes and harvested seven months after planting) and $P_1h_1m_1$ (Crop planted during third week of May using mother rhizomes and harvested six months after planting) recorded high dry rhizome yields per plot as seen from Table **11.**

6.3. Drying per cent

Time of planting, time of harvest and method of propagation had significant impact on the drying per cent.

Planting of rhizomes during the third week of May (P_1) was inferior to other two plantings (P_2 and P_3), while the difference between P_2 and P_3 was not significant (Table 11). Crops harvested seven months after planting (h_2) and eight months after planting (h_3) were significantly superior to the crop harvested six months after planting; the drying per cent in h_1, h_2 & h_3 were 24.69, 27.47 and 27.17 respectively. The difference between h_2 and h_3 was not significant. With regard to the method of propagation, mother rhizomes were significantly superior (26.96) to finger rhizomes (25.94).

6.4. Fresh yield per hectare

All the treatments significantly influenced the fresh rhizome yield per hectare.

A fresh yield of 45.83 q ha^{-1} was obtained from P_1 which differed significantly from P_2 (38.98 q ha^{-1}) and P_3 (31.19 q ha^{-1}). Fresh yield (41.61 q ha^{-1}) obtained from the six month old crop was on par with that (40.39 q ha^{-1}) from the seven month old crop. Both were significantly superior to the eight month old crop (33.99 q ha^{-1}). Mother rhizomes gave fresh yield of 41.45 q ha^{-1}, while the yield obtained from finger rhizomes was 35.88 q ha^{-1}; the difference being significant.

6.5. Dry yield per hectare

Yields from the crop planted during the third week of May (11.45 q ha^{-1}) and first week of June (10.5 q ha^{-1}) were significantly superior to the crop planted during the second week of June (8.49 q ha^{-1}). P_1 and P_2 did not differ significantly. Time of harvest had no influence the dry rhizome yield per hectare. Of the method of propagation, mother rhizome was significantly superior (11.06 q ha^{-1}) to finger rhizome (9.23 q ha^{-1}).

7. Qualitative characters

The data on volatile oil content, volatile oil yield per hectare, oleoresin content and oleoresin yield per hectare are presented in Table 8. The analysis of variance is given in Appendix VII.

Table 8. Effect of planting time, harvesting time and propagation method on qualitative characters.

Treatment	Volatile oil (%)	Volatile oil yield (kg/ha)	Oleoresin (%)	Oleoresin yield (kg/ha)
$P_1h_1m_1$	1.33 (6.67)	17.80	4.34 (11.99)	58.09
$P_1h_1m_2$	2.00 (8.17)	19.48	4.26 (11.92)	41.49
$P_1h_2m_1$	1.58 (7.32)	19.26	5.74 (13.83)	69.96
$P_1h_2m_2$	1.67 (7.40)	19.45	4.52 (12.19)	52.65
$P_1h_3m_1$	2.08 (8.24)	24.88	5.65 (13.73)	67.58
$P_1h_3m_2$	1.42 (6.88)	13.88	4.92 (12.77)	48.09
$P_2h_1m_1$	1.67 (7.40)	18.61	4.72 (12.46)	52.61
$P_2h_1m_2$	1.50 (6.79)	13.39	4.45 (12.11)	39.71
$P_2h_2m_1$	1.58 (7.26)	21.56	3.55 (10.81)	48.44
$P_2h_2m_2$	1.92 (8.05)	18.17	3.27 (10.34)	30.94
$P_2h_3m_1$	1.83 (7.85)	16.29	3.68 (11.03)	32.77
$P_2h_3m_2$	1.92 (8.05)	20.93	4.94 (12.86)	53.86
$P_3h_1m_1$	1.75 (7.63)	17.19	4.21 (11.74)	41.37
$P_3h_1m_2$	1.50 (7.10)	12.55	3.85 (11.27)	32.21
$P_3h_2m_1$	1.33 (6.61)	15.24	2.36 (8.90)	27.04
$P_3h_2m_2$	1.63 (7.32)	13.53	3.43 (10.64)	28.46
$P_3h_3m_1$	1.83 (7.85)	12.93	3.39 (10.50)	23.95
$P_3h_3m_2$	2.08 (8.31)	12.42	2.98 (9.87)	17.79
CD 0.05	NS	NS	NS	NS

(Contd..)

Table 8 continued

Treatment	Volatile oil (%)	Volatile oil yield (kg/ha)	Oleoresin (%)	Oleoresin yield (kg/ha)
Planting time				
P_1	1.68	19.13	4.91	56.31
P_2	1.74	18.16	4.10	43.06
P_3	1.69	13.98	3.37	28.47
CD 0.05	NS	3.70	(0.89)	9.09
Harvesting time				
h_1	1.63	16.50	4.31	44.25
h_2	1.62	17.87	3.81	43.54
h_3	1.86	16.88	4.26	40.67
CD 0.05	NS	NS	NS	NS
Propagation method				
m_1	1.66	18.19	4.18	46.87
m_2	1.74	15.98	4.07	38.36
CD 0.05	NS	NS	NS	7.52

S - Significant
NS - Not significant
P_1 - Third week of May
P_2 - First week of June
P_3 - Second week of June
h_1 - 6 months after planting
h_2 - 7 months after planting
h_3 - 8 months after planting
m_1 - Mother rhizome
m_2 - Finger rhizome

NB: Values in brackets are angular transformed ones.

7.1. Volatile oil content

Time of planting, time of harvest and method of propagation had no significant influence on the volatile oil content.

7.2. Volatile oil yield per hectare

Time of planting was found to have significant influence on the volatile oil yield per hectare. P_1 and P_2 were significantly superior to P_3; but the difference between P_1 and P_2 was not significant. Volatile oil yields in P_1, P_2 & P_3 were 19.13, 18.16 and 13.98 kg per hectare respectively.

Time of harvest and method of propagation did not influence the volatile oil yield significantly.

7.3. Oleoresin content

In respect of the Oleoresin content, early planting by the third week of May (P_1) was significantly superior to mid and late plantings (P_2 and P_3). The difference between P_1 and P_2 was not significant, the oleoresin contents being 4.91% and 4.10% respectively. The oleoresin content in P_3 was 3.37%.

Time of harvest and method of propagation had no significant impact on oleoresin content.

7.4. Oleoresin yield per hectare

Time of planting and method of propagation significantly influenced the oleoresin yield per hectare. P_1 was superior to P_2 and P_3. The highest yield of 56.31 kg ha^{-1} was recorded in P_1 followed by P_2 (43.06 kg ha^{-1}) and P_3 (28.47 kg ha^{-1}). Mother rhizomes were superior (46.87 kg ha^{-1}) to finger rhizomes (38.36 kg ha^{-1}). Time of harvest had no significant effect on oleoresin yield per hectare.

8. Uptake studies

The different plant parts, viz. root, rhizome and leaf were analysed for nitrogen, phosphorus and potassium contents. The total nutrient uptake was worked out and the results are presented in Table 9.

Nutrient contents in different plant parts and the total uptake of nutrients were correlated with the rhizome yield per plot. Regression equations were fitted to assess the individual and combination effects of nutrients on rhizome yield (Table 10 and 11).

8.1. Nutrient contents in the root and yield per plot

Highly significant correlations were obtained between root nutrient contents and rhizome yield ($r_N = 0.92^{**}$; $r_P = 0.53^{*}$; $r_K = 0.94^{**}$).

Table 9. Analysis of plant sample for uptake studies

Treatment	Root			Rhizome			Leaf			Total uptake ($g\ m^{-2}$)		
	N%	P%	K%	N%	P%	K%	N%	P%	K%	N	P	K
$P_1h_1m_1$	2.32	0.29	6.15	2.82	0.28	2.57	3.63	0.25	4.50	29.64	2.97	49.84
$P_1h_1m_2$	1.85	0.29	5.60	2.35	0.25	1.83	3.45	0.23	5.07	23.38	2.87	36.56
$P_1h_2m_1$	2.28	0.31	6.05	2.77	0.25	2.53	3.40	0.22	4.30	27.23	3.53	45.87
$P_1h_2m_2$	2.19	0.31	6.00	2.74	0.26	2.34	2.42	0.23	4.33	25.09	3.33	42.02
$P_1h_3m_1$	2.23	0.29	5.90	2.73	0.24	2.27	2.38	0.20	4.37	25.38	3.10	41.60
$P_1h_3m_2$	1.85	0.27	5.50	2.48	0.25	1.93	2.38	0.23	5.10	23.42	3.06	35.15
$P_2h_1m_1$	2.00	0.25	6.00	2.63	0.24	2.06	3.22	0.24	4.70	24.92	2.68	40.34
$P_2h_1m_2$	1.80	0.28	5.20	2.32	0.25	1.90	3.58	0.23	4.73	22.03	2.16	33.77
$P_2h_2m_1$	2.30	0.26	6.25	2.95	0.23	2.67	2.70	0.25	4.20	30.42	3.35	52.25
$P_2h_2m_2$	1.95	0.25	5.32	2.43	0.24	2.13	2.63	0.19	4.20	20.26	3.23	35.49
$P_2h_3m_1$	1.38	0.23	5.07	2.40	0.25	1.83	2.60	0.21	3.70	19.27	2.16	28.81
$P_2h_3m_2$	2.14	0.26	5.97	2.60	0.27	2.00	2.12	0.21	4.10	23.76	2.57	41.92
$P_3h_1m_1$	1.60	0.24	5.41	2.48	0.22	1.90	3.27	0.21	3.90	19.49	1.84	32.75
$P_3h_1m_2$	1.47	0.24	5.23	2.43	0.23	1.56	3.35	0.22	4.57	18.78	2.21	29.31
$P_3h_2m_1$	2.24	0.26	5.96	2.72	0.28	2.23	2.97	0.24	4.30	24.44	2.97	38.90
$P_3h_2m_2$	1.40	0.24	5.25	2.40	0.19	1.53	2.36	0.21	4.73	19.76	2.47	28.32
$P_3h_3m_1$	1.53	0.24	4.23	2.39	0.29	1.45	2.85	0.23	4.30	17.82	2.72	22.56
$P_3h_3m_2$	1.30	3.26	4.00	2.21	0.21	1.38	2.58	0.25	4.83	15.66	2.33	21.75

8.2. Nutrient contents in the rhizome and yield per plot

Nitrogen and potassium contents showed highly significant correlations with rhizome yield per plot ($r_N = 0.94^{**}$, $r_K = 0.96^{**}$). Correlation between phosphorus content and yield was not significant.

8.3. Nutrient contents in the leaf and yield per plot

No significant correlation was obtained between leaf nutrients and yield per plot.

8.4. Total uptake of nutrients and yield per plot

The three nutrients showed highly significant correlations with yield. Of the nutrients, potassium showed highest correlation ($r_K = 0.98^{**}$) followed by nitrogen ($r_N = 0.96^{**}$) and Phosphorus ($r_P = 0.63^{**}$).

8.5. Multiple regression analysis between yield and nutrients

Multiple linear regression equations were fitted to predict the rhizome yield in relation to the nutrient contents of root and rhizome and total nutrient uptake. Coefficient of determinations (R^2) for the multiple regression equations were 93.5%, 95.22% and 95.67% for nutrient contents in the root, rhizome and for total nutrient uptake respectively. In all these cases, the effect of P was not significant (Table 11).

Table 10. Zero order correlation matrix between rhizome yield and nutrients in different plant parts.

Plant part		yield/plot	N	P	Regression Equation
1. Root					
	N	0.92^{**}	--	--	$Y = 0.005 + 0.31\ N^{**}$
	P	0.53^{*}	0.67^{**}	--	$Y = -0.105 + 2.60\ P^{*}$
	K	0.94^{**}	0.86^{**}	0.48^{NS}	$Y = -0.325 + 0.18\ K^{**}$
2. Rhizome					
	N	0.94^{**}	--	--	$Y = -0.845 + 0.56\ N^{**}$
	P	0.31^{NS}	0.31^{NS}	--	$Y = 0.225 + 1.48\ P^{NS}$
	K	0.96^{**}	0.90^{**}	0.32^{NS}	$Y = -0.015 + 0.30\ K^{**}$
3. Leaf					
	N	0.12^{NS}	--	--	NS
	P	0.27^{NS}	0.23^{NS}	--	NS
	K	-0.24^{NS}	0.17^{NS}	0.47^{NS}	NS
4. Total uptake					
	N	0.96^{**}	--	--	$Y = -0.99 + 0.03\ N^{**}$
	P	0.63^{**}	0.68^{**}	--	$Y = 0.145 + 0.16\ P^{**}$
	K	0.98^{**}	0.97^{**}	0.65^{**}	$Y = 0.081 + 0.014\ K^{**}$

Y yield per plot

NS Not significant

* Significant at 5% level

** Significant at 1% level

Table 11. Multiple regression analysis between rhizome yield and nutrients in different plant parts.

Plant part	Multiple regression equation	R^2 (%)
1. Root	$Y = -0.241+0.156\ N^{*}-0.292\ P^{NS}+0.111\ K^{**}$	93.50
2. Rhizome	$Y = -0.409+0.252\ N^{**}-0.054\ P^{NS}+0.182\ K^{**}$	95.22
3. Leaf	NS	--
4. Total uptake	$Y = 0.059+0.005\ N^{NS}-0.007\ P^{NS}+0.012\ K^{**}$	95.67

R^2 % variation explained by the model

t_{14} 0.05 - 2.145

t_{14} 0.01 - 2.977

Y yield per plot

NS Not significant

* Significant at 5% level

** Significant at 1% level

9. Correlation studies

Correlations between morphological characters and rhizome characters on one hand, and rhizome yield per plot on the other were worked out. The results are furnished in Table 12.

Number of leaves per plant, leaf width, mean leaf area, total leaf area, number of roots, root length, number and girth of main rhizomes, number, length and girth of secondary rhizomes showed highly significant correlations with yield.

Leaf length, length of main rhizomes, number of nodes and internodal length of main rhizomes as well as secondary rhizomes did not show significant linear relations with yield.

10. Chemical characteristics of the soil.

The soil at the experimental plot was high in P and K and low with regard to N, as per the conventional soil test rating (Table 13).

11. Meteorological data

Maximum and minimum temperature, relative humidity and average monthly rainfall were recorded from May 1982 to March 1983 and are depicted in Table 14. It is apparent from the data that the rainfall during the months from June to August was comparatively high.

Table 12. Correlation coefficients for different variables.

Yield/plot	Variables correlated	Correlation coefficient (r)
	A. Vegetative characters	
	a. Number of leaves/plant	0.791**
	b. Leaf length	0.333NS
	c. Leaf width	0.662**
	d. Mean leaf area	0.533*
	e. Total leaf area	0.877**
	B. Root characters	
	a. Number of roots/plant	0.894**
	b. Length of roots	0.932**
	C. Rhizome characters	
	a. Number of main rhizomes	0.889**
	b. Length of main rhizomes	0.325NS
	c. Girth of main rhizomes	0.623**
	d. Number of nodes in main rhizomes	0.426NS
	e. Internodal length of main rhizomes	-0.186NS
	f. Number of secondary rhizomes	0.821**
	g. Length of secondary rhizomes	0.704**
	h. Girth of secondary rhizomes	0.618**
	i. Number of nodes	0.417NS
	j. Internodal length	-0.637NS

NS Not significant
* Significant at 5% level
** Significant at 1% level

Table 13. Chemical characteristics of the soil in the experimental plot

Constituent	Content in the soil		*Rating	Method used for estimation
	Before experiment	After experiment		
Total Nitrogen (%)	0.031	0.033	Low	Macrokjeldhal (Jackson, 1958)
Available P (Kg/ha)	33.06	25.12	High	In Bray-1 extract, chlorostannous reduced molybdo-phosphoric blue colour method.
Available K (Kg/ha)	314.66	319.33	High	In neutral normal ammonium acetate extract _ Flame photometric.
p^H	5.2	5.4	--	1 : 2.5 soil:water suspension using p^H meter.

* Muhr et al.(1965)

Table 14. Meteorological data (From May 1982 to March 1983)

Month	Temperature (°C)		Relative humidity (%)	Average rainfall (mm)
	Maximum	Minimum		
May	33.8	24.5	79.9	173.6
June	30.6	23.1	79.8	657.6
July	29.1	22.92	87.5	600.9
August	28.9	24.3	85.0	575.4
September	30.98	24.0	78.88	67.4
October	32.04	23.13	77.0	277.8
November	31.4	23.93	71.88	98.4
December	31.93	23.19	58.4	5.2
January	33.25	21.64	51.31	Nil
February	34.46	22.7	64.0	Nil
March	36.15	23.76	65.0	Nil

12. Economics of Kaempferia cultivation

In the light of the results obtained for fresh and dry rhizome yields, volatile oil and oleoresin yields, the treatment combination $P_1h_1m_1$ (Crop planted on third week of May using mother rhizomes and harvested six months after planting) was found to be the best. The produce is marketed after drying and making into chips and the economics is worked out based on the prevailing market price of Rs.1,100 $\bar{q}^1$ (Mathrubhumi, 1983). The abstract is given in Table 15 whereas the details are worked out in Appendix VIII. It is evident that a net income of Rs.4,316.00 per hectare could be obtained from the crop planted during the third week of May using mother rhizomes and harvested at six month's maturity.

Table 15. Economics of cultivation of *Kaempferia galanga* L. (for one hectare)

Item	$P_1h_1m_1$ (best treatment)
1. Cost of cultivation	Rs.7,696.00
2. Yield of dry rhizomes	10.92 q ha^{-1}
3. Sale price	Rs.1,100.00 q^{-1}
4. Total income	Rs.12,012.00
5. Net income (4-1)	Rs.4,316.00

Discussion

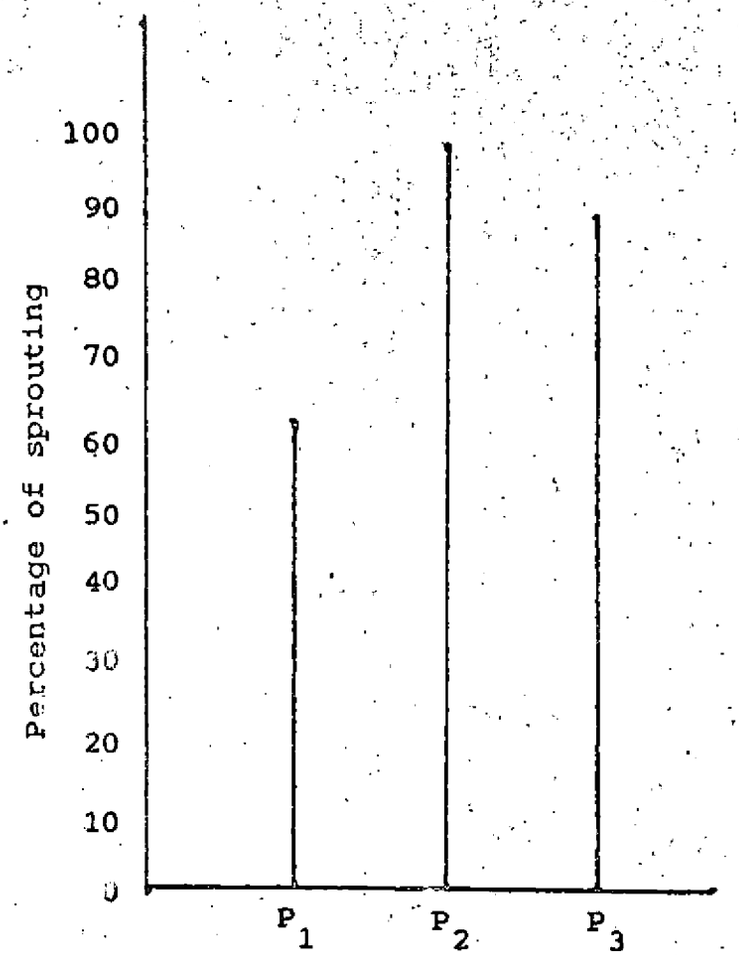
DISCUSSION

Studies to find out the propagation method, planting time and harvesting time for maximum rhizome yield, volatile oil and oleoresin in Kaempferia galanga L. was undertaken at the College of Horticulture, Vellanikkara during 1982-'83. The results are discussed in the following section.

1. Sprouting

Studies on the influence of planting time and propagation method revealed that planting of rhizomes during the first week of June (P_2) was significantly superior to the plantings done during the third week of May (P_1) and second week of June (P_3). Mother rhizomes were significantly superior to finger rhizomes (Table 1; Fig.1; Appendix I)

Kaempferia galanga L., like ginger and turmeric is grown as a rainfed crop. Hence, timely receipt of pre-monsoon showers may be a favourable factor for better sprouting. Under Vellanikkara conditions, the pre-monsoon showers are normally received by the middle of May and monsoon strengthens by the middle of June (Table 14). Therefore the time required for the 'physiological maturity' of the rhizome is considerably reduced in P_2 and P_3 plantings. The difference in the per cent of sprouting between mother and finger rhizome is attributed to the larger size of mother rhizomes. In support, it may be stated that large sized



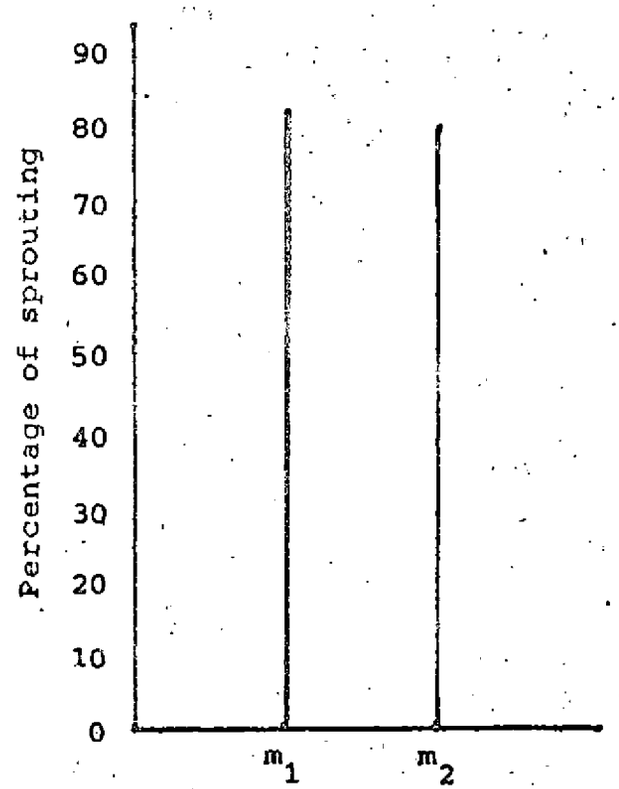


Fig.I. EFFECT OF PLANTING TIME AND PROPAGATION METHOD ON SPROUTING

planting materials contain more amount of nutrients required for growth, causing an increased initial growth. This might have resulted in better sprouting. Timely receipt of rainfall enhanced the physiological activity of the rhizome.

The results obtained are in confirmity with the findings of Hussain and Said (1965) and Chatterjee (1983) in turmeric and of Sharma et al.(1980) in Costus sp.

2. Morphological characters

In the present investigation, vegetative characters such as the number of leaves per plant, leaf width and the total leaf area were significantly influenced by the planting time (Table 2; Fig.2; Appendix II).

The total number of leaves produced were high in P_1 which differed significantly from P_2 and P_3. Significant variation in the leaf width was noticed; P_1 being superior to P_2 and P_3. Regarding total leaf area, P_1 was having the maximum area of 1578.10 cm^2 which was significantly superior to P_2 (1253.68 m^2) and P_3 (914.54 cm^2). Propagation method had no significant influence on vegetative characters.

Crop planted during the third week of May (P_1) established well before the monsoon strengthened. Heavy rainfall during early June and Mid-June was responsible for the retarded growth in P_2 and P_3.

The results obtained here is in a line with the findings of Hari et al.(1978) in turmeric. They found that

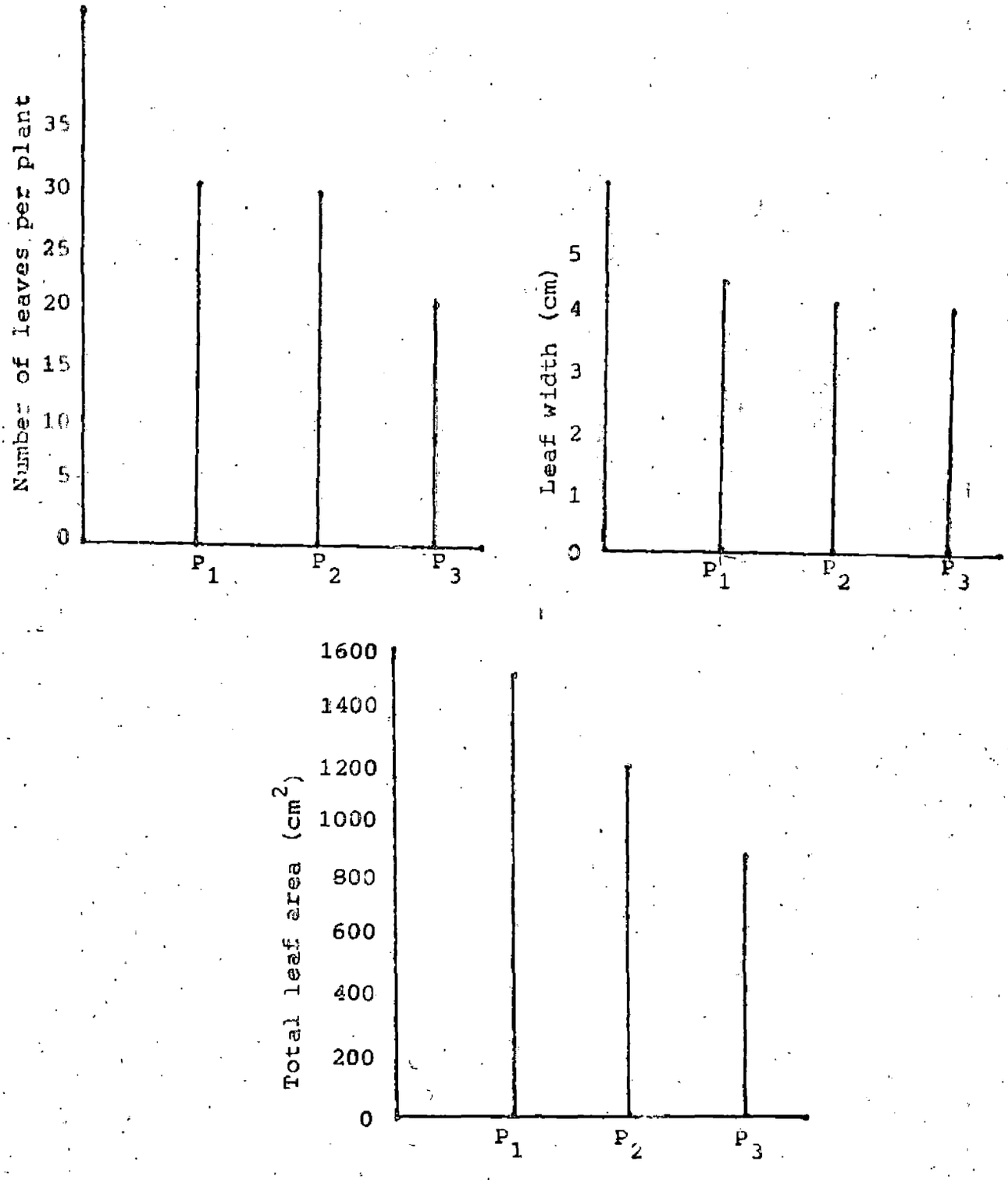


Fig.2. EFFECT OF PLANTING TIME ON MORPHOLOGICAL CHARACTERS

maximum number of leaves was on 10th May planting which differed significantly from 20th May, Ist June, 10th June and 20th June plantings.

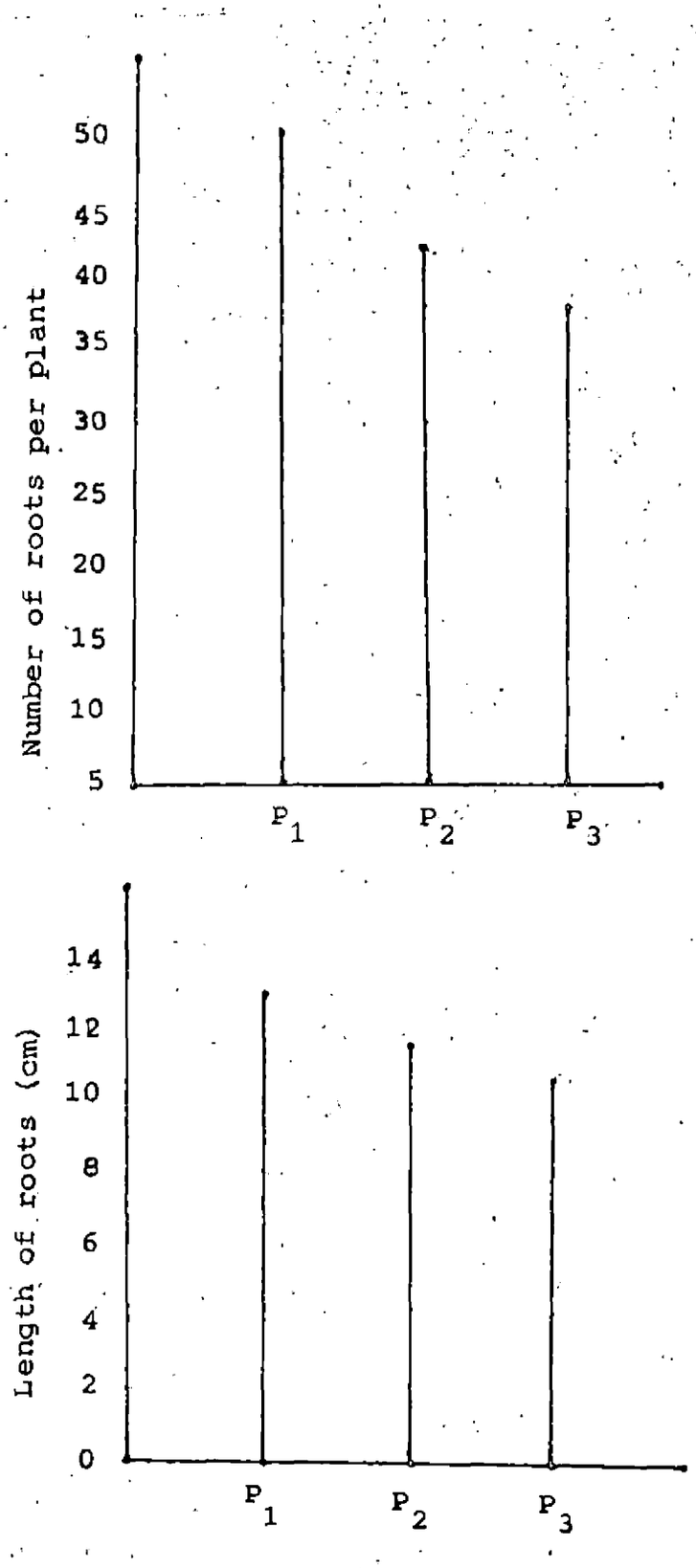
3. Number and length of roots

Number and length of roots were significantly influenced by the planting time. Crop planted during the third week of May (P_1) was superior to other planting treatments (P_2 and P_3). The results are shown in Table 4, Fig.3 and the analysis of variance in Appendix III.

A positive relationship was obtained between vegetative growth and root growth, the trend being better the vegetative growth, better the root growth. Thus it appears that the enhanced requirement of nutrients for vegetative growth is met by the well spread root system expressed in terms of length and number. This root system might have ensured better absorption of nutrients. High levels of potassium and nitrogen observed in the roots (Table 9) may be cited as a positive evidence in this respect.

4. Morphological characteristics of main rhizomes

Number and girth of main rhizomes were significantly influenced by the planting time. P_1 was superior to P_2 and P_3 in respect of the number and girth of main rhizomes. Mother rhizomes were superior to finger rhizomes with regard to the length and internodal length of main rhizomes (Table 5, Fig.4, Appendix IV).



3. EFFECT OF PLANTING TIME ON NUMBER AND LENGTH OF ROOTS

The growth habit of Kaempferia galanga L. is different from those of ginger and turmeric. The leaves are spread flat on the ground and the plant lacks a well defined stem or tillers. Each leaf functions as an 'effective' tiller so that increase in the leaf number results in increased rhizome yield. A highly significant correlation ($r = 0.889^{**}$) was obtained between number of main rhizomes and yield (Table 12). Increase in the girth of main rhizomes contributed to an increase in weight which in turn gave more yield of rhizome per plot. In turmeric, Hari et al.(1978) reported maximum number of rhizomes as well as maximum girth of rhizomes on the 10th May planting.

The length and internodal length of main rhizomes were significantly influenced by the propagation method; mother rhizomes being superior to finger rhizomes. In turmeric, planting material weighing 60 g was reported to be significantly superior to 20 g and 40 g (Chatterjee, 1983). Joseph (1983) reported increased length of primary and secondary rhizomes with an increase in the weight of planting material in Costus sp. These two references are in confirmity with the present findings except for the crop variation.

5. Morphological characteristics of secondary rhizomes

It was observed that the planting time had a significant influence on the number and girth of secondary

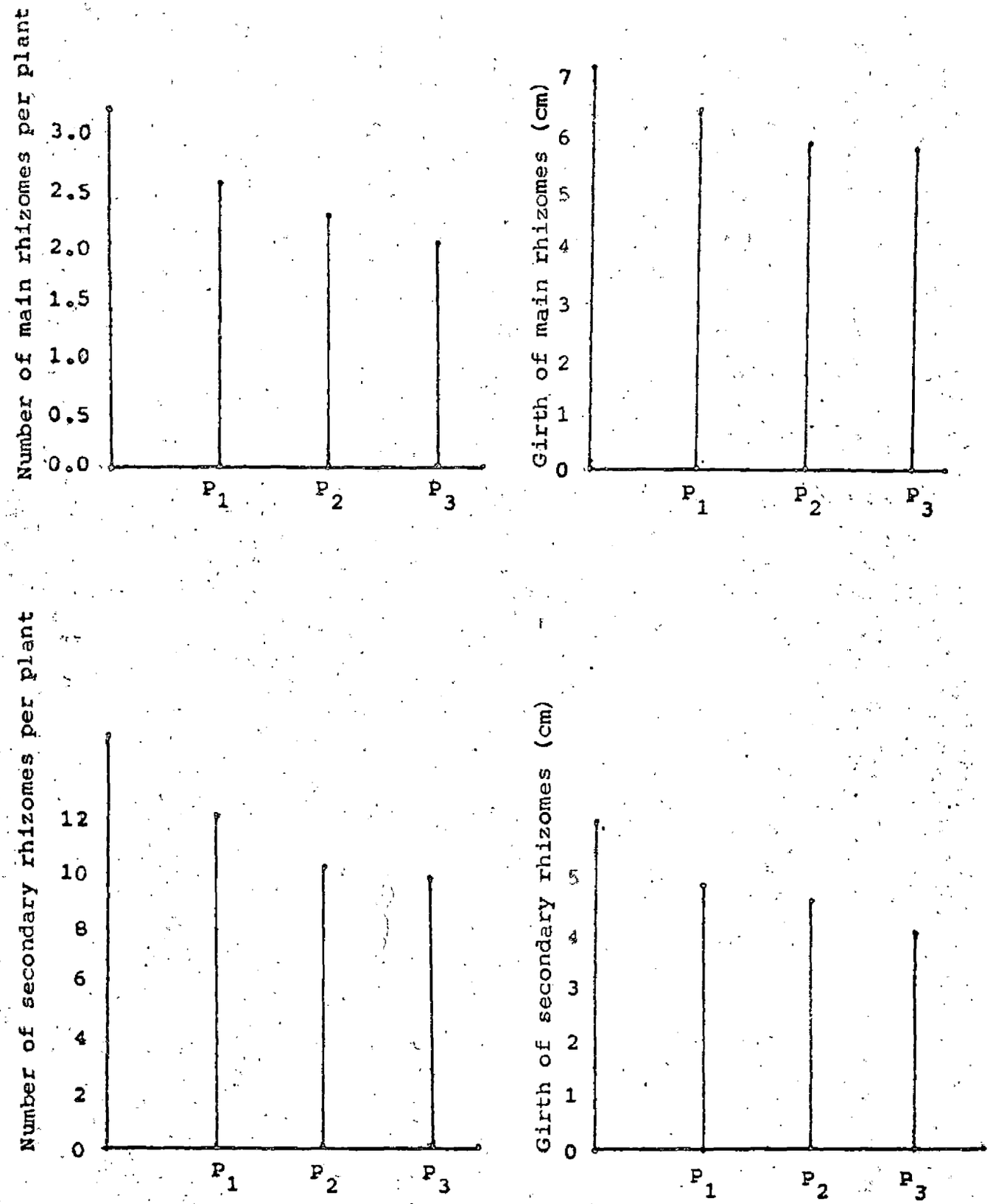


Fig.4. EFFECT OF PLANTING TIME ON NUMBER AND GIRTH OF RHIZOMES

rhizomes; P_1 being superior to P_2 and P_3. Time of harvest also had significant impact on the length of secondary rhizomes; h_1 being superior to h_2 and h_3 (Table 6; Fig.4; Appendix V).

The following findings in turmeric may be quoted in support of these observations. Chatterjee (1983) obtained maximum number of secondary rhizomes in the mid-May planting. Similarly increased girth was also reported in early plantings (Hari et al., 1978).

6. Yield characteristics

Fresh and dry rhizome yield per plot, drying percentage and the projected fresh and dry yields per hectare were significantly influenced by the planting time, harvesting time and propagation method (Table 7; Fig.5; Appendix VI).

A fresh rhizome yield of 2.642 kg was obtained in P_1 planting compared to 2.245 in P_2 and 1.793 in P_3. The dry rhizome yield was also high in P_1 planting. With regard to the drying percentage, P_1 was significantly inferior to P_2 and P_3. The projected fresh and dry yields were high in P_1 (Fresh yield - 45.83 q ha^{-1}; Dry yield - 11.45 q ha^{-1}). Planting, if done before the start of monsoon, the crop becomes well established to withstand the ill-effects of heavy rainfall. Randhawa and Misra (1974) found that early planting by the

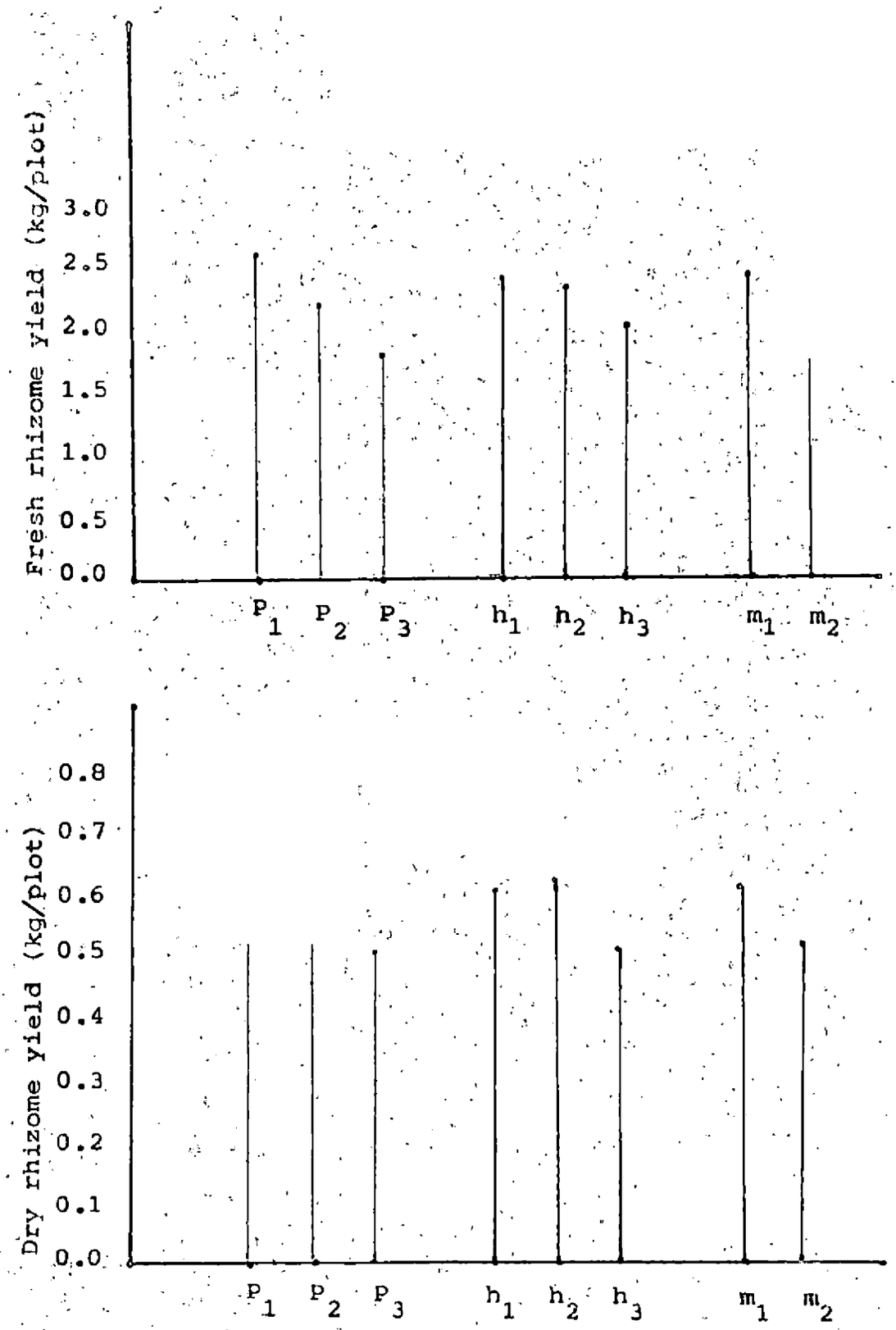


Fig.5. EFFECT OF PLANTING TIME, HARVESTING TIME AND PROPAGATION METHOD ON FRESH AND DRY RHIZOME YIELD PER PLOT.

end of April to the first fortnight of May gave higher yields in turmeric. Under Vellanikkara conditions, Chatterjee (1983) reported early planting by middle of May for higher fresh and dry rhizome yields in turmeric.

Crops harvested six months after planting and seven months after planting were significantly superior to the crop harvested eight months after planting with respect to the fresh rhizome yield. Dry rhizome yield was maximum in h_2. The drying percentage was also high in h_2 while it did not differ significantly from h_3. A maximum fresh yield of 41.61 q ha^{-1} was obtained from h_1, wherein maximum dry rhizome yield (11.12 q ha^{-1}) was obtained from h_2.

There is a strong school of thought that in rhizomatous crops, the high moisture content accounts for higher fresh yields during early harvests. Obviously, the drying percentage decreases. Literature in this line is available with other rhizomatous crops like ginger, turmeric and Costus sp. In ginger, Nybe (1978) obtained maximum yield of green ginger 180 days after planting; but the maximum yield of dry ginger was obtained 210-225 days after planting. In turmeric, Philip et al.(1980) reported maximum yield of both fresh and dry rhizomes 270 days after planting. A six month old crop gave the highest fresh rhizome yield in Costus sp. (Joseph, 1983).

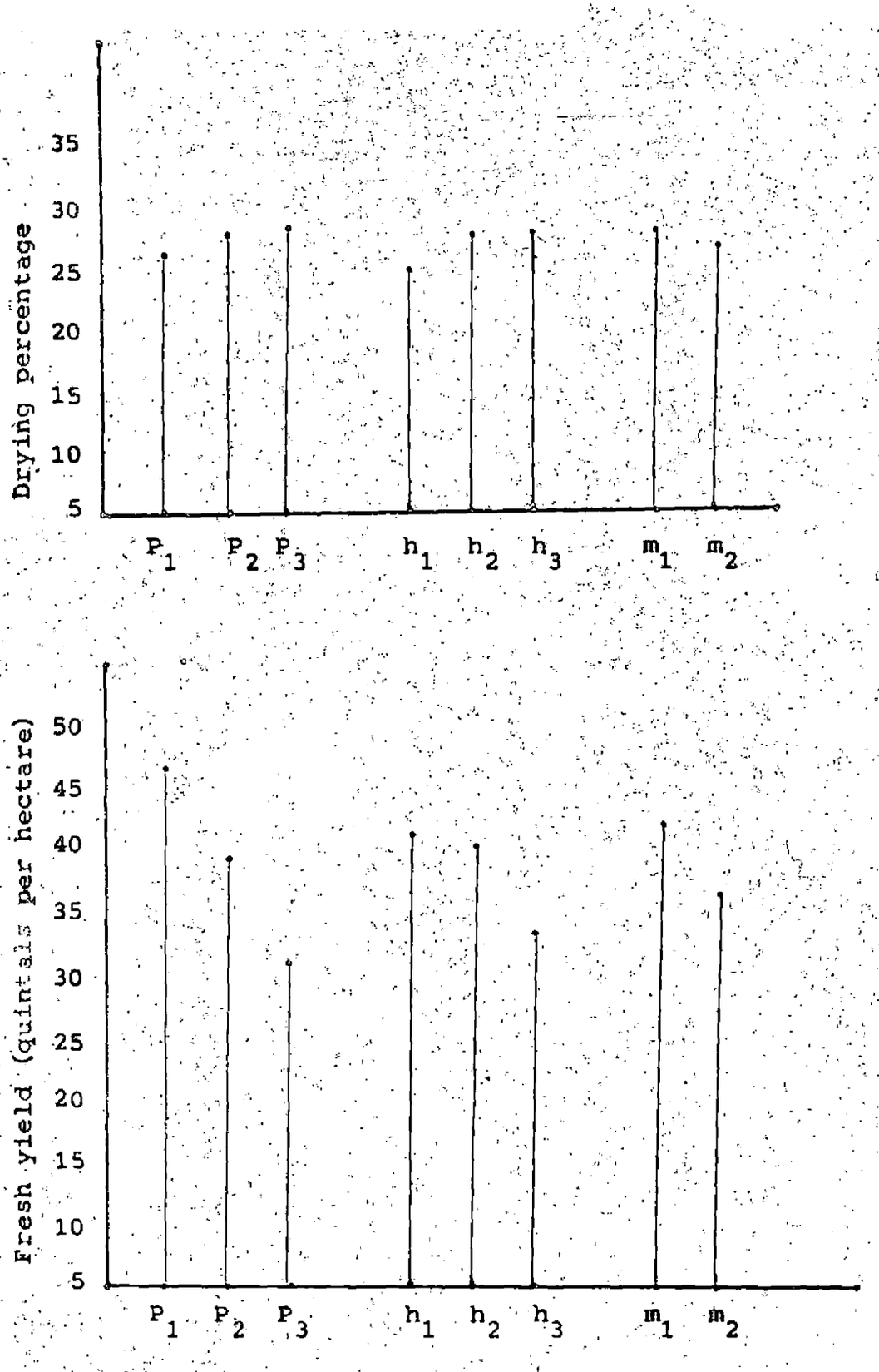


Fig.6. EFFECT OF PLANTING TIME, HARVESTING TIME AND PROPAGATION METHOD ON DRYING PERCENTAGE AND FRESH YIELD PER HECTARE.

Of the propagation methods, mother rhizomes showed superiority ofver finger rhizomes in terms of yield characteristics under discussion. Increased rhizome yields as a result of increase in the weight of planting materials could be attributed to the 'carrier effect'. Compared to light weight planting materials, heavy planting materials contain more nutrients which result in better growth of shoots and roots. Several workers have reported higher yields using heavier planting materials in ginger (Randhawa et al.,1972), in turmeric (Randhawa and Misra, 1974; Chatterjee, 1983) and in Costus sp. (Sharma et al., 1980; Joseph, 1983).

7. Qualitative Characters

Of the qualitative characters studied, the volatile oil yield, oleoresin content and oleoresin yield were significant with respect to the planting time. None of the treatments influenced the volatile oil content significantly.

In Kaempferia galanga L., volatile oil is present in translucent globules (90 to 110 micron in size) located in the cortical cells of rhizomes (Aiyer and Kolammal, 1964). The number of oil globules, therefore determines the volatile oil content. Since it is a genetic character, planting time, harvesting time and propagation method are not expected to have significant impact on the volatile oil content. The increased volatile oil yield in P_1 is attributed to the increased dry rhizome yield.

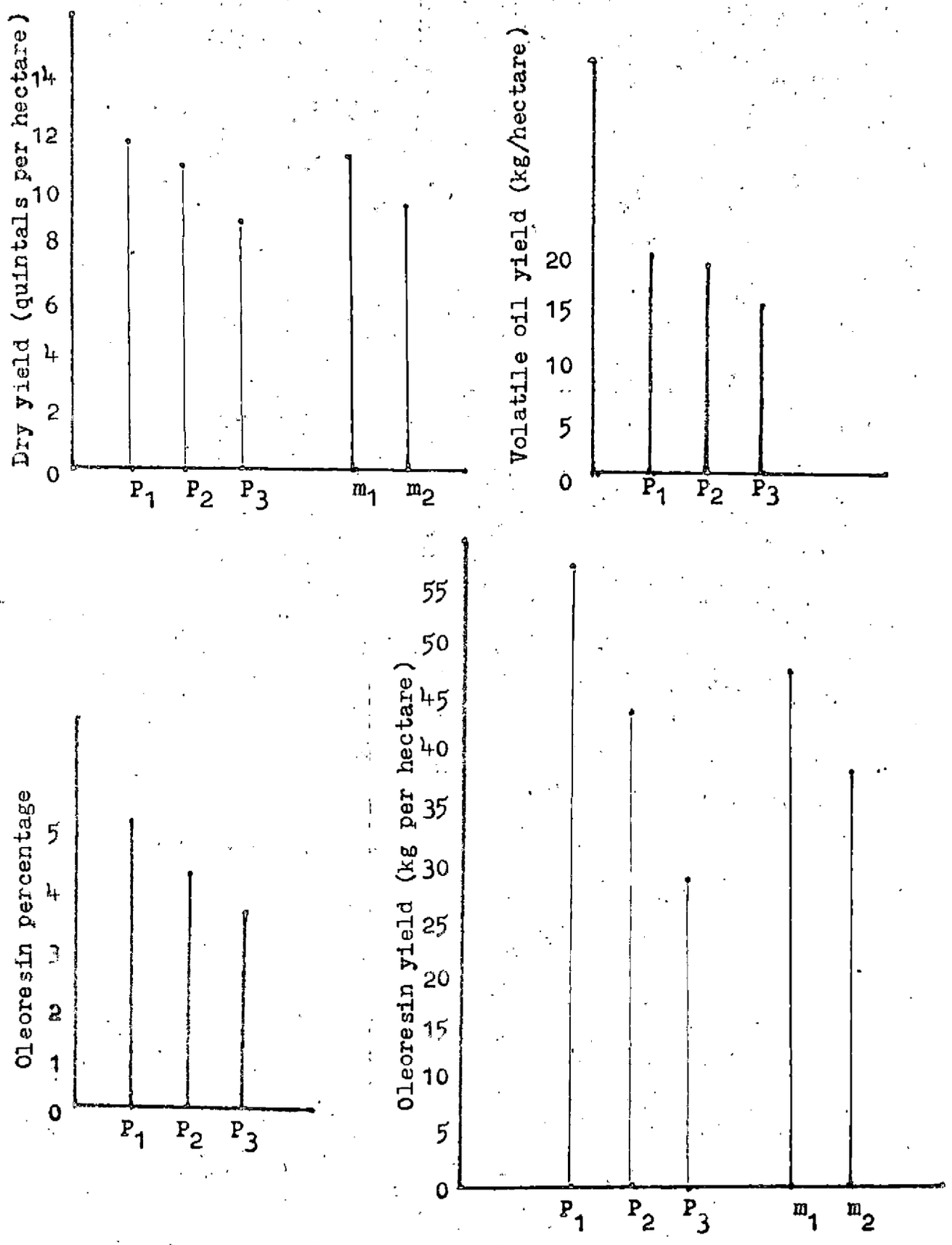


Fig.7. EFFECT OF PLANTING TIME AND PROPAGATION METHOD ON QUALITATIVE CHARACTERS.

Oleoresin represents the total flavour extract of spices which includes pigments, non-volatile pungent principles and fats. The biosynthesis and degradation of these products may be controlled by photoperiods. Photoperiods show significant influence on the mobilisation of photosynthates and allied products to the sink and on enzymatic action for the interconversion of food materials (Leopold and Kriedemann, 1975). Favourable photoperiod could be attributed to the increased oleoresin content in the early planted rhizomes of Kaempferia galanga L. The higher yield of oleoresin in P_1 was attributed to the high rhizome yield per hectare. In turmeric, Chatterjee (1983) obtained highest oleoresin yield from the middle of May planting.

Time of harvest did not show significant influence on the qualitative characters. Since the vegetative growth of the crop ceases five to six months after planting, no favourable advantage could be obtained by retaining the crop after the above period.

With regard to the oleoresin yield, mother rhizomes were superior to finger rhizomes as a result of the high rhizome yield obtained from mother rhizomes. Chatterjee (1983) obtained high oleoresin yield from heavy planting materials in turmeric. High diosgenin yield was reported

in Costus sp. by using heavy planting materials (Joseph,1983).

8. Rhizome yield and uptake of nutrients

Significant correlations were obtained for N, P and K in root, N and K in rhizome and for total uptake of N, P and K. The leaf nutrient contents did not show any correlation with yield (Table 10). Multiple regression equations were fitted to predict the rhizome yield in relation to the nutrient contents in the root and rhizome and on the total nutrient uptake. The nitrogen and potassium contents in the root and the rhizome showed significant effect on rhizome yield. With regard to the total nutrient uptake, the effect was significant for potassium only. A variation (R^2) of 95.67 per cent was obtained for the multiple regression equation between total nutrient uptake and the rhizome yield per plot (Table 11).

This shows that N and K have greater influence on rhizome yield than P; the influence being more for K. High rhizome yield results from a higher uptake of K followed by N.

9. Correlation studies

Among the morphological characters correlated with rhizome yield, number of leaves per plant, leaf width, total leaf area, number of roots, root length, number and girth of main rhizomes, number, length and girth of secondary rhizomes showed highly significant correlations (Table 12).

The studies, thus indicated that these 10 characters could be useful in selecting materials for high rhizome yield in Kaempferia galanga L.

10. Economics of cultivation

At present, the rhizomes are marketed in the form of dried chips; used mainly in ayurvedic preparations. Volatile oil and oleoresin production as in the case of ginger and turmeric, is not practiced on a commercial scale. Therefore, the economics of cultivation was worked out based on the present market price of Rs.1,100.00 per quintal for the dry produce. The treatment combination $P_1h_1m_1$ gave a dry rhizome yield of 10.92 q ha^{-1} and a net income of Rs.4,316.00 (Table 15; Appendix VIII). Higher net income could be expected, if the processing agencies come forward for the manufacture of volatile oil and oleoresin, which would find diversified uses in ayurvedic medicine and perfumery.

Summary

SUMMARY

An investigation was carried out to standardise the propagation method, planting time and harvesting time in Kaempferia galanga L. at the College of Horticulture, Vellanikkara during 1982-'83. The salient features are summarised below:

1. Crop planted during the pre-monsoon period, viz. third week of May exhibited better vegetative characters in terms of leaf number, leaf width and total leaf area. Number and length of roots were also more. Rhizome characters such as number and girth of rhizomes were significantly influenced by the planting time. Yield of rhizome, volatile oil and oleoresin were also high as the planting was done during the third week of May.

2. Mother rhizomes were significantly superior to finger rhizomes as regards the fresh and dry rhizome yields and drying percentage. Oleoresin yield per hectare was high when mother rhizomes were planted.

3. Six month old crop was significantly superior to seven and eight month old crops with respect to fresh rhizome yield. The dry rhizome yield was the maximum in a seven month old crop, but it did not differ significantly a six month old crop.

4. Qualitative analysis of rhizomes showed no significant effect for harvesting time. Thereby, the crop could be harvested six months after planting without delaying the harvest to seven or eight months.

5. Plant nutrients N and K showed highly significant correlations with rhizome yield, K showing predominant effect. Hence, for higher yields, applications of N and K should be resorted to.

6. Characters such as leaf number, leaf width, total leaf area, number and length of roots and number and girth of rhizomes exhibited highly significant positive correlations with yield.

7. Assessment of the individual effects of planting time, harvesting time and propagation method revealed $P_1h_1m_1$ as the best treatment combination. A dry rhizome yield of 10.92 quintals, volatile oil yield of 17.94 kg and oleoresin yield of 49.14 kg ha^{-1} were obtained in $P_1h_1m_1$.

8. Net income of Rs.4,316.00 per hectare could be expected from a six month old crop, planted during the third week of May using mother rhizomes. Higher net income could be expected, provided the processing agencies manufacture volatile oil and oleoresin from the rhizomes.

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* Original not seen.

Appendices

APPENDIX I

Analysis of variance for the effect of planting time and propagation method on per cent of sprouting

Sources of variation	df	Mean squares
Total	53	
Blocks	2	21.69
Planting time (P)	2	3240.91**
Between harvests within the same planting or Error (a)	22	24.25
Propagation method (M)	1	114.18**
P x M	2	60.44*
Error (b)	24	13.36

* Significant at 5% level

** Significant at 1% level

APPENDIX II

Analysis of variance for the effect of planting time and propagation method on morphological characters.

Sources of variation	df	Mean squares				
		Number of leaves	Leaf length	Leaf width	Mean leaf area	Total leaf area
Total	53					
Blocks	2	42.02	1.33	0.30	26.48	157079.60
Planting time (P)	2	267.16**	2.36	2.09*	159.64	3171069.41**
Between harvests within the same planting or Error (a)	22	23.39	0.89	0.44	104.61	193713.45
Propagation method (M)	1	19.97	0.91	0.05	64.14	29269.01
P x M	2	16.59	0.06	0.16	36.76	17351.62
Error (b)	24	15.71	0.44	0.11	29.47	85356.43

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Analysis of variance for the effect of propagation method, planting time and harvesting time on number and length of roots.

Sources of variation	df	Mean squares	
		Number of roots per plant	Root length
Total	53		
Blocks	2	33.64	0.27
Planting time (P)	2	332.28*	14.45*
Harvesting time (H)	2	250.29	0.27
P x H	4	122.63	1.18
Error (a)	16	91.39	3.59
Propagation method (M)	1	17.49	0.78
P x M	2	54.02	1.57
H x M	2	0.96	2.62
P x H x M	4	83.88	1.62
Error (b)	18	38.29	1.04

* Significant at 5% level

APPENDIX IV

Analysis of variance for the effect of propagation method, planting time and harvesting time on the main rhizome characteristics.

Sources of variation	df	Mean squares				
		Number of main rhizomes/ plant	Length	Girth	Number of nodes	Internodal length
Total	53					
Blocks	2	0.035	0.20	0.31	0.07	0.03
Planting time (P)	2	0.79**	0.003	1.74*	0.29	0.013
Harvesting time (H)	2	0.03	0.09	0.18	0.23	0.01
P x H	4	0.12	0.06	0.46	0.34	0.02
Error (a)	16	0.11	0.05	0.44	0.13	0.008
Propagation method (M)	1	0.17	0.25**	0.28	0.07	0.04**
P x M	2	0.11	0.07	0.55	0.10	0.004
H x M	2	0.04	0.004	0.27	0.05	0.003
P x H x M	4	0.13	0.04	0.44	0.10	0.005
Error (b)	18	0.06	0.02	0.18	0.05	0.003

* Significant at 5% level

** Significant at 1% level

APPENDIX V

Analysis of variance for the effect of propagation method, planting time and harvesting time on the secondary rhizome characteristics.

Sources of variation	df	Mean squares				
		Number of secondary rhizomes/ plant	Length	Girth	Number of nodes	Internodal length
Total	53					
Blocks	2	2.57	0.04	0.17	0.19	0.01
Planting time (P)	2	18.64*	0.29	0.53*	0.06	0.01
Harvesting time (H)	2	2.70	0.04*	0.31	0.16	0.01
P x H	4	1.62	0.13	0.14	0.14	0.007
Error (a)	16	4.92	0.07	0.10	0.05	0.004
Propagation method (M)	1	0.52	0.00003	0.06	0.07	0.002
P x M	2	2.59	0.007	0.15	0.009	0.0002
H x M	2	0.16	0.001	0.03	0.007	0.0002
P x H x M	4	4.64	0.03	0.16	0.056	0.0009
Error (b)	18	3.35	0.06	0.15	0.05	0.002

* Significant at 5% level

APPENDIX VI

Analysis of variance for the effect of propagation method, planting time and harvesting time on the yield characteristics.

Sources of variation	df	Mean squares				
		Fresh rhizome yield/ plot	Dry rhizome yield/ plot	Drying per cent	Fresh yield per hectare	Dry yield per hectare
Total	53					
Blocks	2	0.19	0.01	0.34	1089774.59	67444.26
Planting time (P)	2	3.21**	0.14**	27.39**	17828475.34**	753131.99**
Harvesting time (H)	2	0.99*	0.06*	41.82**	5485128.46*	232340.05*
P x H	4	0.28	0.01	11.79	1534901.89	64507.45
Error (a)	16	0.19	0.014	1.90	804535.74	78759.98
Propagation method (M)	1	1.38**	0.15**	14.12*	7681808.11**	848593.27**
P x M	2	0.02	0.002	0.67	99141.35	9786.45
H x M	2	0.17	0.002	3.28	934778.14	129764.65
P x H x M	4	0.19	0.023	3.19	1043669.36	121735.07
Error (b)	18	0.10	0.0095	3.03	581611.32	53565.75

* Significant at 5% level

** Significant at 1% level

APPENDIX VII

Analysis of variance for the effect of propagation method, planting time and harvesting time on qualitative characteristics.

Sources of variation	df	Mean squares			
		Volatile oil content (%)	Volatile oil yield/ hectare	Oleoresin content (%)	Oleoresin yield/ hectare
Total	53				
Blocks	2	0.50	1.30	6.84	149.14
Planting time (P)	2	0.11	241.30*	22.74**	6369.24**
Harvesting time (H)	2	1.59	17.55	3.38	82.34
P x H	4	0.46	25.74	4.58	490.82
Error (a)	16	0.62	32.29	1.57	165.58
Propagation method (M)	1	0.25	140.13	0.18	1522.35*
P x M	2	0.01	3.73	1.97	631.66
H x M	2	1.19	14.39	0.14	308.64
P x H M M	4	1.57	117.43	1.30	424.15
Error (b)	18	0.53	37.97	0.63	189.18

* Significant at 5% level

** Significant at 1% level

APPENDIX VIII

Economics of cultivation of *Kaempferia galanga* L. (for one hectare)

Particulars	Men @ Rs.19	Women @ Rs.18	Amount Rs. P.
1. Cost of seed material (960 kg @ Rs.400 per quintal)			3,840.00
2. Land preparation			
Weeding and digging	10	15	460.00
Taking beds and bunds	15		285.00
3. Planting	2	10	218.00
4. Interculture			
Mulching (collection and application of green leaves)	10	10	370.00
5. Manures and manuring			
Farm yard manure (20 Tonnes)			1,000.00
75 kg Nitrogen (@ Rs.9/kg)			675.00
50 kg P_2O_5 (@ Rs.4.50/kg)			225.00
50 kg K_2O (@ Rs.2.50/kg)			125.00
Transport and application	2	5	128.00
6. Harvesting (Digging out rhizomes)	10		190.00
7. Processing (cleaning, making into chips and drying)		10	180.00
8. Total cost of cultivation			7,696.00
9. (a) Yield of dry rhizome per hectare		10.92 q ha^{-1}	
(b) Total amount @ Rs.1100 per quintal		Rs.12,012.00	
10. Net income (8-9 b)		Rs. 4,316.00	
11. Cost benefit ratio		1 : 1.55	

Based on the expenditure incurred at the experimental plots for the best treatment combination $P_1h_1m_1$.

STANDARDISATION OF PROPAGATION METHOD, TIME OF PLANTING, TIME OF HARVEST AND PHYTOCHEMICAL ANALYSIS OF *Kaempferia galanga* L.

By

RAJAGOPALAN, A.

ABSTRACT OF A THESIS

Submitted in partial fulfilment of
the requirement for the degree of

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Department of Horticulture (Plantation Crops & Spices
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1983

ABSTRACT

A split-plot experiment was conducted at the College of Horticulture, Vellanikkara during 1982-'83 with a view to standardise the propagation method, planting time and harvesting time in Kaempferia galanga L. The treatments included in the investigation were two propagation methods, viz. mother rhizomes and finger rhizomes; three planting time, viz. third week of May, first week of June and second week of June; three harvesting time, viz. six, seven and eight months after planting.

Planting time had significant influence on the number of leaves per plant, leaf width, total leaf area, number and girth of rhizomes and yield characters.

Mother rhizomes planted during the third week of May and harvested after six months was significantly superior to other treatments with respect to the fresh and dry rhizome yields. None of the treatments significantly influenced the volatil oil yield. Planting mother rhizomes during the third week of May positively influenced the oleoresin yield.

Cost benefit analysis indicated a net income of Rs.4,316.00 per hectare from the six month old crop.

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