FINAL REPORT OF ICAR RESEARCH SCHEME

1999

APPENDIX - IV(c)

FINAL REPORT OF ICAR RESEARCH SCHEME

1. Project Title : **Standardisation of agrotechniques in lesser known aromatic and medicinal plants of Zingiberaceae**

2. Sanction No. and date : F. No. 6-21/93 Hort. I. dt. 31.3.1993
(Period of scheme extended upto 30.06.1999 as per order F. No. 6-21/93 Hort. I. Dated 30.9.1999)

3. Date of start : 1.11.1995

4. Date of termination : 30.06.1999

5. (a) Name of institute : Kerala Agricultural University
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6. Technical personnel employed

Name with designation	Date of joining	Date of leaving	Total No. of man months spent
Research Associate (Agron/Hort)	21-1-97	30-8-97	8
Research Associate (Org.Chem/Biochem)	Vacant	--	Nil

7. Total outlay : Rs. 6,37,100/-
Share of ICAR : 100%
Share of participating agency : Nil

8. Total amount spent : Rs.6,37,958/-

Share of ICAR : 100%
Share of participating agency : Nil

9. Objectives and how far these have been achieved

The project envisaged to develop agrotechniques for three selected crops such as *Alpinia calcarata* (*Chittaratha*), *Curcuma* sp. (*Kasthurimanjal*) and *Kaempferia rotunda* (*Chengazhinirkizhangu*) as representative crops of Zingiberaceae family.

The specific objectives were:

i) To identify the optimum stage of harvest in *Alpinia calcarata* (*Chittaratha*).
ii) To find out the optimum spacing and manurial requirements of *Alpinia calcarata* (*Chittaratha*), *Curcuma* sp. (*Kasthurimanjal*) and *Kaempferia rotunda* (*Chengazhinirkizhangu*).
iii) To evaluate the different sources and doses of organic manures and biofertilizers for maximising the yield of *Kaempferia rotunda* (*Chengazhinirkizhangu*).
iv) To study the physico-chemical changes in *Kaempferia rotunda* (*Chengazhinirkizhangu*) rhizomes during storage.
v) To evaluate the important medicinal and aromatic species in the genera of *Alpinia, Curcuma* and *Kaempferia* for essential oils and their chemical consitutents.

All the set objectives of the scheme have been achieved in toto.

10. Approved technical programme

The technical programme comprised the following eight experiments; out of which seven were field trials and one was a laboratory storage study.

i) Optimum stage of harvest in *Alpinia calcarata* (*Chittaratha*).
ii) Spacing and manurial requirements of *Alpinia calcarata* (*Chittaratha*).
iii) Spacing and manurial requirements of *Curcuma* sp. (*Kasthurimanjal*).
iv) Optimum planting spacing in *Kaempferia rotunda* (*Chengazhinirkizhangu*).
v) Screening of organic manures and biofertilizers for maximum yield in *Kaempferia rotunda* (*Chengazhinirkizhangu*).
vi) Fertilizer requirement of *Kaempferia rotunda* (*Chengazhinirkizhangu*).
vii) Physico-chemical changes in *Kaempferia rotunda* (*Chengazhinirkizhangu*) rhizomes during storage.
viii) Evaluation of lesser known medicinal and aromatic plants of Zingiberaceae for essential oils and other chemical constituents.

The Experiment-wise details of the technical programme are furnished under the subhead No.11. Detailed Report.

(a) Remarks of Scientific Panel on earlier Annual Reports

The Scientific Panel made the following comments on the first annual progress report of the scheme for the period from 1.11.1995 to 31.10.1996 as per F. No.6-21/93/Hort. I. dated 10.11.1997 of the ICAR.

1. The posts of Research Associates are not filled and the budget is not fully utilised. It may be taken on priority basis.
2. In all experiments, the treatments, which have wide range/non-significant effect, must be revised and reviewed.
3. In some experiments, the number of treatments is much more. After examination of first year data the superficial treatments may be deleted.
4. In observational part, more critical aspect which clearly indicate the effect of treatment should be studied including quality analysis of at least composite samples.
5. The report is satisfactory, but needs further improvement in next year programme and it may be revised suitably after examining first year data.

The above remarks of the Scientific Panel were taken into account for the implementation of the programme during the succeeding years of study.

10. Detailed Report

The Experiment-wise details of the project and the results obtained are furnished below.

i) Optimum stage of harvest in *Alpinia calcarata* (*Chittaratha*)

Objective : To identify the optimum stage of harvest in *Chittaratha* for obtaining maximum rhizome and oil yield.

Design : RBD.
Replications : 3
Treatment : 15 harvest stages (harvesting at 3 months interval from 6 months after planting till 3 years)

Observations:

Growth parameters : Plant height, tillers, leaves.
Yield parameters : Rhizome yield, oil yield, oil recovery gas chromatogram of the oil

Methodology followed:

The plant materials were hydro-distilled for 5 hours in Clevenger's apparatus for extracting the essential oil. Efforts were made to determine the components of the essential oil using a gas chromatograph (Chemito model 8510) equipped with flame ionisation detector. The constituents of the oil were separated on a 10 feet long stainless steel column loaded with 5% SE 30 on 80-100 mesh chromosorb-W at a nitrogen flow rate of 30ml/min. The oven was programmed to heat from the initial temperature of 110°C to 220°C at the rate of 3°C/min. The injection and detection temperatures were 270°C. Attempts were made to identify the peaks based on coincidence of retention times with authentic standards. Quantification was done by area normalisation method.

Results obtained:

The crop was planted in the first year of the study. Harvesting was done every 3 months as per the treatments. Growth and yield observations were recorded as envisaged. The data of all the harvests were pooled, analysed and presented in tables 1-4 and figures 1-3 below. The results of the trial showed that in *chittaratha* the plant height, in general, increased till 42 months of planting and thereafter it decreased (table 1). The number of tillers/hill could be recorded only up to 27 months, after which, the individual hills were not distinguishable as they merged with each other. The number of tillers/hill increased with the advancement in time. The number of leaves/plant ranged between 5.20 and 13.27 and the maximum value was at 36 months.

On an average *Alpinia* grows to a height of 98cm and produces 24 suckers/plant/year and 10 leaves/plant.

The data on pests and disease incidence (0-9 scale scores) showed that in general the incidence of pests and diseases in *Alpinia* was not very serious and hence no control measures were adopted. The incidence of pests was lower compared to disease incidence. The pests noted were the shoot borers, leaf eating caterpillars and leaf miners. Two fungal diseases were noticed, namely, blight and leafspot diseases. The pests were noted during the early tender stages of growth and development, particularly during the non-rainy period from January to May. Disease incidence was noticed through out the period of growth. Pests and diseases are generally low in *Alpinia* crop.

Data on the yield of rhizome is presented in table 3 and figures 1-2. The yield of rhizome increased steadily up to 36 months and reached a maximum of 45392 kg/ha at 42 months and thereafter it showed a declining trend. The yield of rhizome oil also exhibited a similar trend. The maximum rhizome oil yield recorded was 127.39 l/ha. The gas chromatograms of rhizome oil obtained at different stages are given in appendix. Chemical composition of rhizome oil was studied. The dynamics of cineole, the major component in the oil showed a variation from 13.54% to 42.04%. The cineole content at 36-42 months stage was relatively high (25%).

Data on the root yield is presented in table 4 and figures 1 and 2. The root yield steadily increased, reached a maximum of 19544 kg/ha at 39 months. Root oil yield also exhibited a similar trend reaching a maximum of 127.36 l/ha at 39 months. The oil content in the root was almost three times that in the rhizome. The root possessed intense fragrance and contained high level of essential oil yield. This implies that the root is a very important part in terms of the essential oil content.

Data on the shoot yield is presented in table 3 and figures 1 and 2. The shoot yield reached a maximum at 18 months and remained almost steady thereafter. The rhizome – shoot ratio become one at 36 months. The shoot oil yield was maximum of 70.59 l/ha at 18 months after planting and declined sharply thereafter. The mean oil content was very low (0.11% on fresh weight basis). The gas chromatograms of the shoot oil samples are given in appendix. The chemical components could not be identified due to want of authentic standards.

A comparison of the gas chromatograms (appendix) of oils obtained from, root rhizome and shoot showed that the oils were different in composition. The cineole content was high in rhizome (13.5-42.0%) and low in root and shoot.

Based on the maximum rhizome and oil yields and the oil quality it can be concluded that the optimum stage of harvest in Alpinia is 36-42 months after planting under Odakkali conditions. At this stage substantial quantity oil can also be obtained from the roots which fetches additional income. Due to quality difference the rhizome and root oils are to be extracted and utilised separately.

Table 1. Growth parameters and pest and disease scoring of *Alpinia calcarata* (*chittaratha*) as influenced by time of harvest

Time of harvest (months)	Plant height (cm)	Tillers/hill (No.)	Leaves/plant (No.)	Pest scoring (0-9 scale)	Disease scoring (0-9 scale)
6	37.7	10.47	5.65	2.33	0
9	54.0	12.87	8.33	3.00	1
12	77.5	25.47	9.73	0	0.67
15	98.1	28.53	9.73	0	1.33
18	110.9	34.20	10.80	0.30	3.00
21	105.4	38.40	10.93	0	3.33
24	97.3	46.07	11.73	0	2.33
27	99.6	48.33	8.20	0	3.00
30	104.1	-	9.00	0	3.67
33	119.5	-	10.33	0	5.00
36	111.5	-	13.27	0	4.67
39	116.5	-	9.27	0	3.67
42	129.4	-	11.33	0	3.67
45	109.4	-	9.87	0	1.67
48	94.0	-	5.20	0	2.33
Mean	97.7	30.54	9.56	-	2.62
CD 0.05	20.56	15.105	1.632	-	NS

Table 2. Rhizome yield parameters of *Alpinia calcarata* (*chittaratha*) as influenced by time of harvest

Time of harvest (months)	Fresh yield (kg/ha)	Dry yield (kg/ha)	Oil yield (l/ha)	Oil recovery FWB (%)	Oil recovery DWB (%)	Cineole in oil (%)
6	2837	567	4.40	0.16	0.78	35.14
9	3976	775	4.19	0.11	0.54	20.56
12	9553	1433	14.78	0.16	1.04	42.04
15	12701	2451	30.02	0.23	1.21	35.41
18	14377	2732	44.46	0.31	1.64	17.80
21	16726	5520	35.34	0.21	0.62	18.80
24	18242	5290	43.41	0.24	0.82	24.25
27	24352	6575	54.87	0.22	0.81	27.46
30	22950	7574	65.21	0.28	0.83	13.54
33	26984	9714	64.55	0.23	0.64	30.93
36	44312	12407	104.79	0.23	0.83	21.01
39	36243	7974	88.06	0.24	1.10	28.90
42	45392	9986	127.39	0.28	1.25	27.10
45	36839	8104	78.21	0.21	0.95	28.90
48	35582	7116	71.16	0.20	0.99	38.69
Mean	23404	5881	55.39	0.22	0.93	27.37
CD 0.05	6875.1	1820.9	26.347	0.054	0.214	--

FWB = Fresh weight basis, DWB = Dry weight basis

Table 3. Shoot yield parameters of *Alpinia calcarata* (*chittaratha*) as influenced by time of harvest

Time of harvest (months)	Fresh yield (kg/ha)	Dry yield (kg/ha)	Oil yield (l/ha)	Oil recovery FWB (%)	Oil recovery DWB (%)
6	5028	1055	6.12	0.12	0.58
9	5877	1316	7.25	0.12	0.55
12	21770	4935	31.35	0.16	0.69
15	26448	6225	48.31	0.18	0.76
18	40544	9325	70.59	0.18	0.77
21	38631	10431	23.66	0.06	0.23
24	31218	8389	22.66	0.07	0.27
27	35028	9107	23.35	0.07	0.26
30	29913	9871	26.33	0.09	0.27
33	33067	10251	16.53	0.05	0.16
36	38524	9246	19.30	0.05	0.21
39	42294	7190	51.48	0.12	0.72
42	34381	5845	42.04	0.12	0.72
45	33044	6939	33.04	0.10	0.48
48	31083	5595	37.16	0.11	0.60
Mean	29790	7048	30.61	0.11	0.48
CD 0.05	6313.5	1463.9	11.983	0.039	0.176

FWB = Fresh weight basis, DWB = Dry weight basis

Table 4. Root yield parameters of *chittaratha* (*Alpinia calcarata*) as influenced by time of harvest

Time of harvest (months)	Fresh yield (kg/ha)	Dry yield (kg/ha)	Oil yield (l/ha)	Oil recovery FWB (%)	Oil recovery DWB (%)
6	484	81	1.60	0.33	1.98
9	861	147	3.43	0.40	2.34
12	4107	712	11.68	0.29	1.67
15	7214	1371	21.16	0.29	1.52
18	4103	883	46.35	1.14	5.32
21	5988	1138	33.49	0.56	2.92
24	7579	1668	43.19	0.57	2.58
27	13738	2885	48.60	0.36	1.69
30	11500	3565	82.83	0.74	2.40
33	15544	3886	91.07	0.59	2.36
36	14583	2625	71.37	0.49	2.72
39	19544	3127	127.36	0.66	4.10
42	6706	1006	43.15	0.66	4.37
45	12071	1931	75.01	0.62	3.89
48	18782	3193	93.08	0.49	2.88
Mean	9520	1881	52.89	0.55	2.85
CD 0.05	3661.96	714.32	24.291	0.159	0.790

FWB = Fresh weight basis, DWB = Dry weight basis

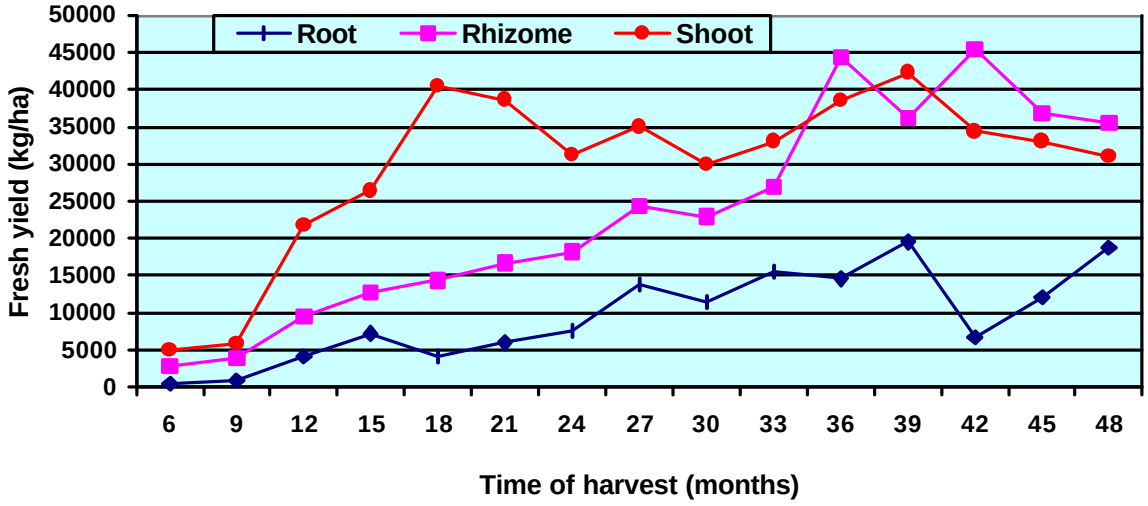

Fig.1. Yields of *Alpinia galanga* as influenced by time of harvest

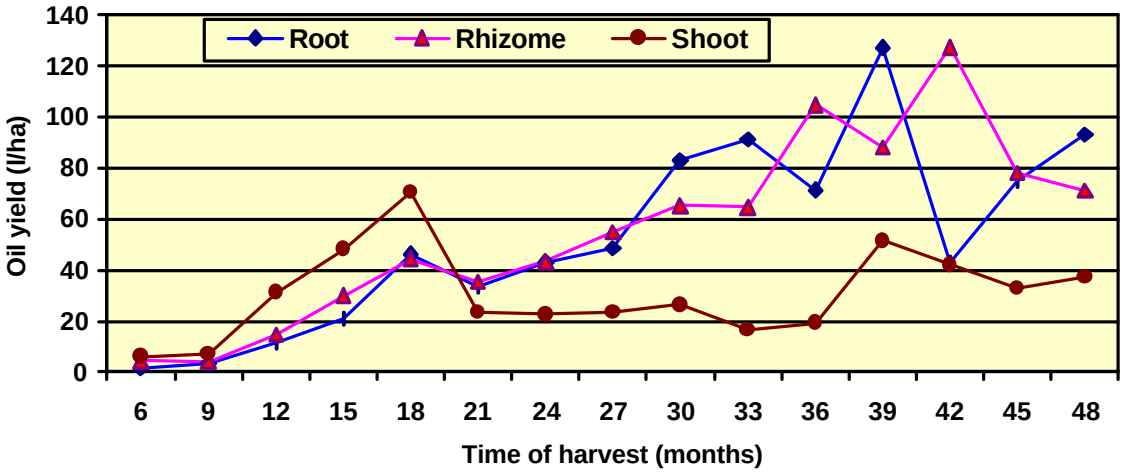

Fig. 2. Oil Yields of *Alpinia galanga* as influenced by time of harvest

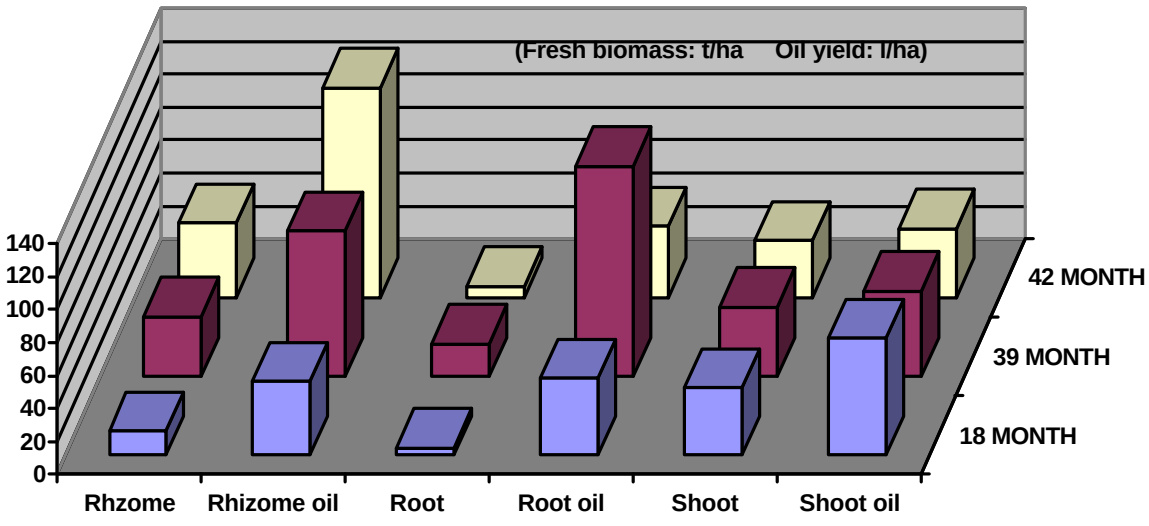

Fig. 3. Effect of time of harvest on the yield of Alpinia galanga

ii) Spacing and manurial requirements of *Alpinia calcarata* (*Chittaratha*)

Objective : To find out the optimum spacing and manurial requirements of *Alpinia calcarata* (*Chittaratha*).

Design : RBD.
Replications : 3
Treatments : 4 x 5 = 20 factorial combinations of
a) four spacings (cm): 30x20, 40x30, 60x40, 60x60

b) five manurial treatments:

1. Control
2. FYM, 20t/ha.
3. $N, P_2 O_5$ and K_2O at 100:50:50 kg/ha
   (N & K in 2 equal splits)
4. Green manuring *insitu* (sowing cowpea at 25 kg/ha uprooting at 45 Days after sowing (DAS) and using as mulch
5. Biofertilizer - Azospirillum at 10 kg/ha.

Observations:

1. Growth parameters : plant height, tillers, leaves.
2. Yield parameters : Rhizome yield, oil yield, oil recovery.
3. NPK status of the soil and removal by the crop.

Results obtained:

The crop was planted in the first year of the programme. Harvesting was undertaken after completing a maturity period of two years. The data on vegetative growth attributes and cowpea biomass production are furnished in table 5. The data showed that spacing and manurial practice significantly influenced all the growth parameters. Plant height was maximum of 88.44cm at 40 x 30 cm spacing which was on par with 60 x 40 cm spacing. Number of plants/hill increased from 38.13 to 68.51 with increase in spacing from 30cm x 20cm to 60 cm x 60cm. The number of leaves/plant increased with wider spacing. Among manurial treatments, FYM application recorded the maximum number of leaves/plant. Cowpea green manure yield increased with increase in spacing and the maximum biomass production was 3472.22 kg/ha at 60x60 cm spacing. On an average over different spacings, the green manure production was 1642.08 kg/ha. Application of FYM at 20 t/ha resulted in the maximum vegetative growth in terms of plant height and number of plants/hill and leaves/hill. On an average over a period of two years, *Alpinia* grows to a height of 84.47 cm and produced 51.78 plants/hill and 10.91 leaves/plant.

The yield data of the trial are furnished in table 6 and illustrated in Figures 4-6. With respect to the main effect, the rhizome yield was maximum at 30 x 20 cm spacing which was on par with 40 x 30 cm spacing. Yield was also maximum with FYM application which was on par with NPK application. The higher yield resulting from FYM or NPK application was due to significantly higher production of tillers/plant, leaves/plant and taller plants. Oil yield also followed similar trend, except that FYM application was significantly superior to all other manurial treatments. Application of biofertiliser (*Azospirillum*) at 10 kg/ha and cowpea green manuring *in situ* resulted in significantly superior rhizome yields over the control, but the oil yields in these three treatments were statistically on par. The higher yields resulting with FYM/NPK application is due to significantly higher production of tillers/hill, leaves/plant and taller plants. The oil recovery did not vary significantly due to the treatments. Over the treatments, the average yield was 41.07 t/ha of fresh rhizome or

11.49 t/ha of dry rhizomes. Fresh rhizomes gave 27.98% dry rhizomes. The oil recovery was 0.20% on fresh weight basis or 0.71% on dry weight basis.

The interaction effects of spacing and manuring treatments on the rhizome and oil yields of *Alpinia* were statistically significant. The fresh rhizome yield was maximum of 60.69t/ha at 30x20 cm spacing with FYM application, followed by 53.30t/ha at 30x20 cm spacing with NPK application (figures 5). Only these two treatments recorded significantly higher rhizome yields over the maximum yield obtained in control treatment. With out any manurial input (control), in other words with the natural fertility at Odakkali conditions, the maximum rhizome yield was 48.96 t/ha at 40x30 cm spacing. The performance of cowpea green manuring was maximum at 40x30 cm spacing (49.93 t/ha). Biofertiliser application recorded the highest rhizome yield (46.60 t/ha) at the narrowest spacing of 30x20 cm.

The oil yield was maximum of 133.52 l/ha at 30x20 cm spacing with FYM application, followed by 103.36 l/ha at 40x30 cm spacing with NPK application (figures 6). Only the treatment 30x20 cm spacing with FYM application recorded significantly higher oil yield over the maximum yield obtained in control treatment. With out any manurial input (control), in other words with the natural fertility at Odakkali conditions, the maximum oil yield was 102.82 l/ha at 40x30 cm spacing.

The nitrogen content in rhizome increased with increase in spacing while the K content in rhizome showed the reverse trend (table 7). Regarding the manuring treatments, N content in rhizome was highest with the application of NPK and green manure, whereas the P content was highest with the application of green manure. The interaction effects of spacing and manuring treatments on the NPK contents of rhizome were statistically significant (fig. 7-9). The N contents of *Alpinia* rhizome were higher at wider spacings (60x60 and 60x40 cm) with the application of NPK whereas it was higher at medium spacings (60x40 and 40x30 cm) with the application of green manure. At the narrowest spacing of 30x20 cm, cowpea green manuring resulted in the build up of P and K status in soil. The status of NPK in soil did not vary significantly due to the treatments (table 7).

On an average over the treatments for two years, *Alpinia* dry rhizomes contained 0.08% N, 0.06% P, 0.44% K and 0.17% Na at the time of harvest. The soil nutrient status was 273.30 kg/ha N, 77.30 kg/ha P_2O_5, 159.54 kg/ha K_2O and 175.84 kg/ha Na_2O after the harvest of the crop. Green manuring had a positive effect on the N and P content of rhizomes.

The results show that the optimum spacing for obtaining maximum rhizome and oil yields in Alpinia is a wider spacing of 40x30 cm under low fertility conditions and a narrow spacing of 30x20 cm under good fertility conditions. Concerning manuring, application of FYM at 20 t/ha/year or NPK at 100:50:50 kg/ha/year produces significantly higher rhizome yields. Application of biofertilizer at 10 kg/ha or cowpea green manuring insitu resulted in significantly superior rhizome yields over the control. However, the marginal benefit-cost ratio works out better for NPK application. Oil recovery was unaffected by the treatments. The nutrient removal by the crop for the production of rhizomes was 9.19:6.89:50.56 kg NPK/ha. Combination and interaction effects of the various manurial treatments are to be studied further in detail.

Table 5. Effect of spacing and manurial treatments on the growth of *Alpinia calcarata* (*Chittaratha*).

Treatment	Hills/ plot (No.)	Plant height (cm)	Plants/ hill (No.)	Leaves/ plant (No.)	Cowpea biomass (kg/ha)
1. Spacing (cm.)					
30 x 20	37.47	82.59	38.13	8.48	868.06
40 x 30	19.27	88.44	50.91	9.62	1041.67
60 x 40	10.93	85.33	49.57	9.27	1186.35
60 x 60	7.27	81.52	68.51	10.76	3472.22
CD (.05)	1.48	7.88	5.29	0.90	1370.14
2. Manuring					
Control	19.08	79.90	53.15	9.23	--
FYM	19.17	90.18	57.10	10.23	--
NPK	19.00	89.48	55.06	9.03	--
GM	17.50	85.98	47.01	9.60	1642.08
BF	18.92	76.81	46.60	9.57	--
CD (.05)	NS	8.81	5.91	1.00	--
Interaction Sp.xMa.	NS	17.62	11.81	2.01	--

Table 6. Effect of spacing and manurial treatments on the yield parameters of *Chittaratha*

Treatment	Fresh rhizome yield (t/ha)	Dry rhizome yield (t/ha)	Oil yield (l/ha)	Oil recovery FWB (%)	Oil recovery DWB (%)
1. Spacing (cm.)					
30 x 20	47.29	13.23	91.29	0.19	0.69
40 x 30	46.42	12.99	93.53	0.20	0.72
60 x 40	36.81	10.31	77.33	0.21	0.75
60 x 60	33.85	9.48	66.36	0.20	0.70
CD (.05)	2.40	0.67	4.69	NS	NS
2. Manuring					
Control	36.63	10.24	75.78	0.21	0.74
FYM	45.14	12.64	94.80	0.21	0.75
NPK	44.86	12.57	86.73	0.19	0.69
GM	38.89	10.90	76.30	0.20	0.70
BF	39.93	11.18	74.91	0.19	0.67
CD (.05)	2.69	0.75	5.25	NS	NS
Interaction Sp.xMa.	5.38	1.50	10.50	NS	NS

Table 7. Effect of spacing and manurial treatments on the nutrient content of *Alpinia* rhizomes and soil

	Nutrient content in rhizome (%)				Nutrient content in soil (kg/ha)			
Treatment	N	P	K	Na	N	P_2O_5	K_2O	Na_2O
1. Spacing (cm.)								
30 x 20	0.05	0.07	0.56	0.19	239.4	85.18	162.50	175.18
40 x 30	0.07	0.05	0.44	0.20	267.4	83.54	160.77	205.52
60 x 40	0.12	0.05	0.34	0.16	234.6	84.77	152.79	156.97
60 x 60	0.08	0.06	0.41	0.12	236.1	91.84	162.12	165.68
CD (.05)	0.022	NS	0.100	NS	NS	NS	NS	24.390
2. Manuring								
Control	0.09	0.04	0.36	0.13	255.6	74.44	157.41	144.55
FYM	0.06	0.06	0.43	0.16	234.9	85.97	159.72	216.44
NPK	0.10	0.05	0.49	0.20	229.3	87.51	161.28	144.70
GM	0.10	0.08	0.46	0.18	248.7	89.18	170.33	210.91
BF	0.05	0.06	0.44	0.18	253.3	94.55	148.99	162.61
CD (.05)	0.025	0.015	NS	NS	NS	NS	NS	27.269
Interaction Sp.xMa.	0.050	0.030	0.224	NS	NS	NS	NS	54.537

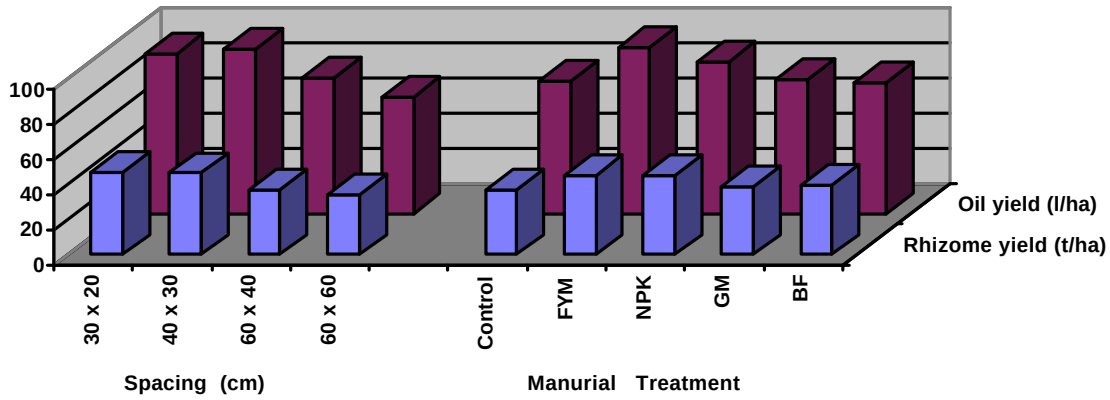

Fig.4. Main effect of spacing and manurial treatments on rhizome and oil yields of *Alpinia galanga*

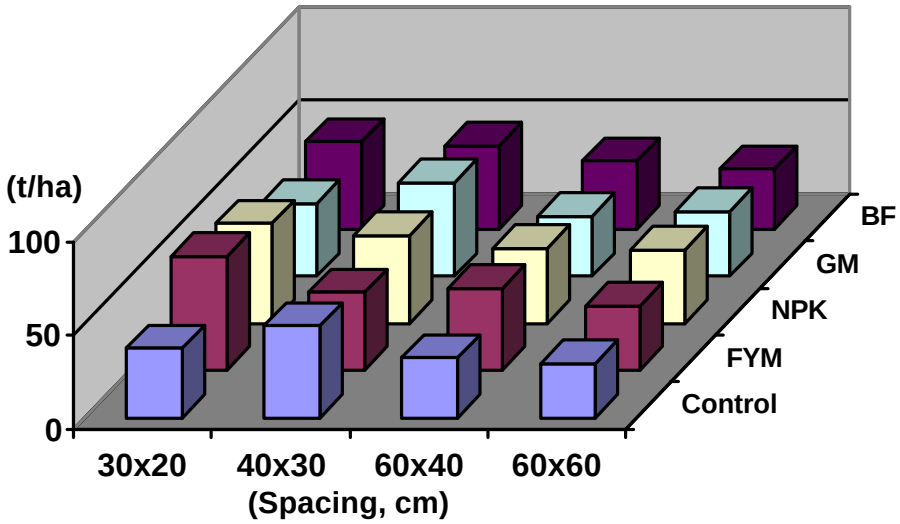

Fig. 5. Interaction effect of spacing and manuring treatments on the fresh rhizome yield of *Alpinia galanga*

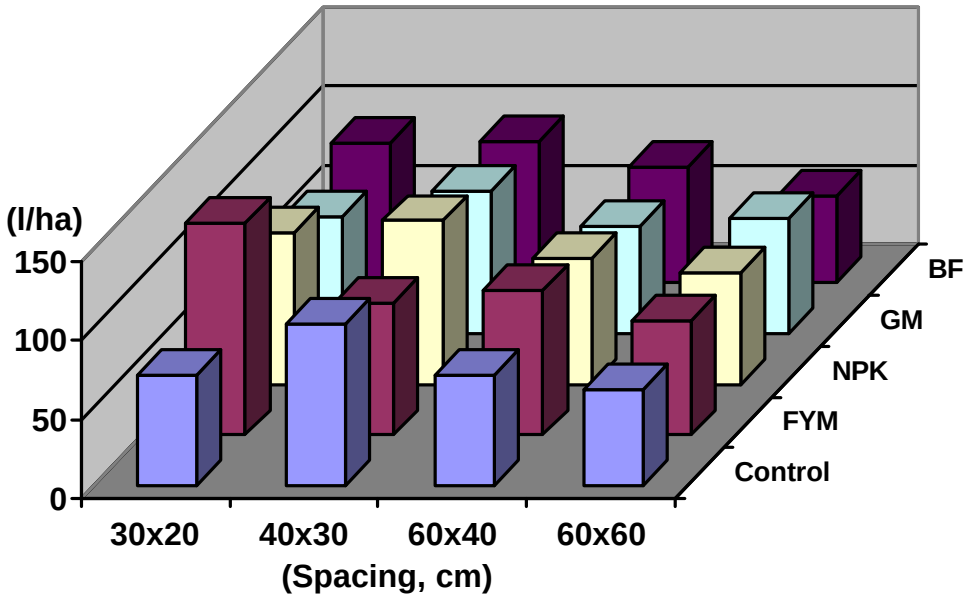

Fig. 6. Interaction effect of spacing and manuring treatments on the oil yield of *Alpinia galanga*

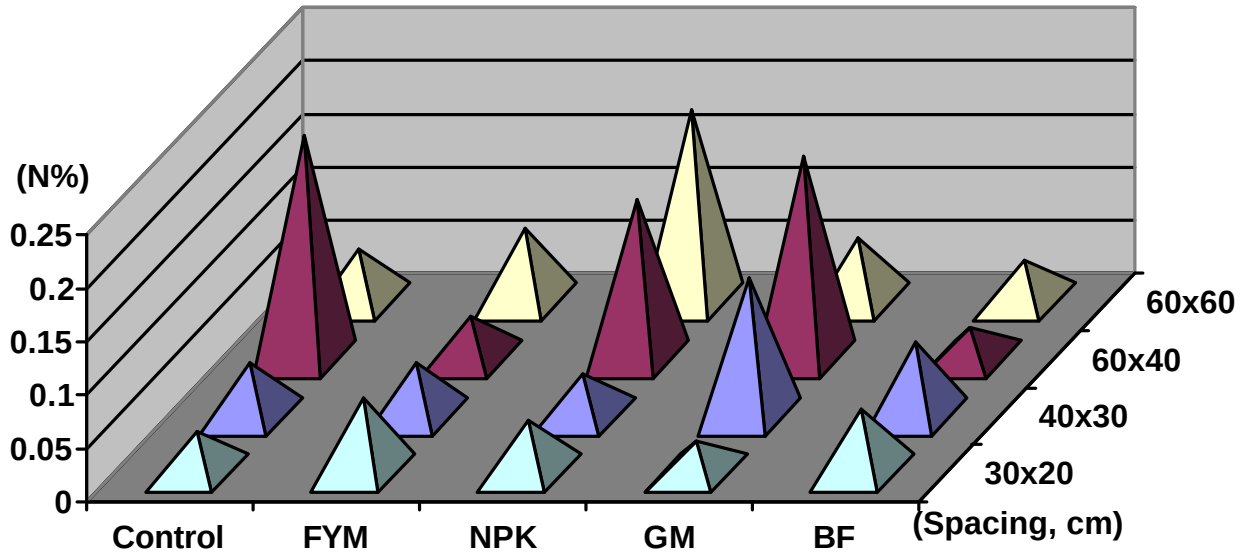

Fig. 7. Interaction effect of spacing and manuring treatments on the nitrogen content of *Alpinia galanga* rhizome

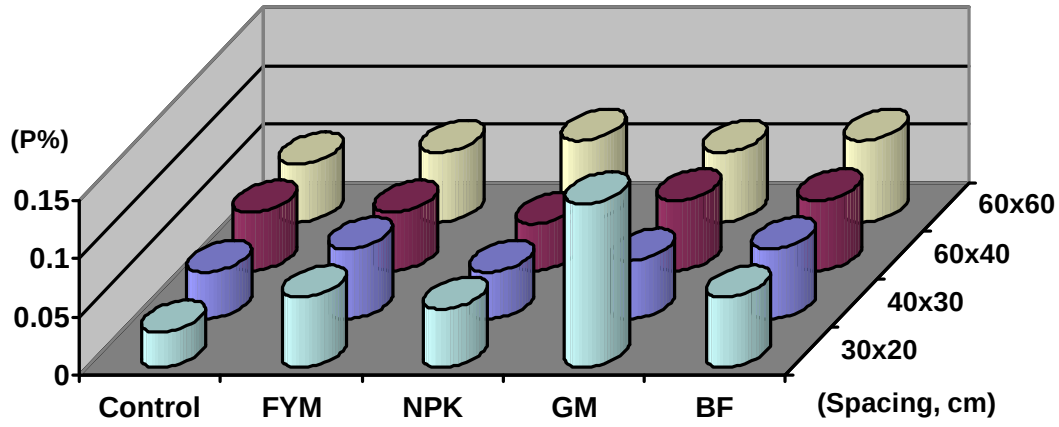

Fig. 8. Interaction effect of spacing and manuring treatments on the phosphorus content of *Alpinia galanga* rhizome

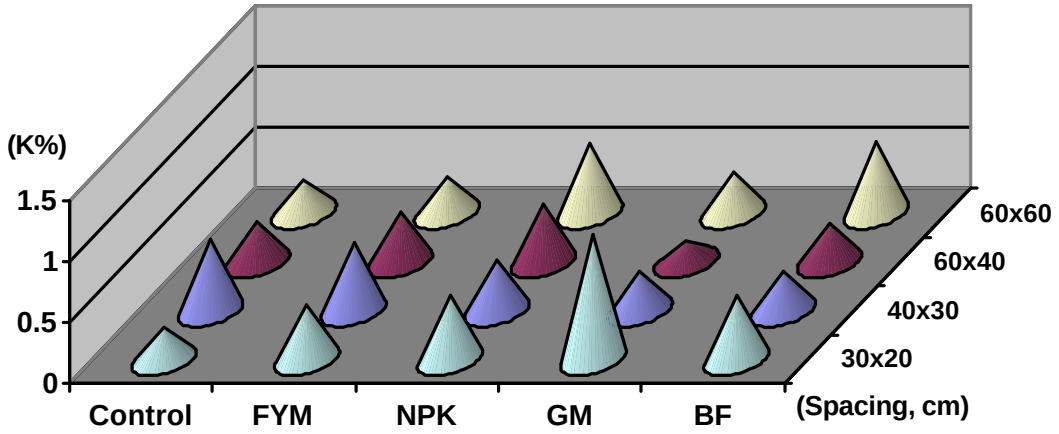

Fig. 9. Interaction effect of spacing and manuring treatments on the potassium content of *Alpinia galanga* rhizome

iii) Spacing and manurial requirements of *curcuma* sp. (*Kasthurimanjal*)

Objective : To find out the optimum spacing and manurial requirement of *Kasthurimanjal*.
Design : RBD
Replications : 3

Treatments : 4 x 5 = 20 factorial combinations of
i) four spacings (cm) : 20x20, 30x20, 30x30, 40x30
ii) five manurial treatment
1. control
2. FYM, 20t/ha.
3. N, P_2O_5 and K_2O at 100:50:50 kg/ha.
4. Green manuring *insitu* (sowing cowpea at 25 kg/ha, uprooting at flowering and using as mulch)
5. Biofertilizer : Azospirillum at 10 kg/ha.

Observations:
Growth parameters : plant height, tillers, leaves
Yield parameters : rhizome yield, oil yield, oil recovery.
NPK status of soil and removal by crop.

Results obtained:

The field experiment was laid out in the second year and also repeated in the third year. Observations on number of hills/plot, plant height, number of plants/hill, number of leaves per plant, yield and quality parameters were recorded. The data for two years were pooled and statistically analysed. The results are furnished in tables 8-10 and figure 10-14. Pooled results showed that spacing affected only the number of plants/hill, which increased with increase in spacing. This indicates that the plant is capable of adjusting the plant population per unit area by regulating the sucker production to a great extent. Here a wider spacing of 60 x 40 cm can be adopted considering the saving in seed rate. With respect to manuring effect, the variation in rhizome and oil yields was statistically significant. Yield was maximum of 34.67 t/ha of fresh rhizomes with FYM application, followed by 28.73 t/ha with NPK. The favourable effect of FYM and NPK application was reflected on the plant growth characteristic also. These yields were significantly superior to the control. Application of biofertiliser and cowpea green manuring, though on par with NPK application, were statistically not different from the control. Oil yield under FYM treatment was significantly higher than that under any other treatment. Application of NPK and biofertiliser was superior to control. Cowpea green manuring significantly reduced the oil yield. Oil recovery was not influenced by the treatments. Competitive effect of cowpea might have reduced the rhizome and oil yield in cowpea green manuring. NPK application significantly reduced oleoresin content in rhizome. The oleoresin content in the rhizome was maximum in the control, followed by cowpea green manuring. Oleoresin yield under FYM treatment was significantly higher than that under any other treatment.

On an average over the treatments, Curcuma grew to a height of 98.20 cm and produced 2.25 plants/hill and 6.38 leaves/plant. The yield was 28.24 t/ha of fresh rhizomes or 7.89 t/ha of dry rhizomes. Dry weight was 27.94%. Oil recovery was 0.33% on fresh weight basis and 1.05% on dry weight basis. Oil yield was 91.79 l/ha. Oleoresin recovery was 5.49% and oleoresin yield was 433.11 kg/ha.

Spacing and manuring also significantly influenced the P and K contents in rhizome (table 10, Figure 12). P content was maximum with FYM application followed by

biofertiliser. K content was maximum with the application of biofertiliser Azospirillum at 10 kg/ha. In general, organic sources of nutrients had a favourable effect on the nutrient contents in the rhizome. The interaction effects of spacing and manuring treatments on the P and K contents of Curcuma rhizomes were statistically significant. P content in rhizome was highest with FYM application at 30x20 cm spacing. whereas K content was highest in the control at 60x40 cm spacing. Application of FYM showed significant build up of soil available P resulting in higher uptake of the nutrient by the plant.

On an average over the treatments for two years, Curcuma dry rhizomes contained 1.47 %N, 0.12% P, 1.41 %K and 0.01 %Na at the time of harvest. The nutrient removal by the crop for the production of rhizomes was 115.96:9.46:111.23kg NPK/ha. The soil nutrient status was 269.39 kg/ha N, 101.54 kg/ha P_2O_5, 150.15 kg/ha K_2O and 67.92 kg/ha Na_2O after the harvest of the crop.

Results show that Kasthurimanjal is highly adaptable to a wide range of spacings, producing similar yields by adjusting the number of plants/hill. Hence a wider spacing of 60x40 cm may be adopted with a saving in seed rate. Concerning manuring, FYM application at 20 t/ha is the best, followed by NPK at 100:50:50 kg/ha for realising maximum yield of rhizome, essential oil and oleoresin. Oil recovery was unaffected by the treatments. Combination and interaction effects of the various manurial treatments are to be studied further in detail. The nutrient removal by the crop for the production of rhizomes was 115.96:9.46:111.23kg NPK/ha.

Table 8. Effect of spacing and manurial treatments on the growth of *Curcuma* sp. (*Kasthurimanjal*) (Pooled mean of two years)

Treatment	Hills/ plot (No.)	Plant height (cm)	Plants/ hill (No.)	Leaves/ plant (No.)	Cowpea biomass (kg/ha)
1. Spacing (cm.)					
30 x 20	56.0	96.74	1.83	6.31	4694
40 x 30	42.93	97.42	2.26	6.21	4380
60 x 40	30.43	100.86	2.36	6.37	7358
60 x 60	23.00	97.77	2.55	6.60	5127
CD (.05)	2.674	NS	0.326	NS	NS
2. Manuring					
Control	38.49	91.18	2.08	6.30	--
FYM	38.25	111.73	2.28	6.38	--
NPK	37.79	100.08	2.51	6.43	--
GM	37.95	94.10	2.26	6.27	5390
BF	37.98	93.90	2.12	6.50	--
CD (.05)	NS	6.750	NS	NS	--
Interaction Sp.xMa.	NS	NS	NS	NS	--

Table 9. Effect of spacing and manurial treatments on the yield parameters of *Curcuma* sp. (*Kasthurimanjal*) (Pooled mean of two years)

Treatment	Fresh rhizome yield (t/ha)	Dry rhizome yield (t/ha)	Oil yield (l/ha)	Oil recovery, FWB (%)	Oil recovery, DWB (%)	Oleoresin content (%)	Oleoresin yield (kg/ha)
1. Spacing (cm.)							
30 x 20	28.642	8.003	97.38	0.34	1.09	5.46	436.96
40 x 30	28.844	8.059	92.31	0.32	1.03	5.69	458.55
60 x 40	29.528	8.250	94.49	0.32	1.03	5.48	452.10
60 x 60	25.927	7.244	82.96	0.32	1.03	5.33	386.11
CD (.05)	NS	NS	NS	NS	NS	NS	NS
2. Manuring							
Control	24.874	6.950	84.57	0.34	1.09	5.99	416.31
FYM	34.666	9.686	110.93	0.32	1.03	5.43	525.95
NPK	28.728	8.027	94.80	0.33	1.06	5.18	415.80
GM	25.807	7.211	77.42	0.30	0.96	5.61	404.54
BF	27.101	7.572	92.14	0.34	1.09	5.24	396.77
CD (.05)	3.3712	0.9419	6.600	NS	NS	0.410	51.805
Interaction Sp.xMa.	NS	NS	NS	NS	NS	Sig	NS

Table 10. Effect of spacing and manurial treatments on the yield and quality of *Curcuma* sp. (*Kasthurimanjal*) (Pooled mean of two years)

	Nutrient content in rhizome (%)				Nutrient content in soil (kg/ha)			
Treatment	N	P	K	Na	N	P_2O_5	K_2O	Na_2O
1. Spacing (cm.)								
30 x 20	1.52	0.13	1.36	0.01	268.9	112.65	141.05	63.28
40 x 30	1.48	0.12	1.27	0.01	271.0	99.07	161.33	71.02
60 x 40	1.44	0.13	1.65	0.01	278.0	94.40	151.49	64.80
60 x 60	1.43	0.12	1.35	0.01	259.6	100.05	146.75	72.58
CD (.05)	NS	0.010	0.10	NS	NS	10.03	NS	NS
2. Manuring								
Control	1.42	0.12	1.47	0.01	276.4	88.79	139.92	64.76
FYM	1.45	0.14	1.43	0.01	267.4	154.21	140.64	73.85
NPK	1.47	0.11	1.22	0.01	271.5	89.30	170.53	66.14
GM	1.48	0.12	1.43	0.01	277.8	88.92	159.91	70.45
BF	1.52	0.13	1.49	0.01	253.9	86.49	139.77	64.40
CD (.05)	NS	0.01	0.110	NS	NS	11.21	22.61	NS
Interaction Sp.xMa.	NS	Sig.	Sig.	NS	NS	NS	NS	NS

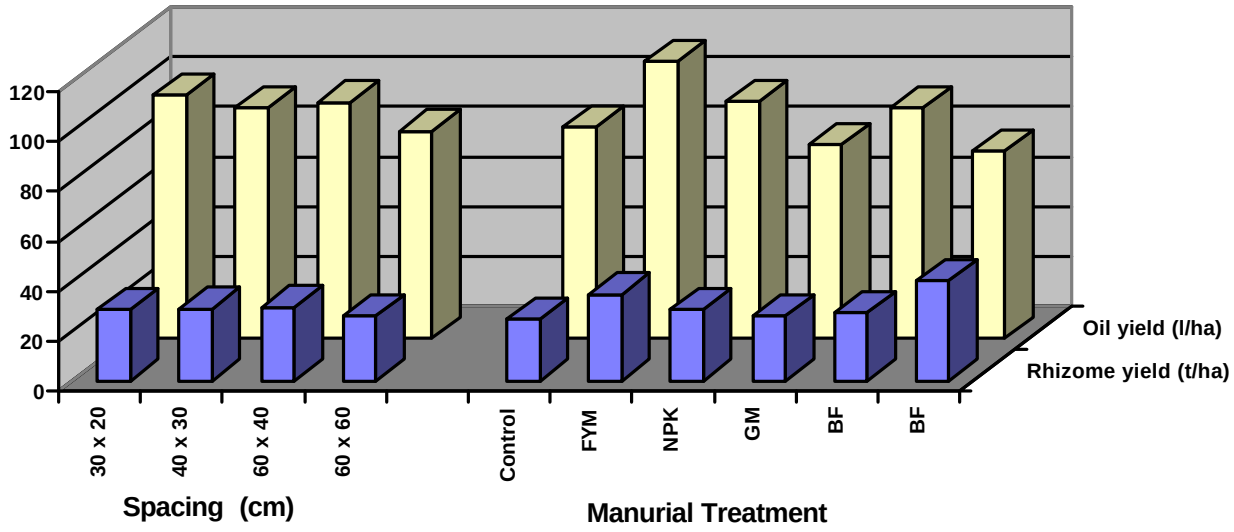

Fig.10. Effect of spacing and manurial treatments on rhizome and oil yields of *Curcuma sp.*

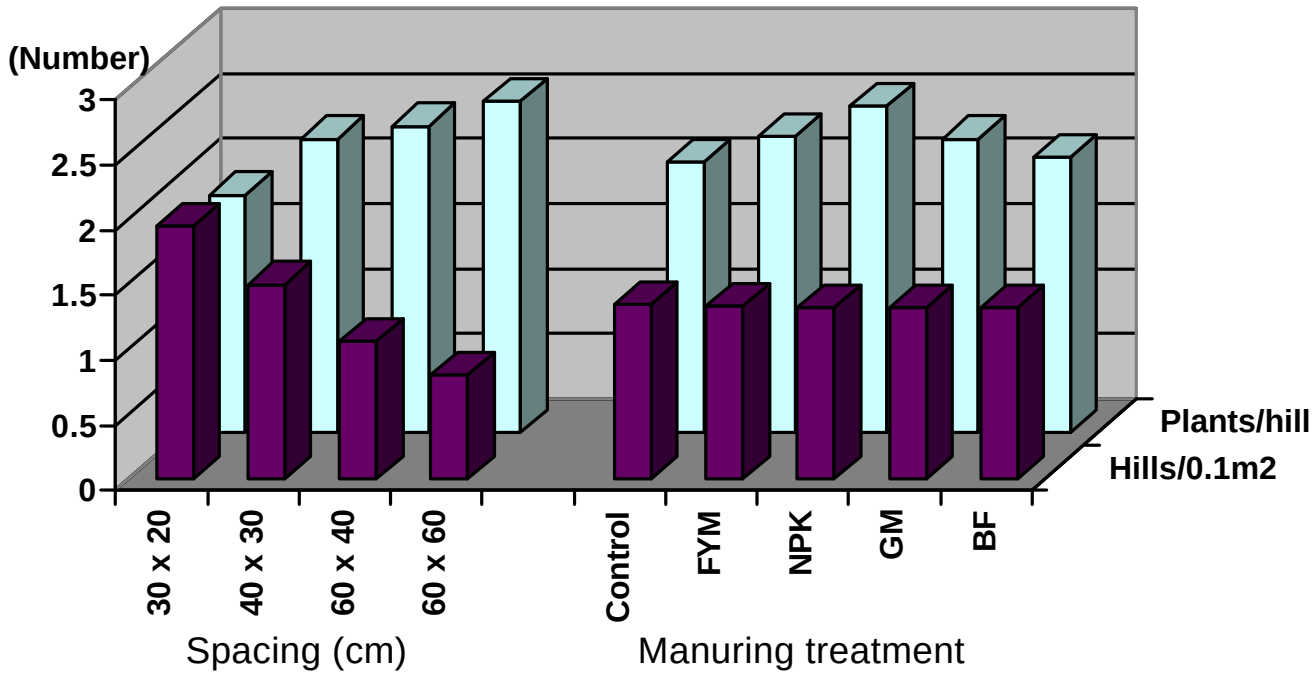

Fig.11. Effect of spacing and manuring treatments on sucker production of Curcuma sp. as against the planted population

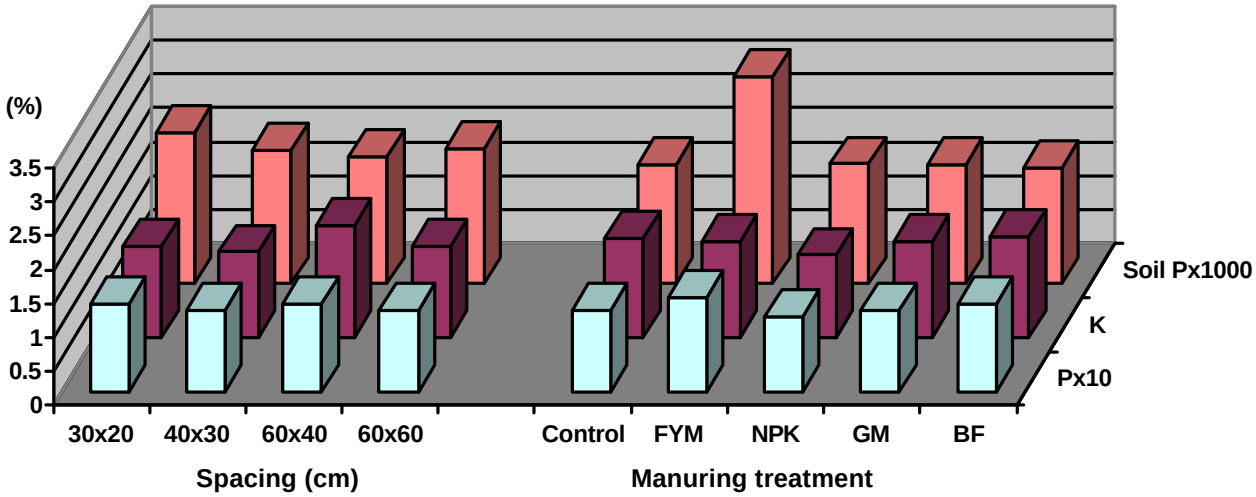

Fig.12. Main effect of spacing and manuring treatments on the P and K contents of Curcuma rhizome and soil

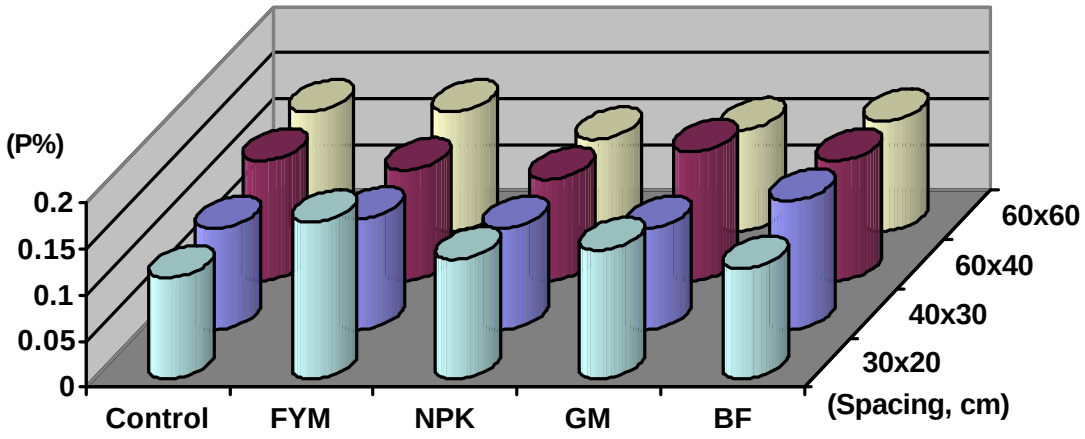

Fig. 13. Interaction effect of spacing and manuring treatments on the phosphorus content of Curcuma rhizome

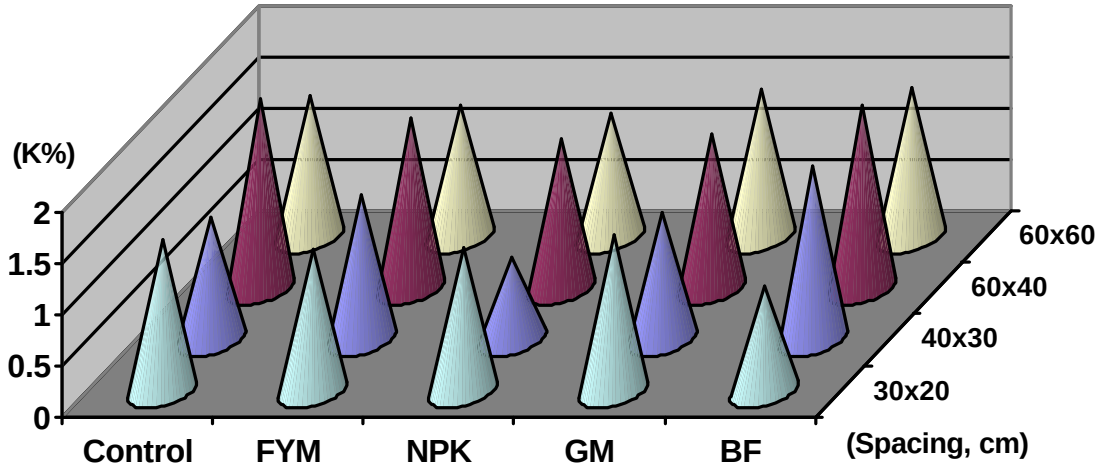

Fig. 14. Interaction effect of spacing and manuring treatments on the potassium content of Curcuma rhizome

iv) Optimum planting spacing in *Kaempferia rotunda* (Chengazhinirkizhangu)

Objective : To find out the optimum spacing and plant population requirement of *Kaempferia rotunda* for maximum yield.
Design : RBD
Replications : 4
Treatments : Five spacings (cm)
30x20, 30x30, 40x30, 60x40, 60x60
Observations:
Growth Parameters : Plant height, tillers, leaves
Yield parameters : Rhizome yield.

Results obtained:

The field experiment was conducted during the second and third years of the study. The observations on number of hills/plot, number of plants/hill, plant height and number of leaves/plant, weed biomass and yield were recorded. The data for two years were pooled and statistically analysed. The results are presented in table 11 and figures 15-17. Pooled data of the trial showed that the spacing treatment significantly affected the growth and yield of *Kaempferia rotunda*. The number of plants/hill gradually increased from narrow spacing to wider spacing, except at 60 x 40 cm where there was an abnormal decline. Plant height in general decreased with increase in spacing. There was no specific trend in the number of leaves/plant and the lowest value was recorded for 60 x 40 cm spacing. Rhizome yield was maximum at the narrowest spacing of 30 x 20 cm and it gradually decreased with increase in spacing and the lowest yield was recorded for 60 x 40 cm spacing. It may be due to the fact that *Kaempferia rotunda* grows uniformly to all the sides and hence equilateral spacing would be more conducive. Weed biomass was also maximum in 60 x 40 cm spacing.

In general over different spacings, *Kaempferia rotunda* grew to a height of 45.26 cm and produced 7.44 plants/hill and 7.02 leaves /plant. The yield was 12.98 t/ha of fresh rhizomes or 3.90 t/ha of dry rhizomes. Fresh rhizomes gave 30% dry rhizomes.

Various trend lines were plotted and regression equations computed and illustrated in figure 17. R^2 values varied from 0.8188 to 0.9977 for the regressions. R^2 value was the maximum of 0.9977 for quadratic (polynomial) function indicating that it is the best fit. Fitting the quadratic (polynomial) function between spacing (X) and yield of rhizome (Y) the following quadratic equation was obtained.

$Y = 28247.3846 - 151672.8937 X + 260818.0707 X^2$ ($R^2 = 0.9977$)
Where, X = the area occupied by a single plant in m^2 and Y = fresh rhizome yield in kg/ha

It was showed that the optimum spacing for maximum yield is 18.64 cm which translates to a plant population of 28.78 plants/m^2 or a seed rate of 3000 kg/ha with a seed bit size of 10-15 g including the weight of root tubers which form an integral part of the seed in *Kaempferia rotunda*. Taking into account all these aspects, an optimum spacing of 20 x 20 cm can be recommended for the crop.

In conclusion, Kaempferia rotunda grows to a height of 45.26 cm and produces 7.44 plants/hill and 7.02 leaves /plant. The average yield is 12.98 t/ha of fresh rhizomes or 3.90 t/ha of dry rhizomes. Fresh rhizomes give 30% dry rhizomes. The optimum spacing is 20 x 20 cm for obtaining maximum rhizome yield which translates to a plant population of 27 plants/m^2 or a seed rate of 3000 kg/ha with a seed bit size of 10-15 g including the weight of root tubers which form an integral part of the seed in Kaempferia rotunda.

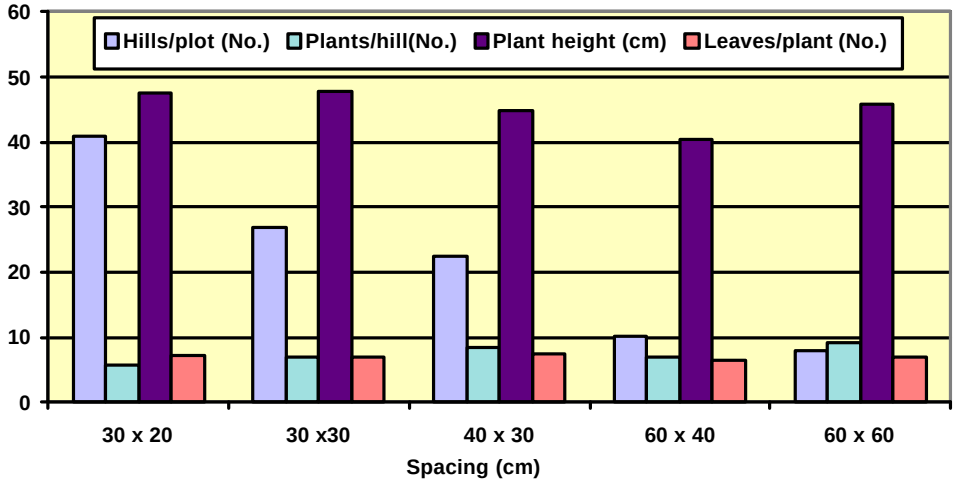

Fig.15. Effect of spacing on the growth parameters of *Kaempferia rotunda*

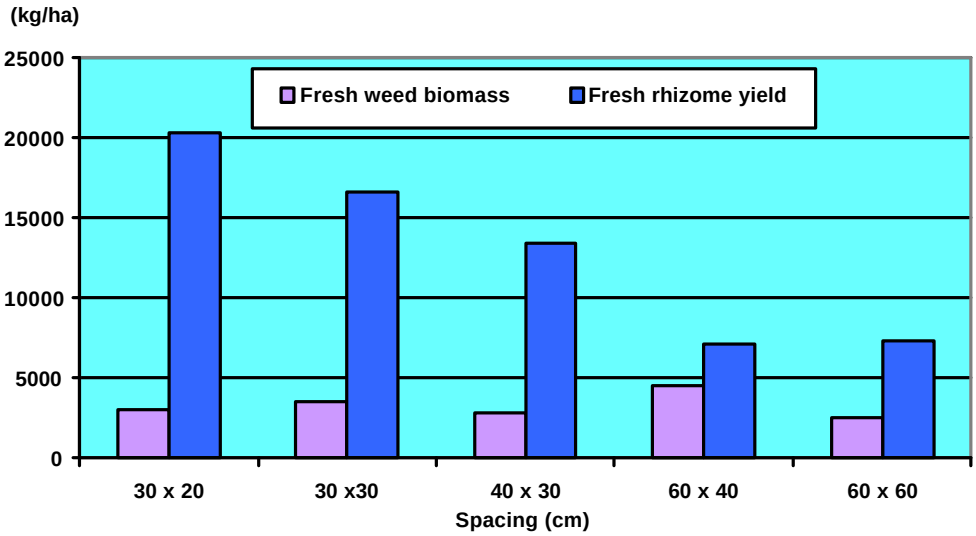

Fig.16. Effect of spacing on weed infestation and rhizome yield in *Kaempferia rotunda*

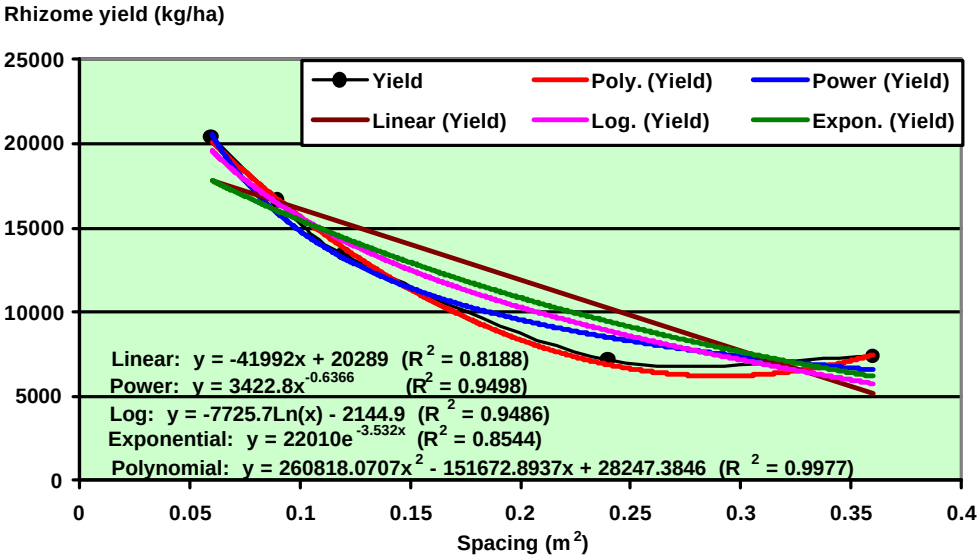

Fig.17. Various trend lines and regression equations between spacing and fresh rhizome yield in *Kaempferia rotunda*

Table 11. Effect of different spacing on the growth and yield of *Kaempferia rotunda* (Pooled mean of two years)

Spacing (cm)	Hills/ plot (No.)	Plants/ hill (No.)	Plant height (cm)	Leaves/ plant (No.)	Fresh weed biomass (kg/ha)	Fresh rhizome yield (kg/ha)	Dry rhizome yield (kg/ha)
30 x 20	40.75	5.75	47.67	7.15	2986	20347	6104
30 x30	26.88	7.05	47.77	6.98	3507	16632	4990
40 x 30	22.38	8.48	44.89	7.38	2813	13420	4026
60 x 40	10.25	6.83	40.28	6.55	4549	7153	2146
60 x 60	7.88	9.10	45.69	7.03	2500	7361	2208
Mean	21.63	7.44	45.26	7.02	3264	12983	3895
CD(0.05)	3.584	1.567	7.015	1.312	1180.5	4136.8	1241.0

v) Screening of organic manures and biofertilizers for maximum yield in *Kaempferia rotunda.*

Objective : To assess the requirement of organic manures and biofertilizers for realising maximum yield in *Kaempferia rotunda*.

Design : RBD
Replications : 3
Treatments : 14 (depicted in table 12)

Observations:
Growth parameters : plant height, tillers, leaves
Yield parameters : Rhizome yield.

Results obtained:

The experiment was laid out in the first year and the treatments were imposed as per the programme. Growth and yield observations were recorded. The trial was repeated during the succeeding year. The data were pooled for two years and statistically analysed. The results are presented in tables 12-13 and figures 18-21. Pooled data showed that the plant stand was maximum in the treatment where mulching was done twice. Stand was good in mulching, FYM, Compost, vermicompost applied plots. However, the plant stand was significantly reduced in Cowpea green manuring, NPK and VAM biofertiliser applied plots (table 12). Plant height was maximum in mulching twice, followed by vermicompost applied and mulched plot. Number of plants/hill was highest in vermicompost applied and mulched plots followed by mulching twice. Sucker production was significantly less in cowpea green manuring and biofertiliser application. Number of leaves/plant was not significantly influenced by the treatments. On an average over the treatments, the plant stand was 26.39 plants/m^2, plant height 27.45 cm and a plant produced 6.15leaves.

Mulching twice (T_7) gave the highest rhizome yield of 12241 kg/ha. Mulching significantly suppressed the weed growth and provided favourable soil conditions for rhizome production, apart from the addition of nutrients (nutrient composition of the mulch was 0.88% N, 0.01% P_2O_5 and 1.00% K_2O). Mulching twice was significantly superior to single basal application because the beneficial effect of mulching was maintained throughout the growth period.

Vermicompost along with mulching gave higher yield than fertiliser and biofertiliser application. None of the biofertilisers gave any beneficial effect. Sources of nutrients such as fertilisers, FYM and biofertilisers did not vary significantly in rhizome yield. It is worth

noting that significant effect over control was observed in treatments where mulching was provided or heavy application of FYM (45t/ha) or compost 30t/hawas resorted to which rendered mulching effect also. *This indicates that mulching is more crucial than manuring for realising better yields in Kaempferia rotunda.*

P content in rhizome was influenced significantly by the treatments. Application of vermicompost and FYM increased the P content of the rhizomes. There was a build up of P in FYM and vermicompost applied plots. Vermicompost along with mulching increased the K content of soil. K content of soil was significantly higher in vermicompost applied plots, lower in FYM applied plots and lowest in cowpea green manured and biofertiliser applied plots.

Table 12. Effect of different manurial treatments on the growth and yield of *Kaempferia rotunda* (Pooled data for two years)

Sl. No	Treatment	Hills/ plot (No.)	Plant height (cm)	Plants/ hill (No.)	Leaves/ plant (No).	Weed biomass (kg/ha)	Fresh rhizome yield (kg/ha)	Dry rhizome yield (kg/ha)
1	Control	17.50	25.60	3.74	6.17	7662	3176	1043
2	FYM, 15t/ha.	20.17	24.40	3.47	6.07	6238	3580	1175
3	FYM, 30t/ha.	20.67	27.85	4.37	6.45	5186	4619	1517
4	FTM, 45t/ha.	22.50	31.62	4.40	6.4	6863	5918	1943
5	Compost, 30t/ha,	20.34	28.72	4.37	5.87	10603	6085	1998
6	Mulch 20t/ha.	22.67	30.27	4.24	5.7	3999	8347	2741
7	Mulch 20t+10t/ha	23.00	34.62	4.80	6.64	2592	12241	4019
8	Cowpea green manure	13.50	24.64	3.10	6.17	8219	4943	1623
9	Vermicompost 15t/ha + mulch	20.34	34.02	5.33	6.67	4589	9524	3127
10	Azospirillum 10kg/ha	18.67	23.42	3.03	5.74	5596	2922	959
11	VAM 10 kg/ha	17.00	22.25	2.73	6.30	7297	3120	1024
12	Phosphobacter 10kg/ha.	18.67	23.79	3.17	6.14	7401	3711	1218
13	Vermicompost 15t/ha	19.67	27.07	3.90	6.17	8193	5326	1749
14	NPK, 100:50:50 kg/ha.	15.34	26.10	4.47	5.60	5802	4340	1425
C.D(0.05)		4.398	4.552	1.234	NS	2041	2724.2	894.4

Table 13. Effect of different manurial treatments on the NPK content of *Kaempferia rotunda* rhizome and soil

Sl. No	Treatment	Nutrient content in rhizome (%)			Nutrient content in soil (kg/ha)		
		N	P	K	N	P_2O_5	K_2O
1	Control	1.17	0.08	1.90	255.93	89.19	213.12
2	FYM, 15t/ha.	1.09	0.11	1.80	264.73	155.27	208.80
3	FYM, 30t/ha.	1.36	0.12	1.89	255.20	187.58	218.88
4	FTM, 45t/ha.	1.30	0.14	1.64	244.20	223.99	212.43
5	Compost, 30t/ha,	1.15	0.08	1.76	250.80	109.68	198.72
6	Mulch 20t/ha.	1.24	0.10	1.82	256.67	88.15	160.37
7	Mulch 20t+10t/ha	1.08	0.08	1.74	239.07	87.13	197.55
8	Cowpea green manure	1.12	0.08	1.75	269.13	78.93	131.31
9	Vermicompost 15t/ha + mulch	1.48	0.15	1.83	270.60	131.21	253.23
10	Azospirillum 10kg/ha	1.20	0.10	1.62	236.87	92.25	175.97
11	VAM 10 kg/ha	1.07	0.09	1.73	236.87	96.35	150.72
12	Phosphobacter 10kg/ha.	1.14	0.08	1.96	239.80	100.45	173.28
13	Vermicompost 15t/ha	1.36	0.10	1.74	266.20	120.95	150.77
14	NPK, 100:50:50 kg/ha.	1.22	0.09	1.84	250.80	118.90	171.36
C.D(0.05)		NS	0.017	NS	NS	41.802	44.464

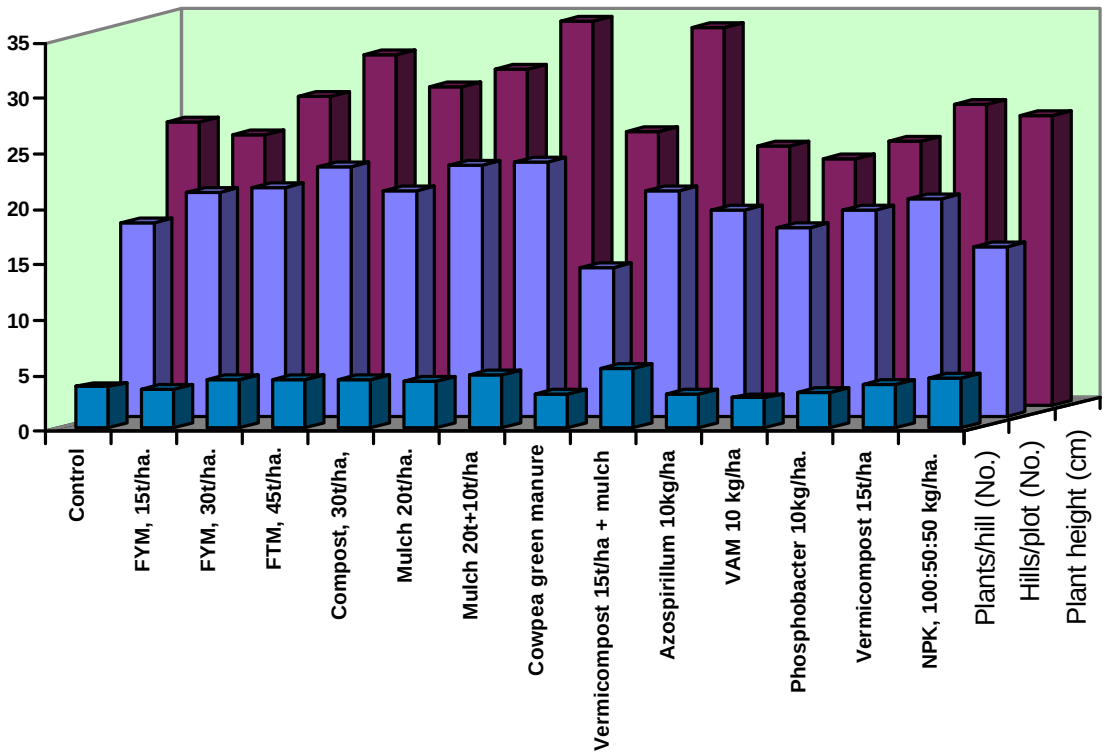

Fig.18. Effect of manurial treatments on the growth parameters of *Kaempferia rotunda*

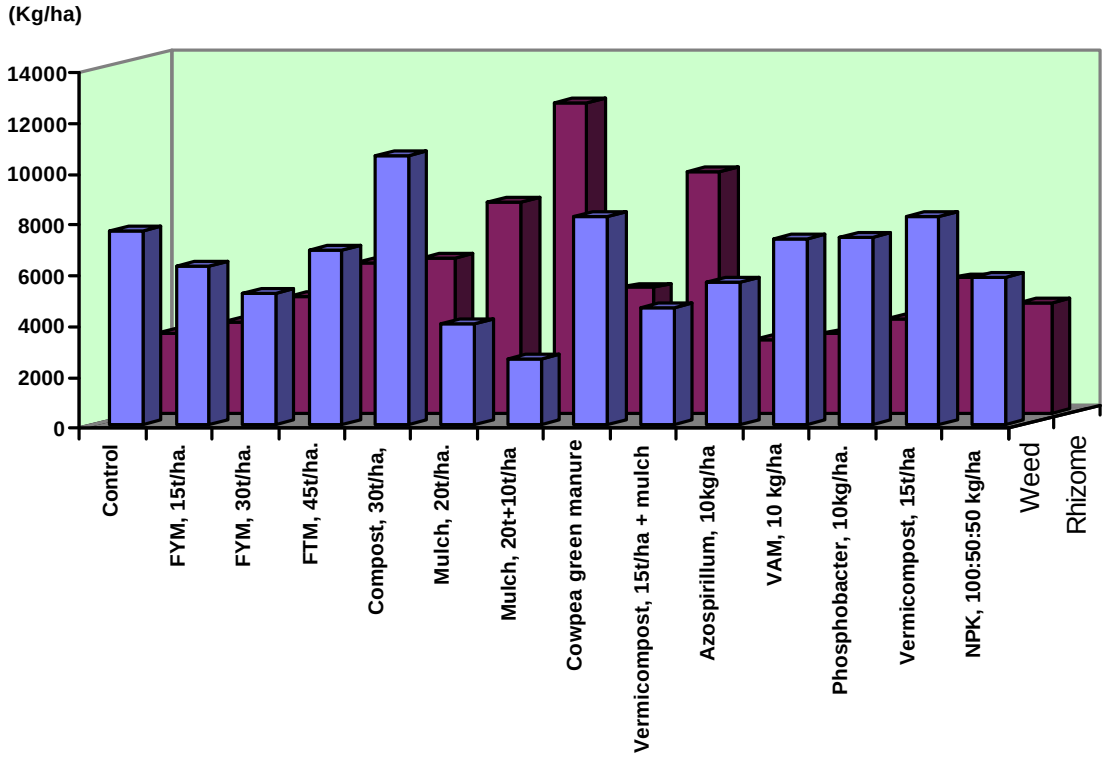

Fig.19. Effect of manurial treatments on weed infestation and rhizome yield in *Kaempferia rotunda*

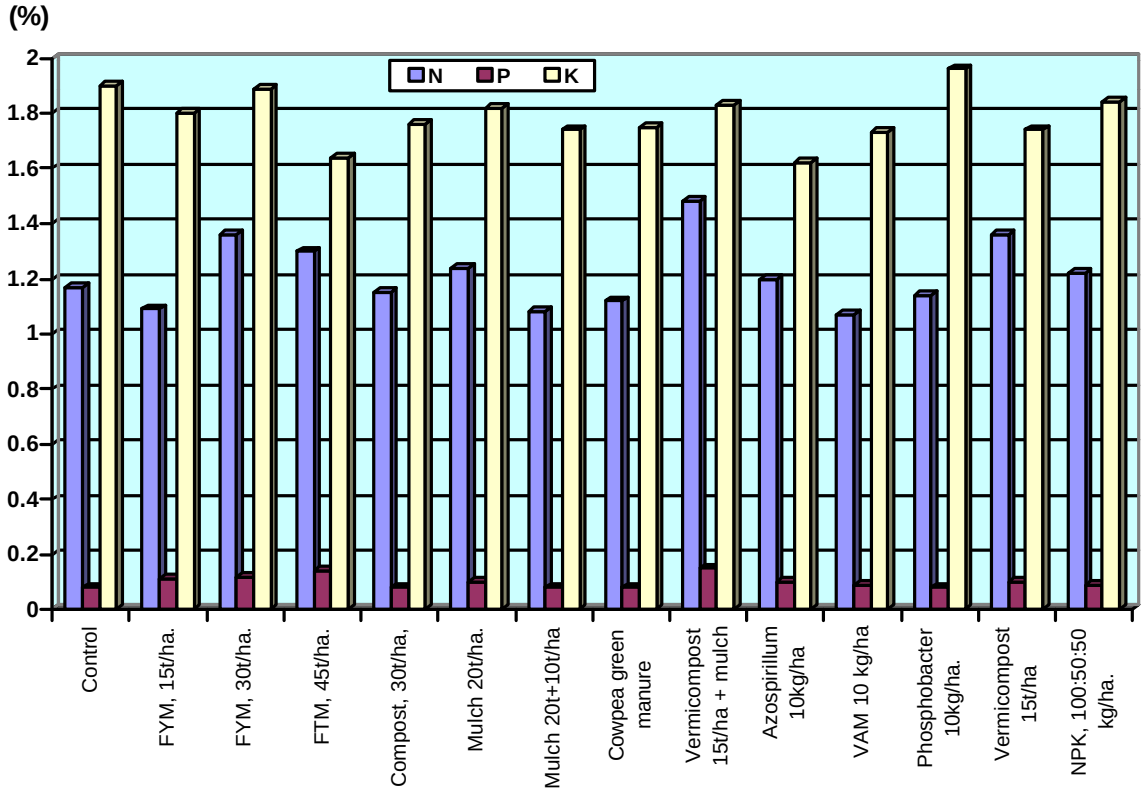

Fig.20. Effect of different manuring treatments on the nutrient content of *Kaempferia rotunda* rhizome

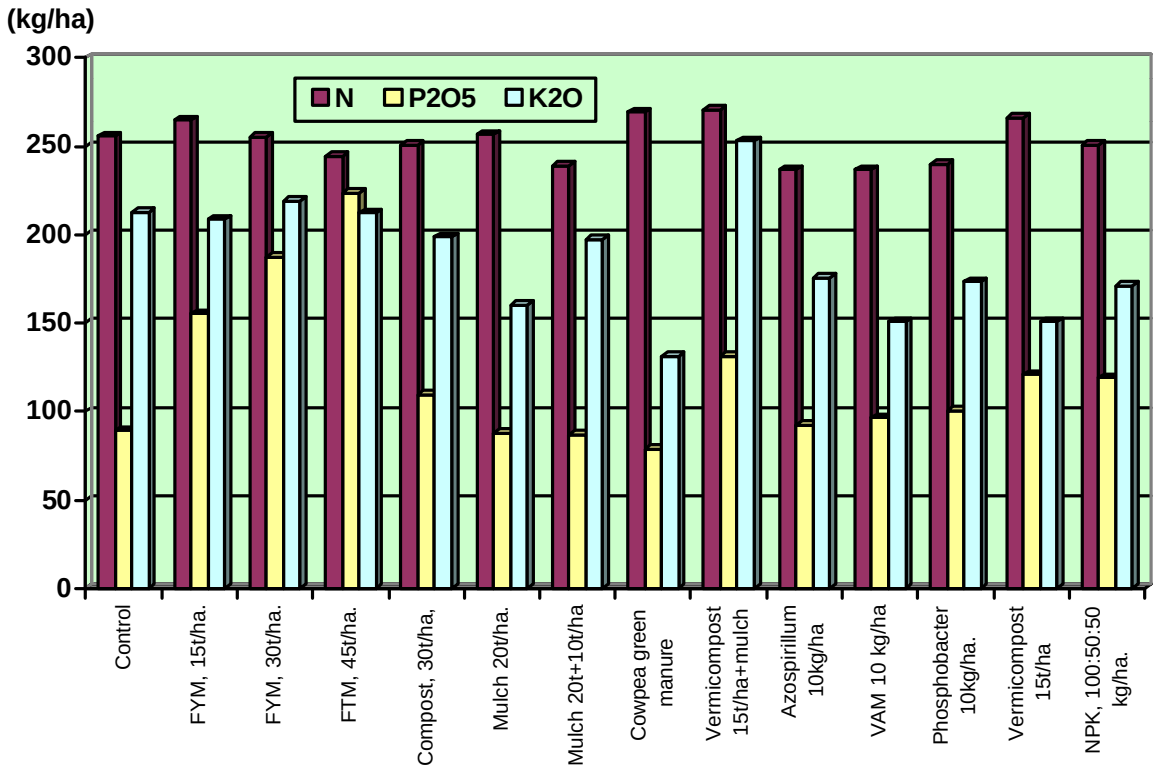

Fig.21. Nutrient status of soil as influened by the manuring treatments on *Kaempferia rotunda*

vi) Fertilizer requirement of *Kaempferia rotunda*

Objective : To find out the fertilizer requirement of K. rotunda for maximum yield.
Design : RBD, Replications : 3
Treatments : 4 x 2 +2 = 10

a) Four levels of N : 50; 100; 150 and 200 kg/ha.
b) Two ratios of N : P_2O_5: K_2O: 1:1:1 and 2:1:1
c) Controls : 1) FYM @ 30t/ha as basal
2) Absolute control

Observations:

Growth parameters : plant height , tillers, leaves
Yield parameters : rhizome yield
NPK status of soil and removal of crop

Results obtained

The field crop was planted in the second year and repeated during the third year. The observations on growth and yield characters were recorded. The data for two years were pooled together and statistically analysed. The pooled results are presented in Tables 14-15. The pooled data showed that the growth and yield of *Kaempferia rotunda* were not significantly influenced by the treatments. It may be noted that all the treatments were uniformly mulched with 20t/ha of spentgrass. All the treatments including the unfertilised control recorded high yields due to the pronounced effect of mulching. This is further evident from the fact that high levels of yield (mean yield of 13123 kg/ha) obtained in this experiment was comparable with the high yields obtained with mulching in the previous manuring experiment. The total crop removal of nutrients was 46.98:5.13:80.30kg NPK/ha. It may also be noted that application of FYM increased the status of NPK in soil and the P content of rhizome. Higher dose of fertiliser application resulted in the build up of available K status in the soil.

Table 14. Effect of fertilizer treatments on the growth and yield of *Kaempferia rotunda* (*Chengazhinirkizhangu*)(Pooled data for 2 years)

Treatment	Hills/ plot (No.)	Plant height (cm)	Plants/ hill (No.)	Leaves/ plant (No).	Dry Weed biomass (kg/ha)	Fresh rhizome yield (kg/ha)	Dry rhizome yield (kg/ha)
1. Levels of N (Kg/ha)							
200	22.84	40.21	7.18	7.39	3160	13194	4294
150	22.67	40.53	6.94	7.62	4060	13438	4373
100	22.83	40.09	7.20	7.39	2778	13160	4283
50	23.08	40.44	6.47	7.19	4306	12951	4215
C.D.(0.05)	NS	NS	NS	NS	836.8	NS	NS
2. Ratio of N:P:K							
1:1:1	22.79	40.33	7.05	7.65	3715	13368	4350
2:1:1	22.92	40.31	6.84	7.15	3438	13120	4237
C.D.(0.05)	NS	NS	NS	NS	NS	NS	NS
Int. Levels x Ratio	NS	NS	NS	NS	NS	NS	NS
3. Controls							
FYM 30t/ha	23.33	37.94	5.67	7.38	4444	13611	4429
absolute control	22.33	37.74	5.34	7.18	6424	12118	3944
C.D.(0.05)	NS	4.81	NS	NS	1184	NS	NS
Control mean	22.84	37.84	5.50	7.28	5417	12847	4181
Rest mean	22.85	40.32	6.95	7.28	3576	13194	4293
Control vs Rest	NS	1.52	0.64	NS	375	NS	NS
General mean	22.85	39.82	6.66	7.37	3958	13125	4271

Table 15. Effect of fertilizer treatments on the nutrient content of *Kaempferia rotunda* and available nutrients in soil (Pooled data for 2 years)

	Nutrient contents in rhizome (%)				Available nutrients in soil (kg/ha)			
Treatment	N	P	K	Na	N	P_2O_5	K_2O	Na
1. Levels of N (Kg/ha)								
200	1.05	0.10	1.86	0.01	244	120.4	185.73	83.07
150	1.11	0.12	1.97	0.01	244	120.2	130.67	91.47
100	1.26	0.11	1.72	0.01	248	114.3	118.53	84.93
50	1.07	0.11	2.01	0.01	152	127.9	95.20	99.87
C.D.(0.05)	NS	NS	0.19	NS	NS	NS	33.65	NS
2. Ratio of N:P:K								
1:1:1	1.16	0.11	1.96	0.01	254	118.0	155.87	93.33
2:1:1	1.08	0.10	1.82	0.01	240	123.4	109.20	86.33
C.D.(0.05)	NS	NS	0.13	NS	NS	NS	23.79	NS
Int. Levels x Ratio	NS	NS	NS	NS	NS	NS	NS	NS
3. Controls								
FYM 30t/ha	1.01	0.16	1.72	0.01	252	261.4	89.60	104.5
Absolute control	1.00	0.14	1.95	0.01	224	156.3	82.13	84.00
C.D.(0.05)	NS	NS	NS	NS	NS	Sig	NS	NS
Control mean	1.00	0.15	1.84	0.01	238	208.9	85.87	94.27
Rest mean	1.12	0.11	1.89	0.01	248	120.7	132.53	89.83
Control vs Rest	NS	Sig	NS	NS	NS	Sig	Sig	NS
General mean	1.10	0.12	1.88	0.01	246	138.3	123.20	90.72

vii) Physico-chemical changes in *Kaempferia rotunda* rhizomes during storage

Objective : To study the effect of drying and storage methods on the quality of *Kaempferia rotunda.*

Design : RBD
Replications : 3
Treatments : 3x3 = 9 factorial combinations of

a) Drying method
- D_1. Drying separated whole fingers in sun for 3-4 days
- D_2. Drying sliced fingers in sun for 2-3 days
- D_3. Oven drying sliced fingers to 13-14% moisture (oven drying at 70°C for 8 hrs each, 3-4 days)

b) Storage methods
- S_1. Storing in gunny bags
- S_2. Storing in plastic bags
- S_3. Storing in airtight containers (metallic)

Observations:

The following observations to be recorded after 6 and 12 months of storage
i) change in weight
ii) Scoring for pests and diseases
iii) Other quality parameters.

Results obtained

The experiment was started in the first year. *Kaempferia rotunda* rhizomes were processed and stored as per treatments. Observations were recorded after every 6 months of storage. The data are presented in tables 16-17. The initial moisture content was 45.10% for sundried whole fingers, 9.80% for sundried sliced fingers and 6.20% for ovendried sliced fingers. With respect to all the characters studied sliced fingers sundried treatment and sliced fingers ovendried treatment were on par. Similarly among the storage methods plastic bag treatment and metallic container treatment were on par (table 16). The interaction between drying and storage methods was not significant. Hence, the effect of factorial combinations of whole fingers sundried and sliced fingers sundried treatments with gunny bag and plastic bag treatment is discussed in detail.

Data on various biochemical parameters of *Kaempferia rotunda* rhizomes after various periods of storage are represented graphically in figures 22 and 23. There was no much reduction in the dry matter of *Kaempferia rotunda* when the sliced material was stored irrespective of the containers. Almost 95% of the dry matter was recorded at the end of two years of storage (figure 23). In the case of whole rhizomes stored in gunny bags 80% of the dry matter could be recovered after two years of storage. However, when the whole fingers were stored in plastic bags the dry matter declined sharply to 20% in six months and finally only 14% of the original rhizome material remained after two years. Besides, the material became fully rotten and unsuitable for use within six months of keeping. Hence this method of storage is totally unsuitable. The high moisture content (45.5%) along with airtight storage in plastic bag would have resulted in microbial degradation of the material. This is evidenced by the quick mobilisation of starch, crude fat and crude fibre during the initial six months period. When the same material was stored in gunny bag the microbial decay was not observed and almost 80% of the material could be recovered after two years. The moisture content of the material in gunny bag dropped down drastically. This is facilitated by the ventilating nature of the gunny bag. This drying up would have prevented its microbiological decay.

Kaempferia rotunda rhizomes were well preserved when it was sliced and dried to 9.8% moisture irrespective of the containers used. The recovery of the stored material was as high as 95% after two years. The olfactory characters were good and the stored material was not affected by micro-organisms and insects to any appreciable extent. The biochemical parameters of the stored material remained steady across the storage period.

It is well indicated that the initial moisture content of the material stored is the most critical factor in deciding its storage life. If the material is sliced and dried to around 10% moisture it can be well preserved in gunny or plastic/aluminium containers for as long as two years. The whole rhizome dried in sun for four days, which contained 45.5% moisture can be satisfactorily stored in gunny bags up to two years.

It is doubtless that drying of sliced rhizomes for four days in sun ensures best preservation. However, an additional expenditure is involved in slicing the rhizomes. Satisfactory results are obtained when whole rhizomes sundried for four days are stored in gunny bag. The latter method offers substantial savings in the processing cost. Considering the economics and practicability storage of whole rhizome in gunny bags after sundrying for four days is recommended. Still better results can be expected if the moisture content of the whole rhizome is further brought down by prolonged sundrying.

Table 16. Effect of drying and storage methods on the quality of *Kaempferia rotunda* rhizomes over two years of storage.

Treatment	Dry matter recovery (%)	Dry wt. (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Protein (%)	Starch (%)
I. Drying Method							
1. Whole fingers sun dried	43.70	49.6	3.96	7.51	22.96	12.50	18.46
2. Sliced fingers sun dried	95.74	9.46	4.31	4.36	5.95	9.21	41.37
3. Sliced fingers oven dried	96.60	7.87	3.76	4.15	6.16	9.07	40.65
CD $_{0.05}$	19.16	5.32	NS	0.94	4.27	0.78	1.88
II. Storage Method							
1. Gunny bags	78.84	8.54	4.33	4.59	5.60	9.76	40.67
2. Plastic bags	75.33	29.89	3.95	5.92	14.57	10.41	30.27
3. Metallic containers	81.34	28.50	3.75	5.51	14.90	10.61	29.54
CD $_{0.05}$	NS	5.32	NS	0.94	4.27	NS	1.875
Int. Drying x Storage	NS	NS	*	NS	NS	NS	NS
III. Period of storage	NS	*	*	*	*	NS	*

Pest incidence: L=Light, M= Medium, H=High

Table 17. Effect of drying and storage methods on the smell, disease and pests incidence in *Kaempferia rotunda* rhizomes over two years of storage.

Treatment	Smell	Fungus	Silver fish	Larvae	Spider
I. Drying Method					
1. Whole fingers sun dried	Bad	Rotten	Rotten	Rotten	Rotten
2. Sliced fingers sun dried	Satisfactory	MH	L	L	M
3. Sliced fingers oven dried	Satisfactory	MH	L	L	L
II. Storage Method					
1. Gunny bags	Satisfactory	H	M	L	M
2. Plastic bags	Bad	M	M	M	L
3. Metallic containers	Bad	M	-	-	-

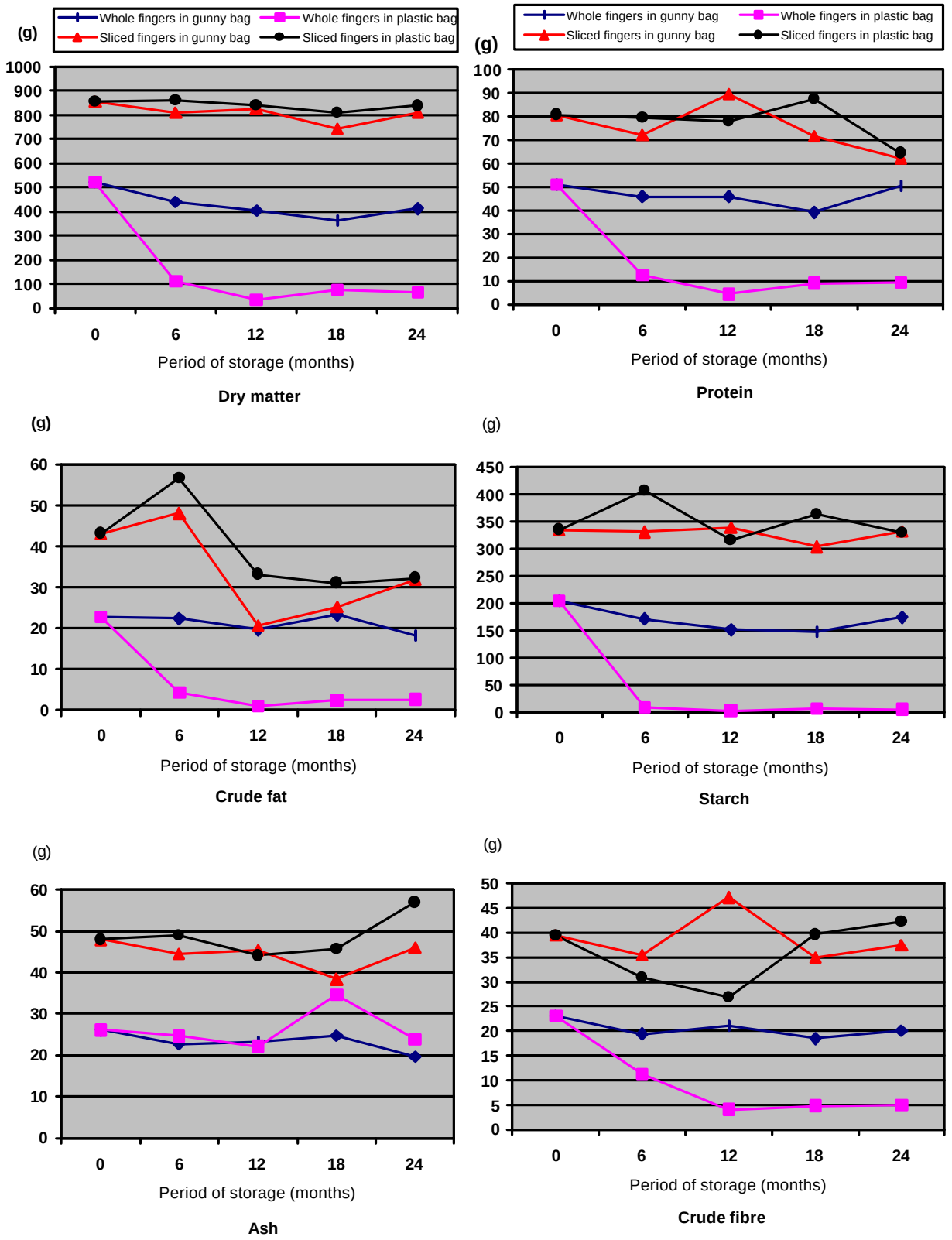

Fig. 22. Biochemical characteristics of *Kaempferia rotunda* rhizome as influenced by periods and methods of storage (actual content on moisture free basis out of 950g)

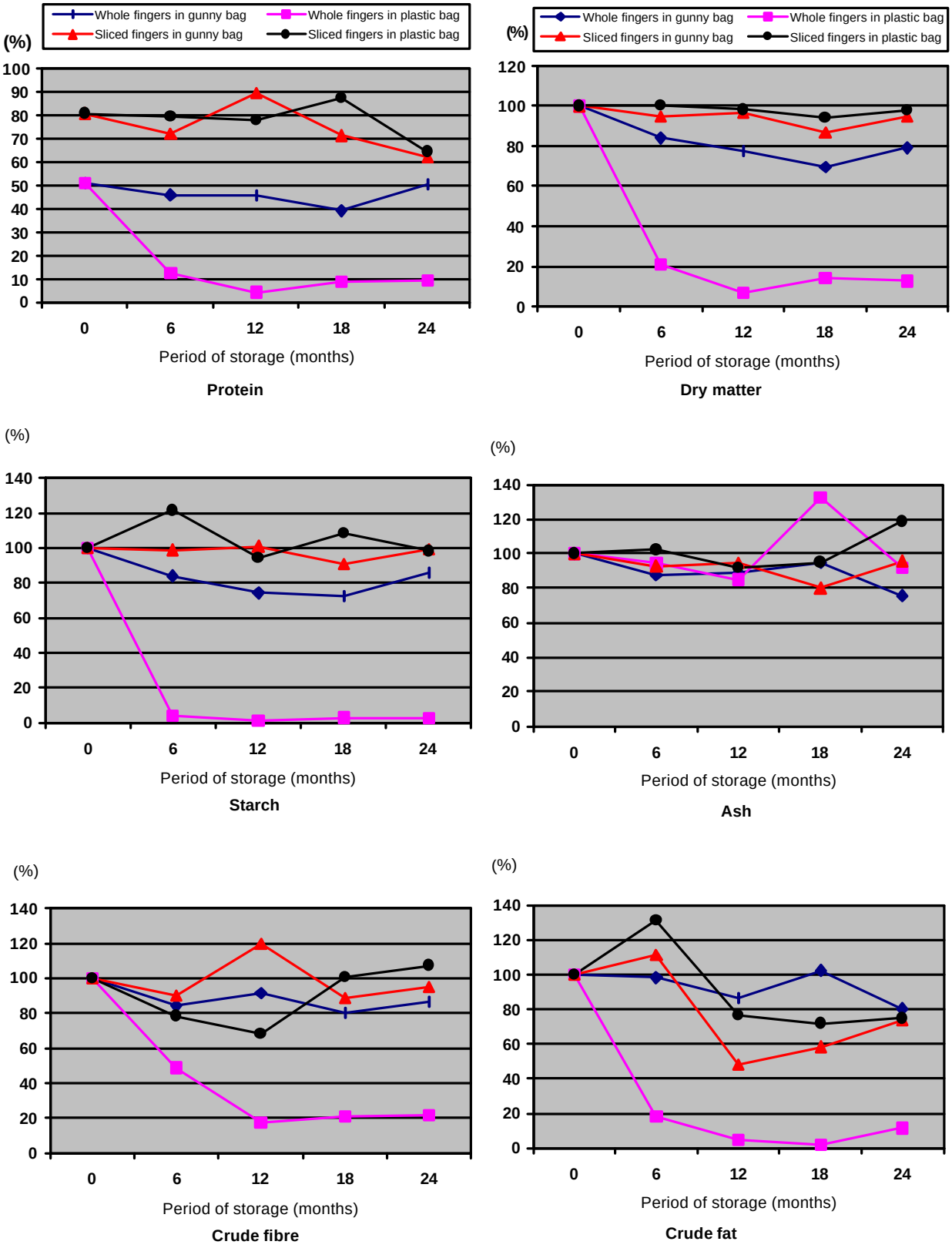

Fig. 23. Biochemical characteristics of *Kaempferia rotunda* rhizome as influenced by periods and methods of storage (percentage of the original content)

viii) Evaluation of lesser known medicinal and aromatic plants of Zingiberaceae family for essential oil and its chemical constituents

Objective:

To evaluate the important species in the genera of alpinia, curcuma and Kaempferia for essential oils and their chemical constituents.

Technical programme

The important species such as *Alpinia calcarata, A. Calcarata, A. allughas*, *Curcuma zedoaria, C. longa, Kaempferia calcarata, K. rotunda*, etc. will be cultivated in small plots. The crop will be harvested at maturity after recording growth and yield observations. The rhizome will be analysed for yield and recovery of essential oils and oleoresins. The gas chromatographic analysis will also be undertaken.

Observations

Growth parameters : Plant height, tillers, leaves

Yield parameters : Rhizome yield, oil recovery characteristics

Gas chromatogram of oil

(a) Growth and yield parameters of Zingiberaceous plants

The field experiment consisted of individual plots of the different Zingiberaceous plants. Growth and yield observations were recorded and the data are presented in table.

Table 18. Growth and yield parameters of Zingiberaceous species

Species	**Spacing (cm)**	**Plant height (cm)**	**Plants/ hill (No.)**	**Leaves/ plant (No.)**	**Fresh rhizome yield (kg/ha)**	**Dry rhizome yield (kg/ha)**
Alpinia spp						
A. calcarata	40x30	70.0	44.0	12.0	19328	3537
A. calcarata	30x30	56.5	12.0	9.0	17872	3753
A. allughas	60x40	190.0	20.0	16.0	22794	4627
Curcuma spp.						
C. longa	30x20	95.8	3.3	15.2	54433	10886
C. zedoaria (Kottackal)	30x20	103.0	3.1	10.3	18762	3758
C. zedoaria (NBPGR)	30x20	88.4	3.1	8.3	20273	4043
C. zedoaria (KAPL)	30x20	97.5	4.4	8.9	19262	3852
C. zedoaria (Peechi)	30x20	98.5	3.2	9.8	18264	3651
C. zedoaria (NRCS)	30x30	110.7	2.2	12.3	56667	10312
C. zedoaria	40x30	124.4	6.8	9.0	21091	4640
C. angustifolia	40x30	119.3	4.8	9.3	32474	6494
Kaempferia spp.						
K. calcarata	30x30	17.0	8.1	3.0	5798	1159
K. rotunda (green)	30x20	27.2	4.8	7.0	12784	3604
K. rotunda (purple)	30x20	37.5	7.2	6.4	13910	4440
K. rotunda (Kottackal)	30x20	47.5	5.7	8.0	10286	2142

K. rotunda (NBPGR)	30x20	29.1	6.3	8.1	8792	1761
K. rotunda (Malappuram)	30x20	25.7	4.5	5.3	5233	1603
Zingiber spp.						
Z. officinale	30x20	73.5	16.4	14.2	23562	4823
Z. zerumbet	40x30	92.7	12.9	10.3	18246	3642
Others						
Costus speciosus	30x20	57.5	3.0	17.0	23074	4216
Maranta arundinacea	30x20	61.5	7.6	7.0	19723	3966
Black ginger	30x20	74.3	4.9	7.3	14204	2832

(b) Nutrient uptake pattern in Zingiberaceous plants

The nutrient contents in the leaf lamina, pseudostem, rhizome and root were determined and the nutrient uptake pattern was studied. The nutrient removal was estimated to be 295:22:54 kg in *Alpinia calcarata,* 93:14:72 kg in *Kaempferia rotunda* and 330:69:97 kg NPK/ha in *Curcuma zedoaria.*

Table 19. Nutrient uptake pattern in Zingiberaceous plants

Plant part	Fresh wt. (g/pl)	Dry wt. (g/pl)	Moisture content (%)	Nutrient content (%) N	P	K	Nutrient uptake (g/plant) N	P	K
Alpinia calcarata (Nutrient removal = 295:22:54 kg NPK/ha)									
Lamina	62.50	20.14	67.78	2.100	0.120	0.318	0.4229	0.0241	0.0690
Root	23.00	4.230	81.63	0.588	0.500	0.374	0.0248	0.0021	0.0158
Rhizome	74.00	16.06	78.30	0.952	0.090	0.154	0.1528	0.0144	0.0247
Pseudostem	48.00	10.98	77.13	10.980	0.120	0.223	0.1014	0.0131	0.0244
Total	207.50	51.40	75.23	1.366	0.1048	0.251	0.7020	0.0539	0.1290
Kaempferia rotunda (Nutrient removal = 93:14:72 kg NPK/ha)									
Lamina	29.50	7.880	73.28	1.148	0.1050	0.529	0.09046	0.00824	0.04168
Root	123.00	9.140	60.26	2.352	0.2400	0.252	0.21497	0.02193	0.02103
Rhizome	180.00	38.56	78.57	0.588	0.1400	0.894	0.22673	0.05398	0.34473
Pseudostem	18.50	3.050	83.51	0.840	0.1050	0.815	0.02562	0.00120	0.02486
Total	251.00	58.63	76.64	0.951	0.1456	0.737	0.55778	0.08539	0.43230
Curcuma zedoaria (Nutrient removal = 330:69:97 kg NPK/ha)									
Lamina	65.50	16.21	75.25	1.400	0.130	0.249	0.227	0.02106	0.0403
Root	110.50	15.94	85.57	0.420	0.120	0.590	0.067	0.01910	0.0940
Rhizome	340.00	93.76	72.42	1.064	0.240	0.262	0.998	0.22500	0.2456
Pseudostem	37.00	6.130	83.43	0.812	0.190	0.131	0.048	0.01160	0.0806
Total	553.00	132.04	76.12	0.991	0.209	0.294	1.319	0.27700	0.3880

(c) Chemical characterisation of Alpinia species

Data on dry matter, essential oil and oleoresin content of rhizome of different *Alpinia* species are given in table 20.

Table 20. Dry matter, essential oil and oleoresin content of *Alpinia spp*.

Plant type	*Dry matter (%)*	*Essential oil (%)*	*Oleoresin (%)*
A. calcarata *type-1**	*21.65*	*0.225*	*2.60*
A. calcarata *type-2*[@]	*20.49*	*0.275*	*3.06*
A. calcarata	*18.30*	*0.075*	*3.56*

** Type-1 is tall* [@] *Type-2 is dwarf*

It was observed that the two types of *Alpinia calcarata* maintained at AMPRS were similar with respect to dry matter content. With regard to essential oil content, type 2 contained higher oil (0.275%) when compared to type 1 (0.225%). As regards oleoresin content also, type 2 was superior (3.06%) to type 1 (2.6%). It is thus summarised that the two types, which are genetically close to each other, exhibit chemically distant characteristics. Type 2 can be adjudged superior as it produced higher yields of essential oil and oleoresin.

The two species of *Alpinia* viz. *A. calcarata* and *A. calcarata* manifested characteristic differences in quality parameters. *A. calcarata* recorded lower dry matter content (18.3%) than *A. calcarata* (20.49 – 21.65%). The essential oil content of this species (0.075%) was much lower than that recorded by the types of *A. calcarata* (0.225 – 0.275%). However, *A. calcarata* exhibited superiority over the other species in the matter of oleoresin content (3.56%). It is thus inferred that in comparison to *A. calcarata*, *A. calcarata* is a poor source of essential oil whereas it is a better source of oleoresin.

The essential oils of the selected plants were subjected to gas chromatographic analysis. Components were identified based on coincidence of retention time with authentic standards.

The relative abundance of four marker compounds viz. α-terpeniol, methyl cinnamate, ethyl cinnamate and cineole in the essential oil of Alpinia spp *are presented in the table 21 and figure 24.*

Table 21. Chemical composition of essential oil of Alpinia spp.

Sample	*Relative abundance (%)*			
	α-Terpeniol	*Methyl cinnamate*	*Ethyl cinnamate*	*Cineole*
A. calcarata *type-1*	*3.81*	*3.93*	--	*34.94*
A. calcarata *type-2*	*4.23*	*7.44*	--	*13.53*
Alpinia calcarata	*3.12*	*6.74*	*21.82*	--

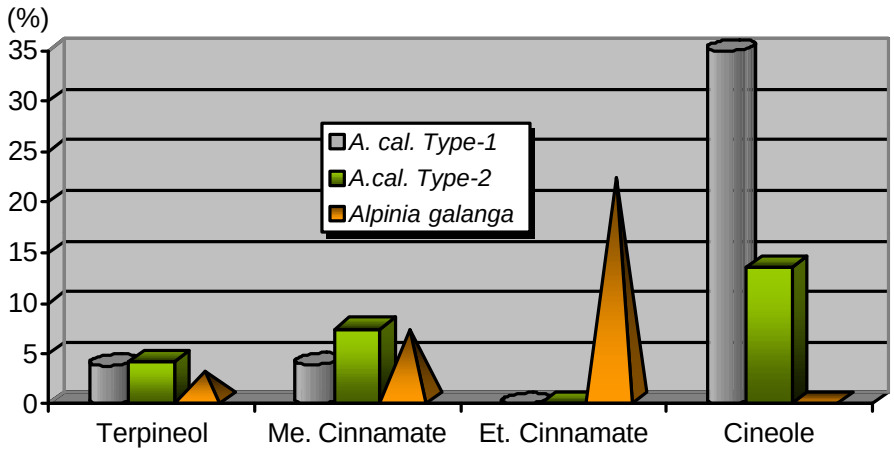

Fig.24. Chemical composition of essential oil of Alpinia species

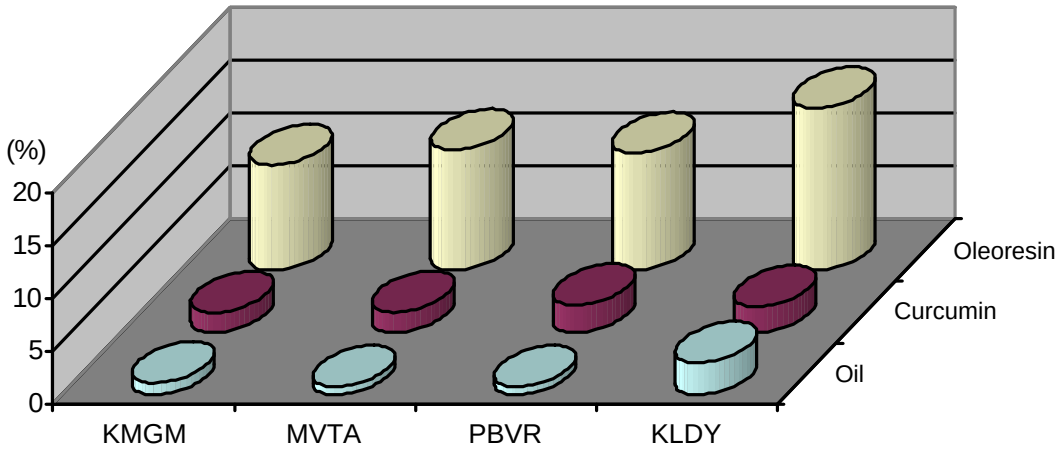

Fig. 25. Chemical composition of market samples of Kasthurimanjal

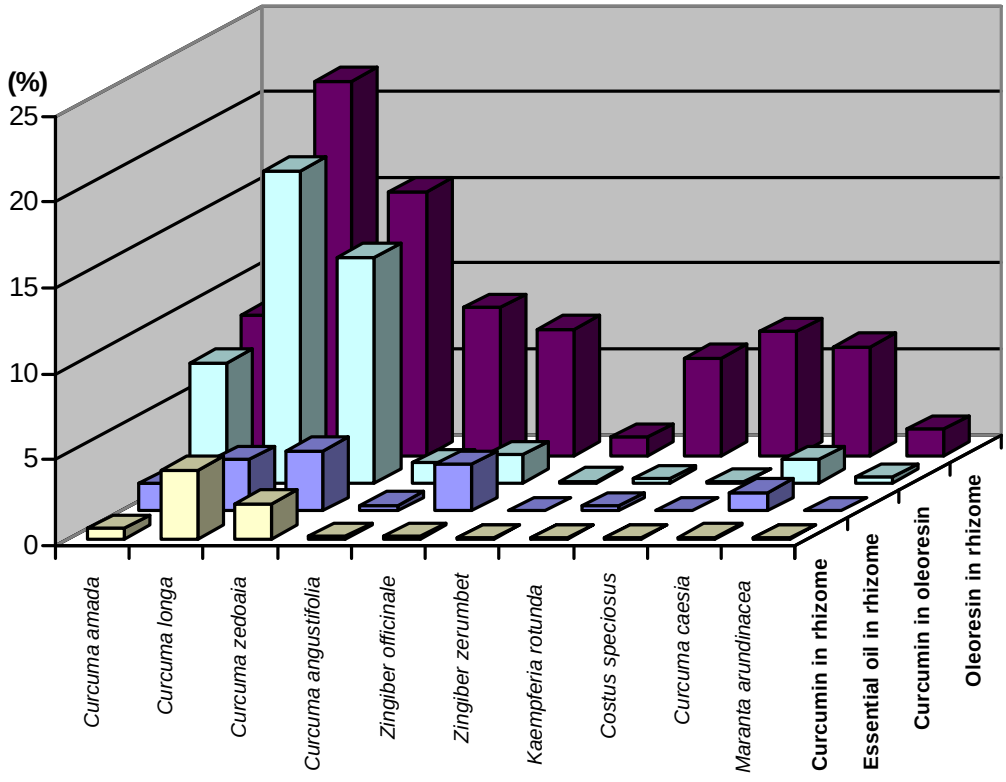

Fig.26. Chemical properties of rhizomes of different Zingiberaceous plants

It was found that in terms of chemical composition of the essential oil, the two types of Alpinia calcarata *exhibited similarity. In the oil of both the types, cineole was the most abundant component. However, significant difference existed between them in the content of methyl cinnamate and also cineole. Type-1 had a high content (34.94%) of cineole when compared to type-2 (13.53%). The reverse was true in the case of methyl cinnamate. Methyl cinnamate content of type-2 (7.44%) was about double that in type-1 (3.81%). A characteristic difference was noticeable in the essential oil of* A. calcarata. *The major constituent in its oil was ethyl cinnamate (21.82%) and this compound was not detected in the oil of* A. calcarata.

(d) Quality variations in the market samples of Alpinia species

The rhizome is the economic part of Alpinia. *In order to ascertain the variation in the quality of Alpinia rhizomes available in the market, samples of rhizomes were collected from various markets in the Ernakulam district and subjected to physical examination and quality studies. The results of the studies are presented in the table 22.*

Table 22 . Physical characteristics of market samples of Alpinia

Sample ID.	*Internodal length (mm)*	*Diameter (cm)*	*Colour*
Angamaly	*7.0*	*13.0*	*Light brown with reddish tinge*
Aluva	*7.0*	*10.5*	*Brown*
Kalady	*8.5*	*13.5*	*Light brown*
Perumbavoor	*6.5*	*10.5*	*Dark brown*
Kothamangalam	*7.5*	*13.8*	*Brown*

The samples of Alpinia rhizomes collected from various markets differed morphologically with respect to internodal length, diameter and colour. However the variations in these characters were not very large.

Data on the quality parameters of the samples are presented in the table 23.

Table 23. Chemical characteristics of market samples of Alpinia

Sample ID.	*Essential oil content (%)*	*Chemical composition of essential oil (%)*				*Oleoresin content (%)*
		α-Terpeniol	*Methyl cinnamate*	*Ethyl cinnamate*	*Cineole*	
Kothamangalam	*0.40*	*3.81*	*3.93*	--	*40.17*	*4.60*
Angamali	*0.30*	*4.23*	*7.44*	*25.63*	*13.53*	*7.78*
Kalady	*0.50*	*3.02*	*6.19*	*20.06*	--	*6.01*
Aluva	*0.44*	*NA*	*NA*	*NA*	*NA*	*5.01*
Perumbavoor	*0.36*	*NA*	*NA*	*NA*	*NA*	*5.35*

NA = Not analysed

Large variations were observed in the quality parameters studied. The essential oil content of the rhizomes ranged from 0.30% to 0.50%. Noticeable differences were

observed in the case of oleoresin content also (4.6 to 7.78%). In the matter of chemical components in the essential oil, Kothamangalam and Angamali samples were more or less similar. However, the former was characterised by a very high content (40.17%) of cineole whereas the latter had a distinctly high level of methyl cinnamate (7.44%). The essential oil in samples collected from Kalady was characterised by the high level of ethyl cinnamate (21.82%) typical of oil of A. calcarata. *Comparing the data on essential oil and oleoresin contents and also based on the nature and composition of essential oil in table 23, it can be inferred that the material collected from Kalady market is not true* Alpinia calcarata, *but more similar to* Alpinia calcarata.

(e) Quality variations in the market samples of Kasturimanjal (Curcuma zedoaria)

Physical characteristics of market samples of *Curcuma zedoaria* were studied in detail. The data obtained are depicted in table 24. The data on the type of rhizome, length, colour, shape and hardness indicated that market samples obtained from Perumbavoor, Kothamangalam and Muvattupuzha were almost similar. Kalady sample differed drastically in the above physical characters from those collected from the other locations.

Table 24: Physical characteristics of market samples of *Kasturimanjal*

Place	**Sample**	***Length (range)* cm**	**Colour**	**Shape**	**Physical character**
Kothamangalam	Primary rhizome	4.5-6.7	Light yellow	Elongated, conical, more in length than in diameter	Hard, do not break easily
Muvattupuzha	Mixture of primary and secondary rhizomes	4.2-6.0	dark yellow	Elongated, nearly cylindrical, slightly tapering end	Do not break easily
Perumbavoor	Primary rhizome predominantly	4.2-5.3	dark yellow	Top shaped, tapering end, marked with internodes	Do not break easily
Kalady	Sliced samples	7.0	brown outside		Not so hard as other samples

The essential oils of *C. zedoaria* of the market samples collected from Perumbavoor, Muvattupuzha, Kothamangalam and Kalady were analysed by GLC. The chromatogram of the oils of samples of Perumbavoor, Muvattupuzha and Kothamangalam were similar. Their essential oil yield was 0.75-1.1% and oleoresin content was 9.94-11.38%. The oil and oleoresin contents of Kalady sample were substantially higher when compared to those of the other three localities.

Table.25. Chemical properties of the market samples of *Kasthurimanjal*

Sl. No.	Location	Oil content of rhizome (%)	Oleoresin content of rhizome (%)	Curcumin content of rhizome (%)	Curcumin content of oleoresin(%)
1	Kothamangalam	1.10	9.94	1.88	18.91
2	Muvattupuzha	0.75	11.38	1.92	16.84
3	Perumbavoor	0.75	11.08	2.60	23.46
4	Kalady	3.00	15.34	2.43	15.84

Though the major components of the essential oil could not be identified, the major component in Kalady samples, which constituted more than 50% obtained at retention time 14.96 min, was absent in other samples. Likewise, the major constituent (45.55%) obtained at retention time 19.84 min. in the oils from other locations was absent in Kalady sample. The content of next major constituent, methoxy ethyl cinnamate ranged from 13.5-16.8% in Perumbavoor, Muvattupuzha and Kothamangalam samples whereas, it was only 2.32% in Kalady sample. Cineole, linalool and limonene were detected in small amounts in Perumbavoor, Kothamangalam and Muvattupuzha samples while they were detected only in traces in Kalady samples.

Data on the physical and chemical characteristics of the market samples indicated that a large variation exists in the quality of *Curcuma zedoaria* available in the crude drug market.

A preliminary study on the quality of the crude drugs of *rasna* and *vanaharidra* collected from the local market showed that there is high variability in the quality among the few samples tested. The variability could be unimaginable if the entire crude drug market in the state was considered. This indicates that the market has no control over the quality of drugs as the supply is mostly from the wild. This means that the quality of end products cannot be maintained which may boomerang the entire health care system in the long run. Under the circumstances cultivation of these medicinal plants is inevitable for sustaining the quality.

(g) Comparative evaluation of the essential oil and oleoresin contents of Zingiberaceous species.

Four *Curcurma* species , viz. *C. amada (mangainchi), C. longa (manjal), C. zedoaria (manjakoova), C. angustifolia (vellakoova),* two *Zingiber* species, viz. *Z. officinale (inchi), Z. zerumbet (ooralichembu), Kaempferia rotunda (chenganeerkizangu), Curcurma caesia* (black ginger), *Maranta arundanacea (kochikoova)* and *Costus speciosus (channakoova)* were evaluated for essential oil and oleoresin.

The maximum essential oil content was reported on *C. zedoaria* (3.5%), followed by *C. longa* and *Z. officinale*. *Z. zerumbet*, *Costus specoisa* and *Maranda arundunaecea* did not have any oil. Among the species which yielded oil, the lowest content was (0.026%) recorded in *Kaempferia rotunda* followed by *C. angustifolia*.

The GLC analysis of the oils of the above species showed high variability. A marker chemical constituent common to the family *Zingiberaceae* could not be identified from the chromatographic analysis.

Table.26. Chemical composition of various *Zingiberacious* plants

Sl. No.	Species	Essential oil in rhizome (%)	Oleoresin in rhizome (%)	Curcumin in rhizome (%)	Curcumin in oleoresin (%)
1	*Curcuma amada (Mangainchi)*	1.57	8.18	0.58	7.04
2	*Curcuma longa (Turmeric)*	2.97	21.82	3.97	18.20
3	*Curcuma zedoaia (Manjakoova)*	3.50	15.36	2.02	13.15
4	*Curcuma angustifolia (Vellakoova)*	0.32	8.62	0.10	1.20
5	*Zingiber officinale (Inchi)*	2.69	7.36	0.12	1.67
6	*Zingiber zerumbet (Ooralichembu)*	0.00	1.06	0.001	0.107
7	*Kaempferia rotunda (Chenganeerkizengu)*	0.26	5.68	0.01	0.24
8	*Costus speciosus (Kolakozhithandu)*	0.00	7.20	0.003	0.04
9	*Curcuma caesia (Black ginger)*	1.06	6.32	0.086	1.36
10	*Maranta arundinacea (Kochikoova)*	0.00	1.54	0.005	0.326

Oleoresin content of the above species was estimated and the values ranged from 1.16 – 19.28%. Maximum oleoresin content was recorded in *C. longa* followed *by Z. officianale* (18.4%) and *C. zedoaria* (15.36%). *C. angustifolia* and *C. amada* had similar contents. Though no oil was recorded in C*ostus speciosus*, it had about 7.2% of oleoresin. The other non-oil containing species like *M. arundinacea* and *Z. zerumbet* had very low oleoresin contents, 1.54% and 1.16%, respectively. These two plants are largely used as a source of easily digestible starch.

Curcumin contents in the rhizome and oleoresin were determined in all the plants. Curcumin content of rhizome was maximum in turmeric (3.97%). C. *amada, C. angustifolia* and *Z. officinale* had curcumin contents in the range of 0.10% to 0.58%. It was negligible in all other species.

Table 27: Chemical constituents identified in the essential oils with GLC

Sl. No	**Name of Plant**	**Name of the compound**	**Content (%)**
1.	*Curcuma amada (Mangainchi)*		
2.	*Curcuma longa (Turmeric)*		
3.	*Curcuma zedoaia (Manjakoova)*		
4	*Curcuma angustifolia (Vellakoova)*		
5.	*Zingiber officinale (Inchi)*	1.linalool/limonine/cineole 2. ethyl cinnamate	7.3 10.17
6.	*Zingiber zerumbet (Ooralichembu)*		
7.	*Kaempferia rotunda (Chenganeerkizengu)*		
8.	*Costus speciosus (channakoova)*		
9.	*Curcuma caesia (Black ginger)*	1. cineole/limonine/ linalool 2. methoxy ethyl cinnamate	0.19 11.58
10.	*Maranta arundinacea (Kochikoova)*		

Curcumin content in oleoresin was 21.82% in *C. longa*; 5.68 – 8.62% in *K. rotunda, C. angustifolia, C. amada, C. speciosus* and ginger. *Z. zerumbet and M. arundinacea* had less than 2% curcumin in their oleoresin.

Zingiberaceae plants, in general, have characteristic aroma and flavour that are attributed to their essential oil and oleoresin contents. Wide variability exists in the chemical constitution of the essential oils of these species. No common chemical marker could be identified for the family *Zingiberaceae*.

12. Summary

The salient findings of study are the following.

In *chittaratha,* harvesting after 42 months of planting gives the maximum rhizome and its oil yields, after 18 months gives highest shoot and its oil yields and after 39 months gives highest root and its oil yields under Odakkali conditions.

The best rhizome yield and oil yield are realized at 40 x 30 cm spacing with the application of FYM at 20 t/ha/year or NPK at 100:50:50 kg/ha/year. Application of biofertilizer at 10 kg/ha or cowpea green manuring *insitu* resulted in significantly superior yields.

Kasthurimanjal is highly adaptable to a wide range of spacings, producing similar yields by adjusting the number of plants/hill. Concerning manuring, FYM application at 30 t/ha is the best followed by NPK at 100:50:50 kg/ha.

In *Kaempferia rotunda* Fitting the quadratic function between spacing and yield of rhizome showed that the optimum spacing for maximum yield is 18.64cm (nearly 25 x 15 cm) which translates to a plant population of 28.78 plants/m2 or a seed rate of 3000-3500kg/ha with a seed size of 10-15 g including the weight of root tubers which form an integral part of the seed.

Mulching had the maximum pronounced effect on the yield of *Kaempferia rotunda* which was followed by the application of compost, FYM and vermicompost. Application of vermicompost and FYM increased the P content of the rhizomes.

The growth and yield of *Kaempferia rotunda* were not significantly influenced by fertilizer treatments. Higher dose of fertilizer application resulted in the build up of available K status in the soil.

The crop removal of nutrients was estimated to be 295:22:54 kg in *Alpinia calcarata,* 93:14:72 kg in *Kaempferia rotunda* and 330:69:97 kg NPK/ha in *Curcuma zedoaria.*

13. Results which can be exploited in pilot or field scale

Ad-hoc package of practices recommendations were developed for

Alpinia calcarata - Chittaratha

Kaempferia rotunda – Chenganeerkizangu
Curcuma zedoaria – Kasthurimanjal

14. Papers/Articles prepared/published:

Joy, P. P, Thomas J., Mathew, S., and Skaria, B. P. 1998. *Zingiberaceous Medicinal and Aromatic Plants*. Aromatic and Medicinal Plants Research Station, Odakkali, Asamannoor PO, Kerala, India.

Thomas J., Joy P. P., Samuel Mathew, Baby P. Skaria. 1998. Indigenous less-known essential oils - A perspective. *PAFAI Journal*, **20**(1):13-20.

Paper presented at 20th Zonal Research and Extension Advisory Committee meeting held on 29th May 1998 at RARS, Pattambi

Yield and quality of *Kaempferia rotunda* under organic farming.

15. Suggestions for future lines of research

The following suggestions are made for future research work.

- Extensive survey of the natural habitat for assessing the distribution pattern and genetic variability
- Habitat analysis and domestication
- Establishment of germplasm, description, cataloguing and characterization at molecular level (DNA finger printing)
- Crop improvement to evolve superior varieties
- Development of organic farming (green technology) including the use of biofertilizers.
- Standardisation of post-harvest handling and storage techniques
- Modernisation of drugs manufacturing processes and clinical evaluation. Possibility of developing intermediary products for saving bulk handling of raw drugs and efficient preservation
- Extensive market survey, assessment of source of supply, details of handling and storage and quality evaluation
- Chemical characterisation including identification of chemical markers.

16. Signature

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