EVALUATION OF KACHOLAM (*Kaempferia galanga* L.) TYPES FOR MORPHOLOGICAL VARIABILITY AND YIELD

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Botany
COLLEGE OF HORTICULTURE
Vellanikkara - Thrissur
Kerala.

1994

DECLARATION

I hereby declare that this thesis entitled "**Evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield**" is a bonafide record of work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled "**Evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield**" is a record of research work done independently by **Miss.Latha, E.V.** under my guidance and supervision and it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of **Miss.Latha, E.V.** a candidate for the degree of **Master of Science in Agriculture** with major in **Plant Breeding and Genetics**, agree that the thesis entitled "**Evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield**" may be submitted by Miss.Latha, E.V., in partial fulfilment of the requirement for the degree.

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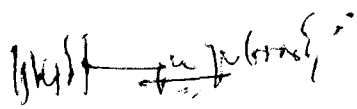

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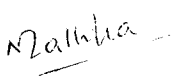

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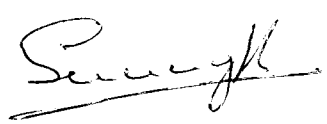

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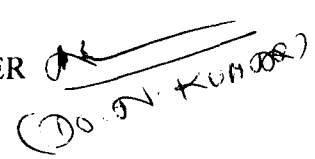

ACKNOWLEDGEMENT

It is my great pleasure to express the deep sense of gratitude and indebtedness to **Dr.T.V.Viswanathan**, Associate Professor, AICRP on M & AP, College of Horticulture, Vellanikkara and the Chairman of my advisory committee for his valuable and erudite guidance, perpetual support and constructive criticism throughout the period of the investigation and in the preparation of this manuscript. I am deeply obliged to him for kind, affectionate and valuable comments and constant inspiration received from him during the period under his guidance.

I wish to acknowledge my heartfelt thanks to **Dr.K.M.N.Namboodiri**, Professor and Head, Department of Agricultural Botany, College of Horticulture, Vellanikkara for his affectionate and timely advice as a member of my advisory committee.

I am deeply obliged to **Dr.V.K.Mallika**, Associate Professor of Botany and a member of my advisory committee for her generous help and encouragement.

I take it as my privilege to express and place on record my heartfelt gratitude to **Sri.K.L.Sunny**, Associate Professor, Department of Agricultural Statistics for his advice and help in the statistical analysis of the data and in the subsequent interpretation. The help rendered by **Smt.Joicy T. John** is also thankfully acknowledged.

My profound sense of gratitude is also due to **Dr.M.A.Salam**, Associate Professor of Agronomy and the Professor incharge of Instructional Farm, Vellanikkara during the period of my investigation for providing necessary facilities.

I wish to acknowledge, Kerala Forest Research Institute, Peechi especially **Dr.Mohammed Ali**, Senior Scientist, Plant Pathology division for providing necessary facilities and whole hearted co-operation in utilizing the leaf area meter available with them.

I take this opportunity to thank **Dr.A.Augustin**, Assistant Professor, AICRP on M & AP for his valuable help in carrying out the chemical analysis.

I wish to record my deep sense of indebtedness to **Dr.J.Thomas**, Associate Professor and Head, Aromatic and Medicinal Plants Research Station, Odakkali for providing facilities and extending a helping hand in the gas chromatographic analysis of oil. No word can truly express my deep sense of gratitude to **Dr.Jim Jose**, Research Associate, AMPRS, Odakkali for the keen interest, affectionate and generous help rendered by him during the analysis.

My sincere thanks and gratitude are due to **Sri.V.K.Raju**, Associate Professor and Head i/c, Department of Processing Technology in taking neat photographs.

My thanks are also due to each and every member of the All India Co-ordinated Research Project on Medicinal and Aromatic Plants and the Department of Agricultural Botany for extending all possible help in the proper conduct of the

programme. The help and co-operation received from all the labourers are thankfully acknowledged.

My sincere thanks are also due to **Smt.Malathy** and **Sri.Joy** for the neat typing and prompt service.

I am extremely grateful to all my friends and collegues for the co-operation and assistance rendered to me throughout the period of my study. I take this opportunity to thank each and every one of them especially **Suja** and **Rekha**. I owe a lot to **Salu**, for being a constant source of moral support and inspiration which helped me much in the timely completion of this work.

My reverential thanks are due to my family members for their sustained interest and co-operation in the successful completion of this work.

The award of ICAR Junior Fellowship is also gratefully acknowledged.

Above all I bow my head before the God Almighty who blessed me with health, strength and confidence always and this small venture is no exception.

LATHA, E.V.

In memory of
my grand parents

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Introduction

INTRODUCTION

Medicines and perfumes have a great potential in the international trade. Medicinal plants form the main base for the manufacture of drugs of indian systems of medicine and homoeopathy. There is no plant, our sages say, devoid of medicinal value. It has been reported that some Indian community or other use as many as 7000 out of 15,000 flowering plants that occur in India, for medicinal purposes. Cultivation of medicinal plants offers considerable scope for rural employment and export for foreign exchange earnings. India has a vast geographical area with high production potential and varied agroclimatic conditions, and we possess many useful and economic species of medicinal plants still remaining unutilised and unimproved. Kacholam (*Kaempferia galanga* L.) is one among them in which not much research work and improvement has been done.

Kaempferia galanga L. is a high value medicinal and aromatic oil yielding plant belonging to the family Zingiberaceae and is widely distributed in the tropics and subtropics of Asia and Africa. The potential of the crop as a medicinal plant is very much exploited in Malasia, Thailand and Philippines. It is an attractive rhizomatous spice plant used in various culinary applications. The economic part of the plant is the underground stem, the rhizome which finds an important place in indigenous medicines as stimulant, expectorant, diuretic and carminative. It promotes or improves digestion and digestive powers. Powdered rhizome mixed with honey is administered against coughs. Decoction of the rhizome is prescribed for dyspepsia, headache, rheumatism and malaria. It cures skin or cutaneous disorders, piles, oedema, fever, epilepsy, splenic disorders, asthma and disease caused by mobidity of 'vada' and 'kapha'. Boiled in oil the rhizomes are applied externally to

remove nasal obstructions. It is used in hair washes because of its antidandruff property. The rhizome is also used for curing inflammatory wounds. 'Kachoradi thailam', 'Kachuradi vattu' and 'Kachuradi choornam' are some of the ayurvedic preparations of Kacholam. It is an ingredient of some of the general tonics like 'Chavanaprasam' and 'Dasamoolarishtam'. The juice of the plant is also an ingredient for certain tonics. Antifungal and larvicidal properties are also reported for this crop. Recently some anticancerous principles have also been identified from Japan. The Pharmaceutical Corporation Kerala Ltd. (Oushadi) alone need 7.5 tonnes of dried rhizome per year for the preparation ayurvedic medicines. The projected requirement of dried rhizome for the major ayurvedic medicine manufacturing industries is 145 tonnes per year. Steam distillation of rhizome yield 2.4 - 4 per cent volatile oil. This oil is utilized in the manufacture of perfumes and curry flavourings. Recently enquiry for purchase of oil has come from France and U.K. for the manufacture of high quality perfumes (Personal communication with Vijaya Deo, Deo Aromatices, Alwaye). Taking into consideration the present market price of dried rhizomes (Rs.65/kg), the cost of 1 kg of oil will come around Rs.8000 at the rate of 1 per cent output on bulk distillation.

Kacholam is suited for cultivation in Kerala and the humid tropical climate of Kerala is suited for its growth. The crop requires simple cultivation and management practices. But no varieties of the crop have been identified in Kerala so far. At present only local cultivars are available with the farmers for cultivation.

Crop improvement programme in Kacholam has not been attempted so far in a serious manner. The crop is propagated by vegetative means and the problem of non-seed set is a major constraint for improvement through conventional methods of breeding.

For any crop improvement programme the first and foremost requirement is a proper assessment of the variability present in the genetic stock. The variability present in the existing types can be exploited by selection. Since the crop is vegetatively propagated the selected types can be maintained as such, and can be multiplied on a large scale. Yield is a dependent factor and it is contributed by a number of other characters. If the yield contributing characters are identified, it is of great value to work out a selection criteria which will contribute much to the crop improvement programme.

The growth pattern of Kacholam is almost similar to that of other crops of Zingiberaceae like ginger and turmeric which perform well as intercrop. So it will be worthwhile to study the performance of the crop under coconut garden so that the crop can be recommended for large scale cultivation in Kerala homesteads under coconut based cropping system.

With these views in mind the present investigations were undertaken to fulfil the following objectives:

To study the extent of morphological variability and yield contributing characters in the local collections of *Kaempferia galanga* L.

To identify types with high yield potential for large scale cultivation.

To propose a selection criteria for *K. galanga* L. genotypes.

To compare the performance of the types under open and as intercrop in coconut garden.

Review of Literature

REVIEW OF LITERATURE

2.1 Origin and Distribution

The genus *Kaempferia* is supposed to have been originated in South East Asia, probably in Burma, where it is considered to have been grown as an evergreen in shady forest conditions and from there, it appears to have emigrated across most of the tropical Asia, and right across Africa (Holtum, 1950). The family Zingiberaceae is chiefly Indo-Malayan in distribution (Willis, 1960). According to Synge (1956) the genus *Kaempferia* is widely distributed in the tropics and subtropics of Asia and Africa. *Kaempferia galanga* L. is distributed throughout the plains of India (Hooker, 1892, Aiyer and Kolammal, 1964). Gamble (1926) reported that it is distributed at low elevations along the west coast. It has been recorded as occurring in Bengal, Deccan, S. Konkan, Kerala etc. (Aiyer and Kolammal, 1964).

2.2 Economic importance of the crop

Medicinal properties of Kacholam have been described by many workers. Even in 17th century Rheede (1678-1703) in Hortus Malabaricus described the morphology of the crop and its medicinal value for curing asthma (Appendix IV). The herb is used as a flavouring for rice. Rhizome and leaves are employed as a perfume in hair washes, powders and other cosmetics. They are used for protecting cloths against insects, and are eaten along with betel and arecanuts as a masticatory (Burkill, 1935 and Quisumbing, 1951).

The rhizomes are considered stimulating, expectorant, carminative and diuretic. They are used in the preparations of gargles. They are administered with honey in coughs and pectoral affections. In Philippines, a decoction of the rhizome is used for dyspepsia, headache and malaria. Boiled in oil, the rhizomes are applied externally to remove nasal obstructions. Roasted rhizomes are applied hot in rheumatism and for hastening the ripening of inflammatory tumours. They are also used as a wash in dandruff and for relieving irritation produced by stinging caterpillars. Mixed with oil, the rhizomes are used as a cicatrizant. In Malaya they are used for chills in elephants. The juice of the plant is an ingredient of some tonic preparations. The leaves are used in lotions and poultices for sore eyes, sore throat, swellings, rheumatism and fevers (Kirthikar & Basu, 1935; Burkill, 1935; Brown, 1941 and Quisumbing, 1951). It is also reported to promote or improve digestion, digestive power and cures or allays skin or cutaneous diseases, piles, oedema, epilepsy, splenic disorders, difficult breathing (Asthama) and diseases caused by the mobidity of 'vada' and 'kapha' (Aiyer and Kolammal, 1964). It removes bad odour of the mouth. Recently larvicidal and anticancerous principles have been obtained from the rhizome extract of *Kaempferia galanga* L. (Kosuge *et al.*, 1985; Kiuchi *et al.*, 1988). The hot water extract of *Kaempferia* rhizomes showed strong larvicidal activity against the larvae of dog round worm *Toxocara canis* (Kiuchi *et al.*, 1988). Mangaly and Sabu (1991) reported the use of *K. galanga* as an ingredient of ayurvedic preparations for skin disorders, rheumatism etc. Toxicity against neonate larvae of *Spodoptera littoralis* was also reported in a contact residual bioassay (Pandit *et al.*, 1993).

2.3 Taxonomy and Cytogenetics

Kaempferia galanga L. is a monocotyledonous plant, belonging to the

family Zingiberaceae of the order Zingiberales. It comes under the series Epigynae (Bentham and Hooker, 1894). Schumann (1904) divided the family Zingiberaceae into two subfamilies viz., Zingiberoideae and Costoideae. The zingiberoideae is further divided into three tribes viz., Globeae, Hedychiae and Zingibereae. The genus *kaempferia* comes under the tribe Hedychiae. There are four sub-genera under the genus *Kaempferia* namely Sincorus, Protanthium, Monolophus and Stachyanthesis (Hooker, 1892). The subgenera Sincorus includes 11 species other than *K. galanga* L. They are *Kaempferia marginata, K. ungustifolia, K. ovalifolia, K. speciosa, K. pandurata, K. prainiana, K. roscoeana, K. parviflora, K. involucrata, K. andersoni* and *K. cocinna.*

Raghavan and Venkatasubhan (1943) studied the cytology of 4 species of *Kaempferia* viz. *K. gibsonii, K. gilbertii, K. rotunda* L. and *K. galanga* L. and reported that they showed a regular polyploid series having chromosome number 24, 36, 54 and 54 respectively. Since the chromosome numbers are all multiples of 6, they ascertained '6' as the basic chromosome number for the genus. They reported that the speciation in this family is due to polyploidy, aneuploidy and structural changes. Raghavan and Arora (1958) assigned a chromosome number of 2n = 54 for *K. galanga* L. Chakravorthi (1948) assigned a chromosome number of 2n = 33 for *K. rotunda* L. and *K. gilbertii* and considered them as triploids. He again found chromosome number of 2n = 28 for *K. cienkowskya* and concluded that the genus *Kaempferia* had all the probabilities to have two distinct Polyploid series, based on x = 11 and x = 14. Sharma and Bhattacharya (1959) reported a chromosome number of 22 for *K. galanga* L. Ramachandran (1969) had the same opinion as Raghavan and Venkatasubhan (1943). According to him *K. galanga* L. is presumably an aneuploid pentaploid. Mahanty (1970) reported that the 2n number of *K. anguistifolia* is 22 and that of *K. brachystemon* is 26. A chromosome number of 2n = 22 had

been assigned for the species *K. elegans* and *K. rosea*. For *K. gilbertii* and *K. rotunda* L. he reported a chromosome number of 2n = 33. Beltran and Kam (1984) found that Asiatic Kaempferias have a basic chromosome number of X = 11 while African ones have X = 14. Rekha (1993) reported that the somatic chromosome number of *K. galanga* L. is 55. She recognised the species as a pentaploid with x = 11.

2.4 Morphology and Floral biology

Kaempferia galanga L. is an annual herb grown for its aromatic rhizome. According to Hooker (1892) *Kaempferia* is a plant with tuberous root stock. Leaves are three to six inches long, spreading flat on the ground, deep green in colour with deltoid tip. Petioles are short and channelled. According to Kirthikar and Basu (1935) the plant is a stem less herb with tuberous aromatic root stock, which possess fleshy, cylindric and nonaromatic root fibres. Leaves are few in number spreading horizontally, lying flat on the surface of the ground and having a length of 6.3 - 12.5 cm and a breadth of 4.5 - 9.0 cm. They are deep green, thin, 10-12 ribbed, rotund, ovoid, deltoid and accuminate. Leaf margins are not thickened or coloured.

Aiyer and Kolammal (1964) described the leaves of Kacholam as deep green orbicular, sub orbicular, orbiculate-ovate or ovate-cordate, with thin membraneous blade, 6.2 to 15 cm long and 5-15 cm wide, smooth above deltoid-acuminate at tip some what woody towards the base and 10-12 ribbed with the margin wavy but not thickened or coloured. Each leaf has a short channeled petiole. They reported vertically oriented tuberous rootstock for Kacholam. It is having several smaller secondary tubers and a cluster of roots most of which are long and narrow white, a few are, shorter and tuberous at their tips. The main tuber is conical in form wider

below, narrower at the tip and distinctly marked with a number of transverse or horizontal or annular scars of scale leaves spaced 3 to 5 mm apart. Directly attached to the nodes are a limited number of smaller tubers which are also vertically oriented. Surface of the tubers are fairly smooth and greyish or light brown colour. Drury (1978) described *K. galanga* L. as a plant with biennial tuberous rhizome, stemless stalked leaves, spreading flat on the surface of the earth which are either ovate, rotund or cordate in shape. Leaf margins are membraneous and wavy.

In *Kaempferia* the inflorescence is reported to be a short scape (Gamble, 1926). The floral morphology has been described by a few workers (Hooker, 1892; Kirthikar and Basu, 1935 and Drury, 1978). According to them 6-12 flowers are produced from an inflorescence. The inflorescence is situated at the centre of the plant between the leaves. Flowers are fugacious, fragrant and open successively. They possess three lanceolate bracts which are green and short. Calyx is having the same length as that of the outer bracts. Coralla tube is 2.5 cm long, lobes are pure white in colour, lanceolate a little shorter than the tube. Both the essential whorls are trimerous. There are two lateral staminodes which are cuneate, obovate and are situated at the base of the ovary and the stigma is filiform. Aiyer and Kolammal (1964) described the androecium with fertile stamen and broad petaloid staminodes. Fertile stamen is with a short arcuate keeled filament expanded above the mutiocous anther into a petaloid quadrate, two cleft or forked crest or appendage. Anthers are two celled and pistil is tricarpellary. They described ovule as inferior 3 celled with many horizontal anatropous ovules on axile placentation within each chamber. Style is long filiform ending in a turbinate stigma. Hooker (1892), Gamble (1926) and Kirthikar and Basu (1935) described the floral morphology of *K. rotunda* as follows. Flowers are born on radical scapes 1 cm long with spreading linear petals nearly as long as the tube. Staminodes are oblong acute white in colour and having a length of

about 3.8 - 5.0 cm, lip is lilac or reddish in colour and is bifid. Anther crest is deeply bifid and anther lobes are lanceolate.

Rajagopalan (1983) described the flowering behaviour in *K.galanga* L. He observed that flowering started in June and ended in September and the peak occurred during July-August. It was also reported that flowers were produced directly from the rhizome and they opened in succession.

2.5 Propagation and Cultivation aspects

Kacholam is propagated vegetatively using rhizome. The plant produces both mother and finger rhizomes. Gopalaswamiengar (1951) reported that propagation of *Kaempferia* is by the division of the rhizome and it can be potted in light soil and liquid manure promotes its growth. The Aromatic and Medicinal Plants Research Station, Odakkali, Kerala has undertaken a study to find out the response of *K. galanga* L. to different spacing and different levels of FYM. Preliminary trials have shown that spacing of 20 x 15 cm and FYM at the rate of 30 tonnes per hectare gave maximum rhizome yield (Annual Progress Report, 1982). Rajagopalan (1983) carried out an investigation to standardise the propagation method, planting time and harvesting time of *K. galanga* L. and reported that mother rhizomes planted during the 3rd week of May and harvested after 6 months were significantly superior. Planting time had significant influence on the number of leaves per plant, leaf width, total leaf area and rhizome yield (Rajagopalan and Gopalakrishnan, 1985).

Phytochemical analysis and nutrient uptake studies on *K. galanga* L. conducted by Rajagopalan *et al.* (1989) revealed that mother rhizomes planted during the 3rd week of May and harvested at six months maturity recorded the maximum essential oil and oleoresin yield. The mean nutrient uptake by the crop

was 22.8 kg N, 28 kg P_2O_5 and 36.9 kg K_2O per hectare. NPK trials conducted at AMPRS, Odakkali indicated that application of 50-75 kg N, 60 kg P_2O_5 and 50-75 kg K_2O per hectare was beneficial for increasing the rhizome and oil yield and oil recovery (Research Report, KAU 1987-90). In another study conducted at AMPRS, Odakkali (1991) it was revealed that application of 30 tonnes of farm yard manure per hectare alone without fertilizer registered the highest yield of fresh rhizome (5197 kg/ha) and the highest oil yield (23.25 t/ha).

A micropropagation trial on *K. galanga* L. was conducted by Vincent *et al.* (1991) and they reported that callus cultures were initiated from vegetative bud explant of *K. galanga* on MS medium supplemented with 2,4 dichlorophenoxy acetic acid (2,4-D) and 6 benzyl amino purine (BAP). Of the different hormonal combinations tested maximum regeneration capacity was exhibited with 1.5 mg/l BAP and 1 mg/l NAA. The axillary bud explant of *K. galanga* L. had the potential to induce multiple shoots as well as roots in the medium containing BA alone or BA + kinetin (Vincent *et al.*, 1992). The mortality rate to tissue culture derived plants was low and about 90 per cent plants survived on transfer to soil. These results demonstrated that *K. galanga* L. can be micropropaged easily.

2.6 Chemical composition of rhizome

Panicker *et al.* (1926) analysed the dried and powdered rhizomes which gave 2.4 - 3.88 per cent of volatile oil. The tuberous rhizome possesses a camphoraceous odour with somewhat bitter aromatic taste resembling that of *Hedychium spicatum*. The compounds such as n-pentadecane, ethyl p-methoxy cinnamate, ethyl cinnamate, 1-s^3 - carene, camphene, Borneol and P-methoxy styrene were reported to be present in the oil (Panicker *et al.*, 1926 and Guenther, 1975). The oil freed

from ethyl P methoxy cinnamate which separates out on cooling the destillate had the following properties:

Specific gravity at 30°/3°.	0.8792 to 0.8914
Specific optical rotation at 30°	-2°36' to -4°30'
Refractive index at 30°	1.4173 to 1.4855
Acid number	0.5 to 1.3
Saponification number	99.7 to 109.0

Pillai and Warriar (1962) conducted investigations on the aromatic resources of Kerala and reported that Petroleum ether extract of the tubers of *K. galanga* L. contained 2.05 per cent of ethyl-p-methoxy cinnamate and 2.87 per cent of a residual essential oil.

The essential oil content of rhizomes collected from Chowgat College Campus has been found to vary depending on the month of collection of the plant material (Nerk and Torne, 1984). Maximum oil content was reported when the plant material was collected in October and minimum, when it was collected in June. The price of the oil was reported as 180-200/kg oil.

Bin Din and Samsudin (1991) reported the presence of cinnamic acid derivatives such as ethyl cinnamate and ethyl p-methoxy cinnamate in *K. galanga*.

Seven species of *Kaempferia* such as *K. galanga* L., *K. parviflora, K. unguistifolia* and *K. rotunda* L. and three other species have been studied by Tuntiwachwuttikul (1991) and reported four major classes of chemicals viz. cinnamate esters, flavanoids, diterpenoids and cyclo hexane oxide derivative.

Tuntiwachwuttikul *et al.* (1992) again studied 4 species of *Kaempferia* such as *K. parviflora, K. unguistifolia* and two unnamed *Kaempferia* species and reported that rhizomes of *K. parviflora* yielded sixteen flavanoids. The major constituent 5,7 dimethoxy flavone was found to be antiinflammatory and the activity was comparable to aspirin. Work on *K. unguistifolia* and an unnamed *Kaempferia* species lead to the isolation of the two cyclohexane diepoxide analogues. The composition of the essential oil of rhizomes of *K. galanga* growing in Malaysia has been investigated by Wong *et al.* (1992) and they reported 54 components of which the major constituents were ethyl trans-P methoxy cinnamate (56.7%), ethyl cinnamate (16.5%), Penta decane (9%), 1,8 cineole (5.7%), gamma-car-3ene (3.3%) and borneol (2.7%). Terpenoid constituents amounted to 16.4 per cent.

2.7 Morphological variability

Kaempferia galanga has not attracted any systematic research work in identifying the extent of variability in this crop. Since the literature available on this crop is scanty, review of studies conducted in related crops like ginger, turmeric etc. are cited here.

2.7.1 Ginger

Morphological characters such as height of the plant, number of tillers, number and length of leaf blade, number of secondary fingers, number of nodes per finger, length, girth and internodal length of primary and secondary fingers were found to differ significantly among ginger types studied (Nybe, 1978). He observed no significant variation among types for breadth of leaves, length of petiole and number of primary fingers. He reported significant difference in germination percentage also. Genetic variability, and heritability were estimated by Mohanty and

Sharma (1979) for a number of characters in different cultivars of ginger. Their study indicated that straight selection can be made to improve almost all characters except the number of tertiary fingers and straw yield. Mohanty (1979) studied the variability and heritability of 14 characters in 28 native and foreign varieties and they reported high genetic co-efficient of variation (GCV), expected genetic advance and heritability estimates for number of secondary rhizome fingers and total root weight. Also heritability estimate was high for leaf breadth, while GCV was high for weight of root tubers. Twenty eight cultivars and strains of *Zingiber officinale* was assessed by Mohanty *et al.* (1981) and reported varietal differences for all the characters studied such as number of tillers, number of leaves, plant height, leaf width, weight of straw, number of adventitious roots, number of root tubers, total number of rhizome fingers, rhizome yield etc. Okwvowulu (1992) compared four exotic cultivars of ginger (Maran, Himachal Pradesh, Wyanad local and Rio-de-jenairo) with Nigerian land races (Taffin Yiwa and Yatsun biri) and recorded significant differences for the root yield, leaf number and shoot height at crop maturity, but the stem tuber yield was not significantly different.

2.7.2 Turmeric

Pillai and Nambiar (1975) and Rao *et al.* (1975) noticed variation in thickness, length, internodal length and colour of rhizomes among turmeric types. Morphological and growth characters such as height of the plant, number of leaves per tiller and per plant, leaf characters, number and length of roots and rhizome characters of mother, primary and secondary finger were found to differ significantly among the types (Philip, 1978). He noticed no significant variation in tiller production among the types. The study revealed that morphological characters were not reliable to classify the types although some of them could be distinguished by rhizome character. Morphological characters such as number of tillers, height of the

plant, number of leaves both on the main plant and tiller, number of roots and number, length, girth and internodal length of primary and secondary fingers were significantly different among the lines (George, 1981). Philip and Nair (1986) reported high heritability for curing percentage, and curcumin and oleoresin contents. Genetic advance was reported to be high for plant height, green yield, curing percentage, leaf blotch resistance and curcumin and oleoresin contents which indicated that selection within the existing germplasm would lead to improvement for that characters. Mukhopadhyay *et al.* (1986) reported significant variation for shoots/clump, leaves/shoot, plant height and yield/plant. GCV was highest for total plot yield and heritability estimate was moderate for shoots/clump. Indiresh *et al.* (1990) also evaluated turmeric cultivars at Brahmavar and observed highly significant variation between the cultivars for many of the characters. The characters viz., yield of cured turmeric, number of primary fingers and yield of secondary fingers were reported to have a good amount of variability, high magnitude of heritability and appreciable expected genetic advance (Jalgaonkar, 1990). Menon *et al.* (1992) also reported significant differences between open pollinated progenies of *Curcuma aromatica* cultivar Nandyal, for all the plant traits except tillers/plant as well as rhizome characters, yield, curing percentage and curcumin content.

2.7.3 *Costus speciosus*

An evaluation of *Costus speciosus* germplasm by Ammal and Prasad (1984) conducted in Tamil Nadu on the basis of height of the plant, length and breadth of leaves, number of leaves and flowers per plant revealed the presence of diploids, triploids and tetraploids, in the species. They also reported that, eventhough the diploids have high diosgenin content, the triploids clones were the most robust.

2.7.4 Induced variability

The effect of gamma irradiation on *Kaempferia galanga* L. has been studied by Viswanathan *et al.* (1992) and it has been found that irradiation treatments at lower dosages viz., 0.5, 0.75 and 1.0 k rad produced stimulatory effect on the germination and period taken for germination of *Kaempferia* rhizomes. Inhibitory effects on these characters were observed at higher doses. Mutagenic effects were evident as variability on leaf colour, leaf shape and arrangement, leaf texture and leaf thickness. Bushy type mutants were noticed in 7.5 k rad and they reported that it can be used as an ideal raw material for crop improvement programmes of *Kaempferia*.

2.8 Correlation studies

2.8.1 Ginger

Analysis of yield and plant characters like number of tillers, height of plant and number of leaves by Kannan and Nair (1965) revealed that plant height was generally associated with yield. Nybe (1978) reported that in ginger length of leaf blade, length of petiole, leaf area index and number, length and girth of primary and secondary fingers were positively correlated with yield. According to Mohanty and Sharma (1979) rhizome yield was positively and significantly correlated with number of stems, leaves, secondary rhizome fingers, tertiary rhizome fingers and total rhizome fingers, plant height, leaf breadth, girth of secondary rhizome fingers and number and weight of adventitious roots. Roy and Wamanan (1990) reported that yield was correlated with shoot height, leaves per clump of shoot and tiller per clump. Four exotic cultivars of ginger were compared with the Nigerian land races by Okuvowulu (1992) and he reported a significant positive correlation between

stem tuber yield and shoot number in Wyanad local and between stem tuber and root yield in Maran.

2.8.2 Turmeric

Philip (1978) reported that morphological characters, such as height of plant, length and breadth of leaf, petiole length, leaf area index, number of leaves per tiller, number of roots per plant, length of roots, length of primary fingers and girth of mother rhizomes were positively correlated with yield.

Mohanty (1979) studied correlation coefficients among different characters and yield components in turmeric and revealed that tall plants with more number of broad leaves like to produce high yielding turmeric types. Nambiar (1979) estimated the inter correlation among the morphological characters and yield in turmeric and the results showed that number of tillers, plant height, and number of fingers had high significant positive correlation with the yield of turmeric. He also reported that the final yield was influenced by the weight of seed material.

Govind *et al.* (1981) showed that number of fingers per plant, number of tillers per plant, height, rhizome length and dry matter percentage contributed 4 per cent towards yield of turmeric rhizome. In an investigation conducted by Mukhopadhyay and Roy (1986) in 25 cultivars of turmeric, a high correlation was observed between plant height and yield per plant at both the phenotypic and genotypic levels. Jalgaonkar *et al.* (1990) reported that the yield of cured turmeric was significantly correlated with yield of secondary fingers. According to him the significant relation of quantitative characters of secondary finger with each other and with those of primary fingers was an indication of the scope for obtaining a good response to selection through direct as well as indirect selection.

2.9 Path coefficient analysis

The theory of path coefficient analysis was first established by Wright (1921). From an overall analysis of path coefficient Usharani and Rao (1981) suggested the character as major contributors towards yield are those which had positive direct effects and those having small negative effect but high genotypic correlation with yield.

In ginger path coefficient analysis was done by Ratnambal (1979). The analysis revealed that the phenotypic correlation between yield of rhizomes and height of pseudostem was quite high and so also the direct effect of height towards the correlation. It was also found that indirect effect of height in manifestation of the correlation between yield and other characters was high. The direct effect of number of leaves on yield was found to be low. Eventhough the length of leaf had a negative direct effect, it was compensated by a high positive correlation between plant height and final yield. In turmeric path coefficient analysis indicated that wherever significant positive correlation between yield and morphological characters were established, it was mainly due to substantial positive contribution by plant height and number of fingers either directly or indirectly. Based on this Nambiar (1979) concluded that plant height (of pseudostem) in turmeric was a single important morphological character for which selection for yield could be made. In turmeric path coefficient analysis revealed that height of the plant and length of secondary fingers were the major contributors towards rhizome yield. Direct effects of number of leaves per tiller and girth of mother rhizome were positive whereas number of nodes per primary finger and petiole length had high negative direct effect on rhizome yield (Geetha, 1985). Another study conducted by Mukhopadhyay and Roy (1986) revealed that plant height had the maximum direct effect on yield, followed by tillers per clump in turmeric. Tillers per clump, leaves per shoot and plant height were

recommended as selection criteria for improving yield.

2.10 Influence of light intensity on morphological characters and yield

Sunlight being the source of energy for plants for photosynthesis, the dry matter accumulation in general are found to be adversely affected by shading. But in ginger, coffee, etc. positive influence was reported. Still in some other crops like pineapple there was no appreciable decrease in dry matter accumulation even upto 75 per cent shading. In crops like tomato, tea, chilli and chickpea also partial shading was found beneficial. Plants vary in their response to shade.

In apple, tomato and many horticultural plants, an increase in total leaf area with shading has been reported (Clark, 1905). Experiments on shaded and unshaded plants indicated that light favours formation of oil (Lubimenko and Nervikoff, 1914). Aclan and Quisumbing (1976) reported positive influence of shading on plant height in ginger. They also reported positive influence of partial shading on yield. Crop under partial shade gave as much yield as that under full sunlight. In turmeric rhizome yield was significantly higher in the open than under shade (Ramadasan and Satheesan, 1980). Bai (1981) also reported that turmeric recorded higher yield under 50 per cent shaded condition. Turmeric produces a relatively dense canopy under natural condition. According to her, performance of ginger was better under shade than in the open. Leaf area in ginger was not appreciably altered by shading. In coleus also the yield of tubers was unaffected by shading.

Duriyaprapan and Britten (1982) noticed increased leaf area development in shaded *Mentha arvensis* plants. Balyan *et al.* (1982) reported that the crop Clocimum came up well under partially shaded conditions in Jammu, though the oil content was slightly low under shaded conditions.

Ravisankar and Muthuswamy (1986) carried out an experiment at TNAU, Coimbatore to study the effect of light intensity on the dry matter production in ginger and the recovery of dry ginger. The crop grown as an intercrop in the six year old arecanut plantation with a light intensity of 15.3 K.lux recorded the highest dry matter production in the plant and accumulation in the rhizome at all stages of crop growth.

Sannamarappa and Sankar (1988) studied the performance of turmeric under four different densities of arecanut. It has been found that in turmeric yield increases with narrower spacing. The biomass production was high with spacing of 1.8 m x 3.6 m.

The effect of shade on plant height and chlorophyl content was positive while it was negative in the case of number of tillers and number of leaves in all the ginger varieties tried by Varughese (1989). Most of the ginger varieties recorded the highest yield at 25 per cent shade. The percentage of dryage of ginger rhizome increased with increase in shading with the maximum dryage at 75 per cent shade. According to her, varieties grown without shade yielded the best quality rhizome. Varughese (1989) also studied the influence of shade on turmeric varieties and reported that all the turmeric varieties recorded highest yield at 0 per cent shade. Plant height and chlorophyl content increased with increasing shade while number of tillers and number of leaves showed a drastic decrease. The percentage of dryage also increased with increase in shading. She concluded that ginger varieties tested were highly suitable for intercropping while turmeric varieties will be suitable for intercropping only under conditions of ample light infilteration.

According to Pillai (1990), in clocimum effect of shade on plant height and spread was positive upto intermediate shade level whereas its effect on number of branches, number of flowering shoots, length of inflorescence and leaf area was negative. The highest total herbage yield, highest value of oil content and oil yield were also recorded by the plant grown in the shade. Physical properties of oil were also significantly influenced by shade.

Nair *et al.* (1991) reported from College of Horticulture, Vellanikkara that growth and yield attributes of Kacholam grown in open conditions were comparable with that grown under shade in coconut gardens. Kacholam grown in open areas recorded a height of 22 cm, fresh weight of 112 g of officinal part per plant and a dry weight of 23.92 g officinal part per plant as against the height of 20 cm, 110 g fresh weight of officinal part and 23.50 g of dry weight of officinal part per plant obtained under shade in coconut garden. The results revealed the possibility of growing Kacholam as intercrop in 8-20 years old coconut plantation.

Jayachandran *et al.* (1992) reported turmeric as a shade tolerant crop. It was found that the yield of turmeric at 25 per cent shade was as par with open condition. Shade intensities beyond 25 per cent reduced the rhizome yield. They recommended turmeric as a suitable crop component for homestead cultivation and for intercropping under coconut and other perennial crops. As a result of shade height of plant increased and tiller production reduced. Reduction in rhizome yield was also observed as a result of 50 per cent and 75 per cent shade.

Plant grown under shade performed better than those in the open in terms of rhizome yield in ginger (George, 1992). The effect of shade on plant height, chlorophyl content, net assimilation rate and percentage dryage was positive and she classified ginger as a shade loving crop. She also reported that plants grown

under shade registered higher value for oil and oleoresin content compared to that grown in the open.

Paul (1992) reported that performance of turmeric cultivars was poor under intercropping in coconut garden. The performance of crop was better in terms of rhizome yield, under medium shade levels of 50 per cent, and classified turmeric as a shade tolerant crop. Effect of shade on plant height and chlorophyl content was positive. But more number of leaves were produced in the open whereas no definite trend could be observed in the number of tillers.

Materials and Methods

MATERIALS AND METHODS

The present investigation on evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield was conducted in the Department of Agricultural Botany, College of Horticulture, Vellanikkara during the period May, 1993 to January, 1994.

3.1 Materials

Germplasm of Kacholam including different local collections viz. Koothattukulam, Ponnukkara, Thodupuzha, Palakkad and Varantharappilly, gathered from cultivators' field, preliminary selections made in the previous season from the Vellanikkara type raised at AICRP on M & AP, based on some morphological characters and yield and an irradiated population of Vellanikkara (M_2 generation), formed the materials for the present study. The total number of entries included in the study was ten (5 collections, 4 selections and 1 irradiated population).

3.2 Methods

3.2.1 The experimental details and design

The above ten entries were put into a comparative yield trial in open and under coconut garden of age 15 years. Two identical and parallel experiments were laid out, one in the medicinal garden, AICRP on M & AP, Main Campus, KAU, Vellanikkara and the other under the coconut garden in Instructional Farm, Vellanikkara. The experimental design was RBD with 3 replications.

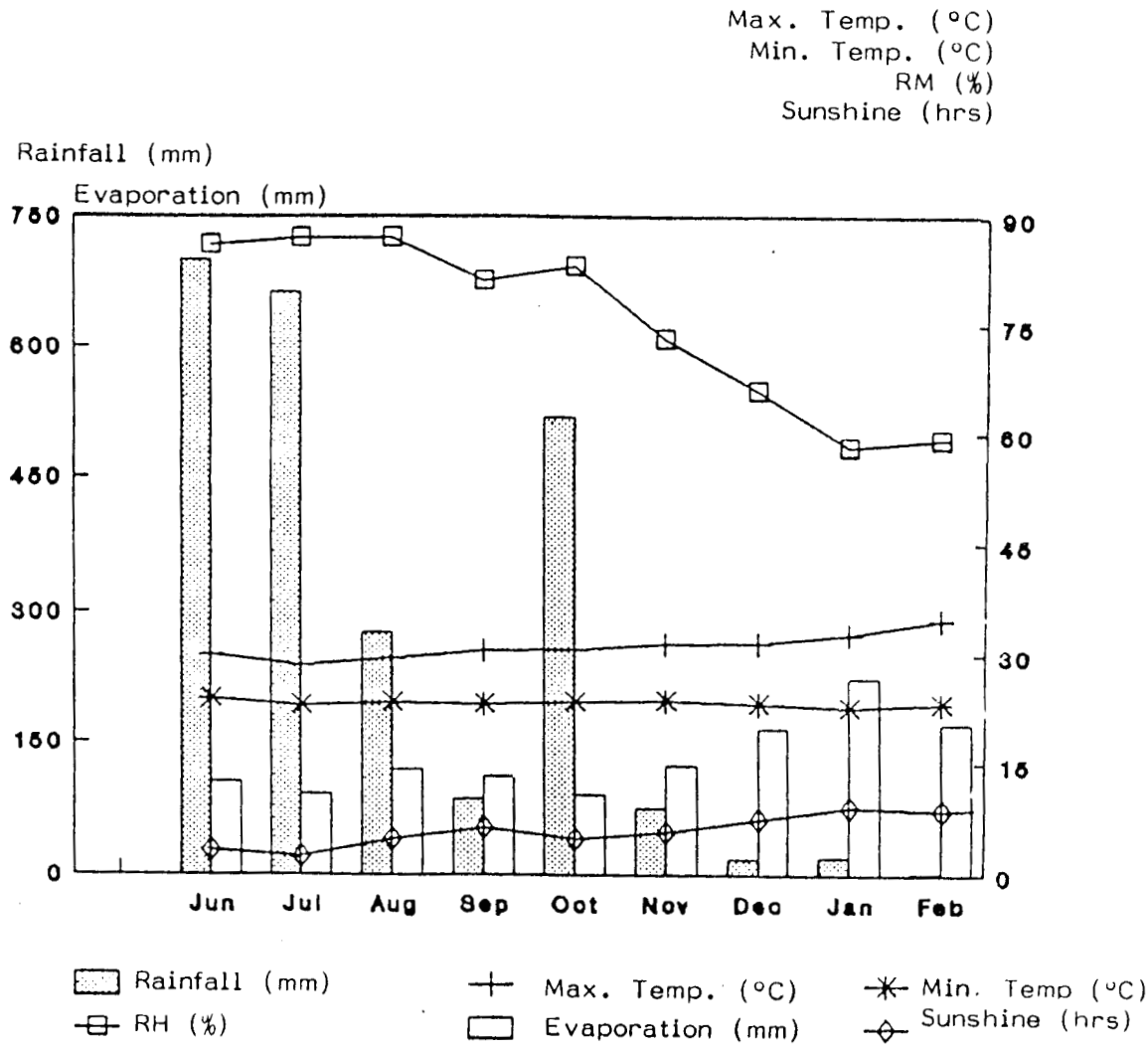


Fig.1. Meteorological data (monthly average) for the crop period (June 1993 - May 1994)

3.2.2 Soil analysis

Composite soil samples were taken and used for the determination of chemical properties and the data are presented below. Texturally the soil is sandy clay loam.

Chemical properties

Constituent	Content		Method employed
	Open field	Coconut garden	
Organic carbon	0.75%	1.0%	Walkley and Black rapid titration method (Jackson, 1958)
Available N_2	295.92 kg/ha	331.5 kg/ha	Alkaline permanganate method (Jackson, 1958)
Available P	7.39 kg/ha	4.8 kg/ha	Ascorbic acid method (Watanabe and Olsen, 1965)
Available K	4.35 kg/ha	2.6 kg/ha	Flame photometry (Jackson, 1958)
Soil reaction (pH)	5.5	5.8	pH meter method. Soil water suspension of 1:2.5 (Jackson, 1958)
Electrical conductivity	0.25 dS m^{-1}	0.1 dS m^{-1}	Conductivity bridge method Soil water extract of 1:2.5 (Jackson, 1958)

3.2.3 Measurement of light intensity in coconut garden

The prevailing shade under the coconut garden was measured using line quantum sensor. Using the instruments 2 sets of measurements were taken, one in the open and the other in the coconut garden, and the percentage of light infilteration in the coconut garden worked out. It was calculated as 50 per cent light infilteration under the coconut garden.

3.2.4 Land preparation

The experimental fields were thoroughly ploughed in the month of May, 3 times to get a uniform soil condition. Raised beds of 3 x 1 m size and 25 cm height were prepared and 30 cm wide channels were made in between the beds. Under coconut garden, beds were prepared along the slope in between the rows of coconut.

3.2.5 Planting

Rhizome bits of 5 g weight with a single bud were used for planting. The spacing adopted was 25 cm x 20 cm. Dried powdered cowdung at the rate of 20 tons per hectare was applied before planting the rhizome in each pit. A population of 56 plants (4 rows and 14 plants per row) per plot was given (186667 plants per hectare). Planting was done in the first week of June with the receipt of monsoon showers.

3.2.6 Crop management

The same crop management practices were given for both the crop. Mulching was done immediately after planting at the rate of 4.5 kg per plot (15 tons per hectare). Fertilizers were applied at the rate of 50:50:50 kg NPK ha^{-1} as recommended by KAU (1993). The full dose of fertilizers was applied 2 months after planting at the time of first weeding. Weeding was done at two months interval.

3.2.7 Sampling technique

Random sampling technique was adopted to select the sample plants for

recording various morphological characters in both the experiments. Ten plants (clumps) were selected at random from each plot, eliminating the boarder rows and labelled. Data for each morphological character were recorded from the same ten labelled plants. For the chemical analysis for extracting oil, rhizomes from these ten sample plants were bulked together to get a representative sample for each plot.

3.2.8 Preharvest observations

i. Germination

The number of rhizomes sprouted per plot was recorded and the germination percentage was worked out.

ii. Number of leaves

Number of leaves produced per plant was recorded from the ten sample plants at 2 months interval and the average worked out for each plot.

iii. Leaf shape

The shape of the leaves of each type was observed visually and recorded as described by Lawrence (1951).

iv. Length and width of leaves

Five 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 base and tip of leaf blade. Width was recorded as the width at the centre of leaf blade. The average length and width of leaves were then computed.

v. Leaf area index

Leaf area index was calculated as the $\frac{\text{Total leaf area}}{\text{Land area}}$

Leaf area was measured using leaf area meter. For this purpose a destructive sampling of 5 plants was taken from each plot, at the time of flowering. The leaves were cut, taken and fed to the instrument which gave reading on total leaf area. From this value, leaf area of 56 plants was calculated which when divided by plot size (3 m^2) gave the leaf area index. The same was repeated one month after flowering.

vi. Days to flowering

In Kacholam the flowers borne on an inflorescence and open successively. The days to first flowering was recorded for each plot.

vii. Spread of flowering

Flowering commenced 45-55 days after planting in this crop. Flowers remained open for 1 day and later withered off and new flowers were produced successively from the same plant. The flowering process continued for 1¼ - 1 3/4 months after planting, starting from last week of July to second week of September. Spread of flowering was recorded as the duration from the day of first flowering to the day of last flowering.

viii. Number of flowers per inflorescence

In Kacholam a single plant is a clump and each sucker may or may not end in a flower bud. For each sample plant the first flower bud was tagged for

taking observation. The flowers in an inflorescence opened one per day in a few case two flowers per day. So every day the number of flowers opened were counted till the flowering was over. Thus the number of flowers per inflorescence was obtained and the mean value calculated.

ix. Number of suckers

The number of suckers produced by each sample plant was recorded and the average worked out.

x. Plant spread

Spread of the plant was measured using a twine in two directions (North South and East West directions) and the average of these two measurements was recorded as the plant spread.

3.2.8 Post harvest observations

i. Number of main and secondary rhizomes

Number of main and secondary rhizomes produced per plant was recorded for the ten observational plants and their mean worked out.

ii. Length of main rhizome

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

iii. Girth of main rhizome

The girth of main rhizomes at the middle was measured using a twine for each sample plant and the average was calculated.

iv. Number of nodes and internodal length of main rhizome

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.

v. Length of secondary rhizome

Five secondary rhizomes were selected at random from each observational plant and the length was measured using a twine and the mean worked out.

vi. Girth of secondary rhizomes

The girth at the middle for the same five secondary rhizomes selected from the observational plant was recorded and the mean worked out.

vii. Number of nodes and internodal length of secondary rhizome

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

viii. Fresh rhizome yield

The ten sample plants were harvested separately and weighed to get the individual plant yield and the average worked out. Rhizome yield per plot and per hectare were also calculated.

ix. Dry rhizome yield

The rhizomes of the ten sample plants were chopped into small bits, dried separately under sun for 5 days. The moisture content in the rhizome was then

found out using immiscible solvent method with toluene as solvent. When the moisture content reduced to 8 per cent, the dry rhizome yield of individual plant was recorded and then the mean worked out. Dry rhizome yield per plot and per hectare were also worked out.

x. Biological yield

It is the total dry matter accumulation including the economic part ie. the rhizome and the uneconomic parts like, leaves, shoot and roots. Biological yield was also recorded for the ten observational plants and the average worked out.

xi. Harvest index

Harvest index is calculated as the $\frac{\text{economic yield}}{\text{biological yield}}$

For each observational plant harvest index was worked out by dividing the dry rhizome yield with the dry plant weight and the mean worked out.

3.2.9 Chemical analysis

i. Oil estimation

One hundred g of dried rhizomes from each replication was ground in a grinding mill to get a fine powder. Fifty g of the powdered sample was used for analysis.

Solvent extract of each sample was taken using hexane as solvent. Fifty g of the sample was reflexed, with 400 ml of the solvent. From the extract, the solvent was evaporated out and the oil obtained was weighed when constant weight reached. The oil was then expressed as percentage.

ii. Quality analysis

The quality of the oil was assessed using gas chromatography in the instrument Chemito 8510 using column SE-30 at a temperature of 130°C - 220°C programming at 5° per minute using N_2 as carrier gas.

3.2.10 Statistical analysis

The data were statistically analysed using the analysis of variance technique for randomised block design according to the procedure suggested by Panse and Sukhatme (1978). For each morphological character the data were analysed separately for the open crop and the crop under shade. Then a pooled analysis was done to compare the performance of the open crop and the intercrop for each character. The components of variance ie. phenotypic variance, genotypic variance and environmental variance were also computed as the procedure suggested by Johnson *et al.* (1955). Heritability was estimated by the method suggested by Burton and Devane (1953) and the expected genetic advance was also worked out for each character, as suggested by Lush (1949) and Johnson *et al.* (1955). Correlation coefficients for each morphological character with yield was worked out as per the technique suggested by Cochran and Cox (1950). Path coefficient analysis was also done using Spar 1 soft ware package to study the direct and indirect effects of yield contributing characters on yield as suggested by Deway and Lu (1959).

Results

RESULTS

The data collected for various characters of the crop were tabulated and subjected to statistical analysis and the results are presented in this chapter.

4.1 Morphological variability in different characters and yield

The data on each character was seperately analysed under open and shaded conditions by analysis of variance technique and then pooled analysis was done to compare the performance of the types under open and shaded conditions.

4.1.1 Germination

There was no significant difference in the germination percentage of the types averaged over the two situations viz. open and shade. Germination percentage of the types ranged between 96.06 per cent and 98.81 per cent. The type Ponnukkara recorded the maximum germination percentage (98.81%) and Vellanikkara irradiated population recorded the minimum value (96.06%). There was no significant difference in the germination percentage of the types between open and shaded conditions. (Table 1).

4.1.2 Number of leaves

The results are presented in Table 2a.

i) Number of leaves 1 month after planting

The pooled analysis showed significant difference between treatments regarding this trait. One month after planting, the number of leaves ranged from 3.17 to 5.73. Ponnukkara (5.73) and Vellanikkara Seln. Br (4.13) were found to be

Plate 1. A view of the Kacholam crop in the field under open condition

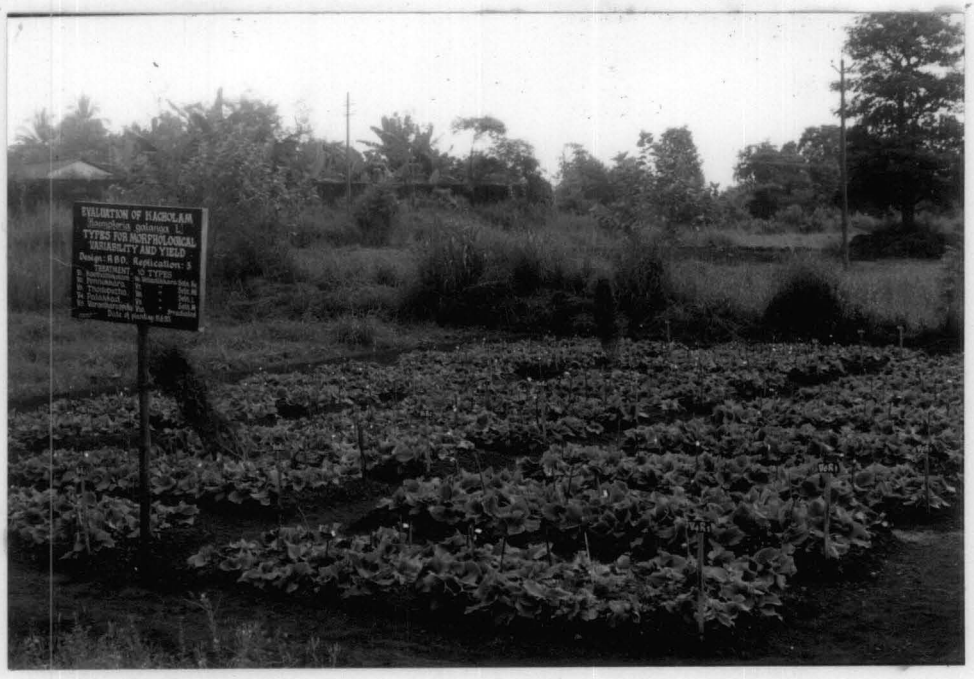

EVALUATION OF HACKLAM
Eleusine coracana L.
TYPES FOR MORPHOLOGICAL
VARIABILITY AND YIELD
Design : R.B.D. Replication : 3
TREATMENT

Plate 2. A view of the Kacholam crop in the field under coconut garden


INTER CROPPING OF
KACHOLAM IN
COCONUT GARDEN

Table 1. Variability in germination of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Types	Germination percentage		
	Open	Shade	Pooled
Koothattukulam	97.62	98.21	97.81
Ponnukkara	98.21	99.40	98.81
Thodupuzha	98.81	95.39	97.10
Palakkad	97.02	97.02	97.02
Varantharappilly	97.02	98.81	97.92
Vellanikkara Seln. Br	98.81	96.43	97.62
Vellanikkara Seln. NR	96.43	98.81	97.62
Vellanikkara Seln. L	97.02	95.83	96.43
Vellanikkara Seln. M	97.62	98.21	97.92
Vellanikkara Irradiated	96.88	95.24	96.06
Mean	97.54	97.33	97.44
SEm±	2.08		1.47
CD (0.05)	NS		NS

Table 2a. Variability in leaf characters of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Type	No. of leaves 1 MAP			No. of leaves 3 MAP			No. of leaves 5 MAP			No. of leaves 6 MAP		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattu-kulam	3.37	3.53	3.45	17.47	14.27	15.87	36.84	29.43	33.14	32.63	25.27	28.95
Ponnukkara	6.20	5.27	5.73	23.20	17.63	20.42	37.20	35.00	36.10	35.13	29.23	32.18
Thodupuzha	3.90	2.87	3.38	14.59	12.70	13.65	28.25	26.53	27.39	29.15	25.70	24.43
Palakkad	3.93	2.90	3.42	16.93	9.60	13.27	28.07	20.00	24.03	26.00	16.67	21.33
Varanthara-ppilly	3.77	3.43	3.60	14.20	14.73	14.47	26.68	25.30	25.99	26.34	21.90	24.12
Vellanikkara Seln. Br	4.43	3.83	4.13	17.00	12.83	14.92	32.27	23.77	28.02	32.73	17.65	25.19
Vellanikkara Seln. NR	3.43	3.13	3.28	13.60	12.97	13.28	24.40	25.80	25.10	28.87	22.90	25.88
Vellanikkara Seln. L	3.77	3.63	3.70	17.93	14.10	16.02	33.37	26.67	30.02	34.73	23.20	28.97
Vellanikkara Seln. M	3.30	3.03	3.17	12.33	12.67	12.50	23.03	24.83	23.93	25.87	22.30	24.08
Vellanikkara irradiated	3.13	3.43	3.28	14.53	14.07	14.30	29.67	28.93	29.30	27.80	25.60	26.70
Mean	3.92	3.51	3.71	16.18	13.56	14.87	29.98	26.63	28.30	29.93	23.04	26.18
SEm±	0.48		0.34	2.64		1.87	3.57		2.57	4.05		2.86
CD (0.05)	0.97		0.68	5.98		NS	7.28		5.22	9.16		NS

MAP - Months after planting

significantly superior to the types Palakkad (3.42), Thodupuzha (3.38), Vellanikkara irradiated (3.28), Vellanikkara Seln. NR (3.28) and Vellanikkara Seln. M (3.17). The performance of the types were significantly different under open and shaded conditions. The leaves produced were more under open condition. Here there was no interaction between the treatments (types) and the two situations. (Fig.2).

ii) Number of leaves 3 months after planting

There was no significant difference in the number of leaves produced by the types, 3 months after planting averaged over the two conditions, open and shade. The average number of leaves ranged between 12.50 and 20.42. Ponnukkara recorded the maximum number of leaves (20.42) and Vellanikkara Seln. M recorded the minimum number of leaves (12.50). The character differed significantly between open and shaded conditions. The types produced more number of leaves under open condition. Here there was significant interaction between the treatments and the situations. Ponnukkara produced the highest number of leaves both under open and shaded conditions. Under open condition Ponnukkara was found to be significantly different from all the types except Koothattukulam and Vellanikkara Seln. L. But under shade it was on par with all the types except Palakkad regarding this trait. Vellanikkara Seln. M recorded the lowest number of leaves in open (12.33), where as Palakkad recorded the lowest number of leaves under shade (9.60).

iii) Number of leaves 5 months after planting

It was found that there was significant difference between the treatments regarding this trait averaged over the two conditions. The character ranged from 23.93 and 36.10. Ponnukkara was found to be significantly superior to all the rest except Koothattukulam. Vellanikkara Seln. M continued its poor performance of producing the minimum number of leaves 5 months after planting also (23.93).

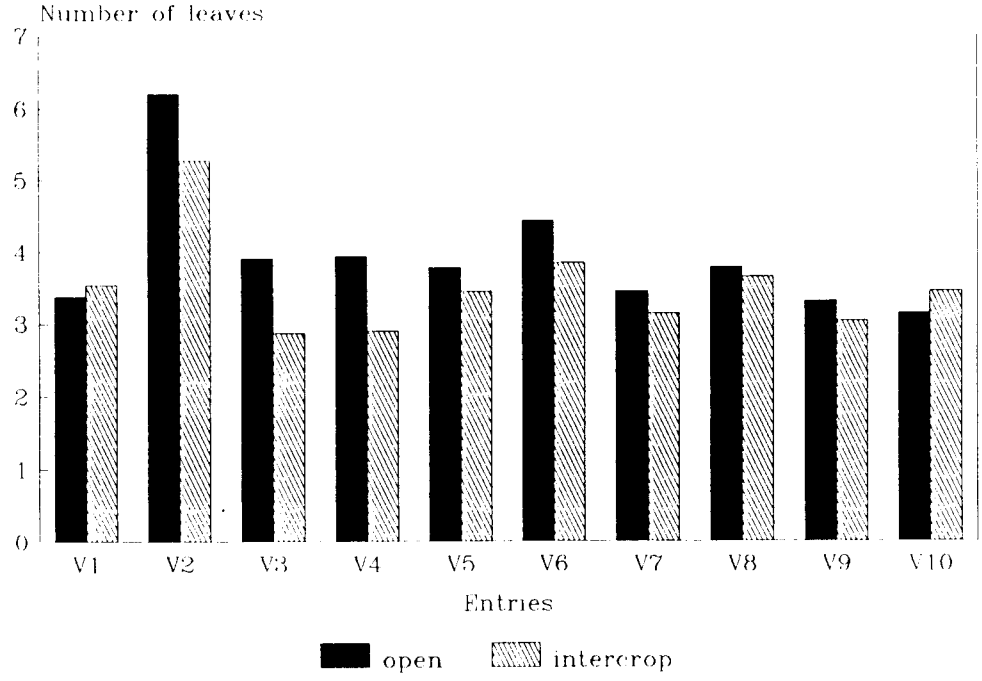


Fig.2. Comparative performance of different types of Kacholam (Kaempferia galanga L.) in the production of leaves (1 month after planting) under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10 - Vellanikkara Iradiated

There was significant difference in the performance of the types between open and shaded conditions. But the interaction was found to be nonsignificant. The performance was better under open condition. Performance of Palakkad was 40.4 per cent more under open condition and that of Vellanikkara Seln. Br was 35.8 per cent more under open condition.

iv) Number of leaves 6 months after planting

The difference between the types in the number of leaves produced, 6 months after planting, averaged over the two conditions was found to be nonsignificant. Ponnukkara recorded the maximum number of leaves (32.18) and Palakkad recorded the minimum (21.33). The performance of the types was significantly better under open condition and here interaction was also found to be significant. Vellanikkara Seln. M was with the minimum number of leaves under open condition (25.87), whereas Palakkad recorded the minimum number of leaves under shade (16.67).

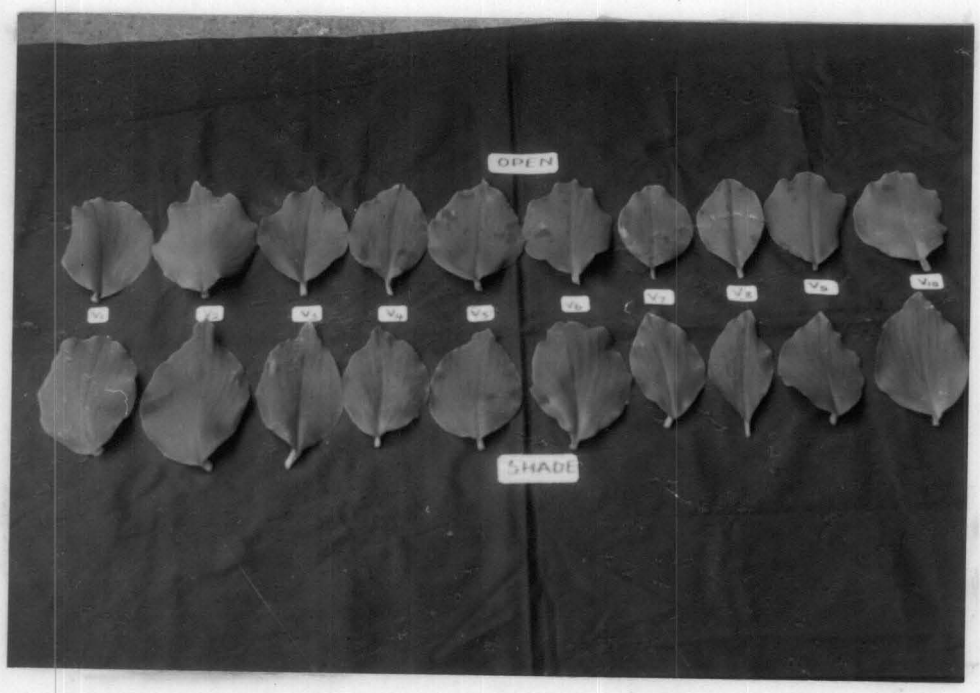
4.1.3 Leaf shape

There was no predominant variability observed in the shape of leaves except length and width. Leaves were some what ovate or obovate in shape with broad, acute base and apex. For the type Koothattukulam the apex of the leaf was some what round and less pointed. The leaf margins were found to be more wavy under open condition compared to shade (Plate 3).

4.1.4 Length of leaves

There was significant difference in the leaf length of types averaged over

Plate 3. Leaf shapes of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions


OPEN
SHADE

the two situations. The length of leaves varied from 11.23 cm to 13.98 cm. Ponnukkara produced leaves with maximum length (13.98 cm) followed by Varantharappilly (13.94 cm), Koothattukulam (13.75 cm), Vellanikkara Seln. Br (13.23 cm) and Vellanikkara Seln. M (13.03 cm) and they were identical statistically. Palakkad recorded the minimum length (11.23 cm) which was on par with Vellanikkara Seln. L (12.08 cm) and Thodupuzha (12.27 cm). There was significant difference in the length of leaves recorded by the types between open and shaded conditions. Crop under shade produced long leaves compared to those under open. Here the interaction was absent (Table 2b).

4.1.5 Width of leaves

From the results of pooled analysis of the character width of leaves it is clear that there was significant difference between the types. Varantharappilly recorded the maximum width (10.24 cm) which was on par with Ponnukkara (9.48 cm), Vellanikkara Seln. M (9.46 cm) and Vellanikkara Seln. Br (9.33 cm). Palakkad produced leaves with minimum width (8.13 cm). There was no significant difference in the width of leaves of the types between open and shaded conditions. (Table 2b). Here interaction was found to be nonsignificant.

4.1.6 Leaf area index

The results are presented in Table 2b and Fig.3.

i) LAI at flowering

At flowering there was no significant difference in the leaf area index averaged over the two situations. The average LAI ranged between 0.43 and 0.82.

Table 2b. Variability in leaf character of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Types	Length of leaves (cm)			Width of leaves (cm)			LAI at flowering			LAI one month after flowering		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattu-kulam	12.87	14.67	13.75	9.23	9.73	9.48	0.98	0.49	0.73	1.13	0.81	0.97
Ponnukkara	12.99	14.98	13.98	8.51	10.00	9.26	0.86	0.78	0.82	0.95	0.85	0.90
Thodupuzha	11.96	12.57	12.27	8.68	8.26	8.47	0.51	0.36	0.43	0.49	0.67	0.58
Palakkad	11.44	11.01	11.23	8.71	7.54	8.13	0.47	0.44	0.46	0.55	0.35	0.45
Varanthara-ppilly	12.51	15.38	13.94	10.45	10.02	10.24	0.56	0.71	0.64	0.69	0.53	0.61
Vellanikkara Seln. Br	13.17	13.29	13.23	9.61	9.30	9.46	0.66	0.58	0.62	0.65	0.61	0.63
Vellanikkara Seln. NR	11.77	13.64	12.70	8.55	9.00	8.77	0.52	0.43	0.47	0.62	0.37	0.49
Vellanikkara Seln. L	11.74	12.41	12.08	8.28	8.21	8.24	0.51	0.42	0.46	0.54	0.33	0.43
Vellanikkara Seln. M	12.56	13.51	13.03	9.45	9.21	9.33	0.50	0.53	0.51	0.64	0.47	0.55
Vellanikkara irradiated	12.13	13.51	12.82	9.13	9.05	9.09	0.60	0.40	0.50	0.60	0.41	0.51
Mean	12.31	13.49	12.90	9.06	9.03	9.05	0.62	0.51	0.56	0.69	0.54	0.61
SEm±		0.73	0.56		0.64	0.47		0.16	0.06		0.12	0.08
CD (0.05)		1.49	1.14		NS	0.95		NS	NS		0.24	0.17

LAI - Leaf area index

Fig.3. Comparative performance of different types of Kacholam (Kaempferia galanga L.) in leaf area index under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10- Vellanikkara Irradiated

Ponnukkara recorded the maximum value (0.82) and Thodupuzha recorded the minimum (0.43). The character was not significantly different between open and shaded conditions. But here the interaction was significant. Under open condition Koothattukulam recorded the maximum LAI value (0.98) but its performance was poor under shade (0.49). Under shade Ponnukkara recorded the highest leaf area index (0.78). Palakkad recorded the minimum value under open condition (0.47) whereas under shade Thoudpuzha recorded the minimum (0.36) .

ii) LAI 1 month after flowering

Here there was significant difference between the types regarding this character averaged over the two conditions. The character ranged between 0.43 and 0.97. Ponnukkara and Koothattukulam were found to be significantly superior to all other types. Vellanikkara Seln. L recorded the minimum LAI value (0.43). The difference in this character among the types between open and shaded conditions was found to be significant. The types under open condition recorded more leaf area index, 1 month after flowering.

All the types except Palakkad, Varantharappilly and Vellanikkara Seln. L recorded high LAI value 1 month after flowering compared to the value at flowering.

4.1.7 Days to flowering

Here there was significant difference in days to flowering between the types pooled over the two situations. The character ranged between 44.50 and 56.00. Ponnukkara had taken the minimum days to first flowering and it was found to be significantly different from all other types except Vellanikkara Seln. Br (47.33). Vellanikkara Seln. L had taken the maximum days to flowering (56.00).

There was significant difference in this character between open and shaded conditions. The number of days taken for first flowering was more for the crop under shade compared to the open crop. Interaction between the types and situations was also found to be significant. Ponnukkara and Vellanikkara Seln. Br had taken the minimum days to first flowering (44.0) under open condition. Under shade Ponnukkara had taken 45 days where as Vellanikkara Seln. Br had taken 50.67 days to first flowering (Table 3).

4.1.8 Spread of flowering

Pooled analysis showed no significant difference in spread of flowering between the types. Ponnukkara had a prolonged flowering period of 49.67 days where as Vellanikkara Seln. L had the shortest period of flowering (35.33). There was significant difference in the spread of flowering of the types between open and shaded conditions. Spread of flowering was more for the open crop. Significant interaction was also present here. Vellanikkara Seln. Br ranked first in spread of flowering under open condition (53.67), whereas it was 5th under shade (41.33). Ponnukkara had a flowering period of 49.67 days under both the conditions. Minimum flowering period was recorded by Vellanikkara Seln. L under open condition (36.67) and Seln. M recorded the minimum flowering period under shaded condition (34.00) (Table 3).

4.1.9 Number of flowers per inflorescence

Here the difference between the treatment means pooled over the two conditions was found to be nonsignificant. The average number of flowers per inflorescence ranged from 5.47 as recorded by Palakkad, to 7.63 as recorded by Vellanikkara Seln. M. There was significant difference among the types between open and shaded conditions. Crop grown in open produced more number of flowers

Table 3. Variability in flowering characters of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Types	Days to flowering			Spread of flowering			No.of flowers per inflorescence		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattukulam	48.67	51.00	49.83	47.67	39.67	43.67	8.03	6.43	7.23
Ponnukkara	44.00	45.00	44.50	49.67	49.67	49.67	6.37	5.67	6.02
Thodupuzha	49.33	53.00	51.17	44.00	43.33	43.67	8.17	5.53	6.85
Palakkad	49.67	53.67	51.67	46.67	41.67	44.17	6.33	4.60	5,47
Varanthara-pilly	48.00	50.67	49.33	48.00	41.33	44.67	6.47	5.23	5.85
Vellanikkara Seln. Br	44.00	50.67	47.33	53.67	41.33	46.67	8.10	4.53	6.32
Vellanikkara Seln. NR	53.67	52.67	53.17	39.00	39.67	39.50	6.50	6.23	6.37
Vellanikkara Seln. L	54.33	57.67	56.00	36.67	40.00	38.33	6.90	4.33	5.62
Vellanikkara Seln. M	46.00	52.67	49.33	48.67	34.00	45.33	7.40	7.87	7.63
Vellanikkara irradiated	51.67	50.33	51.00	43.00	42.00	44.33	7.97	4.97	6.47
Mean	48.93	51.73	49.63	45.70	41.70	43.70	7.22	5.54	6.38
SEm±	2.74		1.94	5.05		3.58	1.12		0.82
CD (0.05)	6.20		4.39	11.42		NS	2.28		NS

per inflorescence. Significant interaction was also present here. Under open condition, Thodupuzha was with the highest number of flowers per inflorescence (8.17) followed by Vellanikkara Seln. Br (8.10) and Koothattukulam (8.03), whereas under shade, Vellanikkara Seln. M ranked first (7.87) followed by Koothattukulam (6.43) and Vellanikkara Seln. NR (6.23). Minimum number of flowers per inflorescence was recorded by Palakkad in open (6.33) and Vellanikkara Seln. L in shade (4.33). (Table 3).

4.1.10 Number of suckers per plant

The number of suckers ranged from 6.80 and 10.62. Ponnukkara produced maximum suckers per plant (10.62) followed by Koothattukulam (9.42). Vellanikkara Seln. M recorded minimum suckers per plant (6.80). There was considerable difference in this character between open and shaded conditions. The types under open condition produced more suckers (Table 4).

4.1.11 Plant spread

There was no significant difference in plant spread of the types averaged over the two situations and between the two situations. But here significant interaction was present. Thodupuzha recorded the maximum plant spread under open condition (29.51 cm) followed by Koothattukulam (28.56 cm) and Vellanikkara Seln. Br (28.49 cm). Under shade Ponnukkara recorded maximum plant spread (29.95 cm) followed by Varantharappilly (29.45 cm) and Koothattukulam (28.53cm). Palakkad recorded the minimum plant spread both under open (26.00 cm) and shaded conditions (22.94 cm) (Table 5).

The variability in overall vegetative growth of the types can be observed in Plate 4 and 5.

Table 4. Variability in number of suckers of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Types	Number of suckers per plant		
	Open	Shade	Pooled
Koothattukulam	11.13	7.70	9.42
Ponnukkara	12.07	9.17	10.62
Thodupuzha	8.50	7.07	7.78
Palakkad	9.20	5.43	7.32
Varantharappilly	8.00	7.53	7.77
Vellanikkara Seln. Br	9.47	6.87	8.17
Vellanikkara Seln. NR	8.40	6.73	7.57
Vellanikkara Seln. L	10.57	7.10	8.83
Vellanikkara Seln. M	6.83	6.77	6.80
Vellanikkara irradiated	8.37	8.67	8.52
Mean	9.25	7.30	8.28

Table 5. Variability in plant spread of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

Types	Plant spread (cm)		
	Open	Shade	Pooled
Koothattukulam	28.56	28.53	28.55
Ponnukkara	28.93	29.95	29.44
Thodupuzha	29.51	27.23	28.37
Palakkad	26.00	22.94	24.47
Varantharappilly	26.53	29.45	27.99
Vellanikkara Seln. Br	28.49	26.48	27.49
Vellanikkara Seln. NR	26.54	27.56	27.05
Vellanikkara Seln. L	27.56	26.07	26.82
Vellanikkara Seln. M	28.07	27.78	27.92
Vellanikkara irradiated	27.53	28.18	27.86
Mean	27.77	27.42	27.60
SEm±	1.06		0.75
CD (0.05)	NS		NS

Plate 4. Variability in the vegetative growth of Kacholam (*Kaempferia galanga* L.) types under open condition

Plate 5. Variability in the vegetative growth of Kacholam (*Kaempferia galanga* L.) types under shaded condition


OPEN
VELLANIKKARA SELECTION


VELLANIKKARA SELECTION
SHADE

4.1.12 Number of mother rhizomes

There was significant difference in the number of mother rhizomes produced by the types averaged over open and shaded conditions. The number of mother rhizomes produced by the types ranged between 1.90 and 2.77. Vellanikkara Seln. Br produced the highest number of mother rhizomes (2.77) which was found to be significantly superior to all other types except Ponnukkara (2.53) regarding this trait. Palakkad produced the least number of mother rhizomes (1.90) which was on par with Vellanikkara Seln. L (2.03) and Vellanikkara Selm. M (2.07). All the types produced more number of mother rhizomes under shaded condition except Varantharappilly which produced more mother rhizomes in open, but the difference was not statistically significant (Table 6).

4.1.13 Length of mother rhizomes

The difference in the length of mother rhizomes produced by the types, averaged over the two situations was found to be nonsignificant. Rhizomes of Ponnukkara recorded the maximum length (3.85 cm) and rhizomes of Vellanikkara Seln. NR and Vellanikkara irradiated population recorded the minimum length (3.35 cm). Performance of the types was the same both under open and shaded conditions regarding this character (Table 6).

4.1.14 Girth of mother rhizomes

There was significant difference in the girth of mother rhizomes of the types averaged over the two situations. The girth ranged between 7.53 cm and 8.05 cm. Rhizomes of Vellanikkara Seln. M was with maximum girth (8.05 cm) which was on par with Vellanikkara Seln. NR (7.93 cm), Vellanikkara Seln. Br (7.90 cm), Ponnukkara (7.88 cm) and Thodupuzha (7.72 cm). Koothattukulam produced

rhizomes with minimum girth (7.53 cm). There was significant difference in the girth of mother rhizomes of the types between open and shaded conditions. Girth was more under open condition for all the types (Table 6).

4.1.15 Number of nodes of mother rhizomes

The pooled analysis showed no significant difference between the treatments. The number of nodes of mother rhizomes ranged from 3.40 to 3.73. But there was significant difference in the number of nodes of mother rhizomes produced by the types between open and shaded conditions. Crop under shade produced more nodes on their mother rhizomes. There was no interaction between the types and situations (Table 6).

4.1.16 Internodal length of mother rhizomes

There was no significant difference in this character of the types pooled over the two conditions and also between the two conditions. Internodal length ranged from 1.00 cm as recorded by Koothattukulam to 1.51 cm as recorded by Thodupuzha. Here also there was no interaction (Table 6).

4.1.17 Number of secondary rhizomes

There was significant difference in the number of secondary rhizomes produced by the types averaged over the two situations, open and shade. The character ranged between 9.63 and 14.20. Ponnukkara was found to be significantly superior to all the rest except Koothattukulam (13.52) and Thodupuzha (12.55). Palakkad recorded the minimum number of secondary rhizomes (9.63) which was on par with Vellanikkara Seln. M (10.33) and Seln. NR (10.72). Performance of the types regarding this trait was significantly different between open and shaded conditions. Crop under open condition produced more number of secondary rhizomes.

Table 6. Variability in mother rhizomes of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions.

Types	No. of mother rhizomes			Length of mother rhizomes (cm)			Girth of mother rhizomes (cm)			No. of nodes			Internodal length (cm)		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattukulam	2.13	2.47	2.30	3.46	3.68	3.74	7.65	7.41	7.53	3.43	3.60	3.52	1.01	0.98	1.00
Ponnukkara	2.33	2.73	2.53	3.73	3.97	3.85	8.11	7.65	7.88	3.27	4.00	3.63	1.14	1.03	1.09
Thodupuzha	2.47	2.47	2.47	3.74	3.62	3.68	8.16	7.28	7.72	3.47	3.77	3.62	1.08	1.07	1.08
Palakkad	1.87	1.93	1.90	3.67	3.41	3.54	7.91	7.21	7.56	3.47	3.80	3.63	1.06	1.07	1.07
Varantharappilly	2.47	2.33	2.40	3.63	3.65	3.64	7.86	7.50	7.68	3.60	3.87	3.73	1.02	1.09	1.06
Vellanikkara Seln. Br	2.67	2.87	2.77	2.83	3.39	3.61	8.31	7.49	7.90	3.73	3.73	3.73	1.03	1.01	1.02
Vellanikkara Seln. NR	2.07	2.59	2.33	3.45	3.35	3.40	8.25	7.61	7.93	3.23	3.56	3.40	1.07	1.06	1.07
Vellanikkara Seln. L	1.93	2.13	2.03	3.45	3.43	3.44	7.83	7.32	7.58	3.20	3.93	3.57	1.08	1.15	1.12
Vellanikkara Seln. M	2.00	2.15	2.07	3.81	3.66	3.74	8.35	7.74	8.05	3.27	3.67	3.47	1.17	1.00	1.09
Vellanikkara irradiated	1.93	2.43	2.18	3.67	3.35	3.51	7.94	7.31	7.62	3.33	3.80	3.57	1.11	1.15	1.13
Mean	2.19	2.41	2.30	3.65	3.55	3.60	8.04	7.45	7.75	3.40	3.77	3.59	1.08	1.06	1.07
SEM ±	0.18		0.14	0.20		0.06	0.24		0.17	0.22		0.16	0.08		0.06
CD (0.05)	0.37		0.28	NS		NS	0.50		0.34	0.04		NS	NS		NS

There was no significant interaction (Table 7).

4.1.18 Length of secondary rhizome

There was no significant difference in the length of secondary rhizomes of the types averaged over the two situations and also between the two situations. The character ranged between 3.05 cm and 3.57 cm (Table 7).

4.1.19 Girth of secondary rhizomes

There was no significant difference in the girth of secondary rhizomes of the types averaged over open and shaded conditions. The character ranged from 5.59 cm which was recorded by Vellanikkara Seln. L to 6.22 cm which was recorded by Vellanikkara Seln. M. There was significant difference in this character between the types grown under open and shaded conditions. The girth of secondary rhizome was more under open condition (Table 7).

4.1.20 Number nodes of secondary rhizome

The pooled analysis showed no significant difference between the types. Ponnukkara recorded the maximum number (4.07) and Palakkad recorded the minimum (3.53). But there was significant difference in the number of nodes of secondary rhizomes recorded by the types between open and shaded conditions. Crop under shaded condition produced secondary rhizomes with more number of nodes (Table 7).

4.1.21 Internodal length of secondary rhizomes

Here also there was no significant difference between types for internodal length of secondary rhizomes averaged over the two situations, open and shade. Internodal length varied from 0.82 cm to 1.00 cm. There was significant difference

Table 7. Variability in characters of secondary rhizomes of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions.

Types	No. of secondary rhizomes			Length of secondary rhizomes (cm)			Girth of secondary rhizomes			No. of nodes			Internodal length (cm)		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattukulam	13.77	13.27	13.52	3.18	3.37	3.28	6.04	5.64	5.84	3.58	4.07	3.82	0.89	0.83	0.86
Ponnukkara	15.53	12.87	14.20	3.33	3.28	3.30	6.15	6.00	6.08	3.73	4.42	4.07	0.90	0.76	0.83
Thodupuzha	12.40	12.70	12.55	3.33	3.32	3.33	6.18	5.53	5.85	3.70	4.13	3.92	0.90	0.76	0.83
Palakkad	10.60	8.67	9.63	3.14	3.12	3.13	5.96	5.91	5.93	3.53	3.53	3.53	0.89	0.89	0.89
Varantharappilly	12.40	10.60	11.50	3.13	3.26	3.19	5.69	5.75	5.72	3.80	4.00	3.90	0.83	0.82	0.82
Vellanikkara Seln. Br	13.93	9.87	11.90	3.46	3.13	3.30	6.14	5.57	5.85	3.80	3.93	3.87	0.91	0.80	0.86
Vellanikkara Seln. NR	11.73	9.70	10.72	3.73	3.41	3.57	5.89	5.69	5.79	3.45	3.73	3.59	1.08	0.92	1.00
Vellanikkara Seln. L	12.75	11.07	11.91	3.14	2.95	3.05	5.70	5.48	5.59	3.57	3.80	3.68	0.88	0.78	0.83
Vellanikkara Seln. M	10.27	10.38	10.33	3.32	3.35	3.33	6.22	6.21	6.22	3.80	3.68	3.74	0.88	0.92	0.90
Vellanikkara irradiated	12.40	12.22	12.30	3.19	3.41	3.30	6.25	5.79	6.02	3.47	4.00	3.73	0.93	0.85	0.89
Mean	12.58	11.13	11.86	3.30	3.26	3.28	6.02	5.76	5.89	3.64	3.93	3.79	0.91	0.84	0.88
SEm±	1.25		0.90	0.22		0.07	0.26		0.18	0.28		0.20	0.08		0.06
CD (0.05)	2.53		1.84	NS		NS	0.52		NS	0.57		NS	0.17		NS

Plate 6. Variability in the per plant yield of rhizomes of different types of Kacholam (*Kaempferia galanga* L.) under open and shaded conditions

Plate 7. Comparative performance of the high yielding types Koothattukulam and Ponnukkara in per plant rhizome production under open and shaded conditions

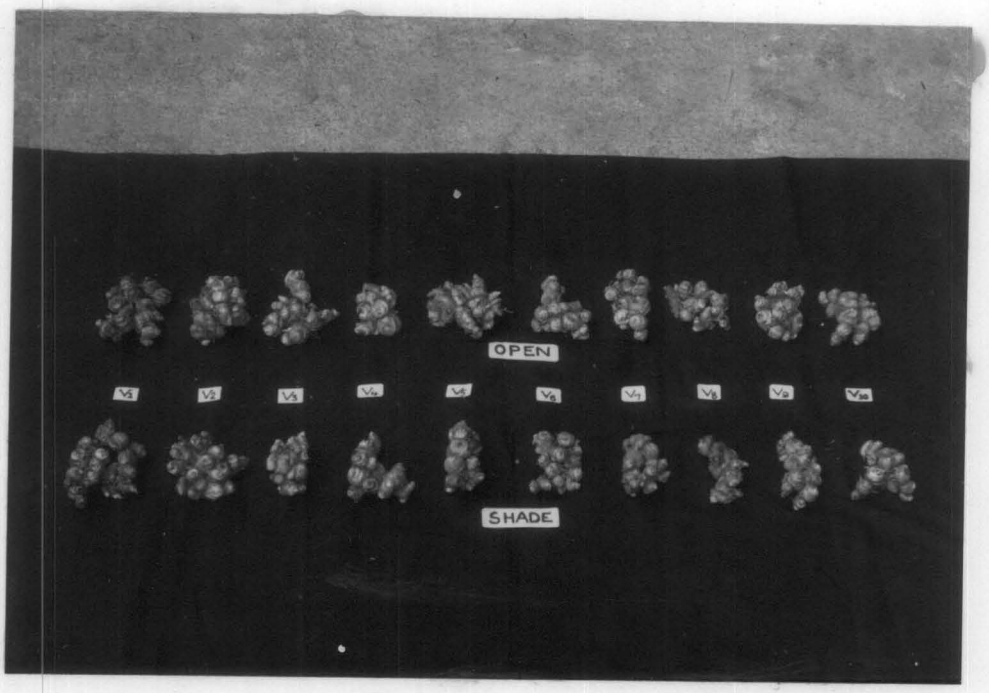
in the internodal length between open and shaded conditions. Internodal length of secondary rhizome was more for the crop under open condition (Table 7).

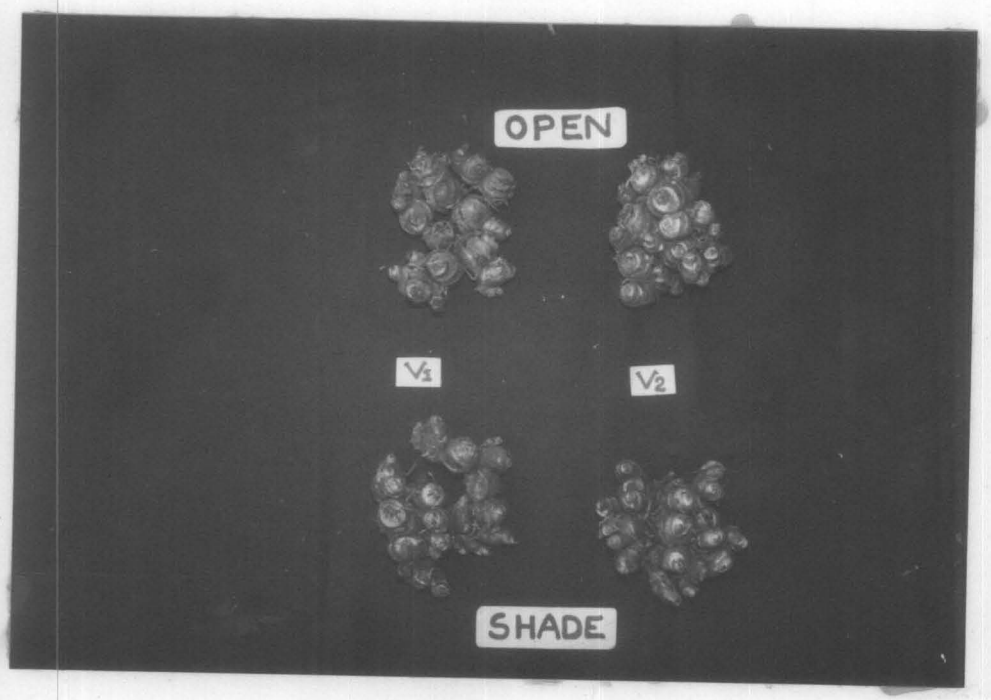
4.1.22 Fresh rhizome yield per plant

It was found that there was no significant difference in fresh rhizome yield of the types averaged over the two conditions open and shade. But when the character was considered for the open crop and intercrop separately there was significant difference between the types. The performance of the types was significantly different between open and shaded conditions. It was found that there was on the average 30.0 per cent more yield under open condition. There was significant interaction between the types and the two situations. Under open condition, Vellanikkara Seln. Br recorded the highest yield of fresh rhizome (74.93 g) followed by Ponnukkara (74.46 g) and Thodupuzha (66.63 g). Whereas under shade Koothattukulam recorded the maximum yield (58.73 g) followed by Ponnukkara (58.16 g) and Varantharappilly (50.45 g). Performance of Palakkad was poor both under open (48.81 g) and shaded conditions (31.22 g). Vellanikkara Seln. Br yielded only 39.97 g of fresh rhizome per plant under shaded condition which was 46.6 per cent less than the yield under open condition (Table 8, Plate 6 and 7).

4.1.23 Dry rhizome yield per plant

There was no significant difference in the dry rhizome yield of the types averaged over open and shaded conditions. But the types differed for this character when considered separately. Dry rhizome yield per plant was found to be the same both under open and shaded conditions. Here interaction was found to be significant. In open Ponnukkara recorded the highest dry rhizome yield per plant (19.81 g) followed by Vellanikkara Seln. Br (19.71 g). Under shade also Ponnukkara ranked


OPEN
V1
V2
V3
V4
V5
V6
V7
V8
V9
V10
SHADE


OPEN
V1
V2
SHADE

first (19.77 g) followed by Koothattukulam (19.40 g) which recorded only 15.61 g under open condition. Vellanikkara Seln. Br recorded only 13.55 g of dry rhizome per plant under shaded condition. Vellanikkara Seln. NR recorded the minimum dry yield (10.00 g) under open whereas Palakkad recorded the minimum dry yield under shaded condition (10.15 g) (Table 8).

Per plot (3 x 1 m^2) and per hectare yield of fresh as well as dry rhizomes for each type were calculated and presented in Table 9 and 10, Fig.4 and 5.

4.1.24 Dry wet ratio

The ratio of dry rhizome yield to fresh rhizome yield of the types averaged over the two situations was found to be statistically the same. The dry wet ratio ranged between 0.25 and 0.31. There was significant difference in the dry wet ratio of the types between open and shaded conditions. Dry wet ratio was more for the crop under shade (32.0 %) (Table 8).

4.1.25 Biological yield per plant

There was no significant difference in the biological yield of the types averaged over the two situations and also between the two situations, open and shade. But there was significant interaction between the types and the conditions. Ponnukkara recorded the maximum biological yield per plant (38.96 g) followed by Vellanikkara Seln. Br (38.92 g) and Vellanikkara irradiated (38.33 g). Ponnukkara recorded the highest biological yield under shade also (38.42 g) followed by Vellanikkara Seln. M (37.78 g) and Koothattukulam (33.23 g) (Table 8).

Table 8. Variability in yield characters of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions.

Types	Fresh rhisome yield g/plant			Dry rhizome yield g/plant			Dry weight ratio			Biological yield g/plant			Harvest index			Oil content (percentage)		
	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shade	Pooled	Open	Shaded	Pooled	Open	Shade	Pooled	Open	Shade	Pooled
Koothattukulam	64.43	58.73	61.58	15.61	19.40	17.50	0.24	0.31	0.27	31.44	33.23	32.29	0.50	0.53	0.52	1.60	2.13	1.87
Ponnukkara	74.46	58.16	66.31	19.81	19.79	19.80	0.27	0.34	0.30	38.96	38.42	38.69	0.52	0.54	0.58	2.20	2.07	2.13
Thodupuzha	66.63	40.39	53.51	16.18	12.46	14.32	0.24	0.32	0.28	30.04	25.18	27.61	0.55	0.49	0.52	2.78	2.60	2.67
Palakkad	48.81	31.22	40.01	13.08	10.17	11.62	0.27	0.33	0.30	26.00	19.60	22.80	0.51	0.44	0.47	1.53	1.33	1.43
Varantharappilly	61.49	50.45	55.97	16.44	16.18	16.31	0.27	0.32	0.29	27.88	29.21	28.55	0.59	0.56	0.58	2.33	1.87	2.10
Vellanikkara Seln. Br	74.93	39.97	57.45	19.71	13.55	16.63	0.26	0.34	0.30	38.92	25.25	32.09	0.51	0.53	0.52	2.53	2.53	2.53
Vellanikkara Seln. NR	51.20	47.32	49.26	10.00	14.66	12.33	0.20	0.31	0.25	22.78	31.83	27.31	0.44	0.46	0.45	2.33	2.60	2.47
Vellanikkara Seln. L	54.42	44.57	49.49	13.97	16.03	15.00	0.26	0.36	0.31	31.22	29.05	30.13	0.45	0.55	0.50	2.47	3.07	2.77
Vellanikkara Seln. M	54.61	47.81	57.21	15.11	15.40	15.26	0.27	0.32	0.30	36.66	37.78	37.22	0.41	0.41	0.41	3.00	2.80	2.90
Vellanikkara irradiated	54.61	47.39	51.00	14.86	14.35	14.61	0.27	0.31	0.29	38.33	28.56	33.45	0.39	0.50	0.43	2.73	2.87	2.80
Mean	60.56	46.60	53.58	15.48	15.20	15.34	0.25	0.33	0.29	32.22	29.80	31.01	0.49	0.50	0.50	2.35	2.39	2.37
SEm±	10.01		7.08	3.34		2.36	0.00		0.00	6.51		3.20	0.08		0.06	0.37		0.27
CD (0.05)	22.65		NS	NS		NS	0.00		NS	NS		NS	NS		NS	NS		0.55

Table 9. Per plot and per hectare yield of fresh as well as dry rhizomes of Kacholam (*Kaempferia galanga* L.) under open condition

Types	Fresh rhizome yield per plot (kg)	Fresh rhizome yield per hectare (tonnes)	Dry rhizome yield per plot (kg)	Dry rhizome yield per hectare (tonnes)
Koothattukulam	3.61	12.03	0.87	2.91
Ponnukkara	4.17	13.90	1.11	3.70
Thodupuzha	3.73	12.43	0.91	3.02
Palakkad	2.73	9.11	0.72	2.44
Varantharappilly	3.47	11.55	0.99	3.29
Vellanikkara Seln. Br	4.20	13.99	1.10	3.68
Vellanikkara Seln. NR	2.87	9.56	0.56	1.87
Vellanikkara Seln. L	3.05	10.16	0.83	2.61
Vellanikkara Seln. M	3.06	10.19	0.85	2.82
Vellanikkara irradiated	3.06	10.19	0.83	2.77

Table 10. Per plot and per hectare yield of fresh as well as dry rhizome of Kacholam *Kaempferia galanga* L.) types under shaded condition

Types	Fresh rhizome per plot (kg)	Fresh rhizome per hectare (tonnes)	Dry rhizome per plot (kg)	Dry rhizome per hectare (tonnes)
Koothattukulam	3.30	10.96	0.99	3.31
Ponnukkara	3.26	10.86	1.11	3.69
Thodupuzha	2.26	7.54	0.70	2.32
Palakkad	1.75	5.82	0.57	1.90
Varantharappilly	2.83	9.42	0.91	3.02
Vellanikkara Seln. Br	2.24	7.46	0.79	2.53
Vellanikkara Seln. NR	2.65	8.83	0.82	2.74
Vellanikkara Seln. L	2.50	8.32	0.70	2.99
Vellanikkara Seln. M	2.68	8.93	0.86	2.87
Vellanikkara irradiated	2.65	8.85	0.80	2.68

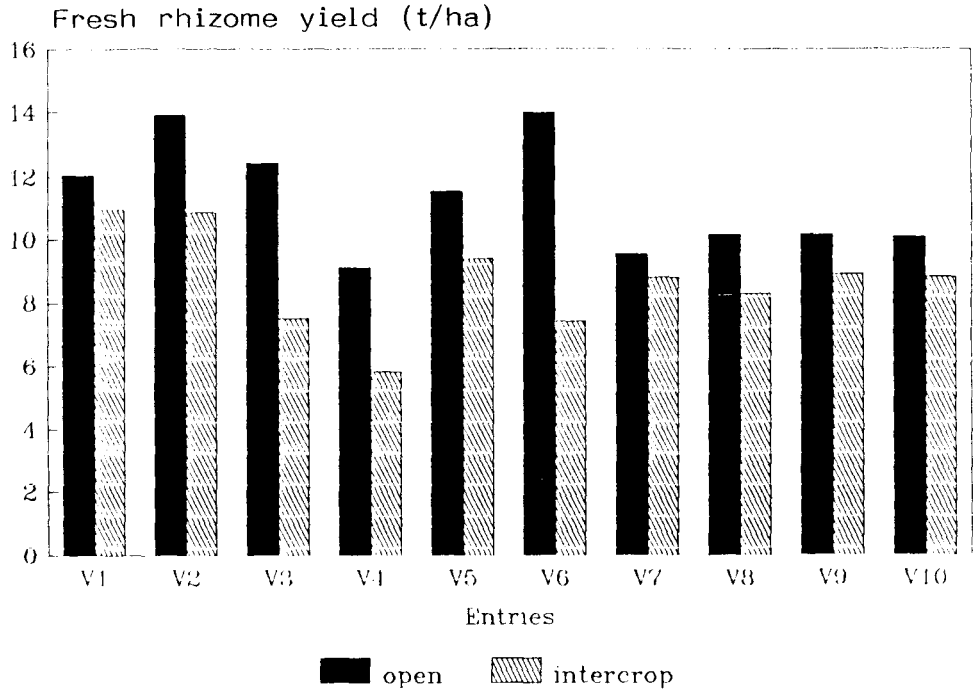


Fig.4. Comparative performance of fresh rhizome yield per hectare of Kacholam (Kaempferia galanga L.) types under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10 - Vellanikkara Irradiated

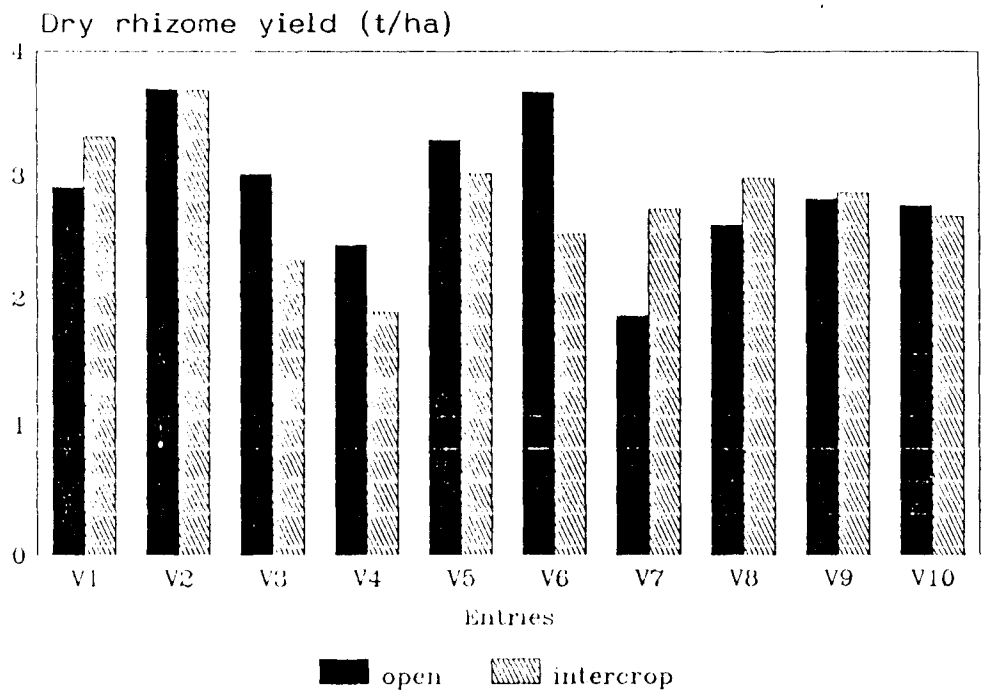


Fig.5. Comparative performance of dry rhizome yield per hectare of Kacholam (Kaempferia galanga L.) types under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10 - Vellanikkara Irradiated

4.1.26 Harvest Index

The pooled analysis showed no significant difference in the treatment means. harvest index of the types ranged from 0.41 as recorded by Vellanikkara Seln. M to 0.58 as recorded by Ponnukkara and Varantharappilly. The types performed similarly both under open and shaded conditions regarding this trait (Table 8).

4.1.27 Oil content

There was singificant difference in the oil percentage of the types averaged over the two situations open and shade. Oil percentage varied from 1.43 per cent to 2.90 per cent. Vellanikkara Seln. M yielded the highest percentage of oil (2.90%) followed by Vellanikkara irradiated type (2.80%) and Vellanikkara Seln. L (2.77%). Palakkad recorded the minimum oil yield (1.43%) which was found to be significantly inferior to all other types except Koothattukulam (1.87%) (Table 8 and Fig.6).

Oil yield per hectare was calculated and presented in Table 11 and Fig.7.

4.1.28 Quality of oil

The gas chromatograph of Kacholam oil of both the crop yielded 3 major peaks of which 2 components were identified (Table 12 and 13). They are paramethoxy ethyl cinnamate, which is a white crystal and ethyl cinnamate. Paramethoxy ethyl cinnamate content ranged between 53.6 per cent and 69.83 per cent for the open crop and 55.78 per cent and 63.90 per cent for the crop under shade. Vellanikkara irradiated population yielded the maximum content of paramethoxy

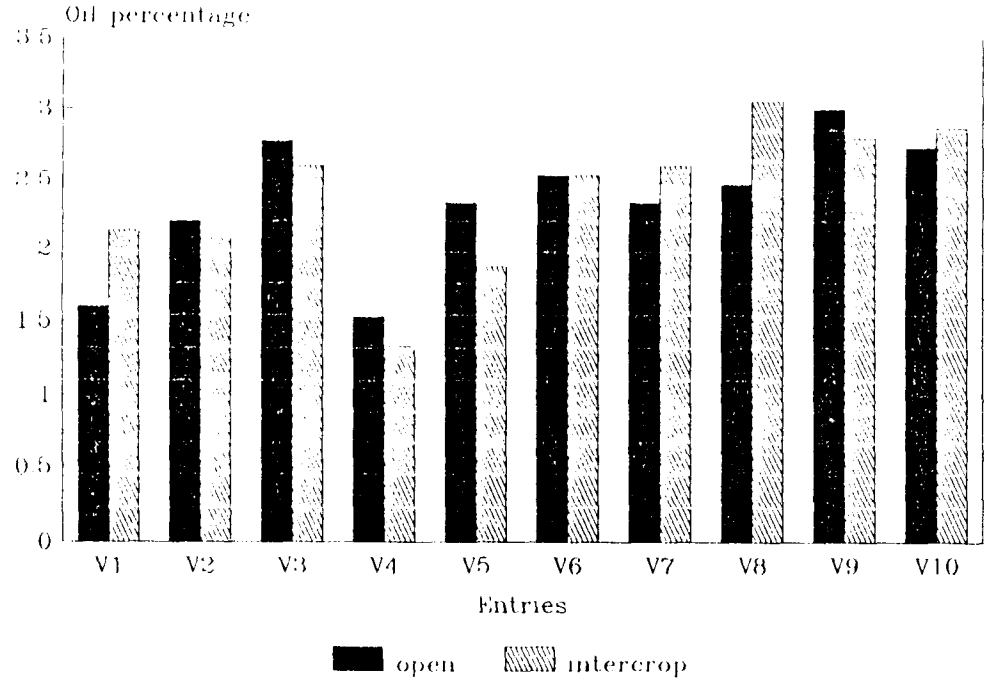


Fig.6. Comparative performance of different types of Kacholam (Kaempferia galanga L.) in oil percentage under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10 - Vellanikkara Irradiated

Table 11. Oil yield per hectare of Kacholam (*Kaempferia galanga* L.) types under open and shaded conditions

	Oil yield per hectare (kg)	
	Open	Shade
Koothattukulam	46.61	70.50
Ponnukkara	81.36	76.47
Thodupuzha	82.45	60.32
Palakkad	37.35	24.67
Varantharappilly	76.59	56.44
Vellanikkara Sel. Br	93.10	63.98
Vellanikkara Sel. NR	43.50	71.16
Vellanikkara Seln. L	64.42	91.85
Vellanikkara Seln. M	84.63	80.33
Vellanikkara irradiated	75.73	76.89

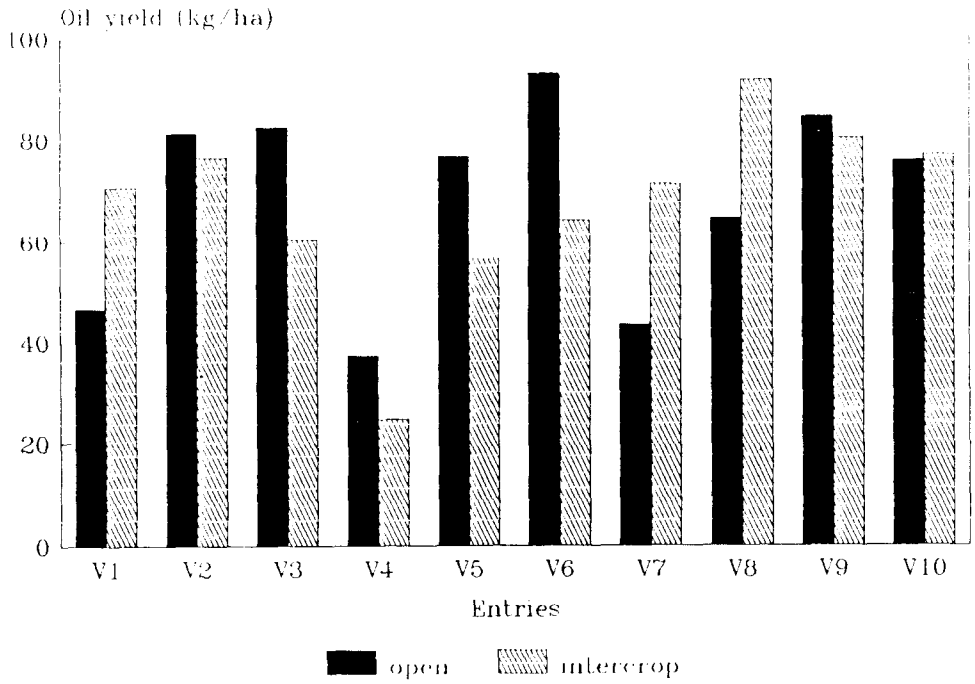


Fig.7. Comparative performance of oil yield per hectare of Kacholam (Kaempferia galanga L.) types under open and shaded conditions

V1 - Koothattukulam
V2 - Ponnukkara
V3 - Thodupuzha
V4 - Palakkad
V5 - Varantharappilly
V6 - Vellanikkara Seln. Br
V7 - Vellanikkara Seln. NR
V8 - Vellanikkara Seln. L
V9 - Vellanikkara Seln. M
V10 - Vellanikkara Irradiated

Table 12. Variation in major components of oil of Kacholam (*Kaempferia galanga* L.) types under open condition

Types	Major components of oil		
	Para methoxy ethyl cinnamat (percentage)	Ethyl cinnamate (percentage)	Unknown component (percentage)
Koothattukulam	61.96	22.74	9.89
Ponnukkara	57.67	23.52	8.53
Thodupuzha	55.70	24.50	8.95
Palakkad	57.05	23.36	9.40
Varantharappilly	64.80	15.69	10.78
Vellanikkara Seln. Br	55.70	24.50	8.95
Vellanikkara Seln. NR	66.23	14.87	9.00
Vellanikkara Seln. L	53.69	22.63	12.10
Vellanikkara Seln. M	59.72	20.19	9.24
Vellanikkara irradiated	69.83	14.63	9.97

Table 13. Variation in major components of oil of Kacholam (*Kaempferia galanga* L.) types under shaded condition

Types	Major components of oil		
	Para methoxy ethyl cinnamate (percentage)	Ethyl cinnamate (percentage)	Unknown component (percentage)
Koothattukulam	61.40	22.65	9.83
Ponnukkara	59.67	19.74	10.61
Thodupuzha	62.06	17.25	9.87
Palakkad	60.46	19.25	9.39
Varantharappilly	61.38	18.09	10.04
Vellanikkara Seln. Br	63.90	17.43	8.72
Vellanikkara Seln. NR	57.16	23.61	10.65
Vellanikkara Seln. L	56.83	21.70	12.19
Vellanikkara Seln. M	55.78	22.82	9.39
Vellanikkara irradiated	56.57	22.87	10.98

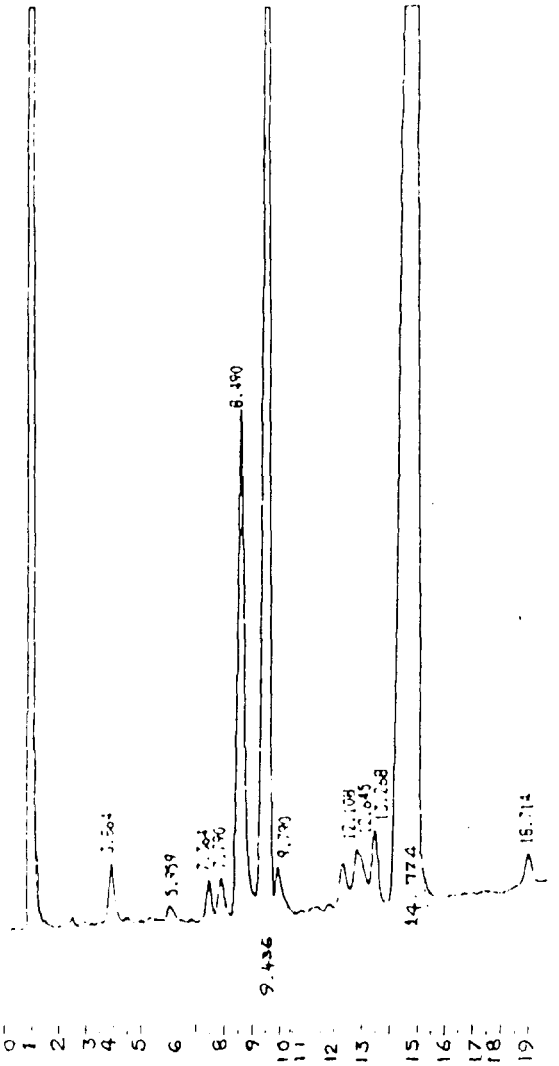
ethyl cinnamate (69.83%) under open condition where as under shade Vellanikkara Seln. Br recorded the maximum content of paramethoxy ethyl cinnamate (63.90%). Vellanikkara Seln. L and Seln. M recorded the minimum content of this component under open and shaded conditions respectively. The content of ethyl cinnamate varied between 14.63 per cent and 24.50 per cent under open condition and 17.25 and 23.61 per cent under shade. Ethyl cinnamate content was maximum in oil of Vellanikkara Seln. Br (24.50%) under open condition and in Vellanikkara Seln. NR (23.61%) under shade.

Oil of the type Koothattukulam was identical regarding its quality under open and shaded conditions. For all the types except Vellanikkara Seln. L the total content of paramethoxy ethyl cinnamate and ethyl cinnamate was found to be more under open condition. Varantharappilly, Vellanikkara Seln. NR and Seln. M were with more paramethoxy ethyl cinnamate under open condition. The rest of the types were with high paramethoxy ethyl cinnamate content under shade. The same 4 types were with less content of ethyl cinnamate under open compared to shade. Vellanikkara Seln. L recorded high content of the 3rd compound both under open and shaded conditions (Fig.8 to Fig.27).

4.2 Correlation studies

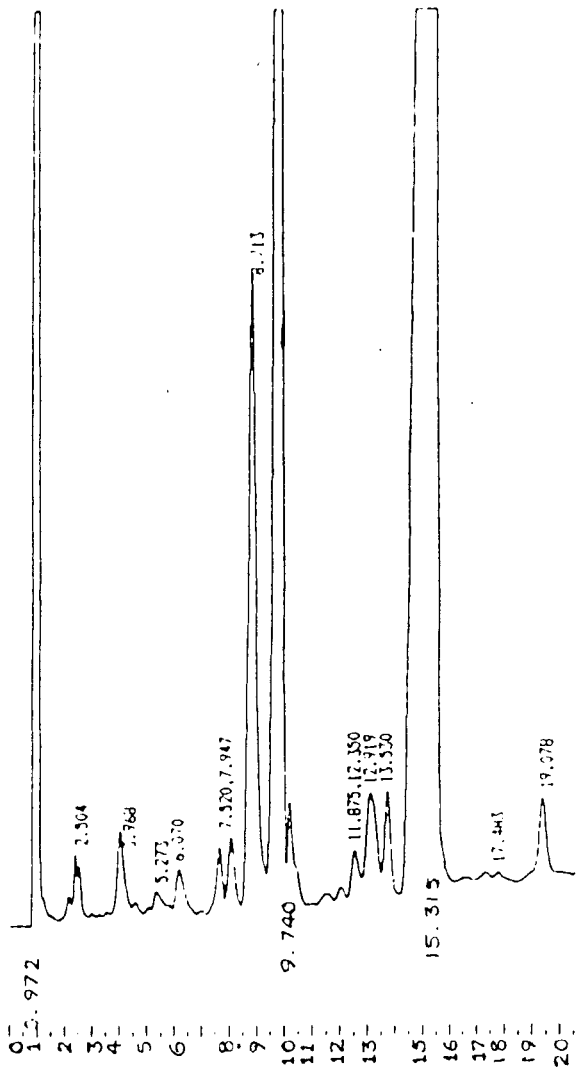
4.2.1 Open crop

The characters, number of leaves (1 month after planting, 3 months after planting, 5 months after planting) length of leaves, leaf area index, spread of flowering, number of suckers per plant, number of mother rhizomes and number of secondary rhizomes were found to be positively and significantly correlated with yield. Days to flowering was found to be negatively correlated with yield (Table 14). Number of leaves 1 month after planting was highly correlated with yield (0.654).



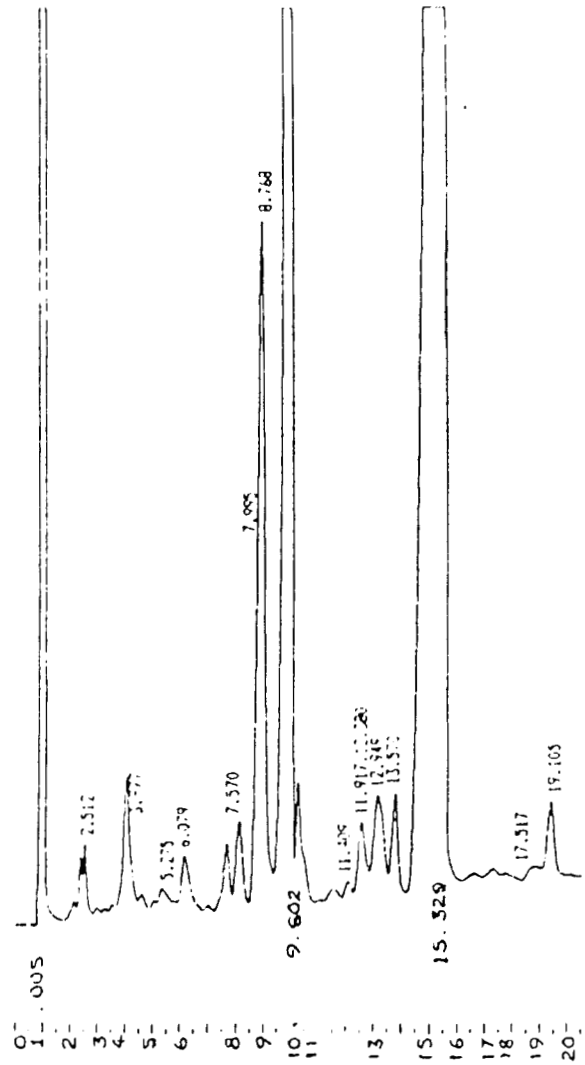
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.864		554106		1.0526	BB
2	7.364		357007		0.6782	PV
3	7.790		433361		0.8232	VV
4	8.489	12596	5206247	14.9534	9.8898	VV
5	9.436	32043	.11972860E 08	38.0400	22.7437	VP
6	9.789		296812		0.5638	TTT
7	12.645		598990		1.1378	BV
8	13.267		606545		1.1522	VP
9	14.774	39596	.32616627E 08	47.0066	61.9587	PB

Fig 8 Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Koothattukulam under open condition



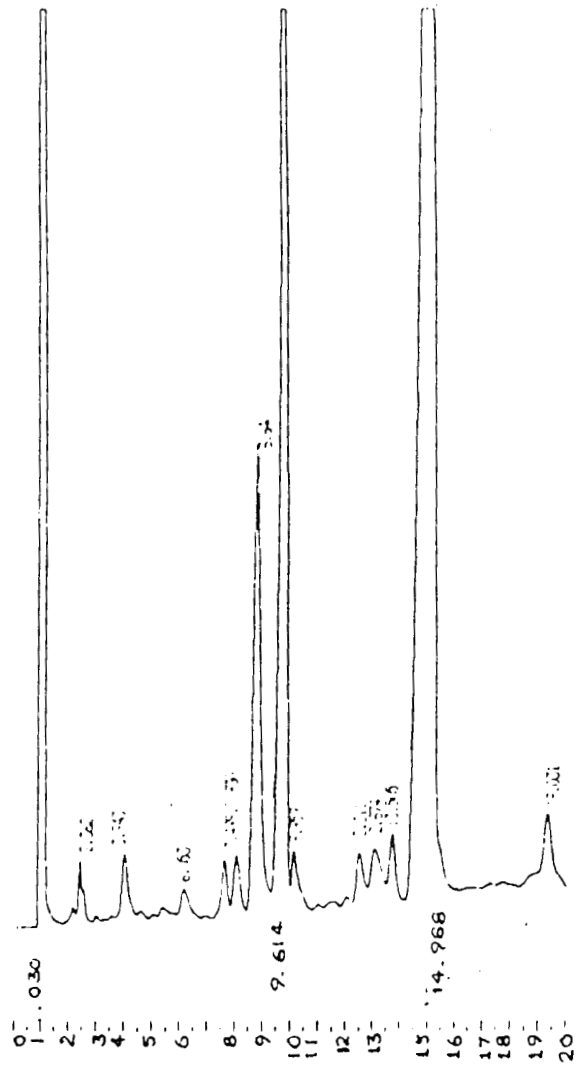
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.304		823946		0.9319	BV
2	3.967	2181	1203439	1.9048	1.3612	VV
3	5.273		398554		0.4508	VV
4	6.070		667301		0.7548	VB
5	7.520		617533		0.6985	BV
6	7.946		791547		0.8953	VV
7	8.713	16249	7541293	14.1916	8.5298	VV
8	9.739	44246	.20794299E 08	38.6438	23.5201	VP
9	10.037		580054		0.6561	TTT
10	12.350		504079		0.5701	BV
11	12.918	2578	1609695	2.2516	1.8207	VV
12	13.529	2610	995247	2.2795	1.1257	VP
13	15.315	46633	.50974772E 08	40.7286	57.6568	PP
14	19.077		908977		1.0281	PB

Fig.9. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Ponnukkara under open condition



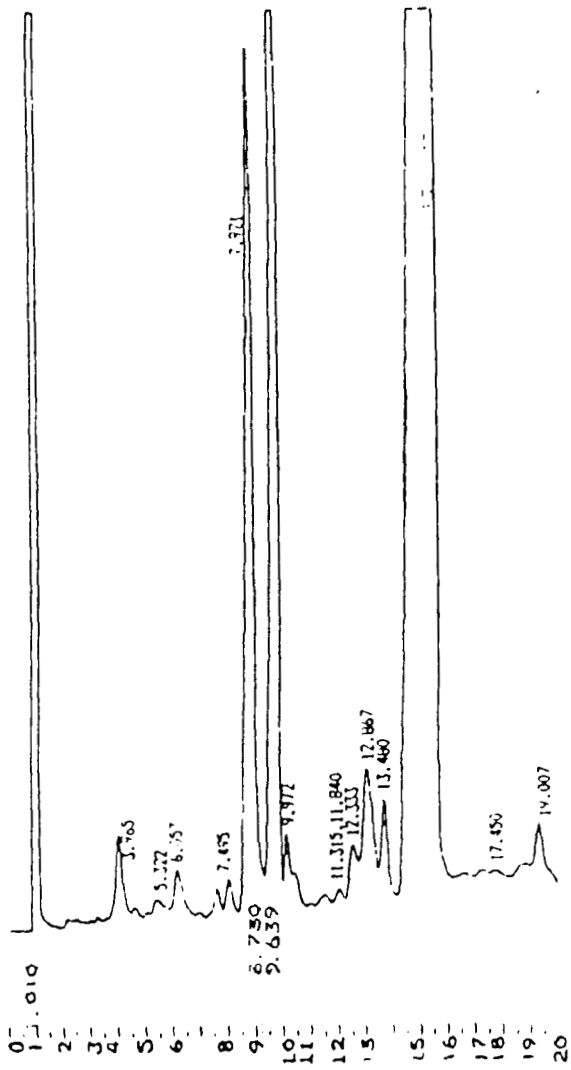
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.512		453300		0.5095	BP
2	3.976	3374	1470840	2.7519	1.6534	PB
3	6.078		605074		0.6802	BB
4	7.569		656060		0.7375	BV
5	7.995	2295	952285	1.8719	1.0705	VV
6	8.767	17549	7962584	14.3134	8.9508	VV
7	9.802	45122	.21792997E 08	36.8027	24.4977	VP
8	10.094	2191	71[illegible]	1.7870	0.8010	TTT
9	12.380		798140		0.8972	BV
10	12.948	2522	1556937	2.0570	1.7502	VV
11	13.570	2574	953935	2.0994	1.0723	VP
12	15.329	46978	.49548748E 08	38.3165	55.6981	PP
13	17.516		444023		0.4991	TTT
14	19.105		1051980		1.1825	PB

Fig.10. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Thodupuzha under open condition



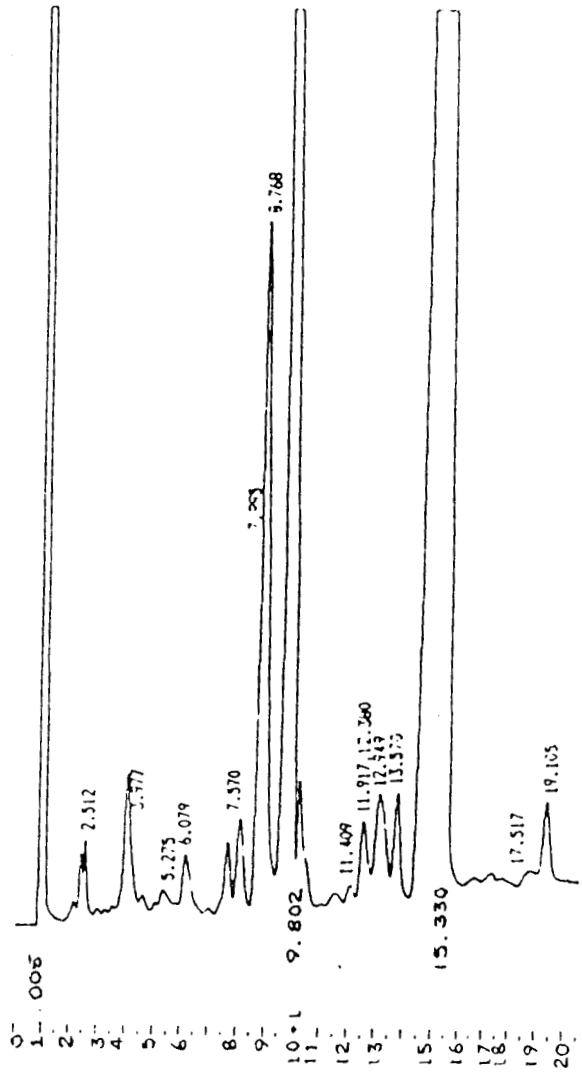
PK#	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.362		294949		0.5385	BB
2	3.943		630313		1.1513	BB
3	6.053		334965		0.6118	BB
4	7.498		527203		0.9629	BV
5	7.929		656130		1.1984	VV
6	8.639	11910	5148374	14.3511	9.4036	VV
7	9.614	33018	.12791421E 08	39.7855	23.3638	VP
8	9.958		364579		0.6659	TTT
9	12.311		279482		0.5086	PB
10	12.874		624046		1.1398	BV
11	13.506		579519		1.0585	VP
12	14.987	38362	.31231581E 08	45.8633	57.0452	PB
13	19.031		1287395		2.3514	TTT

Fig.11. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Palakkad under open condition



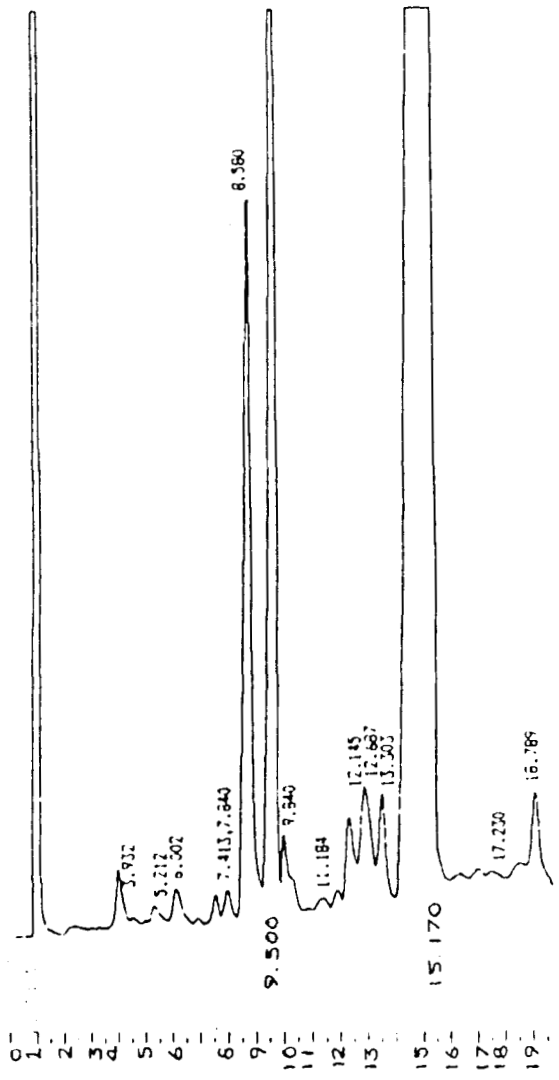
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.965	2204	1067885	1.9215	1.1343	BV
2	5.322		319030		0.3389	VV
3	6.056		722780		0.7678	VP
4	7.921		347694		0.3693	VV
5	8.729	22046	.10145476E 08	19.2202	10.7769	VV
6	9.638	36050	.14774191E 08	31.4293	15.6937	VB
7	9.972		557617		0.5923	TTT
8	12.333		722714		0.7677	VV
9	12.866	3399	2154302	2.9633	2.2884	VV
10	13.480	2610	1066523	2.2755	1.1329	VV
11	15.397	48393	.60999331E 08	42.1902	64.7959	VB
12	19.006		1263116		1.3417	TVT

Fig.12. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Varantharappilly under open condition



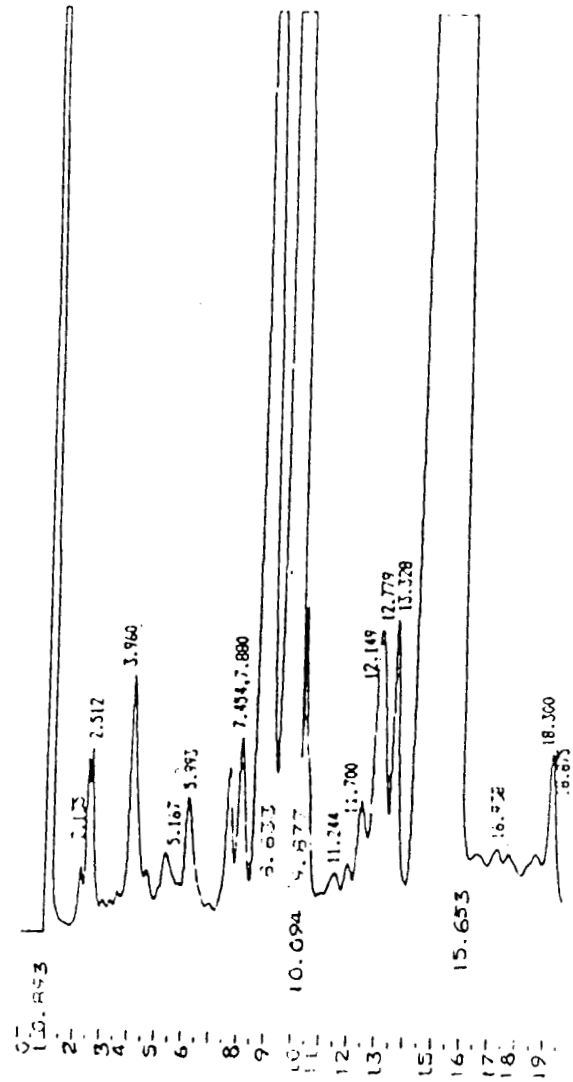
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.512		453300		0.5095	BP
2	3.976	3374	1470840	2.7519	1.6534	PB
3	6.078		605074		0.6802	BB
4	7.569		656060		0.7375	BV
5	7.995	2295	952285	1.8719	1.0705	VV
6	8.767	17549	7962584	14.3134	8.9508	VV
7	9.802	45122	.21792997E 08	36.8027	24.4977	VP
8	10.094	2191	712536	1.7870	0.8010	TTT
9	12.380		798140		0.8972	BV
10	12.948	2522	1556937	2.0570	1.7502	VV
11	13.570	2574	953935	2.0994	1.0723	VP
12	15.329	46978	.49548748E 08	38.3165	55.6981	PP
13	17.516		444023		0.4991	TTT
14	19.105		1051980		1.1825	PB

Fig.13. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. Br under open condition



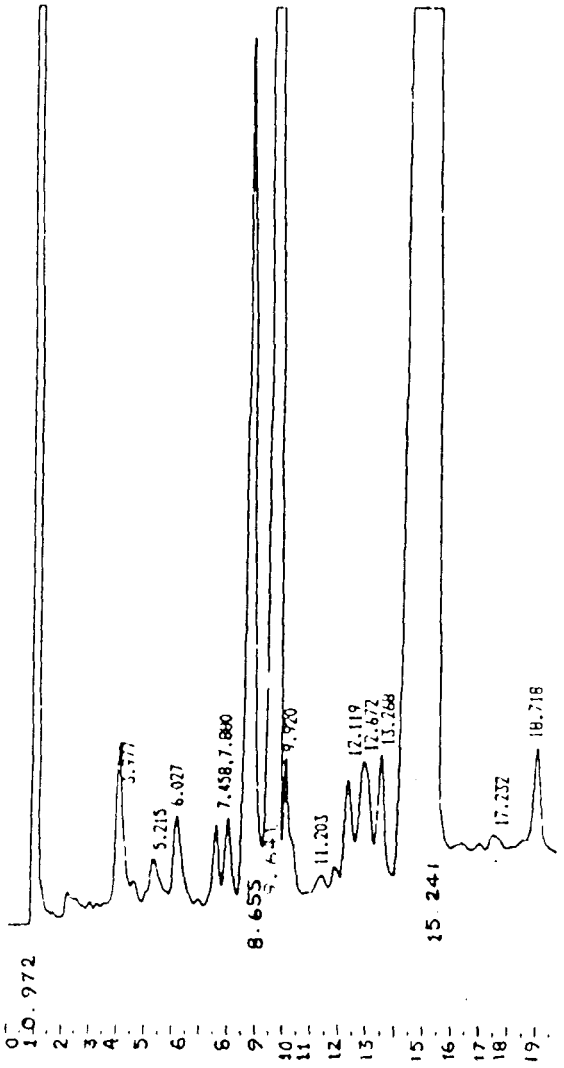
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.932		740687		0.8453	BV
2	5.212		267083		0.3048	VV
3	6.002		544736		0.6217	VP
4	7.839		316438		0.3611	VV
5	8.579	18311	7887219	16.7938	9.0013	VV
6	9.499	33545	.13032989E 08	30.7656	14.8738	VP
7	9.840		527669		0.6022	TTT
8	12.145	2153	1176494	1.9746	1.3427	BV
9	12.686	2903	1847387	2.6625	2.1083	VV
10	13.303	2686	1094556	2.4634	1.2492	VV
11	15.170	47071	.58032767E 08	43.1709	66.2302	VB
12	17.229		527713		0.6022	TTV
13	18.788	2365	1627196	2.1690	1.8570	TVT

Fig.14. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. NR under open condition



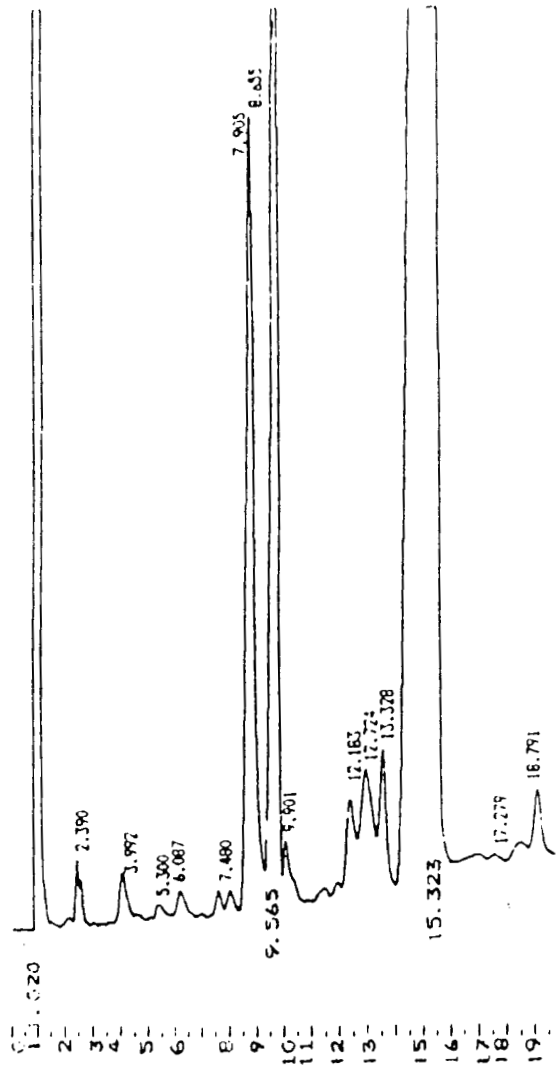
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.135		325971		0.1834	BV
2	2.512	4247	1842259	2.3450	1.0364	VB
3	3.959	5653	2847784	3.1213	1.6020	BV
4	5.166		1034469		0.5819	VV
5	5.993	2725	1602257	1.5046	0.9013	VB
6	7.454	3538	1396782	1.9535	0.7857	BV
7	7.880	4294	1949481	2.3709	1.0967	VV
8	8.833	33608	.21515303E 08	18.5566	12.1034	VV
9	9.876	54571	.40235464E 08	30.1312	22.6344	VP
10	10.094	4624	1210248	2.5531	0.6808	TTT
11	12.148		639764		0.3599	PV
12	12.778	5126	2914051	2.8303	1.6393	VB
13	13.327	5645	1747715	3.1169	0.9832	BP
14	15.653	53471	.95433541E 08	29.5239	53.6860	PB
15	16.937		608569		0.3423	TTV
16	18.299		708484		0.3985	TVV
17	18.875	3609	1750363	1.9927	0.9847	TVT

Fig.15. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. L under open condition



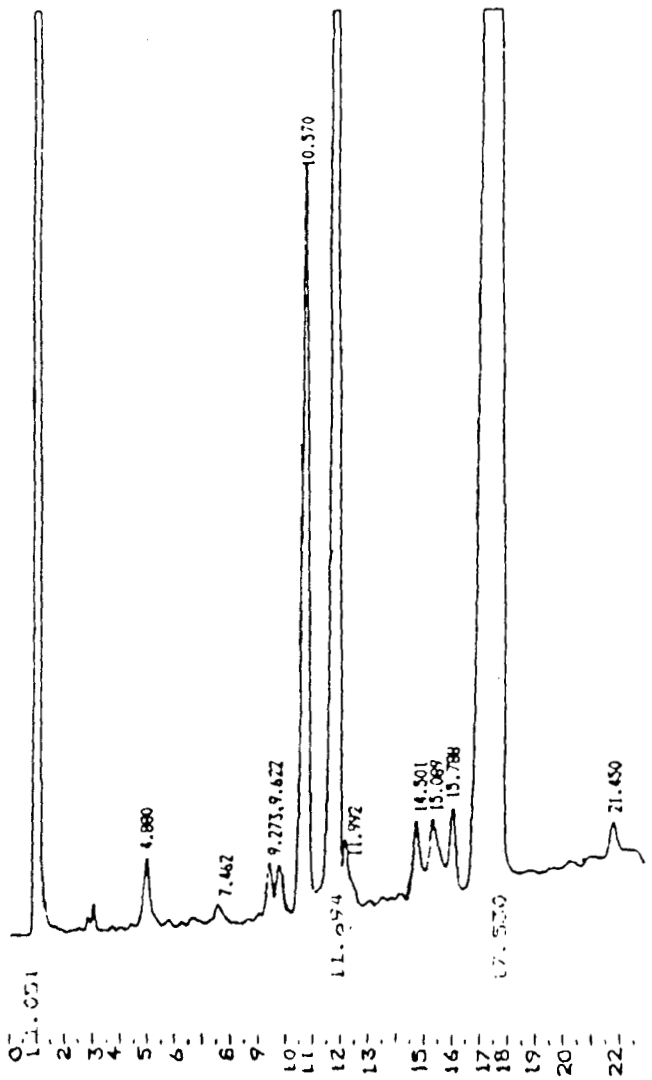
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.976	4266	3164672	3.2807	2.8801	BV
2	5.215		832769		0.7579	VV
3	6.026	2327	1347504	1.7896	1.2263	VB
4	7.457		670216		0.6099	BV
5	7.880		764199		0.6955	VP
6	8.655	21839	.10147750E 08	16.7952	9.2354	PV
7	9.641	43806	.22188699E 08	33.6889	20.1938	VP
8	9.920	2347	739509	1.8049	0.6730	TTT
9	12.11[illegible]		704761		0.6414	PB
10	12.672	2074	1055601	1.5950	0.9607	BP
11	13.267	2527	785641	1.9434	0.7150	PP
12	15.241	48167	.65621485E 08	37.0427	59.7216	PB
13	17.232		544726		0.4957	TTV
14	18.717	2678	1311430	2.0595	1.1935	TVT

Fig.16. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. M under open condition



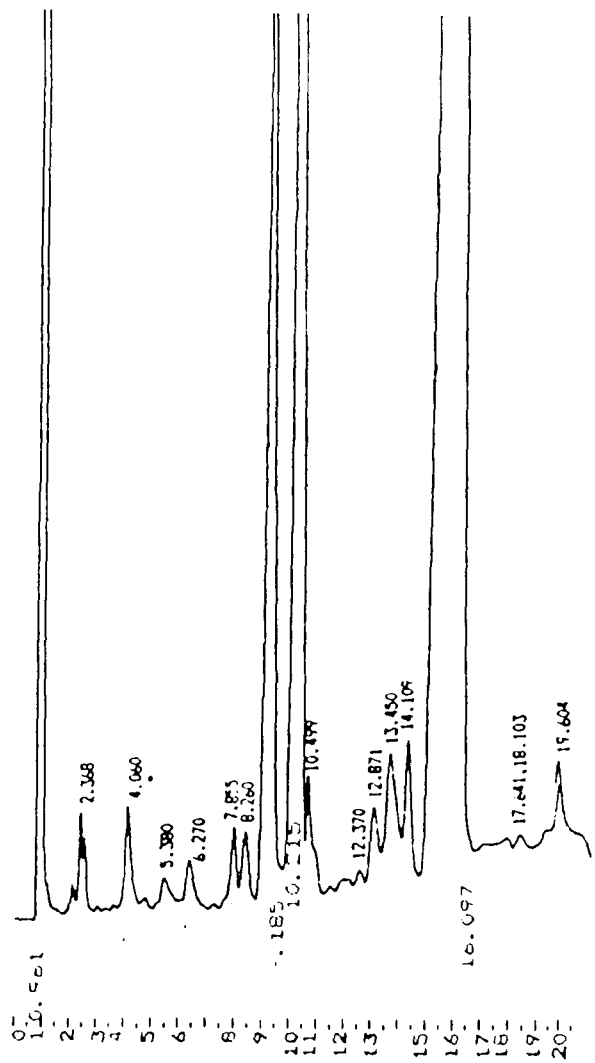
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.389		465328		0.4959	BB
2	3.992		637938		0.6799	BP
3	6.086		347923		0.3708	PP
4	8.655	20090	9356547	19.1355	9.9721	PV
5	9.565	34161	.13724475E 08	32.5380	14.6275	VP
6	9.901		356565		0.3800	TTT
7	12.724		1136716		1.2115	BV
8	13.327	3072	1124791	2.9260	1.1988	VP
9	15.323	47665	.65519670E 08	45.4004	69.8305	PB
10	18.791		1156781		1.2329	TPT

Fig.17. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Irradiated population under open condition



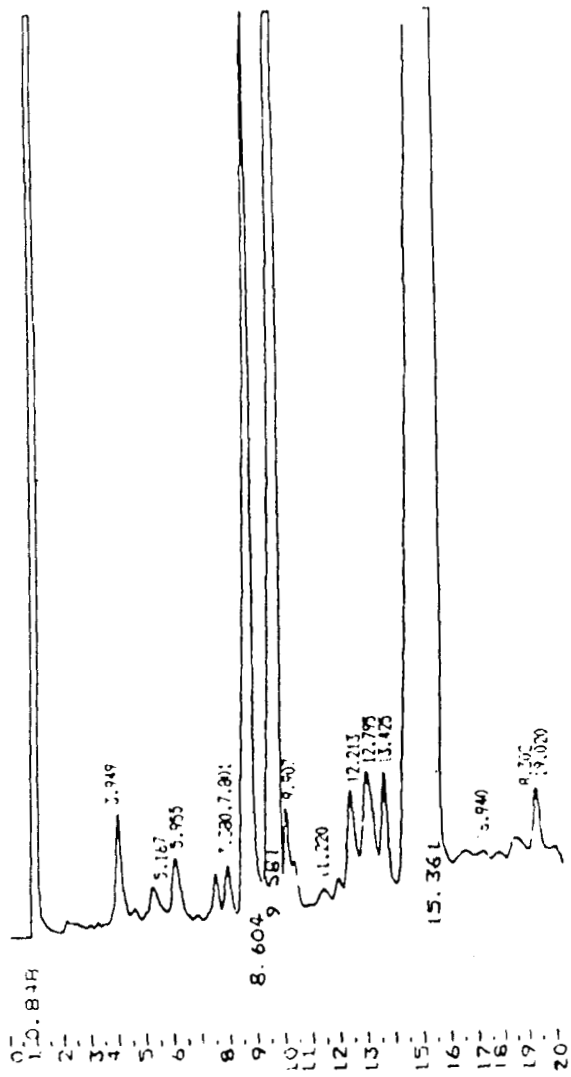
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	4.879		676349		0.8871	BB
2	9.273		407306		0.5342	BV
3	9.622		522293		0.6851	VP
4	10.569	14026	7492385	17.4390	9.8274	PV
5	11.[illegible]	40107	.17267627E 08	36.7617	22.6491	VP
6	15.088		753900		0.9888	BV
7	15.787		705591		0.9255	VP
8	17.529	49967	.46813464E 08	45.7993	61.4030	PB
9	21.450		1600780		2.0997	TTT

Fig.18. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Koothattukulam under shaded condition



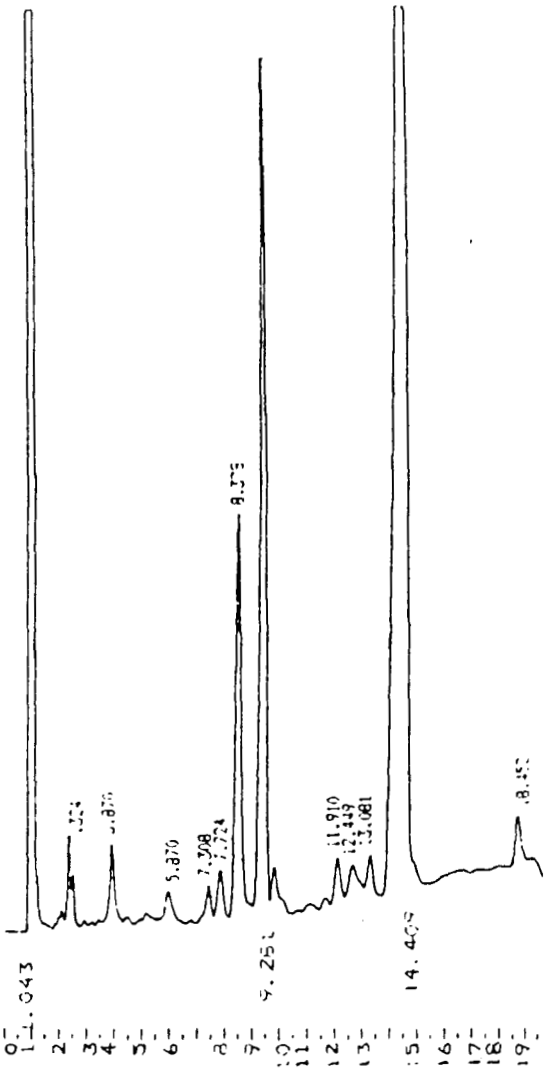
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.367	2254	602554	1.5141	0.5000	BB
2	4.060	2491	1071509	1.6733	0.8891	BV
3	5.379		468044		0.3883	VV
4	6.269		609325		0.5056	VB
5	7.855		707745		0.5872	BV
6	8.260		745274		0.6184	VV
7	9.185	28370	.12786405E 08	19.0575	10.6094	VV
8	10.215	49656	.23784381E 08	33.3564	19.7348	VP
9	10.498		587912		0.4878	TTT
10	12.369		263355		0.2185	PB
11	12.871		830558		0.6891	BV
12	13.450	3143	2004818	2.1113	1.6635	VV
13	14.108	3402	1351702	2.2853	1.1215	VV
14	16.096	57171	.71909433E 08	38.4046	59.6660	VB
15	17.641		389656		0.3233	TTV
16	19.604	2378	2407233	1.5974	1.9974	TVT

Fig.19. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Poonukkara under shaded condition



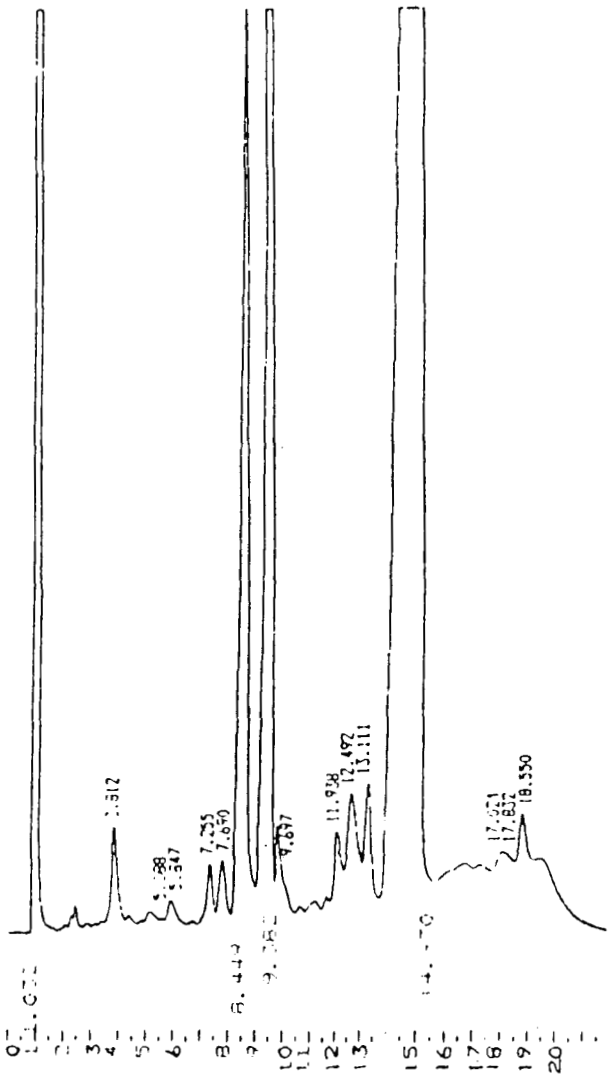
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.948	2725	1266109	2.1177	1.2189	BV
2	5.166		533784		0.5139	VV
3	5.955		862086		0.8299	VP
4	7.380		402846		0.3878	PV
5	7.801		489970		0.4717	VV
6	8.604	23464	.10256686E 08	18.2352	9.8744	VV
7	9.581	41172	.17915691E 08	31.9971	17.2480	VP
8	9.906		705916		0.6796	TTT
9	12.213	2581	1441435	2.0058	1.3877	BV
10	12.795	3030	1993153	2.3548	1.9189	VV
11	13.425	2953	1229643	2.2949	1.1838	VV
12	15.361	52749	.64460509E 08	40.9943	62.0583	VB
13	16.939		566864		0.5457	TTV
14	18.302		550601		0.5301	TVV
15	19.020		1195568		1.1510	TVT

Fig.20. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Thodupuzha under shaded condition



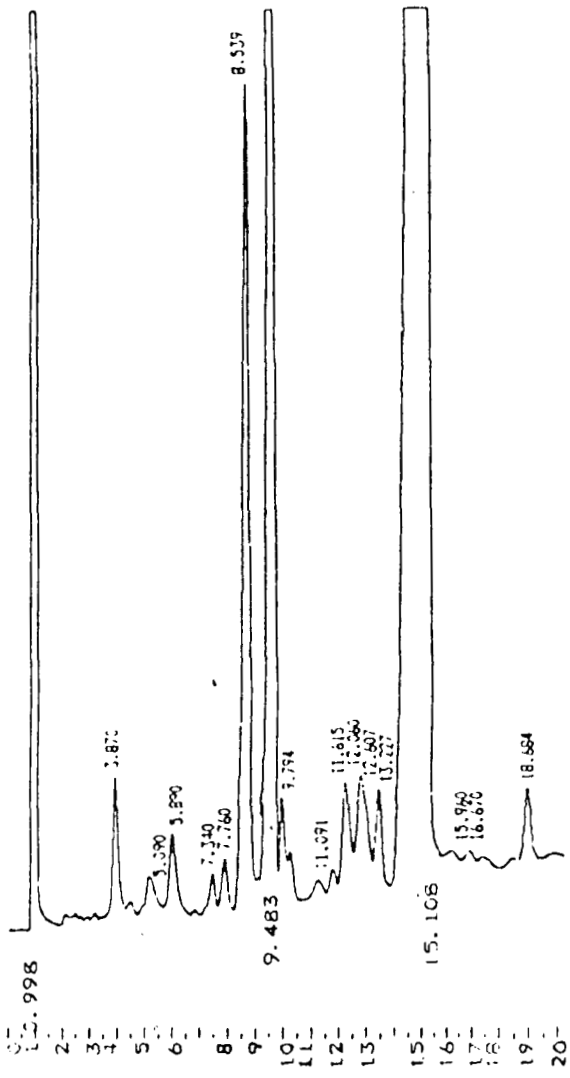
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.324	2231	488884	3.2098	1.2912	BB
2	3.869		656949		1.7351	BB
3	5.870		303374		0.8012	BP
4	7.307		311647		0.8231	PV
5	7.724		446794		1.1800	VP
6	8.377	10217	3554753	14.6994	9.3884	PV
7	9.281	21679	7288460	31.1901	19.2495	VP
8	9.655		356814		0.9424	TTT
9	11.910		578869		1.5288	PV
10	12.448		573567		1.5148	VV
11	13.081		409393		1.0812	VP
12	14.408	35379	.22893677E 08	50.9006	60.4642	PP

Fig.21. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Palakkad under shaded condition



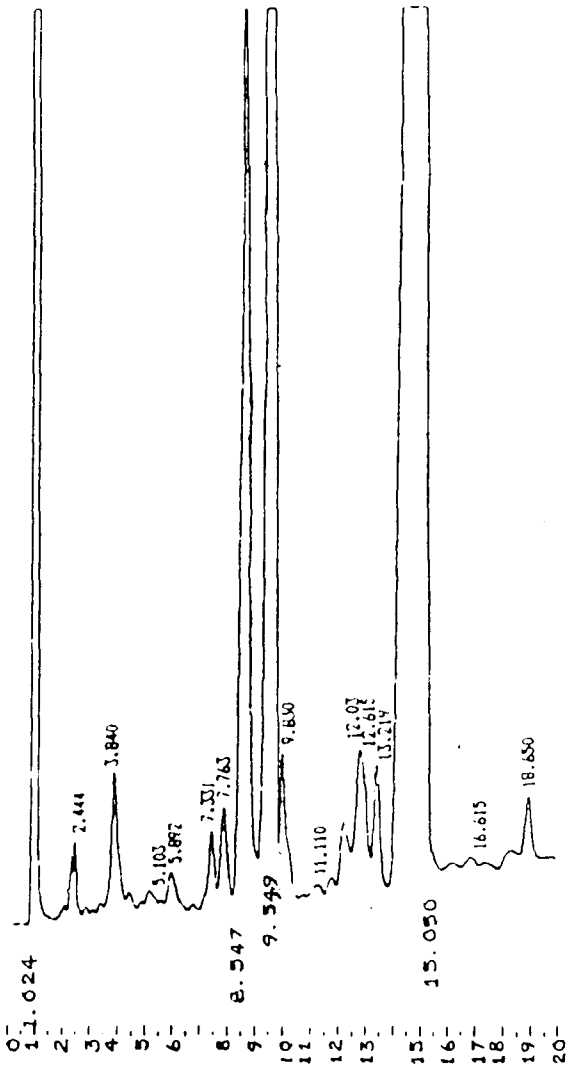
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.812	2344	872902	1.8537	0.8951	BP
2	7.255		464797		0.4766	BV
3	7.689		517874		0.5310	VP
4	8.448	23119	9791994	18.2837	10.0410	PV
5	9.382	42365	.17644866E 08	33.5044	18.0936	VP
6	9.696		494011		0.5066	TTT
7	12.492	2084	1126521	1.6481	1.1552	BV
8	13.111	2649	926775	2.0950	0.9503	VP
9	14.930	51634	.59861229E 08	40.8348	61.3835	PB
10	17.024		1394206		1.4297	TTV
11	17.832		1198931		1.2294	TVV
12	18.550	2251	3225970	1.7802	3.3080	TVT

Fig.22. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Varantharappilly under shaded condition



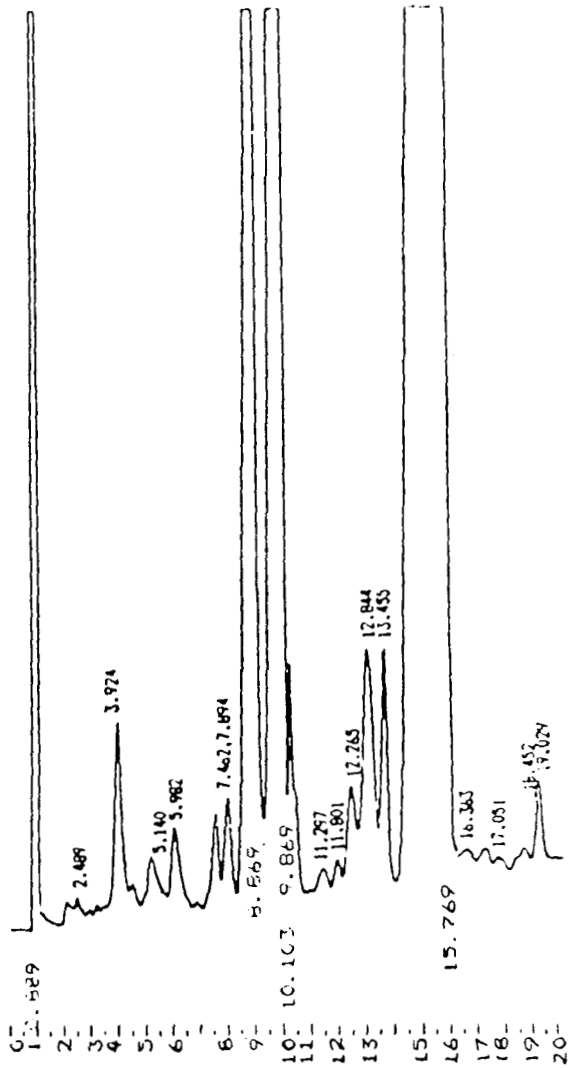
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	3.869	3626	1436012	2.8088	1.4910	BV
2	5.090		590096		0.6127	VV
3	5.890		1020789		1.0599	VP
4	7.339		356181		0.3698	PV
5	7.760		483995		0.5025	VP
6	8.538	21023	8398566	16.2848	8.7204	PV
7	9.483	41215	.16789438E 08	31.9258	17.4328	VP
8	9.794	2061	793826	1.5965	0.8242	TTT
9	12.060	2768	1301118	2.1441	1.3510	VV
10	12.606	2933	1766821	2.2719	1.8345	VV
11	13.226	2524	935935	1.9551	0.9718	VP
12	15.107	52946	.61544367E 08	41.0129	63.9027	PP
13	18.684		892380		0.9266	PV

Fig.23. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. Br under shaded condition



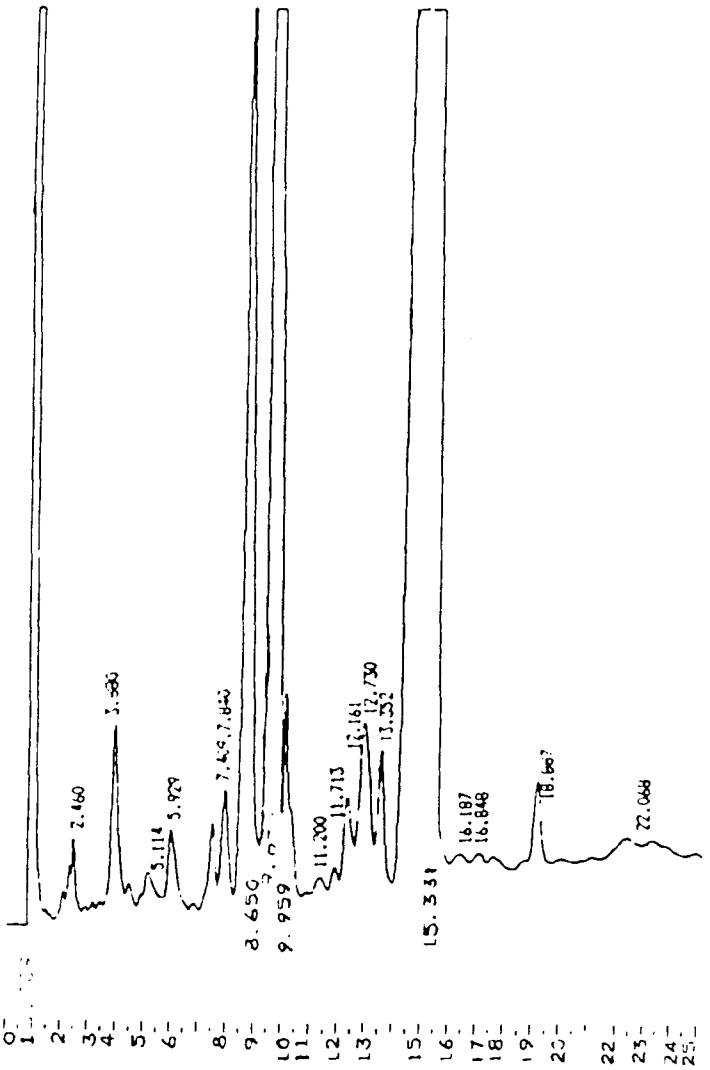
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.444		461050		0.4388	BB
2	3.839	3437	1423408	2.4318	1.3546	BB
3	5.892		390360		0.3715	BB
4	7.331		755771		0.7193	BV
5	7.763	2576	1099362	1.8226	1.0462	VV
6	8.546	24245	.11192511E 08	17.1540	10.6518	VV
7	9.548	50600	.24812611E 08	35.8009	23.6140	VP
8	9.830	2616	818868	1.8509	0.7793	TTT
9	12.038		349848		0.3329	PB
10	12.615	2691	1375235	1.9040	1.3088	BP
11	13.218	2702	841865	1.9117	0.8012	PP
12	15.050	52470	.60056756E 08	37.1240	57.1556	PP
13	16.615		386988		0.3683	TTT
14	18.649		1111281		1.0575	PB

Fig.24. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Soln. NR under shaded condition



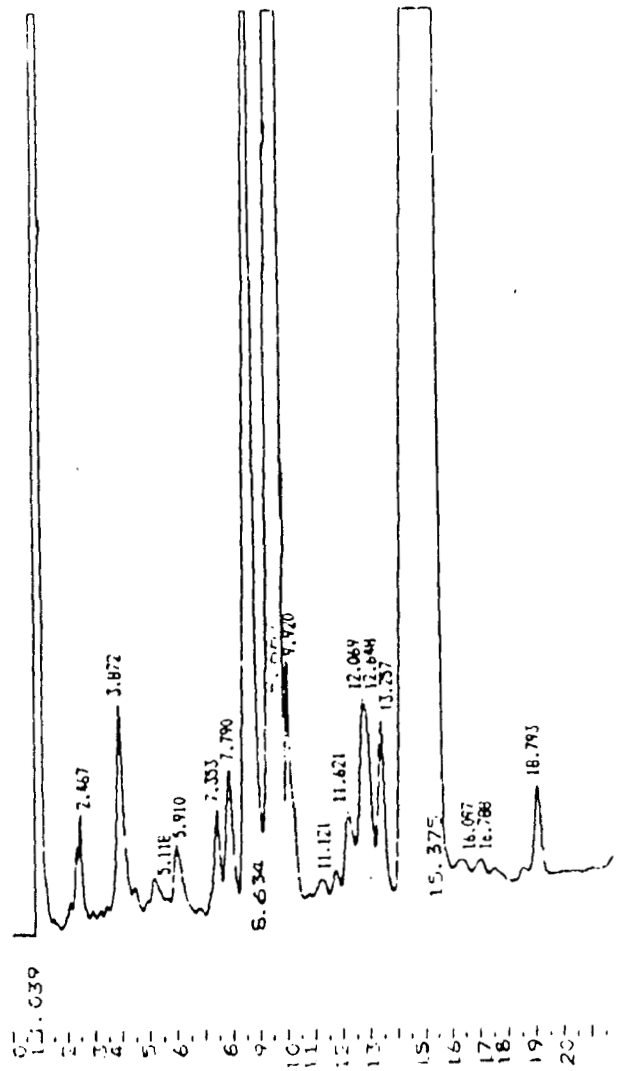
SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.488		731872		0.4319	BV
2	3.924	5049	2694768	2.7781	1.5904	VV
3	5.139		1088119		0.6422	VV
4	5.982	2125	1282223	1.1692	0.7568	VB
5	7.462	2281	868828	1.2551	0.5128	BV
6	7.894	2538	1050984	1.3965	0.6203	VP
7	8.868	35973	.20655210E 08	19.7935	12.1907	PV
8	9.868	57195	.36762355E 08	31.4706	21.6971	VP
9	10.103	3863	1093924	2.1255	0.6456	TTT
10	12.265	2072	904303	1.1401	0.5337	PV
11	12.844	4906	2734635	2.6994	1.6140	VB
12	13.455	5044	1569405	2.7754	0.9263	BP
13	15.768	58495	.96296693E 08	32.1859	56.8341	PP
14	17.051		311687		0.1839	TPT
15	18.452		329318		0.1944	PV
16	19.028	2200	1060206	1.2105	0.6257	VB

Fig.25. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Sein. L under shaded condition



SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.460		1116609		0.9112	BV
2	3.880	4745	2331106	3.1964	1.9023	VV
3	5.114		804504		0.6565	VV
4	5.928		1123827		0.9171	VB
5	7.408	2092	815938	1.4092	0.6658	BV
6	7.839	2853	1215321	1.9219	0.9918	VV
7	8.650	24338	.11502582E 08	16.3951	9.3867	VV
8	9.693	50952	.27959594E 08	34.3234	22.8164	VP
9	9.958	3572	1125359	2.4062	0.9183	TTT
10	12.161		582930		0.4757	PB
11	12.729	3070	1567322	2.0681	1.2790	BP
12	13.352	2685	833228	1.8087	0.6799	PP
13	15.331	52043	.68352817E 08	35.0583	55.7794	PB
14	16.847		326739		0.2666	TVP
15	18.886	2097	1323390	1.4126	1.0799	TPV
16	22.067		1560093		1.2731	TVT

Fig.26. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Seln. M under shaded condition



SRN	R.TIME	HEIGHT	AREA	HT%	AREA%	TYPE
1	2.466	2883	1391111	1.7727	0.9934	VV
2	3.872	5394	2620736	3.3168	1.8725	VB
3	5.117		278593		0.1990	TTT
4	5.909		738701		0.5274	BB
5	7.353	2704	1058976	1.6627	0.7566	BV
6	7.790	3646	1621131	2.2419	1.1583	VV
7	8.634	29335	.15356574E 08	18.0381	10.9721	VV
8	9.666	52800	.32001937E 08	32.4667	22.8650	VP
9	9.920	4195	1240507	2.5795	0.8863	TTT
10	12.068		499787		0.3571	PB
11	12.647	4005	2260705	2.4627	1.6152	BV
12	13.256	3978	1387293	2.4461	0.9912	VP
13	15.375	53688	.79174950E 08	33.0128	56.5695	PB
14	16.787		329962		0.2357	TVT

Fig.27. Gas chromatograph of oil of Kacholam (Kaempferia galanga L.) type Vellanikkara Irradiated population under shaded condition

Table 14. Correlation coefficients for different characters of Kacholam (*Kaempferia galanga* L.) with yield under open and shaded conditions

Character	Correlation coefficients	
	Open	Shade
1. Number of leaves 1 month after planting	0.65**	0.57**
2. Number of leaves 3 months after planting	0.57**	0.65**
3. Number of leaves 5 months after planting	0.42*	0.67**
4. Number of leaves 6 months after planting	0.35	0.63**
5. Length of leaves	0.42*	0.83**
6. Width of leaves	0.15	0.80**
7. LAI at flowering	0.48**	0.37*
8. LAI 1 month after flowering	0.40*	0.45*
9. Days to flowering	-0.57**	-0.54**
10. Spread of flowering	0.58**	0.39*
11. Number of flowers per inflorescence	-0.16	0.31
12. Number of suckers per plant	0.41*	0.62**
13. Plant spread	0.05	0.79**
14. Number of main rhizome	0.44*	0.42*
15. Length of main rhizome	0.13	0.49**
16. Girth of main rhizome	0.01	0.49**
17. Number of nodes of main rhizome	0.18	-0.01
18. Internodal length of main rhizome	-0.07	-0.28
19. Number of secondary rhizome	0.46**	0.52**
20. Length of secondary rhizome	-0.17	0.39*
21. Girth of secondary rhizome	0.11	0.36*
22. Number of nodes of secondary rhizome	0.17	-0.04
23. Internodal length of secondary rhizome	-0.27	0.32

** Significant at 1% level
* Significant at 5% level

4.2.2 Inter crop

In the case of intercrop, the characters, number of leaves (1 month after planting, 3 months after planting, 5 months after planting and 6 months after planting), length of leaves, width of leaves,leaf area index, spread of flowering, number of suckers per plant, plant spread, number of mother rhizomes, length of mother rhizomes, girth of mother rhizomes, number of secondary rhizomes, length of secondary rhizomes and girth of secondary rhizomes were found to be positively and significantly correlated with yield. Days to flowering was negatively correlated with yield (Table 14).

From the correlation studies it has been able to highlight that number of leaves had high correlation with yield in both the conditions.

4.3 Path coefficient analysis

Yield is a contribution of a number of characters referred to as yield contributing characters. Path coefficient analysis was done to partition the association of various yield contributing characters into direct and indirect effects.

Path coefficient analysis was done separately for the crop under open condition and for the crop under shade.

4.3.1 Path analysis for open crop

The analysis was done by taking 8 yield contributing characters having high correlation coefficient value with yield. The direct and indirect effects of each characters on yield are presented in Table 15.

Table 15. Direct and indirect effects of yield contributing characters of Kacholam (*Kaempferia galanga* L.) on yield under open condition

Sl. No.	Characters	Direct effect	Indirect effects							
			No. of leaves 1 month after planting	No. of leaves 5 months after planting	LAI	Days to flowering	No. of suckers per plant	No. of mother rhizomes	No. of secondary rhizomes	Spread of flowering
1	No. of leaves 1 month after planting	0.57	-	0.09	0.04	-0.20	-0.07	0.03	0.01	0.18
2	No. of leaves 5 months after planting	0.21	-0.25	-	0.06	-0.06	-0.13	0.01	0.01	0.06
3	LAI	0.15	0.16	0.09	-	-0.12	-0.06	0.02	0.01	0.23
4	Days to flowering	0.39	-0.29	-0.03	-0.05	-	0.02	-0.05	-0.01	-0.55
5	No.of suckers/ plant	-0.15	0.27	0.19	0.06	-0.05	-	0.01	0.01	0.07
6	No.of mother rhizomes	0.10	0.19	0.03	0.03	-0.19	-0.01	-	0.01	0.30
7	No.of secondary rhizomes	0.02	0.27	0.14	0.06	-0.11	-0.07	0.05	-	0.10
8	Spread of flowering	0.65	0.16	0.02	0.05	-0.34	-0.02	0.05	0.003	-

Residual - 0.32

i) Direct effects

From the table it could be seen that spread of flowering and number of leaves 1 month after planting had high direct effect on yield (0.65 and 0.57 respectively). Days to flowering had a direct effect of 0.40 which was followed by number of leaves 5 months after planting (0.21) and leaf area index (0.15). The direct effects of number of mother rhizomes and number of secondary rhizomes were negligible (0.10 and 0.02 respectively). Number of suckers had a negative direct effect on yield (-0.15).

ii) Indirect effects

a) Number of leaves 1 month after planting

Indirect effect of number of leaves 1 month after planting on yield was the maximum via spread of flowering (0.18). The indirect effect through number of leaves 5 months after planting (0.09), LAI (0.04), number of mother rhizomes (0.03) and number of secondary rhizomes (0.01) were negligible. Indirect effect of the characters via days to flowering and number of suckers per plant were negative and negligible (-0.20 and -0.07).

b) Number of leaves 5 months after planting

The indirect effect of the character on yield was maximum via number of leaves 1 month after planting (0.25). Indirect effect on yield was negative and negligible via days to flowering (-0.06) and number of suckers/plant (0.13). The character had negligible indirect effects on yield via LAI (0.06), number of mother rhizomes (0.01), number of secondary rhizomes (0.01) and spread of flowering (0.06).

c) Leaf area index

LAI had maximum indirect effect on yield via spread of flowering (0.23) followed by the indirect effect via number of leaves 1 month after planting (0.16). It had negative indirect effects via days to flowering (-0.12) and via number of suckers per plant (-0.06). The indirect effects via number of leaves 5 months after planting (0.09), via number of mother rhizomes (0.02) and number of secondary rhizomes (0.01) were found to be negligible.

d) Days to flowering

The indirect effects of days to flowering via all other characters were negative except the effect via number of suckers per plant which was positive but negligible (0.02). The indirect effect was maximum but negative via spread of flowering (-0.55) followed by the effect via number of leaves 1 month after planting (-0.29).

e) Number of suckers per plant

The character had maximum indirect effect via number of leaves 1 month after planting (0.27) followed by via number of leaves 5 months after planting (0.89). Indirect effects of number of suckers per plant via all other characters were negligible and it was negative via days to flowering.

f) Number of mother rhizomes

Number of mother rhizomes had maximum indirect effect via spread of flowering (0.30) followed by via number of leaves 1 month after planting (0.19). All other indirect effects were negligible. Indirect effects via days to flowering and number of suckers per plant were negative and negligible.

g) Number of secondary rhizomes

Indirect effect of number of secondary rhizomes was maximum via number of leaves 1 month after planting (0.27) followed by via number of leaves 5 months after planting (0.14). The indirect effects were negative via days to flowering and number of suckers per plant.

h) Spread of flowering

Spread of flowering had maximum indirect effect via days to flowering, which was negative (-0.34). It was positive and maximum via number of leaves 1 month after planting (0.16).

4.3.2 The crop grown as intercrop

i) Direct effects

In the case of crop grown under coconut garden, plant spread had high and positive direct effect on yield (0.62) followed by number of leaves 5 months after planting (0.27) and spread of flowering (0.13). Number of leaves 1 month after planting and LAI had negligible direct effect on yield. Days to flowering had high direct effect on yield but it was negative (-0.39). Number of mother rhizomes (-0.26), number of suckers per plant (-0.21) and number of secondary rhizomes (-0.15) also had negative direct effects on yield (Table 16).

ii) Indirect effects

a) Number of leaves 1 month after planting

The character had high indirect effect via plant spread (0.39) followed by the effect via days to flowering (0.20) and via number of leaves 5 months after

Table 16. Direct and indirect effects of yield contributing characters of Kacholam (*Kaempferia galanga* L.) on yield under shaded condition.

Sl. No.	Characters	Direct effect	No. of leaves 1 month after planting	No. of leaves 5 months after planting	LAI	Days to flowering	No. of suckers per plant	No. of mother rhizome	No. of secondary rhizome	Spread of flowering	Total spread
1	No. of leaves 1 month after planting	0.02	-	0.20	0.02	0.20	-0.15	-0.09	-0.08	0.06	0.39
2	No. of leaves 5 months after planting	0.27	0.02	-	0.02	0.17	-0.18	0.11	-0.05	0.09	0.45
3	LAI	0.05	0.01	-0.09	-	0.19	-0.17	-0.07	-0.04	0.01	0.19
4	Days to flowering	-0.39	-0.01	-0.12	-0.03	-	0.10	0.21	0.08	-0.04	-0.34
5	No.of suckers/plant	-0.21	0.02	0.24	0.02	0.19	-	-0.11	-0.06	0.08	0.46
6	No. of mother rhizomes	-0.26	0.01	0.12	0.02	0.32	-0.09	-	-0.03	0.05	0.25
7	No. of secondoary rhizomes	-0.15	0.01	0.09	0.01	0.21	-0.09	-0.06	-	0.04	0.36
8	Spread of flowering	0.13	0.01	0.19	0.01	0.12	-0.13	-0.10	0.04	-	0.33
9	Plant spread	0.62	0.02	0.19	0.02	0.21	-0.15	-0.11	-0.09	0.07	-

Residual - 0.31

planting (0.20). The character had negligible indirect effect via LAI (0.02) and via spread of flowering (0.06) whereas it had negative and negligible indirect effects via number of suckers per plant (-0.15), number of mother rhizomes (-0.09) and number of secondary rhizomes (-0.08).

b) Number of leaves 5 months after planting

The character also had maximum indirect effect via plant spread (0.45) followed by via days to flowering (0.17) and via number of mother rhizomes (0.11). The indirect effects via all other characters were negligible.

c) Leaf area index

The direct effect of LAI via plant spread was the maximum (0.19). It's indirect effect via days to flowering was negative (-0.19).

d) Days to flowering

The indirect effect of days to flowering was negative and high via plant spread (-0.34). The effect was positive and maximum via number of mother rhizomes (0.21).

e) Number of suckers per plant

This character also had negative indirect effect via plant spread (-0.46), but it was high. The indirect effect via number of leaves 5 months after planting was high and positive (0.24) followed by via days to flowering (0.19).

f) Number of mother rhizomes

The indirect effect of number of mother rhizomes was maximum via days to flowering (0.32) followed by via plant spread (0.25).

g) Number of secondary rhizomes

The number of secondary rhizomes also had high indirect effect via plant spread (0.36) followed by days to flowering (0.21).

h) Spread of flowering

The indirect effect of spread of flowering via plant spread was 0.33 which was the highest indirect effect followed by number of leaves 5 months after planting (0.19) and days to flowering (0.12).

i) Plant spread

Plant spread which had high direct effect on yield had maximum indirect effect via days to flowering (0.21) followed by number of leaves 5 months after flowering (0.19).

4.4 Components of variance

The variance due to phenotype (Vp); genotype (Vg) and environment were computed and also heritability in the broad sense (h^2) and genetic advance (GA). The results are presented in Table 17 and 18.

4.4.1 Number of leaves 1 month after planting

The character showed a phenotypic variance of 0.94 and a genotypic variance of 0.71 with high heritability (75.70%) and genetic advance (38.47) in open. Under shaded condition, the phenotypic variance (0.78) and genotypic variance (0.34) were comparatively low and also the heritability and genetic advance (42.90 per cent and 19.18 per cent, respectively).

Table 17. Components of variance, heritability and genetic advance of different characters of Kacholam (*Kaempferia galanga* L.) under open condition

Characters	Components of variance			Herita-bility	Genetic advance
	Pheno-typic (Vp)	Geno-typic (Vg)	Environ-mental (Ve)	h^2	
1	2	3	4	5	6
1. Number of leaves 1 month after planting	0.94	0.71	0.23	0.76	38.47
2. Number of leaves 3 months after planting	11.58	8.52	3.06	0.74	31.85
3. Number of leaves 5 months after planting	37.27	16.85	20.42	0.45	18.96
4. Number of leaves 6 months after planting	17.67	10.58	7.09	0.60	17.33
5. Length of leaves	0.67	6.19	0.49	0.28	3.71
6. Width of leaves	0.89	0.20	0.69	0.23	4.88
7. LAI at flowering	0.04	0.02	0.01	0.69	43.25
8. LAI 1 month after planting	0.05	0.03	0.02	0.61	42.39
9. Days to flowering	15.58	11.87	3.71	0.76	12.66
10. Spread of flowering	35.15	21.55	13.60	0.61	16.45
11. Number of flowers per inflorescence	2.04	-0.08	2.12	-0.04	-1.63
12. Number of suckers per plant	4.87	1.37	3.47	0.28	13.86
13. Plant spread	1.93	1.01	0.92	0.53	5.42

Contd.

Table 17. Continued

1	2	3	4	5	6
14. Number of main rhizomes	0.11	0.06	0.05	0.57	17.74
15. Length of main rhizomes	0.05	0.01	0.04	0.20	2.37
16. Girth of main rhizomes	0.13	0.02	0.11	0.14	1.31
17. Number of nodes of main rhizomes	0.06	0.01	0.05	0.21	3.13
18. Internodal length of main rhizomes	0.01	-0.0007	0.01	-0.08	-1.38
19. Number of secondary rhizomes	4.65	1.35	3.30	0.29	10.28
20. Length of secondary rhizomes	0.09	0.01	0.08	0.12	2.12
21. Girth of secondary rhizomes	0.10	0.01	0.09	0.09	0.90
22. Number of nodes of secondary rhizomes	0.08	-0.01	-0.08	-0.12	-1.80
23. Internodal length of secondary rhizomes	0.01	0.002	-0.01	0.22	4.77
24. Rhizome yield (fresh)	106.58	74.75	31.83	0.70	24.62
25. Rhizome yield (dry)	12.57	6.50	6.08	0.52	24.40
26. Oil percentage	0.31	0.18	0.13	0.59	28.75

Table 18. Components of variance, heritability and genetic advance of different characters of Kacholam (*Kaempferia galanga* L.) under shaded condition

Character	Components of variance			Heritability	Genetic advance
	Phenotypic (Vp)	Genotypic (Vg)	Environmental (Ve)	h^2	
1	2	3	4	5	6
1. Number of leaves 1 month after planting	0.78	0.34	0.45	0.43	22.29
2. Number of leaves 3 months after planting	6.13	3.12	3.00	0.51	19.18
3. Number of leaves 5 months after planting	27.50	9.76	17.74	0.36	14.85
4. Number of leaves 6 months after planting	19.10	11.86	7.24	0.62	24.27
5. Length of leaves	2.46	1.32	1.14	0.54	12.87
6. Width of leaves	1.03	0.49	0.54	0.47	10.93
7. LAI at flowering	0.03	0.01	0.02	0.41	29.16
8. LAI 1 month after flowering	0.04	0.03	0.01	0.73	58.39
9. Days to flowering	12.27	9.26	3.01	0.76	10.53
10. Spread of flowering	23.34	18.76	9.58	0.59	14.06
11. Number of flowers per inflorescence	2.27	0.61	1.66	0.27	15.13
12. Number of suckers per plant	1.95	0.68	1.26	0.35	0.14
13. Plant spread	5.68	3.05	2.64	0.54	9.60

Contd.

Table 18. Continued

1	2	3	4	5	6
14. Number of main rhizomes	0.12	0.06	0.06	0.49	14.63
15. Length of main rhizomes	0.09	0.01	0.08	0.13	2.29
16. Girth of main rhizomes	0.08	0.01	0.03	0.06	0.48
17. Number of nodes in main rhizomes	0.08	-0.01	0.09	-0.13	2.10
18. Internodal length of main rhizomes	0.01	0.0003	0.01	0.03	0.61
19. Number of secondary rhizomes	3.33	1.97	1.36	0.59	19.98
20. Length of secondary rhizomes	0.06	0.004	0.06	0.07	1.04
21. Girth of secondary rhizomes	0.13	0.02	0.11	0.12	1.50
22. Number of nodes of secondary rhizomes	0.17	0.01	0.15	0.09	1.80
23. Internodal length of secondary rhizomes	0.01	0.0003	0.01	0.27	7.02
24. Rhizome yield (fresh)	118.83	44.14	74.70	0.37	17.88
25. Rhizome yield (dry)	12.16	4.81	7.35	0.40	20.67
26. Oil percentage	0.48	0.18	0.30	0.37	22.45

4.4.2 Number of leaves three months after planting

The character had a phenotypic variance of 11.58 and genotypic variance of 8.52 and high heritability (7.35%) and genetic advance (32.85) in open condition. In shade the phenotypic variance was 6.13 and genotypic variance was 3.12. The character showed a heritability of 51 per cent with a genetic advance of 19.18 per cent.

4.4.3 Number of leaves five months after planting

Number of leaves 5 months after planting had comparatively a high value for phenotypic variance (37.27) and genotypic variance (16.85). Heritability was 45.2 per cent and genetic advance was 18.96 per cent under open condition.

In shade the character had a phenotypic variance of 27.50 and a genotypic variance of 9.76 which was low and had comparatively low heritability (35.5%) and genetic advance (14.85%).

4.4.4 Number of leaves six months after planting

In open the character had a phenotypic variance of 17.66 and a genotypic variance of 10.58 with a heritability of 59.9 per cent and genetic advance of 17.33 per cent. Under shade the character had comparatively more phenotypic variance (19.10) and genotypic variance with a heritability of 62.1 per cent and genetic advance of 27.27 per cent.

In general the character number of leaves is heritable.

4.4.5 Length of leaves

In open the length of leaves had a very low heritability (0.28%) with a phenotypic variance of 0.67 and genotypic variance of 0.19. The genetic advance was 3.77 per cent. But under shaded condition the character had moderate heritability of 53.7 per cent and a genetic advance of 12.87 per cent with a phenotypic variance of 2.46 and a genotypic variance of 1.32.

4.4.6 Width of leaves

Width of leaves also showed low heritability (22.8%) and genetic advance (4.88) under open condition. The phenotypic variance was 0.89 and the genotypic variance was 0.20. But in shade width of leaves had moderate heritability of 47.2 per cent and a genetic advance of 10.93 per cent. The phenotypic variance was 1.03 and the genotypic variance was 0.49.

4.4.7 Leaf area index

LAI showed high heritability both at flowering (68.6%) and 1 month after flowering (61.1%) in the case of open crop. Genetic advance was also high (43.25 per cent at flowering and 42.39 per cent, 1 month after flowering). Under shade LAI at flowering had moderate heritability,40.6 per cent and it was high at 1 month after flowering (72.7%). Genetic advance was also very high (58.39%) 1 month after flowering compared to GA at flowering (29.16%).

4.4.8 Days to flowering

Days to flowering had a phenotypic variance of 15.58 and a genotypic value of 11.87 in open. It had a high heritability of 76.2 per cent and comparatively

low genetic advance (12.66%). In shade also the character was highly heritable (75.5%) with comparatively low genetic advance (10.53%). The phenotypic variance was 12.27 and genotypic variance was 9.26.

4.4.9 Spread of flowering

The character had a phenotypic variance of 35.15 and a genotypic variance of 21.55 with high heritability (61.3%) and the genetic advance was 16.45 per cent in open. In shade spread of flowering had a phenotypic variance of 23.33 and a genotypic variance of 13.76. The heritability was 58.9 per cent and the genetic advance was 14.06 per cent.

4.4.10 Number of flowers per inflorescence

The character had a phenotypic variance of 2.04 and a negative genotypic variance (-0.08) in open. Heritability (-4.0%) and genetic advance (-1.63%) also were low and negative. But in shade the estimates of variance were positive. Phenotypic variance was 2.27, genotypic variance was 0.62. Heritability was low (27.0%) and genetic advance was 15.13 per cent.

4.4.11 Number of suckers per plant

In open condition, the character had a phenotypic variance 4.84 and a genotypic variance of 1.37. Heritability was low (28.3%) and the genetic advance was only 13.86 per cent. The character had medium heritability in shade (35.20%). But with very low genetic advance (0.14%). The phenotypic variance was 1.95 and the genotypic variance was 0.68.

4.4.12 Plant spread

In open the character had a phenotypic variance of 1.93 and genotypic variance of 1.02. Heritability was 52.6 per cent and genetic advance was only 5.42

per cent. In shade plant spread had a phenotypic value of 5.68 and a genotypic value of 3.05. The heritability was 53.6 per cent and genetic advance was 9.6 per cent.

4.4.13 Characters of mother rhizome

Only the number of mother rhizome was heritable (57.4%) with a genetic advance of 17.74 per cent in open. Length and girth of mother rhizome showed very low heritability (19.6% and 14.4% respectively) with genetic advance of 2.37 per cent and 1.31 per cent respectively. Number of nodes also showed low heritability (20.6%) with a genetic advance of 3.13 per cent. Heritability and genetic advance of internodal length was low and negative (-7.5% and -1.38% respectively). In shade also the same pattern was observed. Only the number of mother rhizomes was heritable (48.8%) with a genetic advance of 14.63 per cent. Length, girth and internodal length had low heritability and genetic advance values. Number of nodes had negative and low heritability and genetic advance (-13.4% and -2.1% respectively).

4.4.14 Characters of secondary rhizome

All the characters of secondary rhizome viz. number, length, girth, number of nodes and internodal length showed low heritability and genetic advance in open. Number of nodes recorded negative values for both heritability and genetic advance (-11.6% and -1.8% respectively). But in shade number of rhizomes recorded comparatively high heritability value (59.2%) and genetic advance (19.98%). All the other characters showed low heritability and genetic advance.

4.4.15 Fresh rhizome yield per plant

The character was highly heritable under open (70.1%) with a genetic advance of 24.62 per cent. The phenotypic variance was 106.58 and the genotypic

variance was 74.75. In shade the character showed medium heritability (37.1%) with a genetic advance of 17.88 per cent. The phenotypic variance was 118.83 and the genotypic variance was 44.14.

4.4.16 Dry rhizome yield per plant

In open the character had a phenotypic value of 12.57 and a genotypic value of 6.50 with a heritability of 51.7 per cent and a genetic advance of 24.4 per cent. In shade the character was comparatively less heritable (39.5%) with a genetic advance of 20.67 per cent. The phenotypic variance was 12.16 and the genotypic variance was 4.81.

Discussion

DISCUSSION

The results on the evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield and comparative performance of the types under open and as intercrop in coconut garden with 50% light infiltration are briefly discussed in this chapter. The results are discussed broadly in 3 subheads viz., 1) Morphological variability of yield contributing characters and yield, 2) Characters correlated with yield and path coefficient analysis and 3) Components of variance.

5.1 Morphological variability of yield contributing characters and yield

Out of the 21 characters studied 11 characters had high correlation with yield. The response of different types to these characters under different situations are discussed in following pages.

5.1.1 Number of leaves

The types were observed at 2 months intervals for the number of leaves produced. From the result it could be seen that in each stage there was considerable variation in the number of leaves produced by the types both under open and shaded conditions. Compared to shaded condition leaf production was more under open condition for all the types. It reveals that leaf production is influenced by light intensity. Ponnukkara ranked first under both the conditions regarding this trait and it was 57.6 per cent superior than Vellanikkara Seln. M which recorded the minimum number of leaves under open condition. Palakkad was the inferior type under shaded condition regarding this trait. Superiority of Ponnukkara was 77.3 per cent over Palakkad and 38.7 per cent over Vellanikkara Seln. M.

This result indicates that influence of environment is not uniform over the types. Ponnukkara can be considered as a stable type. Performance of Palakkad was very poor under shaded condition compared to open condition (34.4%). This indicates that this type is very sensitive to environment.

After 5 months there was a reduction in the number of leaves produced by the types which indicates that vegetative growth is retarding 5 months after planting. All the entries recorded maximum number of leaves 5 months after planting. There after a declining trend was noticed.

Variability in number of leaves has been reported in ginger by several workers (Nybe, 1978; Mohanty *et al.*, 1981; Okwvovulu, 1992). Similar result was obtained in turmeric also. Philip (1978) observed variability in leaf number among the turmeric types he studied. The same result was reported by George (1981), Mukhopadhyay *et al.* (1986) and Menon *et al.*, (1992).

Varughese (1989) observed more number of leaves under open condition compared to shade. The same result was observed in turmeric also (Varughese, 1989; Paul, 1992). The present result is in agreement with these findings.

5.1.2 Length and width of leaves

Significant variation was absent in length and width among the types under open condition. But under shade the types differed significantly in their leaf length and width. Length and width were maximum for Varantharappilly followed by Ponnukkara and Koothattukulam. Palakkad was with the shortest leaf with minimum width under shaded condition. Nybe (1978) reported variability in length of leaf blade in ginger under open condition. Mohanty *et al.* (1981) observed variability in leaf width also. The variability in length and width of leaf blade among the

types under shaded condition may be due to the difference in the inherant ability of the types to respond to limited environmental condition prevailing under coconut garden. The present results reveal the capacity of producing good vegetative growth of Varantharappilly, Ponnukkara and Koothattukulam under shaded condition.

It was found that light intensity had great influence on the length of leaves. Under limited light intensity, the leaves were more elongated than under open condition. Varantharappilly had 22.9 per cent more elongated leaves under shaded condition than under open condition. The leaves of Vellanikkara Seln. NR and Ponnukkara were 15.9 and 15.3 per cent respectively more elongated under shaded condition compared to open condition. It may be an adaptation for the effective utilization of light available under coconut garden. Though the difference was not significant, the entry Palakkad had more lengthy leaves (11.44 cm) under open condition compared to shaded condition (11.01 cm).

5.1.3 Leaf area index

There was considerable variability in the leaf area index among the types studied both under open and shaded conditions. Ponnukkara and Koothattukulam were the best types for this character also. It was also found that, for almost all the types, in open LAI was more 1 month after flowering. But in the case of intercrop, majority of the types recorded high LAI value at the time of flowering. The reason can be attributed to the difference in vegetative growth of the types in different environments. For the intercrop maximum vegetative growth was attained at the time of flowering whereas for the open crop the growth continued even after flowering. Suckering might have stopped early in the case of intercrop. This may be the reason why there was no significant variation in LAI at flowering whereas there was considerable variation in LAI 1 month after flowering, between the open crop and

crop under shade. Clark (1905) reported an increase in total leaf area with shading in apple and tomato. The same result was reported in *Mentha arvensis* plants by Duriyaprapan and Britten (1982). Leaf area in ginger was not appreciably altered by shading (Bai, 1981). A negative effect of shading on leaf area was reported in clocimum by Pillai (1990). In the present study the leaf area was found to be reduced due to shading. LAI is influenced by both the leaf area of individual leaf and number of leaves. Eventhough length is increased in shade, the number of leaves produced is reduced under shaded condition and thus the leaf area index.

5.1.4 Days to flowering

From the results it was found that there was high amount of variability in days to flowering among the types both under open and shaded conditions. Under both the environments Ponnukkara was found to be the early flowering type. Again it was found to be a stable type.

There was considerable difference in days to flowering for the types between open and shaded conditions. Flowering started earlier in the case of open crop compared to the intercrop. It is an indication of the beginning of reproductive phase and completion of vegetative phase. Influence of light on flowering was uniform for all the types except Vellanikkara irradiated type which indicates the sensitivity of the type to the varying environments.

5.1.5 Spread of flowering

Regarding spread of flowering, there was variability among the types. Under both the conditions Vellanikkara Seln. L was having less flowering period. Ponnukkara had a prolonged flowering period under shade condition which was

significantly different from all other types except Vellanikkara irradiated. Vellanikkara Seln. Br. had the maximum spread of flowering under open condition whereas it was very less under shade. Same was the case with Koothattukulam. For all other types the period of flowering was comparable under the different environments. From these results it is evident that the influence of light intensity on spread of flowering is unpredictable and it varies with the types.

5.1.6 Number of suckers per plant

Significant variability was observed in the number of suckers per plant among the types grown under coconut garden where as it was nonsignificant for the open crop. Variation in number of tillers was reported in ginger by Nybe (1978) and Mohanty *et al.* (1981). The same result was obtained in turmeric by Philip (1978), George (1981) and Mukhopadhyay *et al.* (1986). Ponnukkara recorded the maximum number of suckers per plant. Variation in the potential of the types to respond to limited environmental condition might be expressed only under coconut garden. Under open condition there is no limitation in the light resource.

5.1.7 Plant spread

The character plant spread was found to be significantly different among the types both under open and shade. It was one among the few characters for which the types performed similarly under open and shaded conditions. Under the controlled condition with limited light infiltration plant spread is a very important yield contributing factor. With increased plant spread the photosynthetic surface is increased and thus photosynthesis and high tuber formation.

5.1.8 Number of mother rhizomes

There was considerable variability in the number of mother rhizomes, both under open and under shade. Vellanikkara Seln. Br produced the maximum number of mother rhizomes and Palakkad was with the minimum number of mother rhizomes. Mohanty *et al.* (1981) reported variability in the number of rhizome fingers in ginger. The same result was obtained in turmeric (George, 1984 and Indirish *et al.* 1990). Nybe (1978) observed no significant variability in the number of primary fingers in ginger.

Performance of the types regarding this trait was different under the different environments as far as *Kaempferia* is considered. The crop produced more number of mother rhizomes under the coconut garden. Early arresting of vegetative phase is observed in the case of inter crop which necessitates more number of rhizome production under coconut garden.

5.1.9 Length and girth of mother rhizome

There was no significant variation in the length and girth of mother rhizome among the types, both under open and shaded conditions. When pooled over the two conditions there was significant difference in this character. The girth was more under open condition for all the types. This may be due to the high rate of photosynthesis in plants under open condition. High moisture content in the rhizome can be also attributed to the more girth of mother rhizome under open condition. Variability in length and girth of mother rhizome was reported in ginger by Nybe (1978). The same result was obtained in turmeric by George (1981).

5.1.10 Number of secondary rhizomes

There was high amount of variability in the number of secondary rhizomes for the intercrop. But for the open crop number of secondary rhizomes was not variable for the types. This again may be due to the difference in potentialities of the types for the effective utilization of limited resources under shaded condition. Variability in the number of secondary rhizomes was reported in ginger by Nybe (1978). The same was reported in turmeric by Philip (1978).

The number of secondary rhizomes was found to be more under open condition. It is an important yield contributing character and it may be due to the effective photosynthesis under open condition.

5.1.11 Length and Girth of secondary rhizome

There was no significant difference in the length and girth of secondary rhizome among the types under both the conditions. But in ginger significant variation was reported by Nybe (1978). The same was reportd in turmeric by George (1981). The present study was not able to show any variability regarding this trait.

5.1.12 Yield

Fresh rhizome yield, dry rhizome yield and biological yield were found to be significantly different for the types both under open and shaded conditions. Ponnukkara and Vellanikkara Seln. Br. were the superior types regarding the yield (fresh, dry and biological yield). Palakkad and Vellanikkara Seln. L were the inferior types under open. But under the coconut garden the picture was different. Ponnukkara and Koothattukulam performed well but Vellanikkara Seln. Br. was an inferior type under shade. Palakkad maintained its inferiority under shade also. It is

clear from the result that Vellanikkara Seln. Br. is a shade sensitive type whereas Ponnukkara and Koothattukulam are shade tolerant types. Ponnukkara is a stable type which performed well under both the conditions. Mohanty *et al.* (1981) reported varietal differences for the character rhizome yield in ginger. The same result was reported in turmeric by Mukhopadhyay *et al.* (1986).

Comparative study of the types revealed the fact that there was considerable variability in the fresh rhizome yield under open and shaded conditions for all the types. All the types had high fresh yield under open condition. Ponnukkara yielded 28 per cent more under open condition. But there was no significant variability in the dry rhizome yield and biological yield under the varying environments. Vellanikkara Seln. Br. was an exception. It recorded 45.5 per cent more dry yield under open condition. The crop is harvested during December - January when there is scarcity of water in the soil. In coconut garden, under rainfed condition, the water deficit in the soil will be still worse due to the competition by the coconut palm. Hence the rhizomes may get dried. In other words the water content in the rhizome will be less compared to the open crop. The result obtained in the present study on the girth of mother and secondary rhizomes indicated that the girth is more under open condition, which may be probably due to high moisture content in the rhizome of open crop. This might be the reason why the dry yield of rhizome was comparable under open and shaded condition where as the fresh yield was more under open condition.

In turmeric also fresh rhizome yield was reported to be higher in the open than under shade (Ramadasan and Satheesan, 1980 and Varughese, 1989). Nair *et al.* (1991) reported that fresh as well as dry rhizome yield of Kacholam grown in open condition were comparabale with that grown under shaded in coconut garden.

But in ginger yield was reported to be more under shaded condition (Adan and Quisumbing, 1976; Varughese, 1989 and George, 1992). Ravishankar and Muthuswamy (1986) reported that dry matter production and the recovery of dry ginger was more when the crop was grown as an intercrop in arecanut plantation. In the present study the dry rhizome yield was comparable under open and shaded conditions which may not be due to the high dry matter production but due to the increased dryage. The dryage was more for the shade crop.

Kacholam had an average harvest index of 0.5 which was not significantly different among the types and under different environments. It is the proportion of dry matter accumulation in the economic part to the total dry matter production. From the result it is clear that the character is not influenced by the environments and it may be a genetically controlled character. Or the influence is uniform for all the types and under different conditions. It is true in the case of vegetatively propagated crops where there is narrow genetic variation in the population.

5.1.13 Quality aspects

i. Oil content

There was considerable variability in the oil content of the types both under open and under shade. Vellanikkara selections were found to be superior in oil content under both the conditions. Vellanikkara Seln. M yielded 36.4 per cent more oil than the entry Ponnukkara, which was the superior type in rhizome yield under open condition. The same was the case under shade also. This indicates that oil content is not correlated with yield. This necessitates separate selection criteria for yield and oil quantity.

ii. Quality of oil - Major components

Gas chromatograph analysis revealed the presence of 3 major components in oil of Kacholam. Paramethoxy ethyl cinnamate content ranged between 55-65 per cent. Ethyl cinnamate content ranged from 15-25 per cent and there was an unknown component (8-12 per cent). The components were the same in all the types but some amount of variation is noticed in its quantity. No general trend was observed in the quantity under open and shaded conditions. There was a balance between the content of Paramethoxy ethyl cinnamate and ethyl cinnamate. The types with high paramethoxy ethyl cinnamate, were with less amount of ethyl cinnamate. The reason may be attributed to the possibility of conversion of one compound to the other.

The present results reveal that there exists considerable variability among the types in the oil quantity not in its quality.

So the present study on the variability of *Kaempferia* genotypes revealed the presence of variability and scope for selection in the yield contributing characters like number of leaves, leaf area index, days to flowering, spread of flowering, number of suckers per plant, plant spread, number of main rhizomes and number of secondary rhizomes under both the conditions. Under shade, in addition to the above characters length and width of leaves, length and girth of primary and secondary rhizomes showed considerable variability. Direct selection based on yield is also found to be effective.

5.2 Characters correlated with yield and path coefficient analysis

5.2.1 Correlation studies

Leaf characters such as number of leaves 1 month after planting, 3

months after planting, 5 months after planting, length of leaves and leaf area index at flowering and 1 month after flowering were found to be correlated with yield. Under shaded condition, in addition, width of leaves also had high correlation coefficient. In ginger length of leaf blade and leaf area index were reported to be correlated with yield (Nybe, 1978). Number of leaves and leaf breadth were also reported to be having high correlation coefficient with yield in ginger (Mohanty and Sharma, 1979 and Roy and Wamanan, 1990). Philip (1978) reported the presence of correlation between the above leaf characters and yield in turmeric. Number and breadth of leaves were reported to be highly correlated with yield in ginger by Nambiar (1979).

The above result revealed the scope for early selection in Kacholam based on the leaf characters like number of leaves, length and width of leaves and leaf area index. Number of leaves was highly correlated with yield under both the conditions and it is an important early selection criteria.

Flowering characters like days to flowering and spread of flowering were found to be highly correlated with yield under both the conditions. Days to flowering was negatively correlated with yield which means that early flowering types are high yielders. It might be due to the fact that, in the case of early flowering types the vegetative phase is completed well ahead from the reproductive phase and tuber formation phase. Flowering might have forced the plant to stop its vegetative phase. This can indirectly influence the production of more mother rhizomes which in turn influence the production of more number of secondary rhizomes in each mother rhizome. Spread of flowering might be an indirect indication of robust and healthy stand of crop. The types can be selected for these flowering characters also.

One more character which was found to be correlated with yield for both the crop was number of suckers per plant. Kannan and Nair (1965) reported high

correlation of the same character with yield in ginger. Mohanty and Sharma (1969) and Roy and Wamanan (1990) had the same result in ginger. In turmeric also number of tillers was found to be correlated with yield (Nambiar, 1979 and Govind *et al.*, 1981).

Plant spread which had less correlation with yield in open condition was found to be highly correlated with yield in shade. This indicates the necessity of framing separate selection criteria for the types which is to be grown under open condition and as intercrop in coconut garden. Spread of the plant is an indication of the orientation of leaves, rather than number of leaves. Under shade, orientation of leaf is very important since it influences the effective utilisation of limited light resource under coconut garden. In open light is not a limiting factor, where the orientation of leaves or plant spread have little influence on photosynthesis rate and hence yield. So while selecting varieties for intercropping plant spread must be taken as an important parameter.

Among the rhizome characters, number of mother rhizomes and number of secondary rhizomes were found to be highly correlated with yield under both the conditions. In addition, length and girth of mother and secondary rhizomes were also found to be correlated with yield for the intercrop. This is in agreement with the report of Nybe (1978) in ginger. He reported positive and significant correlation of number, length and girth of primary and secondary fingers with yield.

Mohanty and Sharma (1979) revealed the influence of number and girth of secondary rhizome fingers on yield. In turmeric length of primary fingers and girth of mother rhizomes were reported to be positively correlated with yield by Philip (1978). The influence of rhizome length on yield was also reported by Govind *et al.* (1981).

So in the present study it is seen that the following characters had high correlation with yield both under open and shade. Superior entries are found to be early flowering types with more number of leaves, high LAI value, prolonged spread of flowering, more number of suckers per plant, more number of mother and secondary rhizomes. Under shade, plant spread is an important character which was found to be highly correlated with yield. It is also seen that yield and oil content are highly independent characters.

5.2.2 Path coefficient analysis

Correlation studies simply give an idea about the relationship between different morphological characters and yield considering yield as the effect. It simply provides the causal factors to effect. There can be direct and indirect effects for each causal factor to yield and so simple correlation may not explain a true relationship.

The direct and indirect effects of each causal factor is estimated through path analysis. If the correlation coefficient between a causal factor and effect is almost equal to its direct effect, correlation explains the true relationship and a direct selection through the trait will be effective. If the correlation coefficient is positive but the direct effect is negative or negligible, the indirect effect seems to be the cause of correlation. In such situation the indirect causal factors are to be considered simultaneously for selection.

Under open condition the characters, number of leaves 1 month after planting and spread of flowering had maximum direct effect on yield and these direct effects were almost equal to the correlation co-efficients. So here correlation explains a true relationship and a direct selection based on these characters will be effective in improving the yield. Days to flowering also had high direct effect.

Number of suckers per plant had a positive correlation with the yield, but its direct effect on yield was negative. This implies the necessity for simultaneous selection for indirect causal factors. Here the indirect effect was maximum via number of leaves 1 month after planting.

So the present study was able to reveal that there is immense scope for identifying superior genotypes by counting the number of leaves.

Under shaded condition the character plant spread had maximum direct effect on yield which was almost equal to its correlation coefficient. It was followed by number of leaves 5 months after planting. So direct selection based on these characters will be effective. The characters, number of suckers per plant, number of mother rhizomes and number of secondary rhizomes had negative direct effects on yield where as its correlation coefficient was positive. This indicates the reliability of indirect selection and all these three characters had maximum indirect effect via plant spread which again proves plant spread as a selection criteria under shaded condition.

5.3 Components of variance

For the selection to be reliable and effective, the characters should be highly heritable. There should be considerable variation in the population, for the characters to be selected and the selected characters should be highly heritable. The high heritability value should be coupled with high genetic advance also.

The characters number of leaves, leaf area index, days to flowering, spread of flowering, plant spread, number of mother rhizomes, rhizome yield (both fresh and dry) and oil percentage were having high heritability estimates in open condition. Under shaded condition in addition to the above characters, length of

leaves, width of leaves and number of secondary rhizomes were also found to be highly heritable. But the rhizome yield and oil content were less heritable. This might be due to the fact that the rhizome yield was influenced by more number of morphological characters under shade i.e. it is greatly influenced by the environment.

The characters, number of leaves and leaf area index had high heritability coupled with high genetic advance. Early selection based on these characters will be effective and reliable. Rhizome yield (fresh and dry) and oil content also had high heritability and moderately high genetic advance. So direct selection for these characters also will be effective. The other characters, days to flowering, spread of flowering, number of mother rhizomes and number of secondary rhizomes which recorded high heritability had moderate genetic advance under open condition.

For the shaded crop leaf area index (1 month after flowering) had the maximum genetic advance, coupled with high heritability. So it is the most reliable selection parameter for the types to be grown under shaded condition. Number of leaves, spread of flowering, number of mother rhizomes, number of secondary rhizomes, rhizome yield (fresh and dry) and oil content had moderate genetic advance estimate. Direct selection based on yield is not reliable in the case of shaded crop, since the characters are less heritable even though the genetic advance was moderate.

Based on correlation studies, path coefficient analysis and the estimates of heritability and genetic advance, selection criteria can be framed separately for the open crop and the crop to be grown as intercrop in coconut garden.

Under open condition number of leaves, leaf area index, days to flowering and spread of flowering had high correlation and direct effects on yield with moderately high heritability and genetic advance. So selection will be effective for these characters. Direct selection for rhizome yield and oil quantity also will be reliable.

Under shade plant spread is an important parameter but the character recorded moderately high heritability but low genetic advance. Selection will be reliable and effective for number of leaves 5 months after planting, leaf area index and spread of flowering.

Summary

SUMMARY

An investigation on evaluation of Kacholam (*Kaempferia galanga* L.) types for morphological variability and yield was undertaken at the College of Horticulture, Vellanikkara during 1993-94. The experiment was aimed at studying the extent of morphological variability and yield contributing characters in the local collection of *Kaempferia* and to identify types with high yield potential for large scale cultivation. It was also aimed to compare the performance of the types under open and as intercrop in coconut garden. The salient results of the investigation are summarised below.

1. The study on the variability of *kaempferia galanga* types revealed the presence of considerable amount of variability and scope for selection for the characters, number of leaves, leaf area index, days to flowering, spread of flowering, plant spread, number of mother rhizomes, number of secondary rhizomes, fresh rhizome yield, dry rhizome yield, biological yield and oil percentage, under both open and shaded condition.

2. In addition to the above characters length and width of leaves and number of suckers per plant also showed variability under coconut garden.

3. Vellanikkara Seln. Br and Ponnukkara were the best types regarding fresh as well as dry rhizome yield under open condition.

4. Ponnukkara and Koothattukulam performed well under shade regarding fresh as well as dry rhizome yield whereas performance of Seln. Br was poor under shaded condition.

5. Ponnukkara can be considered as a stable type and Vellanikkara Seln. Br is very sensitive to the limited environment under coconut garden.

6. Performance of entry Palakkad was poor under open and shaded condition.

7. Regarding oil yield Vellanikkara selections were the superior types both under open and shaded condition.

8. The types were variable in their oil quantity not in quality. As reported earlier, it is confirmed that 3 major components are present in Kacholam oil. They are paramethoxy ethyl cinnamate (55-65 per cent) ethyl cinnamate (15-25 per cent) and an unknown compound (8-12 per cent).

9. The study on the comparative performance of the types under open and shaded condition revealed that the characters, number of leaves, LAI, spread of flowering, number of flowers per inflorescence, number of suckers per plant, girth of mother rhizomes, number of secondary rhizomes, girth of secondary rhizomes and internodal length were more under open condition, whereas the characters length of leaves, days to flowering, number of mother rhizome, number of nodes on mother rhizomes and secondary rhizomes and dry wet ratio were more under partially shaded condition.

10. The differences in the characters width of leaves, plant spread, length of mother rhizome, internodal length, length of secondary rhizome, dry rhizome yield, harvest index and oil content of the types were nonsignificant between open and shaded condition.

11. Eventhough the fresh rhizome yield was less under shaded condition, dry rhizome yield was comparable which indicates that Kacholam can be grown as an

intercrop in coconut garden also. Among the 10 entries, types Ponnukkara and Koothattukulam showed their superiority under partially shaded condition.

12. The characters, number of leaves, length of leaves, LAI, spread of flowering, number of suckers per plant, number of main rhizomes and number of secondary rhizomes were positively and significantly correlated with yield under open condition. Days to flowering was negatively correlated with yield.

13. In addition to the above characters, width of leaves, plant spread, length and girth of main rhizomes and length and girth of secondary rhizomes were positively and significantly correlated with yield under shaded condition.

14. Rhizome yield and oil yield were found to be two independent characters. This necessitates separate selection criteria for the types with high rhizome yield and oil yield.

15. No morphological character was found to be correlated with oil yield. So independent selection has to be made for identifying varieties with high oil per unit area.

16. Under open condition number of leaves, leaf area index, days to flowering and spread of flowering had high correlation and direct effect on yield with moderately high heritability and genetic advance. So selection will be effective for these characters. Direct selection for rhizome yield also will be reliable.

17. Under shade plant spread was an important parameter which had high correlation and direct effect on yield. But the character recorded moderately high heritability but low genetic advance. Selection will be effective for the characters number of leaves 5 months after planting, leaf area index and spread of flowering for the crop under shade.

Taking into account all the aspects the entry Ponnukkara showed its superiority as a high yielding entry suitable under both the situations namely open and partially shaded condition prevailing in coconut garden.

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Appendices

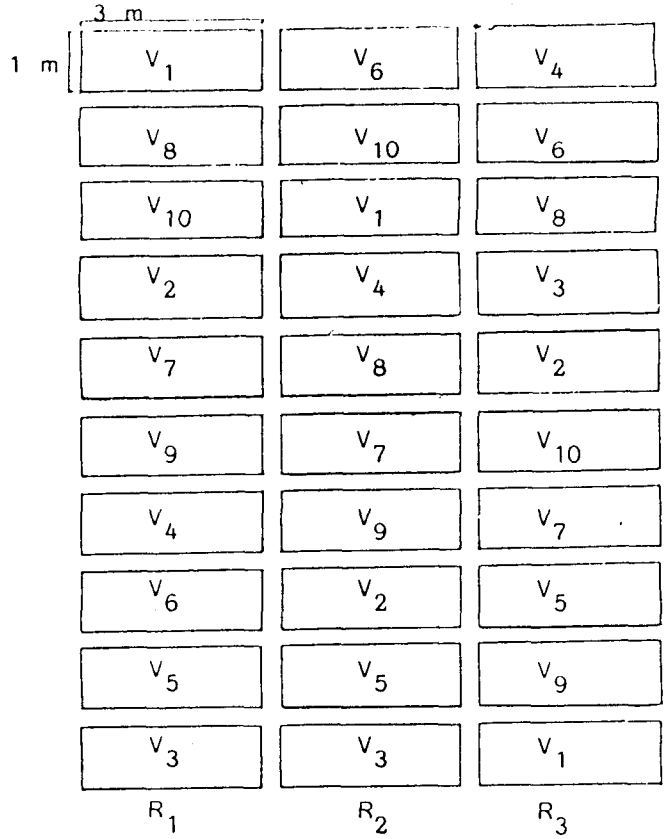
APPENDIX-I

Weather data (weekly average) for the experimental period (from 4-6-1993 to 25-2-1994)

Standard week No.	Month and date	Total rainfall	No. of rainy	Temperature		Relative		Sunshine hours	Evaporation mm/day
				Max. °C	Min. °C	Fore-noon %	After-noon %		
23	June 4-10	236.6	6	29.6	23.3	95	80	1.8	3.5
24	June 11-17	237.9	7	29.2	23.8	95	80	1.8	3.5
25	June 18-24	85.5	4	30.4	24.5	94	73	4.4	3.8
26	Jun3 25-July 1	186.4	5	29.2	23.6	94	82	2.9	3.3
27	July 2-8	188.9	6	28.6	22.7	95	78	2.0	3.1
28	July 9-15	167.8	7	28.7	22.6	92	83	1.8	3.1
29	July 16-22	128.1	6	28.9	22.9	94	76	2.8	2.9
30	July 23-29	101.0	6	28.0	23.1	94	80	2.9	3.1
31	July 30-Aug 5	96.4	6	29.1	23.7	95	76	3.6	3.8
32	Aug 6-12	54.9	4	29.9	23.5	95	75	4.6	3.9
33	Aug 13-19	66.3	6	29.2	23.1	93	78	3.3	3.7
34	Aug 20-26	61.9	4	29.8	23.2	96	74	5.6	4.0
35	Aug 27-Sept 2	33.6	2	29.8	23.5	95	73	6.5	3.4
36	Sept 3-9	23.7	2	29.4	23.0	93	75	3.9	3.05
37	Sept 10-16	11.5	1	30.7	23.1	93	69	7.5	3.45
38	Sept 17-23	23.2	3	31.7	23.4	94	63	8.3	4.1
39	Sept 24-30	14.9	1	31.0	23.2	91	65	6.7	3.9
40	Oct 1-6	149.8	6	29.8	23.4	93	82	3.8	2.9
41	Oct 7-13	181.5	5	29.3	29.2	95	78	2.1	2.5
42	Oct 14-20	102.7	4	31.2	23.2	90	74	4.9	2.8
43	Oct 21-27	83.4	2	31.9	23.5	92	72	6.3	2.8
44	Oct 28-Nov 4	3.2	0	32.5	24.2	80	63	7.1	3.8
45	Nov 5-11	58.3	3	30.4	23.9	84	70	4.0	3.5
46	Nov 12-18	12.7	2	31.8	23.0	91	66	5.6	3.0
47	Nov 19-25	1.2	0	31.8	23.1	72	54	7.6	4.6
48	Nov 26-Dec 2	0.8	0	31.4	24.3	77	60	5.8	5.7
49	Dec 3-9	17.0	2	31.2	22.7	84	62	3.4	3.4
50	Dec 10-16	0.0	0	32.5	21.9	75	47	5.1	5.05
51	Dec 17-23	1.0	0	31.0	23.8	75	59	5.5	5.6
52	Dec 24-31	0.0	0	31.6	23.5	72	47	6.1	6.1
1	Jan 1-7	0.0	0	32.6	23.6	69	44	10.0	7.5
2	Jan 8-14	0.0	0	32.2	22.7	73	43	9.0	7.3
3	Jan 15-21	19.4	1	33.6	23.7	83	49	7.7	4.9
4	Jan 22-28	0.0	0	32.8	22.0	65	32	9.2	9.7
5	Jan 29-Feb 4	0.0	0	33.9	21.0	81	37	9.8	5.9
6	Feb 5-11	0.0	0	34.6	23.8	17	43	7.8	6.3
7	Feb 12-18	1.7	0	34.4	23.1	86	45	8.2	4.7
8	Feb 19-25	0.0	0	35.7	23.0	83	36	7.8	6.1

APPENDIX-II

LAYOUT PLAN - OPEN CONDITION

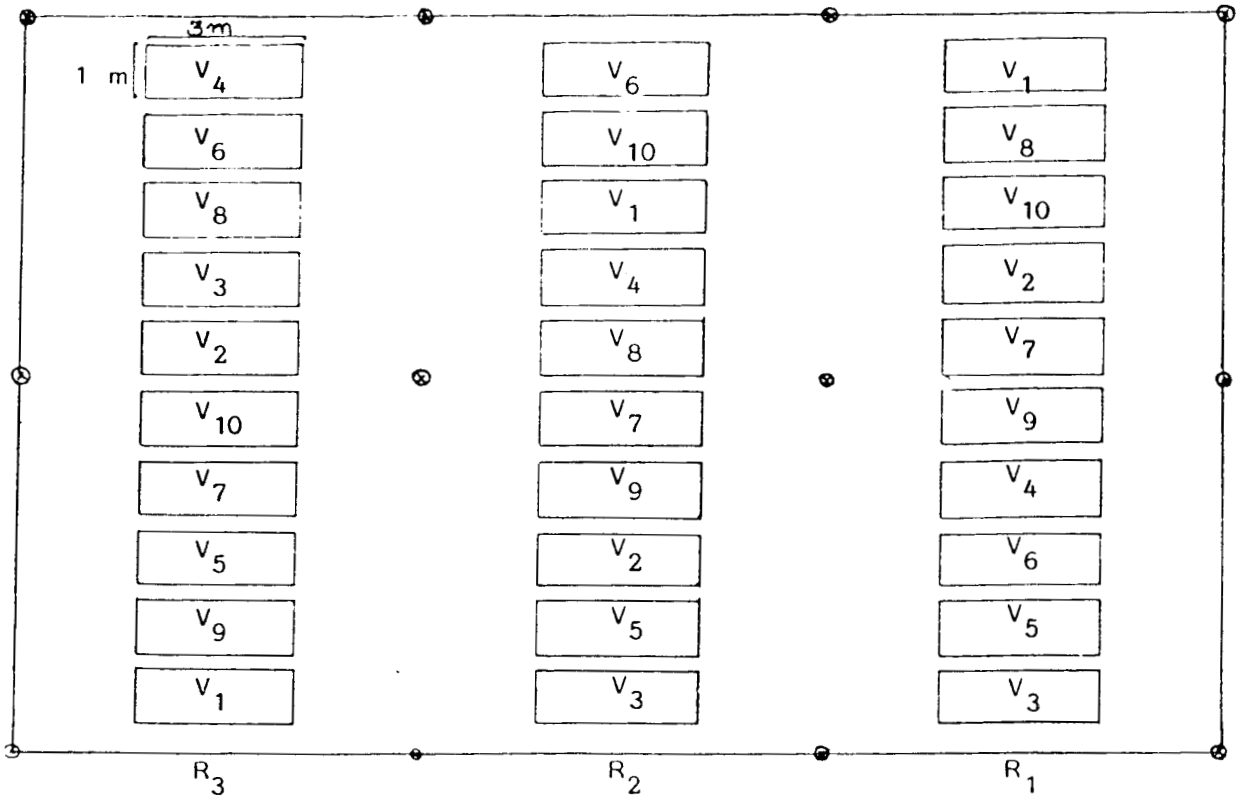


V_1 - Koothattukulam
V_2 - Ponnukkara
V_3 - Thodupuzha
V_4 - Palakkad
V_5 - Varantharappilly
V_6 - Vellanikkara Seln. Br
V_7 - Vellanikkara Seln. NR
V_8 - Vellanikkara Seln. L
V_9 - Vellanikkara Seln. M
V_{10} - Vellanikkara irradiated

R_1 - First replication
R_2 - Second replication
R_3 - Third replication
- Coconut palm

APPENDIX-III

LAYOUT PLAN - COCONUT GARDEN



V_1 - Koothattukulam
V_2 - Ponnukkara
V_3 - Thodupuzha
V_7 - Palakkad
V_5 - Varantharappilly
V_6 - Vellanikkara Seln. Br
V_7 - Vellanikkara Seln. NR
V_8 - Vellanikkara Seln. L
V_9 - Vellanikkara Seln. M
V_{10} - Vellanikkara irradiated
R_1 - First replication
R_2 - Second replication
R_3 - Third replication
- Coconut palm

Pars II. Tab. 41.

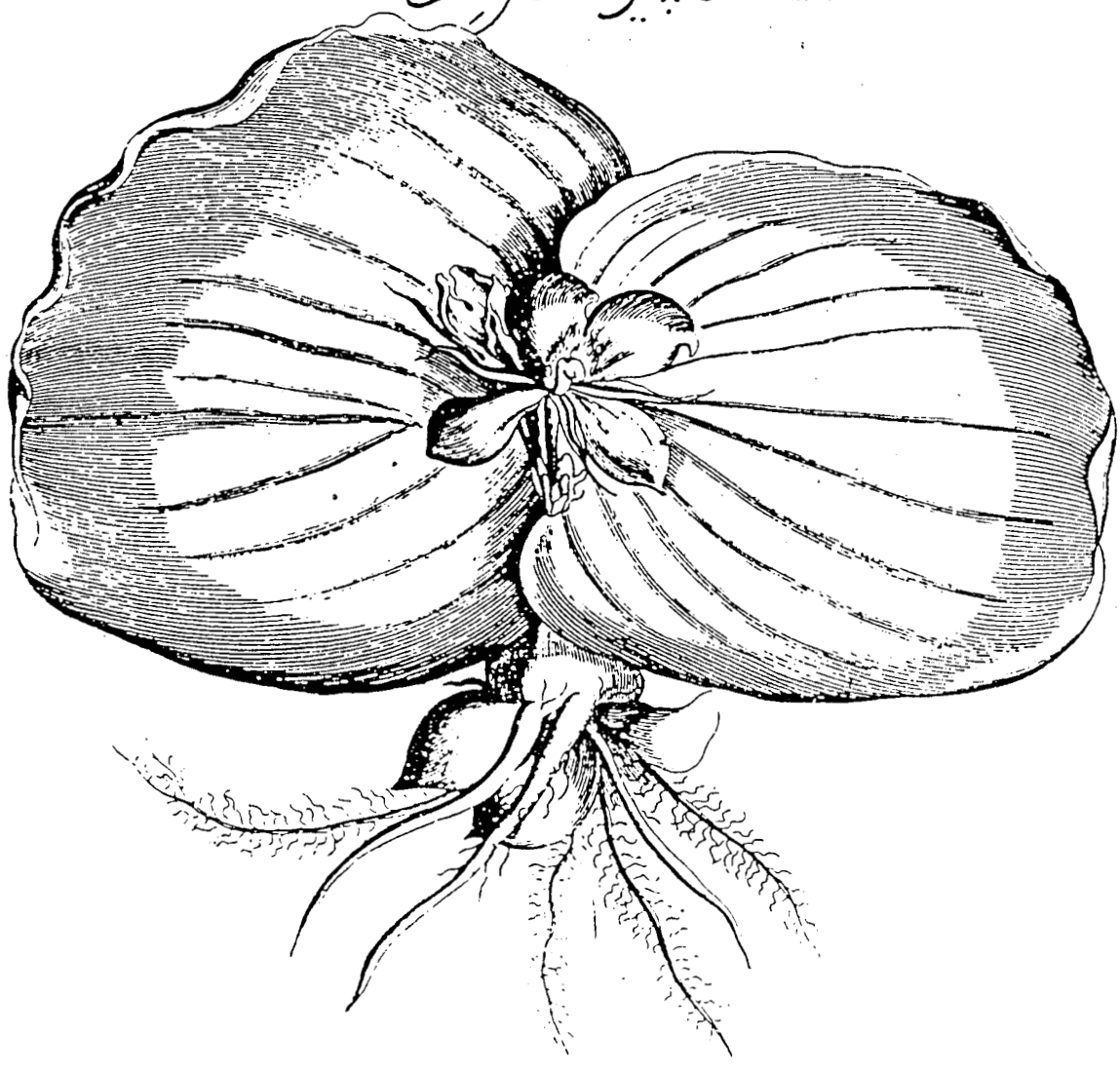
Kaisjula - kelengú Mal.

കച്ചൂലകിഴങ്ങ് Mal.

Capúra - catarí

കാപൂരകച്ചരി Bram.

فحاجيولا فحار هنغاء Arab.



KATSJULA KELENGU.

TABULA XLI.

BRamannes dicunt *Capura Catari* planta naſcens in arenoſis. *Radix* carnoſa, albicans, fibras emittens, & novellis ſe propagans oculis, odoris fragrantis & aromatici, maxime cum ſicca, *Zinziberis* inſtar, albicante ſicca carne, cortice ruffo, rugoſo. Duo ex radice *folia*, pedunculis ſurrectis, latis & cavis exſurgunt, in transverſum extenſa, ex adverſo ſita, ampla, rotundiola, inferius ſinulo cavo, anguſto exciſa, craſſa, carnoſa, glabra, venis ſubtilibus annularibus, quæ folium intus obſcuro tractu ſubeunt, ex media *vena* ſtriata, viroris in ſuperiori parte ſaturi & fuſci, in inferiori, quæ radici obverſa, viridi clari, in oris limbulo rubeſcente inſtructa, odoris grati aromatici. *Flores* ex radice inter folia media ſurrecti exſurgunt, oblongo petiolo ceu collo, tripetali, duo illorum oblongo rotunda & candida, tam interius quam exterius: tertium hiſce oppoſitum, anterius in medio, in duo alia quaſi petala eſt diviſum, interius candidum, in medio & ima parte ad pedem purpureo rubrum, exterius candidum, in pede interiore dilute flaveſcens & virideſcens, ſuntque in totum tribus oblongoanguſtis candidis foliolis ſeu auriculis ſuccincti. Ex florum medio *ſtylus* exſurgit latus, foliaceus, candidus, ad pedem petali purpurei flaveſcentem accumbens, ſuperne in duas ungulas fiſſus, quæ à petalo purpureo ſunt reflexæ. In medio flavus eſt, intus anguſta theciformi cavitate, per quam alius, ſe transmittit *ſtylus* candidus, tenuiſſimus, *gemmula* nodulatus: flores in totum illis *Tsjengeli-nel-Kelengu* non diſſimiles ſunt. In ſuper obſervavimus, quod loco floris emarcidi ac decidui, una nocte flos novellus cum petiolo ferme pollicari è radice exſiliat, ocyus ergo naſcuntur. *Radix* ſiccata in transverſas inciditur lamellas, & divenditur. *Bulbus* cum recenti *butyro* in pillulas redactus, aſthmaticis datur.

TABULA 41.

Parem non habet hæc planta; mihi eſt: *Planta biſoliata, radice tuberoſa, flore tripetalo diſſormi Malabarienſis.*

Appendix-IV. Continued

KATSJULA KELENGU

Brahimins say that the plant called Capura Catari grows in sandy grounds. The root of this plant, fleshy and white-tinted sprouts out filaments called eyes as means for self propagating. These shoots are highly sweet smelling and aromatic. They are similar to Zinziber, being fleshy, white-tinted with bark wringled and reddish. The two leaves at the shoot, rising like a crook (shepherd's), bending inward on sides, round in shape, spreading flat and wide hollow at the lower and narrowing at the verge. These (leaves) are thick and fleshy with finely woven seasonal veins. These veins or streaks go through furrow-like channels; food (sap) being received in the upper part, is absorbed in the interior. The veins are extending towards the root; they look glaringly green and in the mouth side they turn slightly reddening the surface and they produce a pleasing aromatic odour. Flowers come out from the shoot through the centre of these leaves in oblong petals (tri-petals). Two of them take a round oblong shape, inside and outside white in colour. A third twin petal opens up above in the centre. These petals are separate. White in the centre, the inner depth being purple. The outside of this petal is white, on the inner bottom yellow (golden) and green. On the whole these petals are slightly oblong and girded up by three tiny petals akin to the lobe of the ear. From the middle of the flowers shoots out broad, leafy and white stilus lying down towards the yellow part of the purple-coloured petals, fixed above in two hoofs which are reflected by the purple petals. In the middle of the narrow envelop like cavity, which is golden, through which another knoty bud projects itself as a white and very fine stilus; its flowers as a whole are not dissimilar to Tsjengeli-nel-Kelengu (Chingazineer kizangu). Besides we observe that in the place of withered and fallen flowers, overnight new flower is born. The root cut across, are sold separately The bulbs made into pills is given to asthmatic patients.

ABSTRACT

An investigation on the evaluation of Kacholam *(Kaempferia galanga* L.) types for morphological variability and yield was undertaken at the College of Horticulture, Vellanikkara during 1993-94. The experiment was aimed at studying the extent of morphological variability and yield contributing characters in the local collection of *Kaempferia* and to identify types with high yield potential for large scale cultivation. It was also aimed to compare the performance of the types under open and as intercrop in coconut garden. The salient results of the investigation are abstracted below.

There was considerable amount of variability for the characters, number of leaves, leaf area index, days to flowering, spread of flowering, plant spread, number of main and secondary rhizomes, fresh rhizome yield, dry rhizome yield, biological yield and oil percentage both under open and shaded condition. Under coconut garden in addition to the above characters, length and width of leaves and number of suckers per plant showed variability.

There was difference in the performance of the types under open and shaded condition. Fresh rhizome yield was more under open condition whereas dry rhizome yield was comparable which indicates that Kacholam can be grown as an intercrop in coconut garden.

Ponnukkara can be considered as a stable type which performed well under both the conditions. Vellanikkara Seln. Br was found to be a shade sensitive type and the performance of Palakkad was poor under open and shaded conditions.

Regarding oil yield Vellanikkara Selctions were the superior types both under open and shaded conditions.

Rhizome yield and oil yield were found to be two independent characters. This necessitates separate selection criteria for types with high rhizome yield and oil yield.

Under open condition number of leaves, leaf area index, days to flowering and spread of flowering had high correlation and direct effect on yield with moderately high heritability and appreciable genetic advance. So selection will be effective for these characters. For the crop under shade, selection will be effective for the characters, number of leaves 5 months after planting, leaf area index and spread of flowering. Under shade plant spread was an important character which had high correlation and direct effect on yield. But the character recorded moderately high heritability but low genetic advance.

No morphological character was found to be correlated with oil yield. So independent selection has to be made for identifying varieties with high oil content per unit area.