# GENETIC VARIABILITY IN KACHOLAM (*Kaempferia galanga* L.) UNDER OPEN AND PARTIALLY SHADED CONDITIONS.

**DIVYA KRISHNAN**

**2008**

**Department of Plant Breeding and Genetics**
**COLLEGE OF AGRICULTURE**
**VELLAYANI, THIRUVANANTHAPURAM**

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**DIVYA KRISHNAN**

**Thesis submitted in partial fulfillment of the requirement for the degree of**

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**COLLEGE OF AGRICULTURE**
**VELLAYANI, THIRUVANANTHAPURAM,695522**

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I hereby declare that this thesis entitled "**Genetic variability in kacholam (*Kaempferia galanga* L.) under open and partially shaded conditions**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or similar title, of any other university or society.

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**Divya Krishnan**<br>(2006-11-114)

**CERTIFICATE**

Certified that this thesis entitled "**Genetic variability in kacholam (*Kaempferia galanga* L.) under open and partially shaded conditions**" is a record of research work done independently by Miss. Divya Krishnan (2006-11-114) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani
23-09-08

**Dr. (Mrs.). Arya.K**
(Chairperson, Advisory Committee)
Professor,
Department of Plant Breeding & Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522

**Approved by**

*Chairperson*:

**Dr.Arya.K**
Professor,
Department of Plant Breeding & Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

*Members*:

**Dr. P. Manju**
Professor and Head,
Department of Plant Breeding & Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

**Dr.Jessykutty.P.C**
Associate Professor,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

**Dr.Vijayaraghava Kumar**
Professor,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

*External Examiner:*

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# Introduction

# 1. INTRODUCTION

Plants have been used as therapeutic agents from the earliest days of man's existence.The ancient system of Indian medicine is predominantly a plant based materia medica, making use of our native medicinal plants. This trend is slowly surging back in the modern world which has brought about an ever increasing demand for medicinal plants and necessitated their cultivation on a commercial scale .A wide spectrum of variability is existing in most of the important medicinal plants and hence the need for developing improved varieties suited to different agro-ecological conditions

*Kaempferia galanga* L. popularly known as Kacholam in Malayalam, belonging to the family Zingiberaceae is an attractive high valued medicinal and aromatic herb distributed throughout the plains of India. It forms a component of over 50 Ayurvedic medicines. The rhizome is used as a stimulant, expectorant, carminative and diuretic. It promotes digestion, cures skin diseases, dandruff, epilepsy and rheumatism. Recently anticancerous properties have also been identified in kacholam.

As an aromatic crop it finds its major use as a flavouring agent in rice. The oil finds extensive use in flavouring confectionaries, pharmaceuticals, perfumery and many other allied industries. The commercial cultivation of this crop is gaining importance owing to its varied uses and ease with which it can be grown under tropics.

Kacholam is an important medicinal plant of Kerala and the humid tropical climate of Kerala is suited for its growth. Although the cultivation of the crop is relatively easy, not much work has been done in improving the genetic potential of this crop. Improvement of this crop by commercial breeding method is difficult for want of seed production. The crop is propagated by vegetative means and seedlessness is a major constraint for improvement through conventional methods.

In any crop improvement programme, assessment of existing variability in the genetic stock is a pre requisite. The variability present in the existing genotypes can be exploited by selection and since the crop is a vegetatively propagated one, the selected types can be multiplied and maintained on a large scale. Rhizome yield in kacholam is dependent on several contributing characters. If the yield contributing characters are identified, a selection criteria can be worked out which will help in effective selection of high yielding types.

Rapid urbanization and shrinking land resources pose great difficulty in popularising kacholam as a pure crop in Kerala and since most of our farming is homestead based, developing varieties suitable for growing as an intercrop will be of immense value. Hence it is worthwhile to study the performance of kacholam under both open condition and partially shaded condition in coconut gardens.

In this context the present study has been undertaken with the following objectives:-

- To assess the performance of the genotypes under open and partially shaded conditions in coconut gardens.

- To assess the extent of variability present in the populations by estimating parameters like genotypic and phenotypic coefficient of variation, heritability and genetic advance.

- To find out the association of different characters with yield and also among themselves.

- To assess the genetic divergence of genotypes.

- To select adaptable and high yielding genotypes based on the selection index prepared using major characters.

- To identify genotypes with high rhizome yield and volatile oil for large scale cultivation.

# *Review of literature*

# 2. REVIEW OF LITERATURE

## 2.1 ORIGIN AND DISTRIBUTION:-

The genus *Kaempferia* is believed to have originated in Burma, especially South East Asia. The plant belonging to the family Zingiberaceae is of Indo-Malayan origin (Wills, 1960). Reports also revealed that *Kaempferia galanga* L. was widely distributed in tropical and sub tropical regions (Synge, 1956) and also in lower elevations along the West Coast (Gamble, 1926). According to Aiyer and Kolammal (1964) the plant was also found in Kerala, Konkan, Deccan and Bengal.

## 2.2 TAXONOMY:-

Kacholam belonging to Zingiberaceae family comes under the series Epigynae (Bentham and Hooker, 1894). According to Schumann (1904) this family is divided into three tribes viz, Globeae, Hedychiae and Zingiberae. The genus *Kaempferia* comes under the tribe Hedychiae. Hooker (1892) reported that there are four subgenera under the genus *Kaempferia* viz, *Sincorus, Protanthium, Monolophus and Stachyanthesis*. There are fifty five species in the genus *Kaempferia* but only ten are known in India of which *Kaempferia galanga* and *Kaempferia rotunda* are the economically important ones. *Kaempferia galanga* L. can be easily recognized from other species by the ovate–orbicular, horizontal lamina, which is closely appressed to the soil and central inflorescence (Sabu, 2006). The systematic position of *Kaempferia galanga* L. is as follows:-

| | | |
|---|---|---|
| Class | : | Monocotyledons |
| Series | : | Epigynae |
| Order | : | Zingiberales |
| Family | : | Zingiberaceae |
| Sub family | : | Zingiberoideae |
| Tribe | : | Hedychiae |
| Genus | : | Kaempferia |

| | | |
|---|---|---|
| Sub genus | : | Sincorus |
| Species | : | Galanga |

**2.3 IMPORTANCE OF THE CROP:-**

Medicinal value of kacholam in curing asthma was described in Hortus Malabaricus in the seventeenth century by Reede (1678-1703). Leaves of kacholam are also chewed along with betel and arecanut as a masticatory (Burkill, 1935 and Quisumbing, 1951). The rhizomes are considered as a stimulant, expectorant, carminative and diuretic. In Philippines, a decoction of the rhizome is used for dyspepsia, headache and malaria. Kacholam rhizomes are boiled in oil and applied externally to remove nasal obstructions. Roasted rhizomes are applied hot in rheumatism and for hastening the ripening of inflammatory tumors. 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, swelling, rheumatism and fever (Krithikar and Basu, 1935; Burkill, 1935; Brown, 1941 and Quisumbing, 1951). It promotes digestion and cures cutaneous diseases, piles, oedema, epilepsy, splenic disorders, asthma and diseases caused by mobidity of *vada* and *kapha* (Aiyer and Kolammal, 1964). Rhizome extract of kacholam is found to possess larvicidal and anti-cancerous principles (Kosuge et al., 1985). According to Mangaly and Sabu (1991) kacholam is an ingredient of many Ayurvedic preparations against skin disorders and rheumatism and the oil showed toxicity against neonate larvae of *Spodoptera littoralis.* Rhizomes are reported to possess stomachic, carminative and diuretic properties. Kacholam rhizomes and leaves are used for protecting cloths against insects. They are used in perfumery and flavouring food (Anon, 2006).

**2.4 MORPHOLOGY:-**

Kacholam is an aromatic rhizomatous annual herb which spreads horizontally on the ground. It is a plant with tuberous root stock and 3-6 inch long, deep green coloured leaves with deltoid tip (Hooker,1892).The plant is stemless with tuberous aromatic root stock (Krithikar and Basu,1935). According to them, the plant possess fleshy, cylindrical non-aromatic root fibres with a few leaves, lying flat on the ground horizontally spreading with a length of 6.3-12.5cm and a breadth of 4.5-9.0cm. Leaves are thin ,deep, green ,rotund ,ovoid, deltoid,10-12 ribbed with acuminate leaf tip and leaf margins not thickened or coloured. According to Aiyer and Kolammal (1964) kacholam leaves are deep green orbicular, sub-orbicular, orbiculate–ovate or ovate cordate with thin membraneous blade having a length of 6.2-15 cm long and a width of 5-15cm and 10-12 ribbed with the margin wavy but not thickened or coloured. They also reported that each leaf has a short channeled petiole and vertically oriented root stock having a number of several smaller secondary tubers and a cluster of roots most of which are long and narrow and a few are shorter and tuberous. The main tuber is conical shape with a number of transverse or horizontal or annular scars of scales spaced 3-5mm apart. Few number of small tubers are also directly attached to the nodes which are vertically oriented. Tubers are fairly smooth and greyish or light brown in colour.

According to Drury (1978) *Kaempferia galanga* L. is a biennial plant with tuberous rhizome, stem less, stalked leaves, spreading flat on the surface of the earth which are ovate, rotund or cordate in shape. Leaf margins are membranous and wavy.

Sabu (2006) described that rhizome of kacholam is 2 to 3x1 to 2cm, crowded, strongly aromatic. It possesses numerous roots, bearing ovoid to spherical 1.5 to 2 x 0.5 to 1 cm white tubers. It has leafy shoot, stemless, almost horizontal near the ground. Kacholam possess few leaves, 2 to 3 in number. Its lamina is 10 to15 x 6 to10 cm broad, ovate to orbicular, with rounded or subcordate base and broadly pointed tip. It has a hyaline margin, dark green upper surface, glabrous, pale green lower surface, white with violetish tinge towards the tip and more over it is densely hairy.

**2.5 FLORAL BIOLOGY:-**

Gamble (1926) suggested that the inflorescence of kacholam is a short scape. Floral morphology of kacholam has been described by few workers

(Hooker, 1892; Krithikar and Basu, 1935 and Drury, 1978). According to them, the plant bears 6-12 flowers per inflorescence. The inflorescence is located at the centre of the plant between the leaves. Flowers are fugacious, fragrant and open successively. They possess 3 green, short, lanceolate bracts. The corolla tube is 2.5cm long with pure white coloured lobes and both the essential whorls are trimerous. The lateral staminodes are cuneate, obovate and located at the base of ovary.

According to Aiyer and Kolammal (1964) the androecium consists of fertile stamen and broad petaloid staminodes. Fertile stamen is with a short acute keeled filament expanded above the mutiocous anther into a petaloid quadrate, two cleft or forked appendages. There are two celled anthers and tricarpellary pistil. They suggested the ovule as inferior, 3 celled with many horizontal anatropous ovules on axile placentation within each chamber. Style is filiform, long and ends in a turbinate stigma.

Hooker (1892), Gamble (1926) and Krithikar and Basu (1935) explained the floral morphology of *Kaempferia rotunda.* According to them, flowers are borne on radicle scapes 1cm long with spreading linear petals nearly as long as tube. Staminodes acute, white in colour with a length of about 3.8-5.0 cm, lip is lilac or reddish in colour and is bifid and anther lobes are lanceolate.

According to Rajagoplan (1983) *Kaempferia galanga* L. started flowering in June and ended in September. The peak flowering stage was attained during July-August. He also suggested that the flowers are produced directly from the rhizome and opened in succession. Sabu (2006) has studied the inflorescence of kacholam in detail. According to him, inflorescence is sessile with 6-12 or more flowers enclosed in1.5 to 3.5 cm long imbricating leaf sheaths. One flower opens at a time. Bracts are glabrous ovate-acuminate white with light green tip and bifarious with outer larger one and smaller inner ones with 3-4 x1 cm size. Each flower has 2 bracteoles which is 3.5 cm long, transparent, membraneous and glabrous. Calyx is equal or shorter than bracts and glabrous with 3cm long. Corolla tube is 4.5-5.0 cm long with white lobes of 2.5 -3.0 cm long and linear. Labellum is slightly broader with 2.3x 2.5 cm, divided 2/3$^{rd}$ to the base, each lobe again splits shortly into two unequal halves. It is glabrous and white with violet bands in basal half. Lateral staminodes are obovate white, glabrous with a size of 2.5x1.5 cm. Anthers are white, sessile theca with 3mm long. The connective is prolonged into a bilobed crest. Stigma is globular with lateral slit. There are 2 epigynous glands, filiform, erect, embracing the lower part of the style. The ovary is tricarpellary with many ovules on axile placentation.

No much systematic breeding work has been conducted in kacholam to identify the extent of existing variability in morphological, biometrical and biochemical characters. The genetic parameters has not yet been worked out to identify the association of contributing characters to yield in kacholam. Since the literature available on the crop is scanty regarding the above aspects, review of studies conducted in related crops of the same family Zingiberaceae are cited here.

**2.6 INFLUENCE OF LIGHT INTENSITY:-**

The dry matter accumulation in general was found to be adversely affected by shading due to the lack of sufficient quantity of sunlight. Experiments on shaded and unshaded plants indicated that light favours formation of oil (Lubimenko and Nervikoff, 1914).

Positive influence of shading on plant height in ginger was reported by Aclan and Quisumbing (1976). They also reported positive influence of partial shading on yield. Crop under partial shade gave as much yield as that under full sunlight.

According to Ramadasan and Satheesan (1980) rhizome yield in turmeric was significantly higher in open than under shade. Turmeric recorded higher yield under 50 per cent shaded conditions (Bai, 1981). Turmeric produces a relatively dense canopy under natural condition. She also reported that the performance of ginger was better under shade than in open. Leaf area and leaf area index in ginger was not appreciably altered by shading. Her study also revealed that the yield of tubers in coleus was unaffected by shading.

In experiment 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 the crop growth (Ravisankar and Muthuswamy, 1986). Turmeric yield increases with narrower spacing. The biomass production of turmeric was high with spacing of 1.8x3.6m (Sannamarappa and Sankar, 1988).

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

A study conducted by Nair et al. (1991) reported that growth and yield attributes of kacholam grown in open conditions were comparable with that grown under shade in coconut gardens. Accordingly, kacholam grown in open areas recorded a height of 22 cm, fresh weight of 112g of rhizome per plant as against the height of 20 cm, 110g fresh weight of rhizomes and 23.05g of dry weight of rhizomes per plant obtained under shade in coconut garden. He concluded with the possibility of growing kacholam as intercrop in 8-20 years old coconut plantations.

According to Jayachandran et al. (1992) turmeric is a shade tolerant crop. They reported that the yield of turmeric at 25 per cent shade was on par with that under open condition. Shade intensities beyond 25 per cent reduced the rhizome yield. They recommended turmeric as a suitable crop component for homestead cultivation and other perennial crops. Shade increases plant height and decreases tiller production and rhizome yield at 50 per cent and 75 per cent shade.

According to George (1992) performance of plant grown under shade was better than those in open in terms of rhizome yield in ginger. She opined that shade had a positive effect on plant height, chlorophyll content, net assimilation rate and percentage of driage and concluded that ginger is a shade loving crop. She also reported that plant grown under shade registered higher value for oil and oleoresin content compared to that grown in the open.

Turmeric yield was poor under intercropping in coconut garden (Paul, 1992). Under medium shade levels of 50 per cent, the crop showed better rhizome yield. Influence of shade on plant height and chlorophyll content was also positive but more number of leaves was reported in open condition.

Significant difference in the number of primary and secondary rhizomes of ginger was obtained as a result of reduction of light intensity (Wilson and Ovid, 1993 and Jayachadran et al.1991).

According to Latha (1994) there was no significant difference in leaf length in kacholam among the different genotypes over open and shaded conditions but in the case of leaf area, leaf area ratio, girth of secondary rhizomes, length of secondary rhizomes and yield characters there existed significant difference among types under both the conditions.

Kurian et al. (2000) reported that flavour principles of kacholam like oil and oleoresin were slightly high for pure crop than intercrop.

The highest dry weight of leaf was recorded in turmeric at 75 per cent shade level and lowest under open condition. Maximum number of leaves, plant height and more number of tiller productions during all the growth stages may be the reason for maximum leaf dry weight. The dry weight of the roots was found to show an increasing trend under shaded condition (Louis, 2000)

Field experiment conducted at Kasaragod, Kerala to study the influence of agronomic practices on kacholam grown as intercrop in coconut revealed that the crop comes up well under shaded condition. Fresh rhizome of kacholam yield was significantly higher when grown as intercrop in coconut gardens (Mahewarappa et al. 2000). Oil and oleoresin content of the rhizomes increases with increase in shade intensities.

In turmeric, Shanmugavel and Francis (2001) reported that higher oleoresin content and essential oil yield was reported when grown as a sole crop as compared to their growth under storey intercropped conditions.

The study conducted on the influence of shade regimes on photosynthetic rate and stomatal characters of ginger indicated that the enhanced rhizome yield under low levels of shade compared to open condition may be due to higher leaf area in the plants grown under 20 and 40 per cent shade levels (Ajithkumar et al.2002).

A study was conducted to determine the relation of various physiological parameters on the yield of ginger under different shade levels by Sreekala and Jayachandran. (2002). They suggested that higher yield of ginger under shade may be due to higher values of the physiological parameters. The results suggested a positive response of shade on the physiological parameters and yield of ginger, provided the shade intensity is low. No significant relation was observed with regard to leaf area index.

A study conducted on adaptability and performance of ten medicinal plants species as intercrop in oil palm plantations of different age revealed that the performance of kacholam was equally good at all shaded conditions and hence can be recommended as the most suitable intercrop in oil palm plantations of all age groups (Jessykutty, 2003). She also reported that volatile oil content of kacholam rhizomes was higher under partial shade of young oil palm canopy. At higher shade intensity the oil content decreased and was equal to that under open condition. But the oleoresin content was highest under open condition, which was on par with that under young oil palm canopy. According to her there existed significant influence of shade on tiller production, fresh weight of roots and leaves, number of leaves and leaf area index. She also reported that harvest index was high under open condition than under shaded condition. The study also revealed that the rhizome yield was more under open condition.

Three ecotypes of kacholam viz Echippara, Vellanikkara and Thodupuzha were grown as intercrop in coconut plantation providing 50 and 70 per cent shade by Gangadharan and Menon (2003). They reported that rhizome yield was favoured by higher light intensity while essential oil content was promoted by highly shaded conditions. According to them higher rhizome yield is the result of more vegetative growth while higher quality is the net effect of breakdown of primary photosynthates into secondary metabolites.

Ajithkumar (2003) suggested kacholam as a well suited medicinal plant for homestead cultivation under coconut gardens.

According to Depommier (2003) the medicinal plant *Kaempferia galanga* L. requires shade for optimum growth and production of quality rhizomes.

Aromatic and medicinal plants can be ideally grown in a multitier cropping system in Kerala, especially ginger and turmeric in coconut and arecanut farms (Sasikumar, 2003).

A total of eleven turmeric cultivars were evaluated for their performance in partial shade of arecanut canopy and under open condition under sub-Himalayan Teri region of West Bengal. The cultivar 'Suguna' gave highest yield under areca shade and the cultivar 'Sudharsana' produced maximum fresh rhizome yield under open condition (Arunkumar et al.2004)

There is a lot of scope for growing spices in coconut gardens. Spices have been proved as a good intercrop and a good combination for coconut plantations and holdings will be benefited by its cultivation. Annual tuber spices like ginger, turmeric and medicinal and aromatic plants like kacholam, patchouli, *Piper longum* etc. are also grown as intercrop in coconut plantations (Gopalakrishnan, 2004).

According to Nair (2004) intercropping spices with coconut will increase the productivity. The crops ideal for this are spices such as ginger, cardamom, vanilla etc. Many of the shade loving crops like kacholam, turmeric etc can also be successfully grown as intercrop in coconut gardens.

Many of the medicinal and aromatic plants are grown under forest covers and are shade tolerant .So medicinal and aromatic plants can be grown as lower strata species in multistrata systems (Rao et al. 2004).

A pot culture experiment carried out in ginger revealed that volatile oil was maximum under heavier shade levels. The results suggested that shade has got a positive influence on the volatile oil (Sreekala et al. 2004).

The effect of differing light transmission levels on growth, yield, quality and nutrient dynamics of kacholam was studied under single strata, multistrata and No-over-Canopy (Kumar et al., 2005). According to him presence or absence of over canopy seemed to have little effect on kacholam rhizome yield as yield responses under no over canopy ,single strata and multi strata systems are similar. Likewise rhizome quality did not exhibit any remarkable trends with respect to canopy structure.

At 70 per cent shade levels of P and Ca content of leaves and K content of rhizome showed high positive correlation with yield due to positive indirect effect of P and Mn in leaves and dry rhizome yield. At 50 per cent shade, level correlation coefficient revealed that major nutrients had high positive relation with fresh rhizome yield possibly due to enhanced positive indirect effect of P in rhizome, K in leaves and Mg and Mn in rhizome (Gangadharan and Menon, 2006).

A comparative study on productivity of food, beverage and medicinal plants in agroforestry systems showed that the crops like upland rice, ginger and kacholam showed higher productivity in certain agroforestry combinations over sole crops (Kumar, 2006).

In a study conducted on ginger to study the effect of light intensity on different growth traits, plant height increased with decreased light intensity and number of tillers per plant increased significantly under normal light condition compared to reduced light condition. Increase in plant height at reduced light intensity may be due to apical dominance and suppression of lateral growth leading to more of vertical growth. The study also revealed that higher fresh yield of rhizome, leaf area and leaf area ratio under normal light condition than under reduced light intensity (Vastrad et al. 2006).

The above ground and below ground biomass observations of different medicinal plants like *Aloe vera,Alpina galanga*,*Coleus forskohlii ,Andrographi*s *paniculata ,Stewia rebaudiana ,Catharathus roseus* and *Ocimum sanctum* were significantly different between open and arecanut shaded conditions. The mean economic yield under open condition was significantly higher when compared to the crops grown under shade of arecanut (Channabasappa et al.2007)

According to Prabhu (2007) kacholam is a suitable medicinal plant which can be grown as an intercrop in coconut garden which offers good scope for increasing the yield.

The Central Plantation Crops Research Institute (CPCRI) recommended the herbal plants like kacholam, arrowroot, vetiver, chittadalodakam, thippili and aleovera as crops suited for intercropping in coconut gardens (Chandrashekar, 2008).

**2.8 VARIABILITY:**

Genetic variability for yield and yield contributing traits in the base population is essential for successful crop improvement (Allard, 1960). The larger is the variability; the better is the chance of identifying superior genotypes.

Pillai and Nambiar (1975) and Rao et al. (1975) noticed variation in thickness, length, internodal length and colour of rhizomes among turmeric types.

According to Nybe (1978) 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 and germination percentage were found to differ significantly among ginger types. He also observed no significant variation among types for breadth of leaves ,length of petiole and number of primary fingers.

According to Philip (1978) there exists significant difference among different types of turmeric in morphological and growth characters such as height of the plant, number of leaves per tiller, plant height, leaf characters, length of roots and rhizomes and characters of mother, primary and secondary fingers. 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.

Mohanty (1979) studied the variability and heritability of fourteen characters in 28 native and foreign varieties of ginger and he reported high values for genetic coefficient of variation (GCV), expected genetic advance and heritability estimates for number of secondary rhizomes and total root weight. Heritability estimate was also high for leaf breadth while genotypic coefficient of variation was high for weight of root tubers.

Mohanty and Sharma (1979) studied genetic variability and heritability 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 number of tertiary fingers and straw yield.

George (1981) reported that morphological characters such as number of tillers, height of the plant, number of leaves both on the main plant and tiller, number of roots, length, girth and internodal length of primary and secondary fingers were significantly different among the various lines of turmeric.

Mohanty et al. (1981) examined twenty eight cultivars and strains of *Zingiber officinale* and suggested varietal difference 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.

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

High heritability for curing percentage, curcumin and oleoresin content was reported by Philip and Nair(1986) in turmeric. Genetic advance was reported to be high for plant height ,green yield, curing percentage ,leaf blotch resistance and curcumin and oleoresin content with which he suggested that selection within the existing germplasm would lead to improvement for those characters.

Significant variation was observed for shoots per clump, leaves per shoot, plant height and yield per plant in a germplasm collection of turmeric lines (Mukhopadhayay et al. 1986). Genetic coefficient of variation was highest for total plot yield while heritability estimate was moderate for shoots per clump.

Turmeric cultivars at Brahmavar were found to have high significant variation between the cultivars for many of the characters studied viz., yield of cured turmeric, number of primary fingers and yield of secondary fingers (Jalgaonkar et al., 1990).

Reports also showed significant difference between open pollinated progenies of *Curcuma aromatica* cultivar Nandiyal, for all the plant traits except tillers/plant as well as rhizome characters, yield, curing percentage and curcumin content (Menon et al., 1992).

Indiresh et al. (1992) studied the genetic variability in turmeric and reported highly significant variation in characters such as plant height, petiole length, fresh rhizome yield, length of primary and secondary fingers per plant, girth of primary and secondary fingers and weight of mother rhizome.

Comparative study between four exotic cultivars of ginger viz., Maran, Himachal Pradesh, Wayanad local and Rio-de-jenario and two Nigerian land races viz., Taffin Yiwa and Yatsun biri showed significant difference for root yield, leaf number and shoot height at crop maturity but the stem tuber yield was not significantly different (Okwvowulu,1992).

Prakash and Krishnan (1994) observed variations in various accessions and inter varietal hybrid of *Curcuma forskholii* at different stages of growth.

Korla and Tiwar (1999) evaluated 24 genotypes of ginger (*Zingiber officinale*) for yield and yield components under rainfed and irrigated conditions at Solan. The study revealed significant effects of rainfed and irrigated conditions on pseudostem length, tillers per plot, leaf length, leaf breadth and yield per plant.

Significant genotypic differences were observed for pseudostem length, rhizome length, rhizome breadth and yield /plant.

Singh et al. (1999) evaluated 18 cultivars of ginger for growth, yield and quality in Nagaland during 1992. The cultivar Thingladium, Nadra and Khasi local were the tallest, had most tillers per plant and highest rhizome yield.

Genotypic coefficient of variation was studied in ginger genotypes by Yadav (1999) and Singh and Mittal (2003).The genotypic coefficient of variation was high for length and weight of secondary and primary rhizomes and rhizome yield.

Lynrah and Chakrabarthy (2000) evaluated the performance of 25 genotypes of turmeric including C*urcuma longa*, *Curcuma aromatica* and *Curcuma caesia* during 1994-95 which revealed significant variation with respect to growth, yield and quality parameters due to genotypes. Among the genotypes, black turmeric (*Curcuma caesia*) a semi wild type showed the most vigorous growth and yield with higher number of tillers, leaves and leaf area per clump.

Poduval et al. (2001) studied *Curcuma aromatica* cv.Kasthuri, *Curcuma zeodoaria* cv, Manjakoova and 13 cultivars of *Curcuma domestica* for yield in a field experiment conducted in West Bengal during 1997 and revealed that the cultivars of *C.aromatica* and *C.zeodoaria* yielded more than the cultivars of *Curcuma domestica.*

Narayanpur et al. (2003) analysed 16 cultivars of turmeric for morphological and yield characteristics where plant height, number of leaves, number of tillers and leaf area index differed significantly. High significant variations were noticed among the cultivars for fresh and cured rhizome yield for which the reason was attributed to genetic characteristics and their response for particular agro-climatic conditions.

Kurian et al. (2004) reported that the dry rhizome yield of turmeric varieties from KAU viz. Kanthi ,Sobha ,Sona and Varna ranged from 4.02 to 8.27 t/ha with a driage ranging from 18.88 to 20.15%.

A study was carried out using 50 accessions of mango ginger (*Curcuma amada Roxb*) collected from farmer's house holds of Kerala. The study revealed that there existed significant variation between the accessions. Phenotypic coefficient of Variation (PCV) was higher in all cases than Genotypic Coefficient of Variation (GCV). Heritability varied from 15.83% to 65.02%. Genetic advance was also high for vegetative and yield characters (Jayasree et al. 2006).

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**2.9 CHEMICAL COMPOSITION OF RHIZOME:-**

Dried, powdered kacholam rhizomes gave 2.40-3.88 per cent of volatile oil .Its rhizome possess a camphoracious odour with a bitter aromatic taste like that of *Hedychium spictum*. According to Panicker et al. (1926) and Guenther (1975) kacholam oil consists of compounds like n-pentadecane, ethyl p-methoxy cinnamate, ethyl cinnamate, 1-$s^3$ carene camphene, and Borneol and P-methoxy styrene. They reported that the oil which separates out on cooling the distillate had 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° | — | 1.473 to 1.4855 |
| Acid number | — | 0.5 to 1.3 |
| Saponification number | — | 99.7 to 109.0 |

Based on an investigation conducted on the aromatic resources of Kerala by Pillai and Warriar(1962), it was found that ether extract of kacholam tubers contain 2.05 per cent of ethyl –p-methoxy cinnamate and 2.87 per cent of residual essential oil.

According to Nerk and Torne (1984) rhizomes collected from Chowgat College campus found to vary in essential oil content depending on the month of collection of the plant material. Maximum oil content was reported when the plant material was collected in October and minimum in June.

Zakaria and Ibrahim (1987) screened 14 species of Zingiberaceae family and showed the presence of alkaloids, terpenoids, flavanoids and saponins in trace amounts in the rhizomes of turmeric and ginger.

Pathania et al. (1990) observed greatest variation for curcumin content (0.28 to 8.76%) while examining 23 collections of *Curcuma longa* for agronomic and quality characters. Variation for volatile oil was also determined to classify genotypes into four groups.

Bin Din and Samsudin (1991) reported that *K.galanga* contains cinnamic acid derivatives such as ethyl cinnamate and ethyl p-methoxy cinnamate.

Seven species of *K.galanga* L. have been studied by Tuntiwachwuttikul (1991) and reported that they consists of four major classes of chemicals via., cinnamate esters, flavanoids, diterpenoids and cyclohexane oxide derivatives.

Tuntiwachwuttikul (1992) again studied four species of *Kaempferia* and reported that rhizomes of *Kaempferia parviflora* yielded 16 flavanoids. The major constituent 5, 7 dimethoxy flavanone was found to be anti-inflammatory and the activity was comparable to aspirin. The essential oil of rhizomes of *K.galanga* growing in Malaysia consists of ethyl trans-P methoxy cinnamate (56.7%), ethyl cinnamate (16.5%), Penta decane (9%), 1,8-cineole (5.7%), gamma –car-3 ene (3.3%), borneol (2.7%) and 16.4% of terpenoids.

The essential oil from five *Curcuma* spp including *Curcuma domestica* and *Curcuma aromatica* were analyzed by Zwaving and Bos (1992). The results showed that *Curcuma domestica* yielded 3.50 per cent and C*urcuma aromatica* yielded 9.40 per cent of essential oil.

In a study conducted on different kacholam types by Latha (1994), it was found that oil percentage of kacholam rhizomes varied from 1.43 per cent to 2.90 per cent. According to her the two major components of kacholam oil was paramethoxy ethyl cinnamate and ethyl cinnamate

Shahi et al. (1994) evaluated 40genotypes of turmeric and data were collected on dry matter, oleoresin and curcumin content. Significant differences were observed due to genotypes and genotype x environmental interaction .High yielding genotypes showed high dry matter content with wide adaptability and stability.

Jena and Das (1997) studied the influence of microbial inoculants on quality of turmeric and revealed that the microbial inoculation resulted in a higher protein content (8.47%) which was 7.9% more than that of the lowest value of 7.85% in uninoculated control.

Garg et al. (1999) studied the essential oil and curcumin content of 27 accessions of *Curcuma longa* from the Tarai belt. The oil content of the rhizomes varied between 0.16 and 1.94 per cent on fresh weight basis. The curcumin content was also found to vary from 0.16 to 1.15 percentage on dry weight basis.

Korla et al. (1999) evaluated 24 ginger clones under rainfed and irrigated conditions. The analysis of variance indicated significant differences among the clones for ginger oil, oleoresin and crude fibre content. However growing conditions exerted no significant effects on crude fibre content.

Singh et al. (2000) reported significant association of essential oil content with rhizome yield per plant and percentage of oleoresin content in ginger.

Niranjan et al. (2003) analyzed the foliage of three species of *Curcuma* viz *Curcuma longa, Curcuma zedoaria* and *Curcuma amada* cultivated on sodic soil and found out a total chlorophyll (0.35to1.20 mg/g) essential oil (3.7 to 5.3 %) and protein content (3.6 to 6.8 %).

Twenty four genotypes of ginger were evaluated for yield and quality attributes under rainfed and irrigated conditions at Solan by Tiwari (2003). Significant difference among the genotypes were observed for ginger oil, oleoresin, fibre and dry matter content irrespective of the two growing conditions.

Kurian et al. (2004) reported that the unique feature of turmeric varieties viz, Kanthi, Sobha, Sona and Varna is that they have more than 7 per cent curcumin in composite sample and 5.0 per cent in fingers. The volatile oil ranged from 4.24 to 5.15 percentages.

Padmapriya and Chezhiyan (2004) analyzed turmeric rhizomes and reported the chemical compositions as moisture (13.1%), protein (6.3%), fat (5.1%), minerals (3.5%) fibre (2.6%) and carbohydrate (69.4%).

The rhizomes of kacholam contain 2.4- 3.9 % of an essential oil. In Kerala, the mother rhizomes of kacholam sown during the third week of May and harvested after six months yielded maximum essential oil (19.1 kg/ha) and oleoresin (56.3 kg/ha). It also contains a monoterpene ketone,3-caren-5-ene.(Anon,2006).

The essential oil was isolated by hydro-distillation of the rhizomes of six accessions of *Alpinia galanga* L. collected from Kerala. The oil percentage in these collections ranged from 0.27 to 0.62. Essential oil were analysed and thirty components were identified .Major components present in this oil were 1,8-cineole(60-70), α-terpenol(1.08-4.31), α-pinene(5.42-7.41), terpinen-4-ol (1.95-2.42) ( Raina et al.,2007).

**2.10 CORRELATION STUDIES:-**

Kannan and Nair (1965) analysed yield and plant characters like number of tillers, height of plant and number of leaves in ginger and reported that plant height was generally associated with yield. 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 (Nybe, 1978).

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 in turmeric were positively correlated with yield. (Philip, 1978).

Correlation studies conducted in turmeric cultivars indicated that weight of primary, secondary and mother rhizomes had different effect on yield (Mohanty, 1979). The study also revealed that tall plants with more number of broad leaves produce high yielding turmeric types.

In ginger, rhizome yield was positively and significantly correlated with number of 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 (Mohanty and Sharma, 1979).

Number of tillers, plant height and number of fingers had high significant positive correlation with yield of turmeric (Nambiar, 1979). He also reported that the final yield was influenced by the weight of seed material.

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 (Govind et al. 1981).

A high correlation was observed between plant height and yield per plant at both phenotypic and genotypic levels (Mukhopadhyay and Roy, 1986). Jalgaonkar et al. (1990) reported that the yield of cured turmeric was significantly correlated with yield of secondary fingers. He also reported that the yield of cured turmeric was significantly correlated with yield of secondary fingers and there was significant relation of quantitative characters of secondary finger with each other and with those of primary fingers.

Roy and Wamanan (1990) reported that yield was correlated with shoot height, leaves per clump of shoot and tillers per clump in ginger.

Twelve yield components of ten genotypes of *Curcuma longa* were evaluated for genetic variance and yield correlations by Jalgaonkar et al. (1990). Cured yield of all the genotypes was found significantly and positively correlated with yield of secondary fingers.

Okuvowala (1992) compared four exotic cultivars of ginger with the Nigerian land races and reported a significant positive correlation between stem tuber yield and shoot number in Wayanad local and between stem tuber and root yield in Maran.

In turmeric, phenotypic coefficient of variation was higher than the genotypic coefficient of variation in general. Genotypic coefficient of variation was very high for fresh rhizome yield (63.30) indicating the high degree of genetic variability for this character (Indiresh et al., 1992).

Ali et al. (1994) studied genotypic coefficient of variation in ginger genotypes and reported that genotypic coefficient of variation was high for length and weight of secondary and primary rhizomes and rhizome yield per plant.

In kacholam, 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 in open condition while under shade, plant spread recorded moderately high heritability but low genetic advance (Latha, 1994).

Stability in rhizome yield and its determining characters in turmeric were evaluated by Shahi et al. (1994) and it revealed that stability in rhizome yield was associated with length and girth of rhizome, number of leaves and tillers per plant.

Correlation coefficient between yield and its component characters in kacholam indicated significant positive association of yield with number of leaves, tillers, leaf length, plant spread and rhizome number (Kanakamony, 1997).

Fifteen ginger cultivars were studied for variability and association of characters among them by Prasad et al. (1998).High coefficient of variability was observed for number of tillers followed by number of leaves .Moderate to low variability was noticed for length and breadth of rhizomes, breadth of leaves, number of primary fingers, rhizome weight per plant, plant height and length of leaves.

Chandra et al. (1999) evaluated the performance of 25 genotypes of turmeric at Meghalaya for three consecutive years .Among the 19 characters studied, weight of primary finger rhizome, number of primary and secondary finger rhizomes per clump, plant height, length of leaf, diameter and weight of primary rhizome, internodal distance of primary finger rhizome and rhizome yield per hectare were significantly and positively associated with fresh rhizome yield per clump.

Korikanthimath et al. *(*1999) evaluated 12 elite clones of cardamom along with a local control for yield during 1994. All the five yield components studied were positively correlated with yield.

The coefficient of variation for 18 important horticultural traits was estimated in 26 accessions of ginger by Yadav (1999). The study observed that the genotypic coefficient of variation was high for length and weight of secondary rhizomes, weight of primary rhizomes, number of secondary and primary rhizomes and rhizome yield per plot.

An investigation was carried out on 22 genotypes of turmeric by Hazra et al. (2000) to elucidate the role of different growth characters and components of rhizome yield. Genetic variability and correlation were studied to assess the direct and indirect relationships in respect of growth characters and yield of the growth characters only. Leaves per clump at 180 days after planting exhibited significantly positive phenotypic correlation with yield.

In *Curcuma longa* number of leaves per clump, leaf area, leaf area index and number of primary and secondary fingers had strong positive association with rhizome yield at both genotypic and phenotypic levels (Jana et al. 2001).

The genotypic correlation coefficient was in general higher than the phenotypic correlation coefficient thus revealing strong association at genotypic level between the characters in turmeric (Shanmugasundaram et al. 2001 and Reddy, 1987).

Singh et al. (2003) studied the genetic variation for rhizome yield and components in 65 turmeric genotypes and observed that the greatest variation was recorded for yield, followed by weight of mother rhizome per plant, plant height, weight of primary rhizome per plant and number of leaves. The phenotypic coefficient of variation was generally higher than genotypic coefficient of variation .The result suggested that superior genotypes may be obtained through selection based on the number and weight of primary and secondary rhizomes.

In *Curcuma longa* correlation studies showed that number of leaves per clump, leaf area, leaf area index and number of primary and secondary fingers had strong positive association with rhizome yield at both genotypic and phenotypic levels (Narayanpur and Hanashetti, 2003: Singh et al. 2003).

Correlation analysis of 11 characters of turmeric (*Curcuma longa*) carried out using 22 genotypes revealed that plant height ,leaf length ,thickness of primary and secondary rhizomes and number of secondary rhizomes had significant positive association with rhizome yield (Tomar et al.2005).

Forty one turmeric genotypes were evaluated at ICAR Research complex for North Eastern Hilly Region, Umaiam, and Meghalaya. The study revealed that all the characters under study viz., plant height ,number of clumps per plant, number of leaves per plant , number of primary and secondary rhizomes, length of mother rhizomes and yield per plant showed positive correlation with yield both at phenotypic and genotypic levels(Yadav et al.2006).

**2.11 PATH COEFFICIENT ANALYSIS:-**

The character which contributes towards yield are those which had positive direct effects and those having small negative effect but high genotypic correlation with yield. Phenotypic correlation between yield of rhizomes and height of pseudostem in ginger was quite high and so also the direct effect of height towards the correlation (Ratnambal, 1979). 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. Even though 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 analysis showed that significant positive correlation between yield and morphological characters and it was 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 of yield could be made.

According to Geetha (1985), in a study conducted in turmeric, the direct effects of number of leaves per tiller and girth of mother rhizome was positive where as number of nodes per primary finger and petiole length had high negative direct effect on rhizome yield.

In turmeric, plant height had the maximum direct effect on yield, followed by tillers per clump(Mukhopadhayay and Roy, 1986).Tillers per clump, leaves per shoot and plant height were recommended as selection criteria for improving yield.

Path coefficient analysis of important yield attributes of kacholam indicated that number of rhizomes had the maximum direct effect on yield followed by plant spread, leaf length and leaf breadth (Kanakamony, 1997).

Panja et al. *(*2002) reported a negative direct effect of number of primary rhizomes and significant positive association with yield due to high indirect effect with number of leaflets and thickness of secondary rhizomes in turmeric.

High positive direct effect of leaflet length and thickness of secondary rhizome with yield was reported in ginger by Abraham and Latha (2003).

Path analysis of 11 characters of turmeric (*Curcuma longa*) carried out using 22 genotypes revealed plant height, leaf length, thickness of primary and secondary rhizomes and number of secondary rhizomes to have positive direct effect on rhizome yield. These traits may be given due emphasis while making selections for improvement in rhizome yield of turmeric (Tomar et al. 2005).

**2.12 GENETIC DIVERGENCE:-**

$D^2$ analysis was carried out on a set of 18 genotypes of ginger (*Zingiber officinale*) involving eight metric traits. The genotypes could be grouped into three clusters and while inter cluster $D^2$ values ranged from 338.99 to 2029.63, intra cluster $D^2$ values ranged from 18.41 to 45.05. The major forces for divergence were rhizome per plant, oleoresin and fiber contents (Singh et al. 2000).

Fifty four turmeric (*Curcuma longa*) cultivars were evaluated by subjecting to $D^2$ statistic to assess the genetic diversity and it showed wide diversity among the cultivars and they were grouped into six clusters. Inter cluster distance values also showed wide genetic divergence among the cultivars. Based on cluster mean values ,the cultivars PTS-38 and Duggirula in cluster I(high cured yield) PCT-5 and PCT-8 in cluster III (high curcumin content, essential oil and oleoresin contents) and PCT-13,PCT-14 and PCT-10 in cluster IV(short duration, medium yield with good curcumin content) were identified as potential parents for future breeding programme (Rao et al.,2005).

An investigation carried out for the characterization of kasthuri turmeric collected from various sources revealed that the environment had negligible effect on the characters analysed and its $D^2$ analysis showed that various accessions of kasthuri turmeric were spread over different cluster and some accessions having some similarity formed a single cluster(Alex,2005) .

# Materials and Methods

# 3. MATERIALS AND METHODS

The present study on "Genetic variability in kacholam (*Kaempferia galanga* L.) under open and partially shaded conditions in coconut gardens" was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2007-2008.

## 3.1 MATERIALS:

A survey was conducted in farmers' fields throughout Kerala and the adjoining areas of southern districts of Tamil Nadu and the genotypes were collected from Kasaragod, Kanzhangad, Kannur, Kozhikode, Wayanad, Malappuram, Madavur, Ponnukkara, Palakkad, Trichur, Ernakulam, Koothattukulam, Alappuzha, Idukki, Kottayam, Ponneyekkad, Pathanamthitta, Kollam, Thiruvananthapuram, Neyyattinkara, and Kanyakumari district (Tamil Nadu) . These along with the released varieties Kasthuri and Rajani formed the materials for the above investigation. The details of the genotypes are given in Table 1.

## 3.2 METHODS:

### 3.2.1 THE EXPERIMENTAL DETAILS AND DESIGN:

All the 22 genotypes collected from different locations were planted in open condition and also in partially shaded condition in coconut garden. The two identical and parallel experiments were laid out in a Randomised Block Design with three replications.

### 3.2.2 PLANTING:

The experimental fields were thoroughly ploughed to obtain a fine tilth and raised beds of $1.5m^2$ size and 25cm height were prepared with 40cm wide channels between the beds. Healthy and viable rhizomes of the genotypes cut into small bits with one or two viable buds were used as the planting material for the


**Plate.1. Field View**

present study. Planting was done with the onset of the first monsoon showers during May 2007 in small pits on the bed at a spacing of 20x15 cm and at a depth of 4-5cm with 25 plants per bed. Dried powdered cowdung was applied before planting at the rate of 20t/ha.

**Table.1.Details of accessions of kacholam (*Kaempferia galanga* L.) collected:**

| Sl.No. | Genotypes | Places |
|---|---|---|
| 1 | $KG_1$ | Kannur |
| 2 | $KG_2$ | Madavur |
| 3 | $KG_3$ | Ponnukara |
| 4 | $KG_4$ | Palakkad local |
| 5 | $KG_5$ | Kanyakumari dist (TN) |
| 6 | $KG_6$ | Kasaragod |
| 7 | $KG_7$ | Kasthuri |
| 8 | $KG_8$ | Kottayam |
| 9 | $KG_9$ | Neyyattinkara |
| 10 | $KG_{10}$ | Ponneyekkad |
| 11 | $KG_{11}$ | Kanzhangad |
| 12 | $KG_{12}$ | Koothattukulam |
| 13 | $KG_{13}$ | Pathanamthitta |
| 14 | $KG_{14}$ | Poojappura |
| 15 | $KG_{15}$ | Kollam |
| 16 | $KG_{16}$ | Rajani |
| 17 | $KG_{17}$ | Wayanad |
| 18 | $KG_{18}$ | Kozhikode |
| 19 | $KG_{19}$ | Idukki |
| 20 | $KG_{20}$ | Ernakulam |
| 21 | $KG_{21}$ | Alleppey |
| 22 | $KG_{22}$ | Malappuram |

### 3.2.3 CROP MANAGEMENT:

Crop management practices were same for both experiments. Fertilizers were applied at the rate of 50:50:50 kg NPK $ha^{-1}$ at the time of first weeding as recommended in the Package of Practice Recommendations (KAU, 2007). After planting, the beds were mulched with green leaves at the rate of 15t/ha.Weeding and earthing up were done at two months interval.

**3.2.4 SAMPLING TECHNIQUE:**

Random sampling technique was adopted to select the sample plants for recording various observations in both the experiments. Five plants were selected at random from each plot and labelled, eliminating the border rows for recording observations. The rhizomes from these five sample plants were bulked and used for biochemical analysis.

**3.2.5 BIOMETRICAL OBSERVATIONS:**

**3.2.5.1.** Number of days for sprouting:

The number of days taken from the date of sowing to the emergence of sprouts above the ground level was recorded.

**3.2.5.2.** Number of leaves per plant:

Number of leaves produced per plant was recorded on five sample plants at two months interval from sowing till senescence of leaves.

**3.2.5.3.** Leaf length:

Leaf length was measured from tip of leaf blade to base on the third leaf from the top from the five sample plants at two months interval and expressed in centimetre.

**3.2.5.4.** Leaf breadth:

Leaf breadth was measured at two months interval from the widest part of the leaf. The same leaves which were taken for measuring leaf length was used for this observation and expressed in centimetre.

**3.2.5.5.** Plant spread:

Plant spread was measured in two directions ie, North-South and East-West directions on the 135$^{th}$ day of sowing when the plants attained maximum vegetative phase. The average of these two values was recorded as plant spread in centimetre.

**3.2.5.6.** Fresh weight of leaves:

The weight of leaves of individual sample plants was taken immediately after harvest and expressed in grams.

**3.2.5.7.** Fresh weight of roots:

The weight of roots of sample plants was measured individually immediately after harvest and expressed in grams.

**3.2.5.8.** Number of suckers per plant:

The number of suckers from each sample plant was counted and the data was recorded.

**3.2.5.9.** Dry weight of leaves per plant:

The leaves of sample plants were oven dried separately for 12 hours at 60-70°C and their weight was measured and expressed in grams.

**3.2.5.10.** Dry weight of roots per plant:

Roots from the sample plants were oven dried separately for 12 hours at 60-70°C and their dry weight was measured and expressed in grams.

**3.2.5.11.** Length of mother rhizome per plant:

Length of mother rhizome produced by the five sample plants was measured individually, averaged and expressed in centimetres.

**3.2.5.12.** Girth of mother rhizome per plant:

Girth of mother rhizome at the middle portion was measured using a twine for each sample plant, averaged and expressed in centimetres.

**3.2.5.13.** Number of secondary rhizomes per plant:

Number of secondary rhizomes produced from each sample plant was recorded and average was taken.

**3.2.5.14.** Length of secondary rhizome per plant.

Length of the biggest secondary rhizomes from each of the sample plant was measured and mean expressed in centimetres.

**3.2.5.15.** Girth of secondary rhizomes per plant:

The girth of the secondary rhizomes was recorded at the middle portion from sample plants and mean expressed in centimetres.

**3.2.5.16.** Fresh yield of rhizomes per plant.

Weight of rhizomes from individual sample plant was recorded separately immediately after the harvest and the mean expressed as grams per plant.

**Plate.2.Kacholam Flower**

**3.2.5.17.** Dry yield of rhizomes per plant:

Rhizome weight of individual sample plants after sun drying for five days was recorded and mean value expressed as grams per plant

**3.2.5.18.** Drying percentage:

The ratio of dry yield of rhizomes to fresh yield of rhizome per plant is termed as driage or drying percentage. The drying percentage was calculated separately for individual sample plants and its average was worked out and expressed as percentage.

**3.2.5.19.** Incidence of pest and diseases:

The plants were frequently examined for occurrence of disease and pest incidence.

**3.2.6 PHYSIOLOGICAL CHARACTERS:-**

**3.2.6.1.** Leaf Area:

Leaf area was calculated using leaf area metre at bimonthly intervals from the second month and expressed in square centimetres.

**3.2.6.2.** Leaf Area Index:

Leaf area index was calculated at bimonthly interval from the second month onwards as

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}}$$

Leaf area was measured using leaf area meter. From this, total leaf area of the sample plants per plot was calculated which when divided by plot size of $1.5m^2$ gave the leaf area index.

**3.2.6.3.** Leaf Area Ratio:

Leaf area ratio was calculated using the formula:

$$LAR = \frac{\text{Leaf area}}{\text{Total plant biomass}}$$

For each sample plant, the leaf area ratio was worked out separately by dividing the values of leaf area at different growth stages with the total dry weight of plants.

**3.2.6.4.** Harvest Index:

Harvest index was calculated using the formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

For each sample plant, harvest index was worked out separately by dividing dry rhizome yield with the total dry weight of plants and its mean was worked out.

**3.2.7 BIOCHEMICAL CHARACTERS:**

**3.2.7.1.** Oleoresin:

Oleoresin was estimated from dried powdered rhizome by soxhlet distillation method (AOAC, 1975) and expressed as percentage on dry weight basis.

100 g dried powdered rhizome was distilled with 250 ml acetone for 2 hours and oleoresin was collected after desolventization and weight recorded.

**3.2.7.2.** Volatile Oil:

Coarsely ground powder of fresh rhizomes was used for estimation of volatile oil. The method adopted was hydro-distillation using Clevenger distillation apparatus. Four hours distillation was done and oil was collected. The oil content was expressed in percentage (V/W) on dry weight basis (AOAC, 1975).

### 3.2.8 STATISTICAL ANALYSIS:

The analysis of variance for each character for the two experiments was worked out and the pooled analysis was also done to compare the performance of the crop for each character under open and partially shaded conditions.

**3.2.8.1.** Analysis of variance:

The analysis of variance was worked out with the replicated data and the variations between and within genotypes were worked out. The difference between genotypes was tested using CD values.

**3.2.8.2.** Genotypic and Phenotypic Coefficients of variation:

The estimation of genotypic and phenotypic coefficients of variation was carried out from the analysis of variance as follows.

$$\text{Phenotypic Coefficient of Variation, PCV} = \frac{\sigma_p}{\overline{X}} \times 100$$

$$\text{Genotypic Coefficient of Variation, GCV} = \frac{\sigma_g}{\overline{X}} \times 100$$

Where $\sigma_p$ and $\sigma_g$ are phenotypic and genotypic standard deviations respectively and $\overline{X}$ denotes mean of characters under study .The PCV and GCV are classified as given below (Sivasubramanian and Madhavamenon, 1973).

| **Category** | **Range** |
|---|---|
| Low | Less than 10% |
| Moderate | 10-20% |
| High | More than 20% |

**3.2.8.3.** Heritability:

The heritable portion of the phenotypic variance called as heritability was worked out which gives a good index for transmission of characters from parents to offsprings. Heritability in broad sense was calculated as a percentage (Jain 1982).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where $\sigma^2$ g and $\sigma^2$ p are the genotypic and phenotypic variances of the trait.

Heritability percentage was categorized by Johnson et al. (1955) as follows:

| **Category** | **Range** |
|---|---|
| Low | 0-30% |
| Moderate | 30-60% |
| High | More than 60% |

**3.2.8.4.** Genetic advance:

Genetic advance which is an important parameter in selection is the improvement in the mean genotypic value of the selected lines over the mean genotypic value of parental lines.

Genetic advance was estimated as

$$GA = \frac{kh^2 \sigma p}{\bar{X}} \times 100$$

Where k is the standardized selection differential (k=2.06) at 5% selection intensity (Miller et al. 1958) and $\bar{X}$ is the mean of the character over all accessions.

The range of genetic advance is classified as follows (Johnson et al. as1955):

| **Category** | **Range** |
|---|---|
| Low | Less than 10% |
| Moderate | 10-20% |
| High | More than 20% |

**3.2.8. 5.** Correlation:

Correlation coefficient is a statistical measure which gives the degree and direction of relationship of two or more variables. The genotypic correlation coefficient which shows the inherent association between two characters denoted as i and j were worked out as

$$\text{Genotypic correlation } (rg_{ij}) = \frac{\sigma\, g_{ij}}{\sigma g_i \times \sigma\, g_j}$$

Where $\sigma\, g_{ij}$ is the genotypic covariance between the characters i and j. $\sigma g_i$ is the genotypic standard deviation for the character i and $\sigma g_j$ is the genotypic standard deviation for the character j.

**3.2.8.6.** Path analysis:

Path analysis measures the cause of association between two characters. The direct and indirect effects of component characters on yield were estimated through path analysis technique developed by Wright (1954).

The direct and indirect effects were rated as follows by Lenka and Mishra (1973)

| **Category** | **Range** |
|---|---|
| Negligible | 0.00-0.09 |
| Low | 0.10-0.19 |
| Moderate | 0.20-0.29 |
| High | 0.30-1.00 |
| Very high | More than 1.00 |

The simultaneous equations that give the estimates of path coefficients are as follows.

$$\begin{matrix} P_1 \\ P_2 \end{matrix} \begin{pmatrix} r_{1y} \\ r_{2y} \\ \\ \end{pmatrix} \begin{pmatrix} 1 & r_{12} & r_{13} & \ldots & r_{1j} & \ldots & r_{1k} \\ & 1 & r_{23} & \ldots & r_{2j} & \ldots & r_{2k} \\ \\ \end{pmatrix} \begin{pmatrix} \\ \\ \\ \end{pmatrix}$$

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$r_{iy}$ $r_{ij}$ $r_{ik}$

$P_i$

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$r_{ky}$ 1

$P_k$

i.e., $R_y = R_x . P$

$\underline{P} = \underset{\sim}{R}_x^{-1} . \underline{R}_y$

Where $R_y$ is the vector of $r_{iy}$, the genotypic correlation between $i^{th}$ trait with yield Y.

i,j = 1,2,…k

$R_x$ is the matrix of $r_{gij}$, the genotypic correlation between $i^{th}$ trait with $j^{th}$ trait.

$P_i$ = path coefficient of $X_i$

The residual factor (R) which measures the contribution of other factors not defined in the casual scheme was estimated by the formula

$$R^2 = 1- \Sigma P_i r_{gij}$$

Indirect effect of different characters on yield is obtained as $P_{irij}$ for the $i^{th}$ character via $j^{th}$ character.

**3.2.8.7.** $D^2$ Analysis

Genetic divergence was studied using Mahalanobis $D^2$ statistic as described by Rao (1952). The genotypes were clustered by Tocher's method.

**3.2.8.9.** Selection Index

The various genotypes were discriminated based on nine characters using the selection index developed by Smith (1947) using the discriminant function of Fisher (1936).

The selection index is described by the function $I = b_1x_1 + b_2x_2 + \ldots + b_kx_k$. The function $H = a_1G_1 + a_2G_2 + \ldots + a_kG_k$ where H denotes the genetic worth of the plant and $G_1, G_2, \ldots G_k$ are the genotypic values of the plant with respect to the characters $X_1, X_2, \ldots X_k$. . The economic weightages assigned to each character is assumed to be equal to unity i.e., $a_1, a_2, \ldots a_k = 1$. The regression coefficients $b_1, b_2, \ldots b_k$ are estimated in such a way that the correlation between H and I is maximum. The procedure will reduce to an equation of the form $b = P^{-1}G_a$, where P is the phenotypic and G is the genotypic variance covariance matrix respectively from which the b values were solved out.

# Results

# 4. RESULTS

The data collected for various morphological, biometrical and biochemical characters were 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 separately analysed statistically under open and partially shaded conditions by analysis of variance technique and the pooled analysis was done to compare the performance of the genotypes under open and partially shaded conditions.

Pooled analysis showed significant difference between genotypes averaged over two conditions for all characters.

### 4.1.1. Variability in number of days for sprouting:

The character differed significantly between open and partially shaded conditions. Under open condition minimum number of days for sprouting was recorded by the genotype $KG_{18}$ (15.00) which was on par with the following genotypes $KG_{16}$ (18.00), $KG_{9}$ (18.33), $KG_{8}$ (18.33), $KG_{11}$ (18.00), $KG_{20}$ (17.66) $KG_{3}$ (16.67), $KG_{5}$ (17.33), $KG_{10}$ (16.66), $KG_{21}$ (16.66) and $KG_{22}$ (15.33) whereas the genotype $KG_{17}$ (27.00) took maximum number of days for sprouting which significantly differed from other genotypes. Under partially shaded conditions in coconut gardens the genotype $KG_{20}$ (24.00) showed delayed sprouting which was on par with almost all other genotypes and earlier sprouting was recorded by genotypes $KG_{5}$ and $KG_{22}$ (16.00) which were on par with genotypes $KG_{12}$ (17.00), $KG_{10}$ (17.33) and $KG_{9}$ (17.00). In pooled analysis the genotype $KG_{22}$ recorded minimum number of days for sprouting (15.66) which was on par with genotypes $KG_{5}$ (16.67), $KG_{9}$ (17.66) and $KG_{10}$ (17) and the genotype $KG_{17}$ (25.33) took maximum days for sprouting which significantly differed from other genotypes except the genotype $KG_{4}$ (23.50). A significant interaction was exhibited between the genotypes and the two situations for the genotypes such as $KG_{3}$, $KG_{6}$, $KG_{16}$,

**Table.2. Number of days for sprouting of different genotypes of kacholam under open and partially shaded conditions:**

| Genotypes | Number of days for sprouting | | |
|---|---|---|---|
| | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 23.33 | 20.33 | 21.83 |
| $KG_2$ | 23.00 | 21.00 | 22.00 |
| $KG_3$ | 16.66 | 21.33 | 19.00 |
| $KG_4$ | 23.33 | 23.66 | 23.50 |
| $KG_5$ | 17.33 | 16.00 | 16.66 |
| $KG_6$ | 23.00 | 19.66 | 21.33 |
| $KG_7$ | 19.66 | 24.00 | 21.83 |
| $KG_8$ | 18.33 | 21.33 | 19.83 |
| $KG_9$ | 18.33 | 17.00 | 17.66 |
| $KG_{10}$ | 16.66 | 17.33 | 17.00 |
| $KG_{11}$ | 18.00 | 19.66 | 18.83 |
| $KG_{12}$ | 20.33 | 17.00 | 18.66 |
| $KG_{13}$ | 22.00 | 19.66 | 20.83 |
| $KG_{14}$ | 21.33 | 18.66 | 20.00 |
| $KG_{15}$ | 22.33 | 21.33 | 21.83 |
| $KG_{16}$ | 18.00 | 23.00 | 20.50 |
| $KG_{17}$ | 27.00 | 23.66 | 25.33 |
| $KG_{18}$ | 15.00 | 21.66 | 18.33 |
| $KG_{19}$ | 19.33 | 21.66 | 20.50 |
| $KG_{20}$ | 17.66 | 24.00 | 20.83 |
| $KG_{21}$ | 16.66 | 21.00 | 18.83 |
| $KG_{22}$ | 15.33 | 16.00 | 15.66 |
| | | | |
| Mean | 19.66 | 20.40 | 20.03 |
| SE of mean | 1.21 | 0.88 | 1.11 |
| CD (5%) Between genotypes | 3.47 | 2.53 | 2.22 |
| CD (5%) Open x Shade | 0.67 | | |
| CD (5%) Genotype x Condition | 3.14 | | |

$KG_{17}$, $KG_{18}$, and $KG_{20}$ (Table 2). From the results it was clear that the genotypes sprouted earlier under partially shaded condition than under open condition.

**4.1.2. Variability in number of leaves:**

The observations on number of leaves at different growth stages are depicted in Table 3.

**4.1.2.1. Two months after planting:**

There was no significant difference in performance of genotypes under open and partially shaded condition regarding this trait at two months after planting. But in pooled analysis there existed significant difference between the genotypes. The genotype $KG_1$ (4.00) produced more number of leaves which was on par with almost all other genotypes except genotypes $KG_2$ (3.40), $KG_7$ (3.30), $KG_8$ (3.13), $KG_9$ (3.46), $KG_{19}$ (2.43), $KG_{20}$ (2.90) and $KG_{21}$ (2.90) while minimum number of leaves was produced by genotype $KG_{19}$ (2.43).

**4.1.2.2. Four months after planting:**

The genotypes showed significant difference under open and partially shaded conditions. The numbers of leaves produced were more under partially shaded condition than under open condition. Under partially shaded condition number of leaves was maximum for the genotype $KG_{21}$ (12.46) which differed significantly from all other genotypes whereas minimum number of leaves was produced by genotype $KG_{12}$ (5.73) followed by the genotypes $KG_{13}$ (5.80), $KG_3$ (6.40), $KG_5$ (6.40), $KG_7$ (6.4), $KG_{16}$ (6.26), $KG_{17}$ (6.20), $KG_{19}$ (6.40), $KG_{20}$ (6.26) and $KG_{22}$ (6.26).

**4.1.2.3. Six months after planting:**

At six months after planting also the character, number of leaves produced per plant differed significantly between open and partially shaded conditions. Under open condition, the genotype $KG_{16}$ (14.13) showed maximum number of leaves which was on par with genotypes $KG_3$ (12.73), $KG_{10}$ (13.3), $KG_{11}$ (12.86),

**Table.3. Number of leaves of kacholam genotypes at different growth stages:**

| Genotypes | Number of leaves per plant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | **Open** | **Shade** | **Pooled** | **Open** | **Shade** | **Pooled** | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 4.20 | 3.80 | 4.00 | 6.46 | 7.13 | 6.80 | 10.40 | 12.26 | 11.33 |
| $KG_2$ | 3.13 | 3.66 | 3.40 | 6.00 | 6.60 | 6.30 | 12.26 | 15.80 | 14.03 |
| $KG_3$ | 3.60 | 3.73 | 3.66 | 5.80 | 6.40 | 6.10 | 12.73 | 15.93 | 14.33 |
| $KG_4$ | 3.40 | 3.60 | 3.50 | 6.13 | 7.00 | 6.56 | 13.40 | 14.93 | 14.16 |
| $KG_5$ | 3.80 | 3.93 | 3.86 | 6.93 | 6.40 | 6.66 | 11.80 | 13.93 | 12.86 |
| $KG_6$ | 3.80 | 3.33 | 3.60 | 7.26 | 6.66 | 6.96 | 11.20 | 14.60 | 12.90 |
| $KG_7$ | 3.53 | 3.06 | 3.30 | 7.00 | 6.40 | 6.70 | 12.00 | 13.80 | 12.90 |
| $KG_8$ | 3.26 | 3.00 | 3.13 | 6.46 | 6.93 | 6.70 | 11.73 | 14.86 | 13.30 |
| $KG_9$ | 3.40 | 3.46 | 3.46 | 5.80 | 6.66 | 6.23 | 12.46 | 16.46 | 14.46 |
| $KG_{10}$ | 3.73 | 3.60 | 3.66 | 5.53 | 7.00 | 6.26 | 13.33 | 14.73 | 14.03 |
| $KG_{11}$ | 4.00 | 3.60 | 3.80 | 6.26 | 7.00 | 6.63 | 12.86 | 13.26 | 13.06 |
| $KG_{12}$ | 3.86 | 3.66 | 3.76 | 6.80 | 5.73 | 6.26 | 12.53 | 15.86 | 14.20 |
| $KG_{13}$ | 3.53 | 3.66 | 3.60 | 7.80 | 5.80 | 6.80 | 13.00 | 13.06 | 13.03 |
| $KG_{14}$ | 3.53 | 3.80 | 3.66 | 8.53 | 6.73 | 7.63 | 13.40 | 15.06 | 14.23 |
| $KG_{15}$ | 3.20 | 3.80 | 3.50 | 7.33 | 6.73 | 7.03 | 13.83 | 17.20 | 15.51 |
| $KG_{16}$ | 3.40 | 3.73 | 3.56 | 6.13 | 6.26 | 6.20 | 14.13 | 17.26 | 15.70 |
| $KG_{17}$ | 3.93 | 3.13 | 3.53 | 6.20 | 6.20 | 6.20 | 12.73 | 15.46 | 14.10 |
| $KG_{18}$ | 3.80 | 3.33 | 3.56 | 6.40 | 6.66 | 6.53 | 13.06 | 14.80 | 13.93 |
| $KG_{19}$ | 2.60 | 2.26 | 2.43 | 5.80 | 6.40 | 6.10 | 8.33 | 10.33 | 9.33 |
| $KG_{20}$ | 2.66 | 3.13 | 2.90 | 7.86 | 6.26 | 7.06 | 11.06 | 11.20 | 11.13 |
| $KG_{21}$ | 2.86 | 2.93 | 2.90 | 8.13 | 12.46 | 10.30 | 10.06 | 11.86 | 10.96 |
| $KG_{22}$ | 3.93 | 3.26 | 3.60 | 5.86 | 6.26 | 6.06 | 10.06 | 12.00 | 11.03 |
| | | | | | | | | | |
| Mean | 3.51 | 3.43 | 3.47 | 6.66 | 6.80 | 6.73 | 12.11 | 14.30 | 13.20 |
| SE of mean | 0.64 | 0.20 | 0.25 | 0.20 | 0.25 | 0.23 | 0.55 | 0.40 | 0.45 |
| CD (5%)Between genotypes | 0.82 | 0.60 | 0.52 | 0.59 | 0.72 | 0.46 | 1.45 | 1.15 | 0.91 |
| CD (5%) Open x Shade | NS | | | 0.14 | | | 0.27 | | |
| CD (5%) Genotype x Condition | NS | | | 0.77 | | | 1.28 | | |

**Variability in leaves under open condition**


**Plate.3.Narrow Leaves**

$KG_{13}$ (13), $KG_{14}$ (13.4), $KG_{15}$ (13.83), $KG_{17}$ (12.73) and $KG_{18}$ (13.06) while the genotype $KG_{19}$ (8.33) produced minimum leaves which differed significantly from other genotypes. Under partially shaded condition also, maximum number of leaves was recorded by the genotype $KG_{16}$ (17.26) which was on par with two genotypes viz., $KG_{15}$ (17.20) and $KG_{9}$ (16.46) and minimum by genotype $KG_{19}$ (10.33) which significantly differed from all other genotypes except the genotype $KG_{20}$ (11.20). In pooled analysis also the genotype $KG_{16}$ (15.70) showed maximum number of leaves at six months after planting which was on par with the genotype $KG_{15}$ (15.51) and the genotype $KG_{19}$ (9.33) showed minimum number of leaves which differed significantly from rest of the genotypes. There was significant effect between treatments and two situations except for the genotypes $KG_{13}$ and $KG_{20}$.

In general, leaves produced were more under partial shade condition (Table 3) and also the crop showed a steady increase in number of leaves from two months to six months after planting.

### 4.1.3. Variability in leaf length:

The data recorded in the length of leaves at different growth stages were statistically analysed and are presented in Table 4.

#### 4.1.3.1. Two months after planting:

The character varied significantly under open and partially shaded conditions. Under open condition maximum leaf length was recorded by the genotype $KG_{19}$ (13.76cm) which was on par with three genotypes namely $KG_{1}$ (13.4cm), $KG_{10}$ and $KG_{13}$ (13.2cm). Under partially shaded condition, maximum leaf length was recorded by the genotype $KG_{13}$ (13.86cm) which differed from all other genotypes except $KG_{10}$ (12.83cm). Minimum leaf length was recorded by genotype $KG_{21}$ (7.36cm) in pooled as well as open and partially shaded conditions which differed significantly from all other genotypes. In pooled analysis the genotype $KG_{13}$ (13.53cm) recorded maximum leaf length which differed significantly from all other genotypes except genotype $KG_{10}$ (13.02cm).

**Table.4. Leaf length of kacholam at different growth stages:**

| Genotypes | Leaf length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 13.40 | 12.46 | 12.93 | 15.33 | 13.60 | 14.46 | 16.33 | 14.40 | 15.36 |
| $KG_2$ | 11.90 | 12.00 | 11.95 | 12.70 | 13.66 | 13.18 | 15.03 | 14.40 | 14.71 |
| $KG_3$ | 11.56 | 12.50 | 12.03 | 12.23 | 13.93 | 13.08 | 13.00 | 14.73 | 13.86 |
| $KG_4$ | 12.76 | 11.66 | 12.21 | 15.66 | 12.10 | 13.88 | 16.60 | 13.80 | 15.20 |
| $KG_5$ | 12.30 | 12.10 | 12.2 | 13.43 | 12.73 | 13.08 | 15.66 | 14.86 | 15.26 |
| $KG_6$ | 9.63 | 9.60 | 9.65 | 11.36 | 12.33 | 11.85 | 13.06 | 14.93 | 14.00 |
| $KG_7$ | 11.50 | 11.20 | 11.35 | 13.20 | 14.46 | 13.83 | 13.80 | 14.20 | 14.00 |
| $KG_8$ | 11.63 | 11.60 | 11.61 | 14.26 | 14.40 | 14.33 | 16.00 | 16.06 | 16.03 |
| $KG_9$ | 12.73 | 11.10 | 11.91 | 13.23 | 14.20 | 13.71 | 15.03 | 15.53 | 15.28 |
| $KG_{10}$ | 13.20 | 12.83 | 13.01 | 14.53 | 12.90 | 13.71 | 15.53 | 14.93 | 15.23 |
| $KG_{11}$ | 11.20 | 10.33 | 10.76 | 13.80 | 14.46 | 14.13 | 15.66 | 16.20 | 15.93 |
| $KG_{12}$ | 13.10 | 12.46 | 12.78 | 15.53 | 15.73 | 15.63 | 16.73 | 15.80 | 16.26 |
| $KG_{13}$ | 13.20 | 13.86 | 13.53 | 14.26 | 13.73 | 14.00 | 15.46 | 15.80 | 15.63 |
| $KG_{14}$ | 11.66 | 10.93 | 11.30 | 12.86 | 12.86 | 12.86 | 14.00 | 13.66 | 13.83 |
| $KG_{15}$ | 11.06 | 8.80 | 9.93 | 12.93 | 11.33 | 12.13 | 13.80 | 12.03 | 12.91 |
| $KG_{16}$ | 10.20 | 9.80 | 10.00 | 10.86 | 11.20 | 11.03 | 12.93 | 11.93 | 12.43 |
| $KG_{17}$ | 10.93 | 10.63 | 10.78 | 12.73 | 16.53 | 14.63 | 14.26 | 16.93 | 15.60 |
| $KG_{18}$ | 11.60 | 11.36 | 11.48 | 12.40 | 12.40 | 12.40 | 13.53 | 15.13 | 14.33 |
| $KG_{19}$ | 13.76 | 12.10 | 12.93 | 15.50 | 13.20 | 14.35 | 16.26 | 14.80 | 15.53 |
| $KG_{20}$ | 11.00 | 11.33 | 11.16 | 12.13 | 12.50 | 12.31 | 14.23 | 14.40 | 14.31 |
| $KG_{21}$ | 7.40 | 7.33 | 7.36 | 9.00 | 8.30 | 8.65 | 10.83 | 9.86 | 10.35 |
| $KG_{22}$ | 11.40 | 11.46 | 11.43 | 14.06 | 15.93 | 15.00 | 15.33 | 15.73 | 15.53 |
| | | | | | | | | | |
| Mean | 11.68 | 11.25 | 11.47 | 13.27 | 13.29 | 13.28 | 14.68 | 14.55 | 14.62 |
| SE of mean | 0.18 | 0.35 | 0.28 | 0.16 | 0.45 | 0.34 | 0.23 | 0.39 | 0.32 |
| CD (5%) Between genotypes | 0.53 | 1.003 | 0.57 | 0.46 | 1.30 | 0.68 | 0.67 | 1.13 | 0.65 |
| CD (5%) Open x Shade | 0.17 | | | NS | | | NS | | |
| CD (5%) Genotype x Condition | 0.79 | | | 0.96 | | | 0.91 | | |

#### 4.1.3.2. Four months after planting:

There was no significant difference in the performance of genotypes under both conditions at four months after planting. But in pooled analysis the genotype $KG_{12}$ (15.63cm) recorded maximum leaf length which was on par with the genotype $KG_{22}$ (15.00cm). Poor performance of the genotype $KG_{21}$ (8.65cm) was continued at four months after planting also, under open and partially shaded conditions. Significant difference between genotypes and conditions existed with respect to leaf length at four months after planting.

#### 4.1.3.3. Six months after planting:

The result revealed no difference in length of kacholam leaves when it was grown under open or partially shaded condition. In pooled analysis the genotype $KG_{12}$ (16.27cm) has recorded the longest leaf which differed significantly from all others except the following genotypes viz., $KG_8$ (16.03cm), $KG_{11}$ (15.93cm) and $KG_{13}$ (15.63cm). The genotype $KG_{21}$ recorded the shortest leaf length both under open and partially shaded condition and over pooled analysis. Between the different genotypes studied and two conditions there was significant interaction for genotypes like $KG_1$, $KG_3$, $KG_4$, $KG_6$, $KG_{15}$, $KG_{17}$, $KG_{18}$ and $KG_{19}$ (Table 4). The leaf length showed an increasing trend from two months to six months after planting and crop attained maximum leaf length at six months after planting.

### 4.1.4. Variability in leaf breadth:

The observations on the breadth of leaves at second, fourth and sixth months after planting are given in Table 5.

#### 4.1.4.1. Two months after planting:

The genotypes differed significantly under open and partially shaded conditions regarding this character. Under open and partial shade the genotype $KG_1$ produced broader leaves (10.60 and 10.56cm respectively) and genotype

**Table.5. Leaf breadth of kacholam at different growth stages:**

| Genotypes | Leaf breadth (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 10.60 | 10.56 | 10.58 | 11.43 | 10.90 | 11.16 | 12.80 | 11.40 | 12.10 |
| $KG_2$ | 8.13 | 7.96 | 8.05 | 9.63 | 9.30 | 9.46 | 11.20 | 11.26 | 11.23 |
| $KG_3$ | 8.73 | 7.56 | 8.15 | 9.13 | 9.20 | 9.16 | 11.40 | 11.60 | 11.50 |
| $KG_4$ | 9.36 | 9.36 | 9.36 | 11.13 | 9.80 | 10.46 | 12.20 | 11.46 | 11.83 |
| $KG_5$ | 8.26 | 9.03 | 8.65 | 9.76 | 9.60 | 9.68 | 10.93 | 11.13 | 11.03 |
| $KG_6$ | 7.46 | 7.83 | 7.65 | 8.46 | 9.36 | 8.91 | 11.40 | 12.20 | 11.80 |
| $KG_7$ | 8.66 | 7.46 | 8.06 | 9.66 | 9.30 | 9.48 | 11.86 | 11.46 | 11.66 |
| $KG_8$ | 9.03 | 8.96 | 9.00 | 11.06 | 9.56 | 10.31 | 13.40 | 11.60 | 12.50 |
| $KG_9$ | 9.70 | 10.13 | 9.91 | 11.23 | 10.83 | 11.03 | 13.66 | 13.40 | 13.53 |
| $KG_{10}$ | 10.33 | 9.00 | 9.66 | 11.46 | 10.56 | 11.01 | 13.40 | 12.66 | 13.03 |
| $KG_{11}$ | 8.90 | 8.70 | 8.80 | 11.20 | 9.36 | 10.28 | 12.66 | 10.53 | 11.60 |
| $KG_{12}$ | 10.10 | 10.23 | 10.16 | 12.13 | 10.73 | 11.43 | 13.33 | 11.46 | 12.40 |
| $KG_{13}$ | 10.60 | 8.96 | 9.78 | 12.13 | 10.06 | 11.10 | 14.33 | 11.40 | 12.86 |
| $KG_{14}$ | 9.63 | 8.36 | 9.00 | 10.30 | 9.40 | 9.85 | 11.33 | 11.26 | 11.30 |
| $KG_{15}$ | 8.93 | 6.86 | 7.90 | 10.00 | 9.63 | 9.81 | 12.20 | 11.86 | 12.03 |
| $KG_{16}$ | 8.33 | 6.60 | 7.46 | 9.53 | 8.33 | 8.93 | 12.66 | 11.73 | 12.20 |
| $KG_{17}$ | 9.70 | 6.80 | 8.25 | 10.66 | 7.93 | 9.30 | 11.66 | 12.33 | 12.00 |
| $KG_{18}$ | 9.26 | 6.60 | 7.93 | 10.70 | 9.63 | 10.16 | 12.60 | 12.46 | 12.53 |
| $KG_{19}$ | 8.83 | 7.26 | 8.05 | 9.76 | 9.60 | 9.68 | 11.93 | 13.26 | 12.60 |
| $KG_{20}$ | 9.06 | 7.46 | 8.26 | 11.00 | 9.80 | 10.40 | 13.20 | 13.20 | 13.20 |
| $KG_{21}$ | 4.60 | 4.46 | 4.53 | 5.73 | 5.63 | 5.68 | 9.00 | 9.53 | 9.26 |
| $KG_{22}$ | 8.96 | 8.96 | 8.96 | 11.26 | 9.36 | 10.31 | 12.73 | 12.86 | 12.80 |
| | | | | | | | | | |
| Mean | 8.96 | 8.14 | 8.55 | 10.33 | 9.45 | 9.89 | 12.27 | 11.82 | 12.04 |
| SE of mean | 0.20 | 0.21 | 0.21 | 0.17 | 0.28 | 0.24 | 0.33 | 0.28 | 0.31 |
| CD (5%) Between genotypes | 0.58 | 0.61 | 0.43 | 0.50 | 0.80 | 0.48 | 0.95 | 0.83 | 0.63 |
| CD (5%) Open x Shade | 0.13 | | | 0.24 | | | 0.19 | | |
| CD (5%) Genotype x Condition | 0.61 | | | 0.69 | | | 0.89 | | |

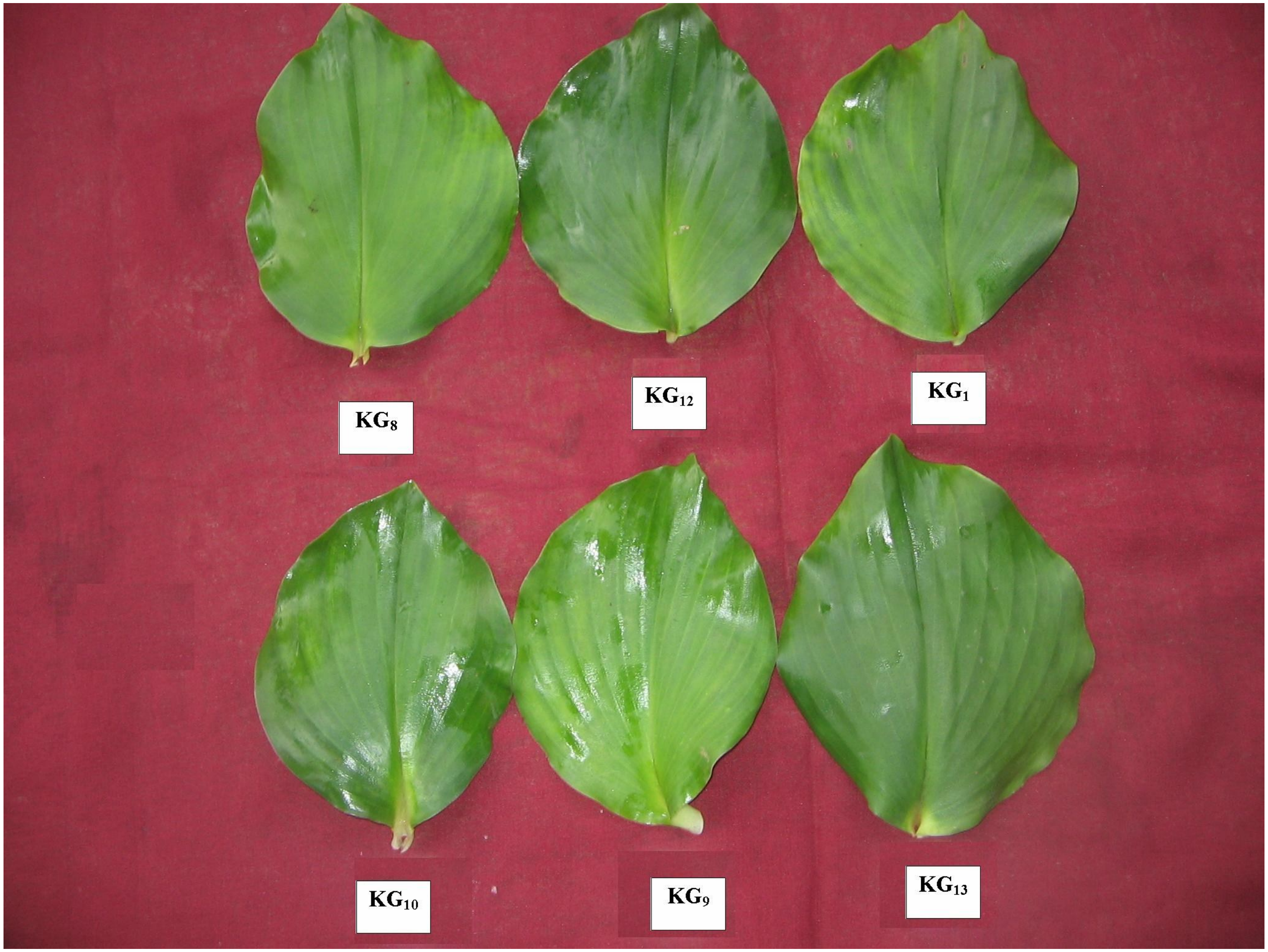



**Plate.4.Broad Leaves**

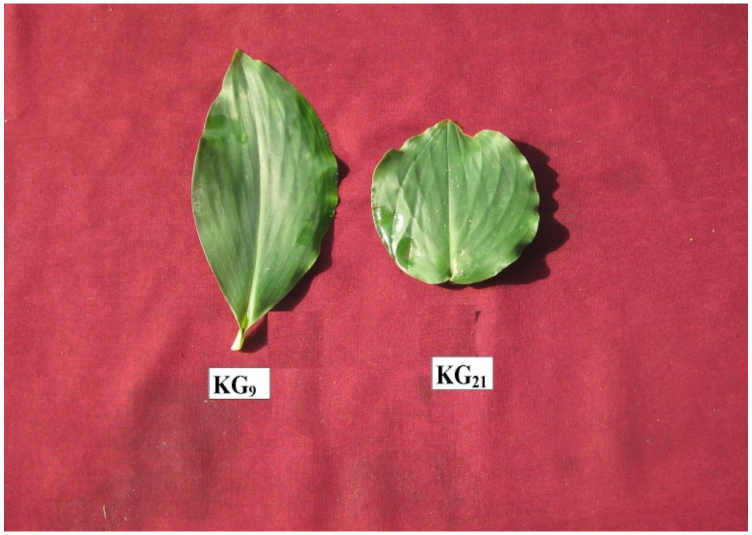
$KG_{21}$ produced narrow leaves (4.60 and 4.46 cm respectively). In pooled analysis also leaf breadth was maximum for the genotype $KG_1$ (10.58cm) and minimum leaf breadth was recorded by genotype $KG_{21}$ (4.53cm) which differed significantly from all other genotypes.

**4.1.4.2. Four months after planting:**

There existed significant difference in the performance of genotypes under open and partially shaded conditions. Under open condition, the genotypes $KG_{12}$ and $KG_{13}$ (12.13cm) performed better which differed significantly from all other genotypes. Under partially shaded condition the genotype $KG_1$ (10.9cm) performed better which differed significantly from other genotypes except the genotypes $KG_9$ (10.83cm), $KG_{10}$ (10.56cm), and $KG_{12}$ (10.73cm). In pooled analysis maximum leaf breadth was recorded by genotype $KG_{12}$ (11.43cm) which was on par with the genotypes $KG_1$ (11.16cm), $KG_9$ (11.03cm), $KG_{10}$ (11.01cm) and $KG_{13}$ (11.1cm) and minimum by the genotype $KG_{21}$ (5.68cm) which differed significantly from all other genotypes.

**4.1.4.3. Six months after planting:**

There was significant difference between open and partially shaded condition for leaf breadth at six months after planting. Under open condition maximum leaf breadth was recorded by the genotype $KG_{13}$ (14.33cm) which was on par with the genotypes $KG_8$ (13.40cm), $KG_9$ (13.66cm) and $KG_{10}$ (13.40cm) and under partially shaded condition maximum leaf breadth was found in genotype $KG_9$ (13.40cm) which differed significantly from all other genotypes except genotypes $KG_{10}$ (12.66cm), $KG_{19}$ (13.26cm), $KG_{20}$ (13.20cm) and $KG_{22}$ (12.86cm). Maximum leaf breadth was recorded by the genotype $KG_9$ (13.53cm) on pooled analysis which was on par with the genotype $KG_{10}$ (13.03cm) and minimum leaf breadth was recorded by genotype $KG_{21}$ (9.26cm) over pooled analysis and under both conditions, which differed significantly from all other genotypes. The difference between the genotypes like $KG_1$, $KG_8$, $KG_{12}$,



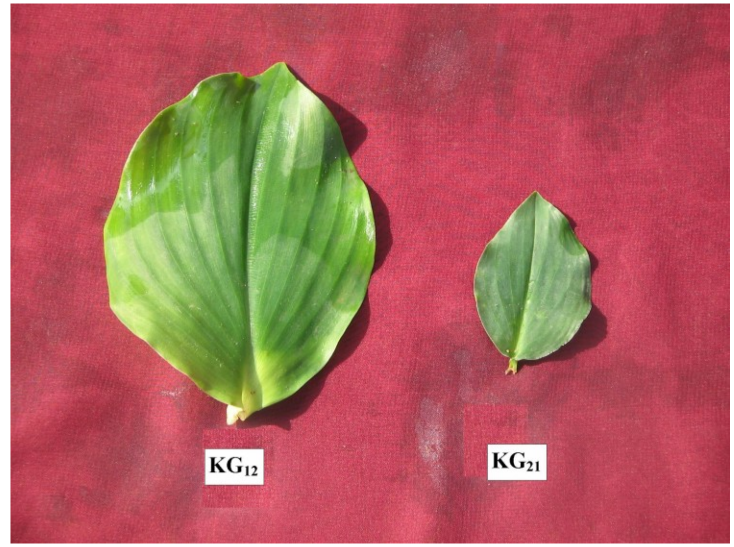




**Plate. 5. Leaf size and leaf shape variability**

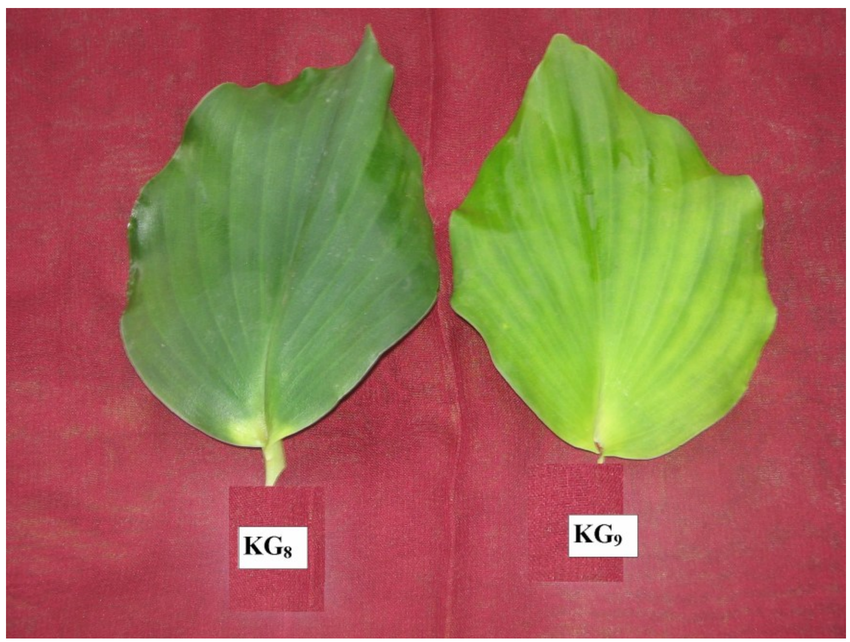



**Plate.6. Variability in leaf colour**

$KG_{13}$ and $KG_{19}$ with the two conditions, viz., open and partial shade was significant.

Leaf breadth also showed an increasing trend through out its growth stages. The result revealed that leaf breadth was more under open condition than under partially shaded condition which may be due to the more harvest of sunlight by the plants under open condition.

**4.1.5. Variability in leaf area:**

The results of variability in leaf area of kacholam at different growth stages and under different growth conditions are presented in Table 6.

**4.1.5.1. Two months after planting:**

Under open condition the genotype $KG_1$ (69.41 $cm^2$) recorded highest leaf area which was on par with the genotype $KG_{13}$ (68.45 $cm^2$) and under partial shade also the genotype $KG_1$ (64.41 $cm^2$) showed highest leaf area and it differed significantly from all other genotypes. The genotype $KG_1$ (66.91 $cm^2$) recorded highest leaf area in pooled analysis averaged over both conditions and it was on par with the genotype $KG_{13}$ (64.60 $cm^2$) and the lowest leaf area was recorded by the genotype $KG_{21}$ with leaf area 16.33 $cm^2$ which differed significantly from all other genotypes.

**4.1.5.2. Four months after planting:**

From Table 6 it was clear that at four months after planting, under open condition and in pooled analysis maximum leaf area was shown by the genotype $KG_{12}$ (92.26 and 87.45 $cm^2$ respectively) which differed significantly from the rest, but under partially shaded condition it was on par with genotype $KG_9$ (75.12 $cm^2$). Under both conditions minimum leaf area was produced by genotype $KG_{21}$ (24.07 $cm^2$) which differed significantly from all other genotypes.

**Table.6. Leaf area of kacholam at different growth stages:**

| Genotypes | Leaf area ($cm^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 69.41 | 64.41 | 66.91 | 85.71 | 72.47 | 79.09 | 102.23 | 80.33 | 91.28 |
| $KG_2$ | 47.32 | 46.74 | 47.03 | 59.83 | 62.09 | 60.96 | 82.44 | 79.32 | 80.88 |
| $KG_3$ | 49.39 | 46.22 | 47.81 | 54.64 | 62.66 | 58.66 | 72.38 | 83.74 | 78.06 |
| $KG_4$ | 58.48 | 53.45 | 55.97 | 85.30 | 57.98 | 71.64 | 99.00 | 77.35 | 88.18 |
| $KG_5$ | 49.71 | 53.45 | 51.58 | 64.15 | 59.75 | 61.95 | 83.76 | 80.97 | 82.36 |
| $KG_6$ | 35.12 | 37.06 | 36.09 | 47.06 | 56.47 | 51.77 | 72.80 | 89.03 | 80.92 |
| $KG_7$ | 48.73 | 40.89 | 44.81 | 62.40 | 65.79 | 64.09 | 80.07 | 79.43 | 79.75 |
| $KG_8$ | 51.37 | 50.86 | 51.12 | 77.22 | 67.36 | 72.29 | 104.82 | 91.17 | 98.00 |
| $KG_9$ | 60.40 | 55.09 | 57.74 | 72.66 | 75.12 | 73.89 | 100.43 | 101.84 | 101.14 |
| $KG_{10}$ | 66.69 | 56.40 | 61.55 | 81.47 | 66.65 | 74.0 | 101.77 | 92.66 | 97.21 |
| $KG_{11}$ | 48.74 | 43.87 | 46.31 | 75.59 | 66.13 | 70.86 | 97.06 | 83.41 | 90.24 |
| $KG_{12}$ | 64.67 | 62.21 | 63.44 | 92.25 | 82.63 | 87.44 | 109.06 | 88.67 | 98.86 |
| $KG_{13}$ | 68.45 | 60.84 | 64.64 | 84.62 | 67.83 | 76.23 | 108.44 | 88.11 | 98.28 |
| $KG_{14}$ | 54.86 | 44.76 | 49.81 | 64.82 | 58.98 | 61.90 | 77.58 | 75.27 | 76.42 |
| $KG_{15}$ | 48.33 | 29.56 | 38.94 | 63.21 | 53.40 | 58.31 | 82.21 | 69.90 | 76.05 |
| $KG_{16}$ | 41.63 | 31.62 | 36.62 | 50.66 | 45.64 | 48.15 | 80.15 | 68.46 | 74.31 |
| $KG_{17}$ | 51.93 | 35.35 | 43.64 | 66.41 | 64.00 | 65.21 | 81.35 | 102.11 | 91.73 |
| $KG_{18}$ | 52.55 | 36.69 | 44.62 | 64.90 | 58.39 | 61.65 | 83.56 | 92.48 | 88.02 |
| $KG_{19}$ | 59.47 | 42.97 | 51.22 | 74.05 | 61.96 | 67.99 | 94.99 | 95.98 | 95.48 |
| $KG_{20}$ | 48.82 | 41.44 | 45.13 | 65.25 | 59.85 | 62.55 | 91.86 | 92.98 | 92.42 |
| $KG_{21}$ | 16.65 | 16.02 | 16.33 | 25.26 | 22.88 | 24.07 | 47.72 | 46.01 | 46.87 |
| $KG_{22}$ | 49.99 | 50.21 | 50.10 | 77.49 | 73.05 | 75.27 | 95.47 | 98.98 | 97.23 |
| | | | | | | | | | |
| Mean | 51.94 | 45.46 | 48.70 | 67.95 | 61.87 | 64.91 | 88.60 | 84.46 | 86.53 |
| SE of mean | 1.43 | 1.88 | 1.74 | 1.40 | 2.73 | 2.24 | 2.55 | 3.44 | 3.10 |
| CD (5%) Between genotypes | 4.09 | 5.39 | 3.46 | 4.0 | 7.82 | 4.47 | 7.29 | 9.86 | 6.18 |
| CD (5%) Open x Shade | 1.04 | | | 1.34 | | | 1.86 | | |
| CD (5%) Genotype x Condition | 4.90 | | | 6.32 | | | 8.74 | | |

#### 4.1.5.3. Six months after planting:

There existed significant difference between open and partially shaded conditions regarding this character. Under open condition, maximum leaf area was recorded by genotype $KG_{12}$ (109.06 $cm^2$) which was on par with genotypes $KG_1$ (102.23 $cm^2$) and $KG_{10}$ (101.77 $cm^2$). Under partially shaded condition, maximum leaf area was recorded by genotype $KG_{17}$ (102.11 $cm^2$) which was on par with genotypes $KG_9$ (101.84 $cm^2$), $KG_{10}$ (92.62 $cm^2$), $KG_{18}$ (92.4 $cm^2$), $KG_{19}$ (95.98 $cm^2$), $KG_{20}$ (92.98 $cm^2$) and $KG_{22}$ (98.98 $cm^2$).There existed significant interaction between conditions and the genotypes like $KG_1$, $KG_4$, $KG_8$, $KG_{11}$, $KG_{12}$, $KG_{13}$, $KG_{15}$, $KG_{16}$ and $KG_{17}$. In pooled analysis the leaf area recorded was highest in genotype $KG_9$ (101.14 $cm^2$) which differed from all other genotypes except $KG_8$ (98.00 $cm^2$), $KG_{10}$ (97.21 $cm^2$), $KG_{12}$ (98.86 $cm^2$), $KG_{13}$ (98.28 $cm^2$), $KG_9$ (95.48 $cm^2$) and $KG_{22}$ (97.23 $cm^2$). The lowest leaf area was recorded by the genotype $KG_{21}$ (46.87 $cm^2$) in pooled analysis and also under both conditions which differed significantly from other genotypes.

From the above results it was clear that kacholam produced larger leaves when grown under full sunlight and leaf area increased with growth of the crop. Under open condition the crop captures more of the radiation and converts it into photosynthates which are reflected in the broader leaves with more leaf area.

### 4.1.6. Variability in leaf area ratio:

Table 7 reveals the results of variability in leaf area ratio observed in different genotypes when grown under full sunlight and partial shade in coconut gardens.

#### 4.1.6.1. Two months after planting:

A significant difference was exhibited by the genotypes between open and partially shaded conditions. Under open condition the genotype $KG_{19}$ (1.73) performed well which differed significantly from all other genotypes. Under partial shade, the genotype $KG_{13}$ (1.53) gave the highest value which differed significantly from all other genotypes. In pooled analysis the leaf area ratio was

**Table.7. Leaf area ratio of kacholam at different growth stages:**

| Genotypes | Leaf Area Ratio ($cm^2/g$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 1.27 | 1.18 | 1.23 | 1.57 | 1.32 | 1.45 | 1.88 | 1.47 | 1.67 |
| $KG_2$ | 1.07 | 1.04 | 1.06 | 1.36 | 1.38 | 1.37 | 1.87 | 1.76 | 1.82 |
| $KG_3$ | 1.22 | 1.09 | 1.16 | 1.35 | 1.48 | 1.42 | 1.80 | 1.98 | 1.89 |
| $KG_4$ | 1.50 | 1.41 | 1.46 | 2.19 | 1.54 | 1.87 | 2.55 | 2.05 | 2.30 |
| $KG_5$ | 1.22 | 1.41 | 1.31 | 1.57 | 1.57 | 1.57 | 2.06 | 2.13 | 2.10 |
| $KG_6$ | 0.92 | 0.78 | 0.85 | 1.23 | 1.19 | 1.21 | 1.91 | 1.88 | 1.90 |
| $KG_7$ | 0.93 | 0.93 | 0.93 | 1.19 | 1.50 | 1.35 | 1.53 | 1.81 | 1.67 |
| $KG_8$ | 1.06 | 1.18 | 1.12 | 1.59 | 1.56 | 1.58 | 2.16 | 2.11 | 2.14 |
| $KG_9$ | 1.10 | 1.06 | 1.08 | 1.32 | 1.45 | 1.39 | 1.82 | 1.97 | 1.90 |
| $KG_{10}$ | 1.23 | 1.07 | 1.15 | 1.51 | 1.26 | 1.39 | 1.89 | 1.75 | 1.82 |
| $KG_{11}$ | 0.90 | 0.87 | 0.88 | 1.39 | 1.31 | 1.35 | 1.79 | 1.65 | 1.72 |
| $KG_{12}$ | 1.05 | 1.15 | 1.10 | 1.50 | 1.53 | 1.52 | 1.77 | 1.64 | 1.71 |
| $KG_{13}$ | 1.39 | 1.53 | 1.46 | 1.72 | 1.68 | 1.70 | 2.21 | 2.21 | 2.21 |
| $KG_{14}$ | 1.35 | 0.95 | 1.15 | 1.60 | 1.25 | 1.42 | 1.91 | 1.59 | 1.75 |
| $KG_{15}$ | 1.19 | 0.73 | 0.96 | 1.56 | 1.32 | 1.44 | 2.03 | 1.74 | 1.89 |
| $KG_{16}$ | 1.15 | 0.82 | 0.99 | 1.40 | 1.19 | 1.30 | 2.22 | 1.79 | 2.00 |
| $KG_{17}$ | 1.27 | 0.87 | 1.07 | 1.63 | 1.59 | 1.61 | 2.00 | 2.54 | 2.27 |
| $KG_{18}$ | 1.44 | 1.01 | 1.23 | 1.79 | 1.61 | 1.70 | 2.30 | 2.56 | 2.43 |
| $KG_{19}$ | 1.73 | 1.17 | 1.45 | 2.15 | 1.69 | 1.92 | 2.76 | 2.62 | 2.69 |
| $KG_{20}$ | 1.21 | 1.17 | 1.19 | 1.62 | 1.69 | 1.65 | 2.28 | 2.63 | 2.46 |
| $KG_{21}$ | 0.38 | 0.41 | 0.40 | 0.59 | 0.59 | 0.59 | 1.11 | 1.19 | 1.15 |
| $KG_{22}$ | 1.10 | 1.05 | 1.07 | 1.70 | 1.52 | 1.61 | 2.10 | 2.07 | 2.08 |
| | | | | | | | | | |
| Mean | 1.17 | 1.04 | 1.10 | 1.52 | 1.42 | 1.47 | 2.00 | 1.96 | 1.98 |
| SE of mean | 0.011 | 0.050 | 0.044 | 0.030 | 0.065 | 0.050 | 0.060 | 0.100 | 0.080 |
| CD (5%) Between genotypes | 0.10 | 0.15 | 0.093 | 0.097 | 0.18 | 0.10 | 0.18 | 0.28 | 0.16 |
| CD (5%) Open x Shade | 0.028 | | | 0.032 | | | 0.050 | | |
| CD (5%) Genotype x Condition | 0.12 | | | 0.14 | | | 0.23 | | |

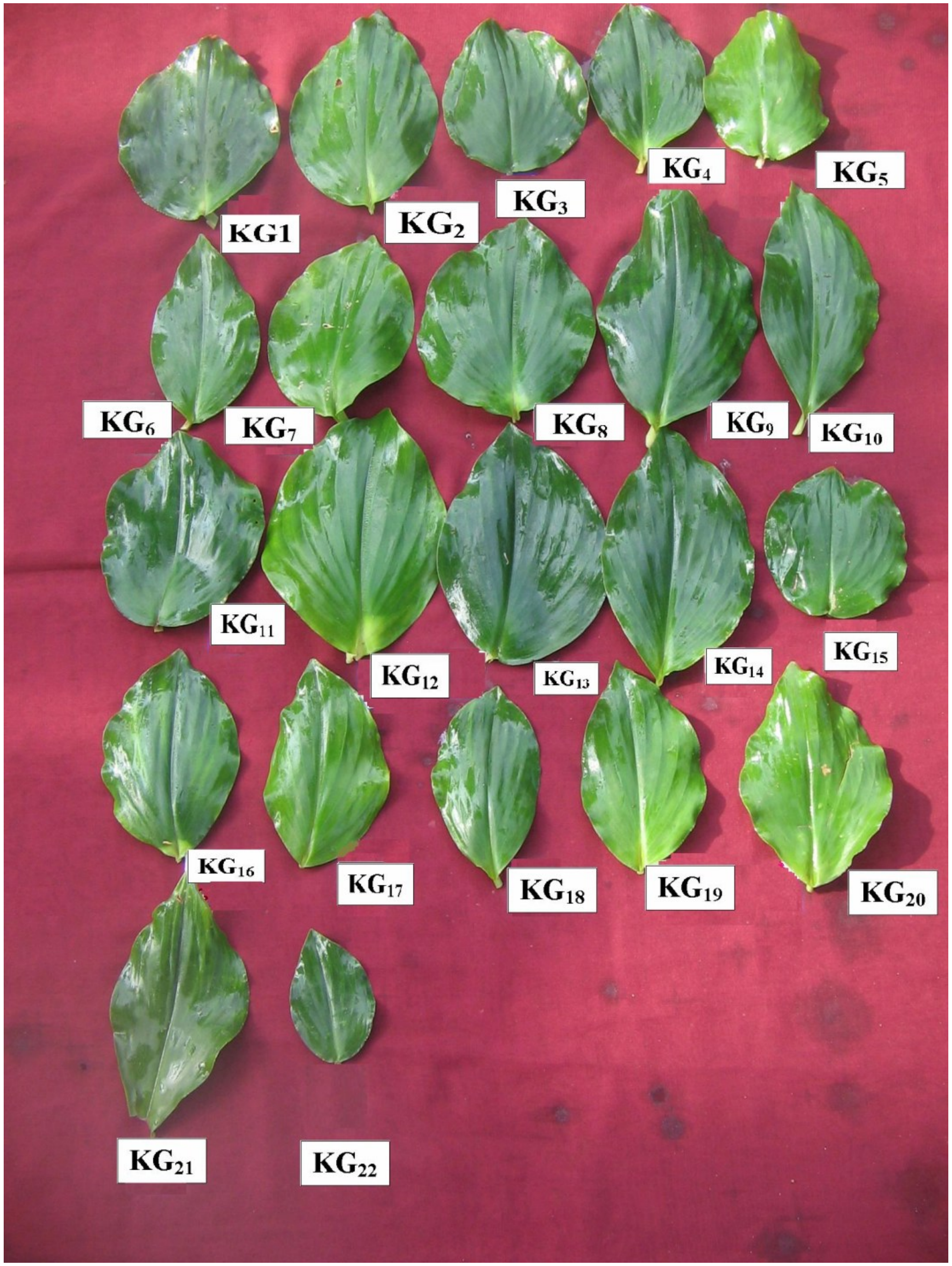



**Plate.7. Leaf shapes of different genotypes**

maximum in genotype $KG_4$ and $KG_{13}$ (1.46) which was on par with the genotype $KG_{19}$ (1.45) and minimum leaf area ratio was reported by the genotype $KG_{21}$ (0.40) which differed significantly from all other genotypes under both the conditions and over pooled analysis.

**4.1.6.2. Four months after planting:**

There was significant difference between the two conditions, open and partial shade. Under open condition the genotype $KG_4$ (2.19) recorded maximum leaf area ratio which differed significantly from all other genotypes except $KG_{19}$ (2.05). Under partial shade maximum leaf area was found in genotypes $KG_9$ and $KG_{20}$ (1.69) which was on par with the following genotypes namely $KG_4$ (1.53), $KG_{13}$ (1.68), $KG_{17}$ (1.59), $KG_{18}$ (1.61) and $KG_{22}$ (1.52) (Table 7). In pooled analysis maximum leaf area ratio was observed in the genotype $KG_{19}$ (1.92) which was on par with the genotype $KG_4$ (1.87). Leaf area ratio was found to be minimum in genotype $KG_{21}$ (0.59) in pooled analysis as well under both conditions.

**4.1.6.3. Six months after planting:**

There existed significant difference between the two conditions viz., open and partially shaded condition. Crops showed maximum leaf area ratio under open conditions. Under open condition the genotype $KG_{19}$ (2.76) which recorded maximum leaf area ratio differed significantly from other genotypes and under partial shade, maximum leaf area ratio was recorded by genotypes KG19 and $KG_{20}$ (2.63) which differed significantly from other genotypes except genotypes $KG_{18}$ (2.56) and $KG_{17}$ (2.54). Minimum leaf area ratio was recorded by the genotype $KG_{21}$ (1.15) in all cases which differed significantly from all other genotypes. The character leaf area ratio exhibited significant interaction of genotypes $KG_1$, $KG_4$, $KG_6$, $KG_{14}$, $KG_{15}$, $KG_{16}$, $KG_{17}$ and $KG_{20}$ with the conditions. At six months after planting maximum leaf area ratio was shown by genotype $KG_{19}$ (2.69) when data was pooled over both conditions (Table 7).The leaf area ratio was more under full sunlight than under partial shade.

**4.1.7. Variability in leaf area index:**

The observations on leaf area index was statistically analysed and results are presented in Table 8.

**4.1.7.1. Two months after planting:**

The character showed significant difference under both conditions. Under open condition, the genotype $KG_1$ (1.15) recorded maximum leaf area index which was followed by genotypes $KG_{10}$ (1.10) and $KG_{13}$ (1.14) and under partial shade also the genotype $KG_1$ (1.07) recorded maximum leaf area index followed by the genotype $KG_{12}$ (1.03) and $KG_{13}$ (1.01).The genotype $KG_1$ recorded maximum leaf area index in pooled analysis (1.11) and minimum leaf area index was showed by the genotype $KG_{21}$ (0.27) in all the cases which differed significantly from other genotypes.

**4.1.7.2. Four months after planting:**

There was significant difference between the two conditions of growth .Under open condition, genotype $KG_{12}$ (1.53) recorded maximum leaf area index and genotype $KG_{21}$ (0.42) recorded minimum. Under partially shaded condition, the genotype $KG_{12}$ (1.37) which recorded maximum leaf area index was on par with the genotype $KG_9$ (1.25) and minimum leaf area index was recorded by the genotype $KG_{21}$ (0.38) which differed significantly from other genotypes. In pooled analysis maximum leaf area index was showed by the genotype $KG_{12}$ and minimum by genotype $KG_{21}$ (1.45 and 0.40).

**4.1.7.3. Six months after planting:**

There existed significant difference between open and partially shaded conditions. Under open condition maximum leaf area index was recorded by the genotype $KG_{12}$ (1.81) followed by the genotypes namely, $KG_1$ (1.70), $KG_8$ (1.74) and $KG_{10}$ (1.69) and minimum by the genotype $KG_{21}$ (0.79) which differed significantly from other genotypes. Under partially shaded condition maximum

**Table.8. Leaf area index of kacholam at different growth stages:**

| Genotypes | Leaf Area Index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2MAP | | | 4MAP | | | 6MAP | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 1.15 | 1.07 | 1.11 | 1.42 | 1.20 | 1.31 | 1.70 | 1.33 | 1.52 |
| $KG_2$ | 0.78 | 0.77 | 0.78 | 0.99 | 1.03 | 1.01 | 1.37 | 1.32 | 1.34 |
| $KG_3$ | 0.82 | 0.77 | 0.79 | 0.91 | 1.04 | 0.97 | 1.20 | 1.39 | 1.30 |
| $KG_4$ | 0.97 | 0.89 | 0.93 | 1.42 | 0.96 | 1.19 | 1.65 | 1.28 | 1.47 |
| $KG_5$ | 0.82 | 0.89 | 0.86 | 1.06 | 0.99 | 1.03 | 1.39 | 1.34 | 1.37 |
| $KG_6$ | 0.58 | 0.61 | 0.60 | 0.78 | 0.94 | 0.86 | 1.21 | 1.48 | 1.34 |
| $KG_7$ | 0.81 | 0.68 | 0.74 | 1.04 | 1.09 | 1.06 | 1.33 | 1.32 | 1.32 |
| $KG_8$ | 0.85 | 0.84 | 0.85 | 1.28 | 1.12 | 1.20 | 1.74 | 1.51 | 1.63 |
| $KG_9$ | 1.00 | 0.91 | 0.96 | 1.21 | 1.25 | 1.23 | 1.67 | 1.69 | 1.68 |
| $KG_{10}$ | 1.11 | 0.94 | 1.02 | 1.35 | 1.11 | 1.23 | 1.69 | 1.54 | 1.62 |
| $KG_{11}$ | 0.81 | 0.73 | 0.77 | 1.26 | 1.10 | 1.18 | 1.61 | 1.39 | 1.50 |
| $KG_{12}$ | 1.07 | 1.03 | 1.05 | 1.53 | 1.37 | 1.45 | 1.81 | 1.47 | 1.64 |
| $KG_{13}$ | 1.14 | 1.01 | 1.07 | 1.41 | 1.13 | 1.27 | 1.80 | 1.46 | 1.63 |
| $KG_{14}$ | 0.91 | 0.74 | 0.83 | 1.08 | 0.98 | 1.03 | 1.29 | 1.25 | 1.27 |
| $KG_{15}$ | 0.80 | 0.49 | 0.64 | 1.05 | 0.89 | 0.97 | 1.37 | 1.15 | 1.26 |
| $KG_{16}$ | 0.69 | 0.52 | 0.61 | 0.84 | 0.76 | 0.80 | 1.33 | 1.14 | 1.23 |
| $KG_{17}$ | 0.86 | 0.58 | 0.72 | 1.10 | 1.06 | 1.08 | 1.35 | 1.70 | 1.52 |
| $KG_{18}$ | 0.87 | 0.61 | 0.74 | 1.08 | 0.97 | 1.02 | 1.39 | 1.54 | 1.46 |
| $KG_{19}$ | 0.99 | 0.71 | 0.85 | 1.23 | 1.03 | 1.13 | 1.58 | 1.59 | 1.59 |
| $KG_{20}$ | 0.81 | 0.69 | 0.75 | 1.08 | 0.99 | 1.04 | 1.53 | 1.54 | 1.54 |
| $KG_{21}$ | 0.27 | 0.26 | 0.27 | 0.42 | 0.38 | 0.40 | 0.79 | 0.76 | 0.78 |
| $KG_{22}$ | 0.83 | 0.83 | 0.83 | 1.29 | 1.21 | 1.25 | 1.59 | 1.64 | 1.62 |
| | | | | | | | | | |
| Mean | 0.86 | 0.75 | 0.81 | 1.13 | 1.03 | 1.08 | 1.47 | 1.40 | 1.44 |
| SE of mean | 0.008 | 0.001 | 0.028 | 0.025 | 0.044 | 0.036 | 0.040 | 0.057 | 0.051 |
| CD (5%) Between genotypes | 0.068 | 0.09 | 0.057 | 0.067 | 0.13 | 0.074 | 0.122 | 0.164 | 0.103 |
| CD (5%) Open x Shade | 0.017 | | | 0.022 | | | 0.031 | | |
| CD (5%) Genotype x Condition | 0.081 | | | 0.125 | | | 0.145 | | |

**Variability in leaf shape under partially shaded condition**

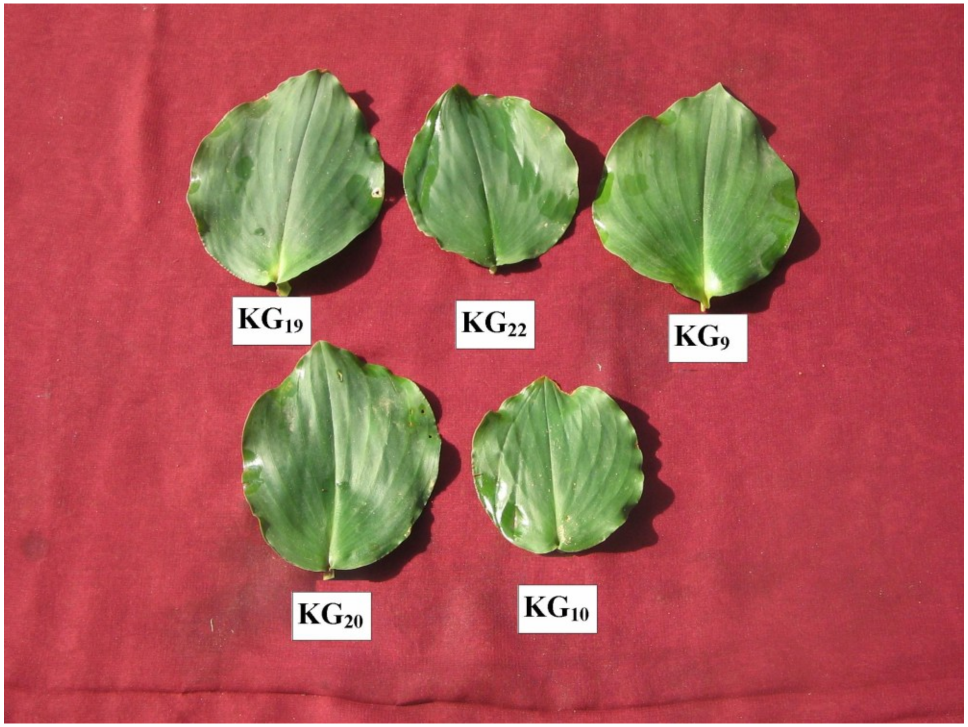



**Plate.8 . Broad leaves**

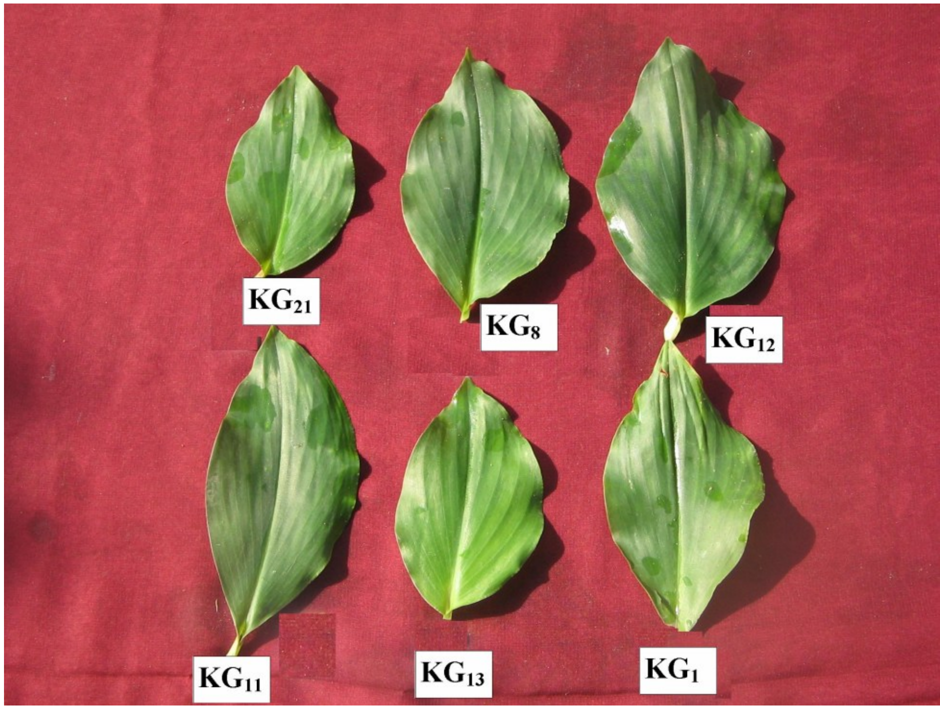



**Plate. 9. Narrow leaves**

leaf area index was recorded by genotype $KG_{17}$ (1.70) and was on par with the genotypes $KG_{19}$ (1.59) and $KG_{22}$ (1.64) and minimum by genotype $KG_{21}$ (0.76) which differed significantly from other genotypes. At six months after planting the pooled analysis revealed that maximum leaf area index was recorded by the genotype $KG_9$ (1.68) which was on par with the genotypes such as $KG_{19}$ (1.59) $KG_{13}$ (1.63) and $KG_{12}$ (1.64). The genotype $KG_{21}$ (0.78) recorded minimum leaf area index and it differed significantly from other genotypes.

From Table 8 it was clear that the variability in leaf area index at second, fourth and sixth month after planting differed significantly between the genotypes, the two conditions and between the genotypes and conditions.

**4.1.8. Variability in plant spread:**

The spread of the plant was statistically analysed over the two growing conditions at two different growth stages and results are given in Table 9.

**4.1.8.1. Ninety days after planting:**

There existed significant difference between open and partially shaded conditions. Under open condition maximum plant spread was recorded by genotype $KG_{22}$ (19.63cm) which differed significantly from other genotypes. Under partially shaded condition, maximum plant spread was recorded by the genotypes $KG_9$ (19.63cm) followed by the genotypes $KG_{22}$ (18.60cm), $KG_1$ (18.50cm), $KG_5$ (18.46cm), $KG_7$ (18.56cm), $KG_8$ (18.50cm), $KG_{10}$ (18.50cm) $KG_{11}$ (18.60cm), $KG_{12}$ (18.76cm), $KG_{13}$ (18.30cm), $KG_{17}$ (19.1cm) and $KG_{22}$ (18.6cm). Minimum plant spread was recorded by the genotype $KG_{21}$ (15.10cm) which was on par with genotypes $KG_{20}$ (16.63cm) $KG_{15}$ (16.26cm) and $KG_4$ (16.3cm). In pooled analysis maximum plant spread was recorded by the genotype $KG_{22}$ (19.11cm) which differed significantly from other genotypes. Minimum plant spread was recorded by genotype $KG_{21}$ (14.8cm) which differed significantly from other genotypes.

**Table.9. Plant spread of different kacholam genotypes at different growth stages:**

| Genotypes | Plant spread (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 90DAP | | | 135 DAP | | |
| | Open | Shade | pooled | Open | Shade | Pooled |
| $KG_1$ | 15.15 | 18.50 | 16.82 | 27.26 | 28.36 | 27.81 |
| $KG_2$ | 15.30 | 17.66 | 16.48 | 25.16 | 25.80 | 25.48 |
| $KG_3$ | 15.53 | 15.70 | 15.61 | 24.06 | 27.90 | 25.98 |
| $KG_4$ | 17.36 | 16.30 | 16.83 | 30.26 | 30.46 | 30.36 |
| $KG_5$ | 15.53 | 18.46 | 17.00 | 25.03 | 27.03 | 26.03 |
| $KG_6$ | 15.06 | 17.36 | 16.21 | 24.73 | 27.76 | 26.25 |
| $KG_7$ | 16.90 | 18.56 | 17.73 | 27.16 | 29.36 | 28.26 |
| $KG_8$ | 18.26 | 18.50 | 18.38 | 30.83 | 30.70 | 30.76 |
| $KG_9$ | 16.93 | 19.63 | 18.28 | 26.63 | 30.83 | 28.73 |
| $KG_{10}$ | 17.83 | 18.53 | 18.18 | 29.33 | 30.60 | 29.96 |
| $KG_{11}$ | 17.70 | 18.63 | 18.16 | 29.56 | 31.73 | 30.65 |
| $KG_{12}$ | 18.50 | 18.76 | 18.63 | 29.26 | 30.86 | 30.06 |
| $KG_{13}$ | 18.46 | 18.30 | 18.38 | 31.23 | 29.16 | 30.20 |
| $KG_{14}$ | 18.36 | 17.96 | 18.16 | 29.06 | 25.73 | 27.40 |
| $KG_{15}$ | 15.20 | 16.26 | 15.73 | 23.76 | 20.43 | 22.10 |
| $KG_{16}$ | 15.66 | 17.03 | 16.35 | 25.23 | 25.30 | 25.26 |
| $KG_{17}$ | 16.33 | 19.10 | 17.71 | 25.86 | 28.16 | 27.01 |
| $KG_{18}$ | 15.63 | 14.73 | 15.18 | 24.86 | 25.30 | 25.08 |
| $KG_{19}$ | 15.33 | 15.70 | 15.51 | 21.93 | 25.26 | 23.60 |
| $KG_{20}$ | 16.30 | 16.63 | 16.46 | 24.53 | 24.40 | 24.46 |
| $KG_{21}$ | 14.50 | 15.10 | 14.80 | 19.16 | 19.56 | 19.36 |
| $KG_{22}$ | 19.63 | 18.60 | 19.11 | 31.93 | 31.23 | 31.58 |
| | | | | | | |
| Mean | 16.61 | 17.54 | 17.08 | 26.67 | 27.54 | 27.11 |
| SE of mean | 0.18 | 0.53 | 0.23 | 0.28 | 0.56 | 0.55 |
| CD (5%) Between genotypes | 0.54 | 1.524 | 0.488 | 0.18 | 1.63 | 1.013 |
| CD (5%) Open x Shade | 0.14 | | | 0.34 | | |
| CD (5%) Genotype x Condition | 0.66 | | | 1.56 | | |

#### 4.1.8.2. 135 days after planting:

There existed significant difference between open and partially shaded condition. Under open condition maximum plant spread was found in genotype $KG_{22}$ (31.93cm) and minimum in genotype $KG_{21}$ (19.16cm) which differed significantly from other genotypes. Under partially shaded condition maximum plant spread was recorded by genotype $KG_{11}$ (31.73cm) and was on par with the genotypes such as $KG_4$ (30.46cm), $KG_8$ (30.8cm), $KG_9$ (30.83cm), $KG_{12}$ (30.86cm) and $KG_{22}$ (31.23cm) and minimum by genotype $KG_{21}$ (19.56cm) which differed significantly from other genotypes. In pooled analysis the genotype $KG_{22}$ (31.58cm) recorded maximum plant spread which was followed by genotypes $KG_8$ (30.76cm) and $KG_{11}$ (30.65cm) and the genotype $KG_{21}$ (19.36cm) recorded minimum plant spread which differed significantly from other genotypes. There existed a significant interaction between the performance of genotypes like $KG_3$, $KG_6$, $KG_9$, $KG_{11}$, $KG_{14}$, $KG_{15}$, $KG_{17}$ and $KG_{19}$ over the two conditions. Plant spread was greater in partially shaded condition at different growth stages. It may be an adaptation for the effective utilization of light in coconut gardens and to produce more substrates the plant spreads more under shade.

### 4.1.9. Variability in fresh and dry weight of leaves:

Observations on fresh weight and dry weight of leaves were statistically analysed and results are presented in Table 10.

#### 4.1.9.1. Fresh weight of leaves:

A significant difference between open and partially shaded condition was present in the performance of the genotypes. Under open condition maximum fresh weight of leaves was recorded by genotype $KG_{10}$ (34.20g) which was on par with genotypes $KG_7$ (33.00g), $KG_9$ (33.23g) and $KG_{12}$ (32.66g). Minimum fresh weight of leaves was recorded by the genotype $KG_{20}$ (16.80g) and it was on par with genotypes such as $KG_{16}$ (18.40g) $KG_{18}$ (18.40g) and $KG_{19}$ (17.00g). Under partially shaded condition maximum fresh weight of leaves was recorded by the genotype $KG_{12}$ (39.73g) which differed significantly from all other genotypes and minimum fresh weight was recorded by genotype $KG_{20}$ (17.40g) was on par with two genotypes viz., $KG_{18}$ (17.13g). In pooled analysis maximum fresh weight was recorded by the genotype $KG_{12}$ (36.20g) which was on par with genotype $KG_{10}$ (34.83g) and minimum fresh weight recorded by $KG_{20}$ (17.10g) and it differed significantly from all other genotypes. A significant difference was exhibited between genotypes and conditions in their performance and the crop showed maximum fresh weight for leaves under partially shaded condition than under open condition.

**4.1.9.2. Dry weight of leaves:**

The genotypes exhibited significant difference between open and partially shaded conditions. Under open condition the genotype $KG_{10}$ (14.66g) showed maximum dry weight which was on par with genotype $KG_{9}$ (14.00g) and the genotype $KG_{19}$ (7.20g) which showed lowest dry weight differed significantly from other genotypes. Under partially shaded condition $KG_{10}$ (15.26g) showed maximum dry weight of leaves which differed significantly from other genotypes and the genotype $KG_{18}$ (7.53g) showed minimum dry weight was on par with the genotypes $KG_{4}$ (8.06g), $KG_{15}$ (8.13g) and $KG_{21}$ (8.93g). Dry weight of leaves was maximum for the genotype $KG_{10}$ (14.96g) in pooled analysis and it differed significantly from all other genotypes and minimum was recorded by the genotype $KG_{18}$ (7.50g) which was on par with the genotype $KG_{19}$ (8.23g). For genotypes such as $KG_{4}$, $KG_{5}$, $KG_{6}$, $KG_{7}$, $KG_{9}$, $KG_{13}$, $KG_{15}$ and $KG_{16}$ there exhibited a significant interaction with conditions

**4.1.10. Variability in root characters:**

The variability in root characters were studied and analysed and results are given in Table 10.

**4.1.10.1. Fresh weight of roots:**

From the Table 10 it was clear that the fresh weight of roots was maximum for the genotype $KG_{12}$ in pooled analysis and also under open and

**Table.10. Leaf and root characters of kacholam:**

| Genotypes | Leaves per plant | | | | | | Roots per plant | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh weight (g) | | | Dry weight (g) | | | Fresh weight (g) | | | Dry weight (g) | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 32.00 | 30.66 | 31.33 | 11.66 | 12.73 | 12.20 | 20.60 | 22.86 | 21.73 | 11.53 | 8.26 | 9.90 |
| $KG_2$ | 24.66 | 28.53 | 26.60 | 12.66 | 12.33 | 12.50 | 20.26 | 21.73 | 21.00 | 10.66 | 10.06 | 10.36 |
| $KG_3$ | 24.73 | 22.86 | 23.80 | 11.88 | 10.86 | 11.37 | 14.20 | 19.20 | 16.70 | 5.40 | 9.53 | 7.46 |
| $KG_4$ | 19.53 | 19.93 | 19.73 | 11.00 | 8.06 | 9.53 | 12.73 | 15.26 | 14.00 | 5.60 | 5.93 | 5.76 |
| $KG_5$ | 19.60 | 18.66 | 19.13 | 11.66 | 9.26 | 10.46 | 12.00 | 14.33 | 13.16 | 5.73 | 5.73 | 5.73 |
| $KG_6$ | 19.33 | 19.53 | 19.43 | 9.46 | 12.73 | 11.10 | 12.13 | 13.73 | 12.93 | 5.86 | 6.33 | 6.10 |
| $KG_7$ | 33.00 | 30.33 | 31.66 | 12.86 | 10.80 | 11.83 | 17.26 | 17.26 | 17.26 | 9.66 | 7.86 | 8.76 |
| $KG_8$ | 22.00 | 24.80 | 23.40 | 11.40 | 13.33 | 12.36 | 14.70 | 14.60 | 14.65 | 7.40 | 7.33 | 7.36 |
| $KG_9$ | 33.26 | 36.93 | 35.10 | 14.00 | 12.66 | 13.33 | 18.33 | 16.86 | 17.60 | 9.13 | 7.66 | 8.40 |
| $KG_{10}$ | 34.20 | 35.46 | 34.83 | 14.66 | 15.26 | 14.96 | 14.73 | 15.60 | 15.16 | 6.60 | 6.93 | 6.76 |
| $KG_{11}$ | 30.93 | 26.60 | 28.76 | 12.60 | 12.73 | 12.66 | 17.20 | 17.20 | 17.20 | 8.40 | 8.26 | 8.33 |
| $KG_{12}$ | 32.66 | 39.73 | 36.20 | 13.40 | 12.13 | 12.76 | 20.66 | 23.90 | 22.28 | 11.40 | 10.80 | 11.10 |
| $KG_{13}$ | 23.40 | 35.66 | 29.53 | 11.60 | 7.93 | 9.76 | 15.06 | 18.93 | 17.00 | 12.10 | 10.13 | 11.11 |
| $KG_{14}$ | 18.80 | 19.00 | 18.90 | 12.20 | 11.20 | 11.70 | 13.80 | 14.66 | 14.23 | 6.46 | 11.46 | 8.96 |
| $KG_{15}$ | 21.93 | 19.33 | 20.63 | 11.53 | 8.13 | 9.83 | 15.66 | 17.86 | 16.76 | 7.33 | 10.33 | 8.83 |
| $KG_{16}$ | 18.40 | 18.93 | 18.66 | 12.20 | 9.33 | 10.76 | 12.93 | 13.60 | 13.26 | 5.13 | 6.73 | 5.93 |
| $KG_{17}$ | 24.03 | 28.00 | 26.01 | 11.60 | 11.20 | 11.4 | 15.66 | 15.80 | 15.73 | 6.40 | 6.26 | 6.33 |
| $KG_{18}$ | 18.40 | 17.13 | 17.76 | 8.73 | 7.53 | 8.13 | 15.00 | 16.20 | 15.60 | 6.53 | 6.13 | 6.33 |
| $KG_{19}$ | 17.00 | 18.73 | 17.86 | 7.20 | 9.26 | 8.23 | 13.60 | 14.60 | 14.10 | 6.40 | 7.13 | 6.76 |
| $KG_{20}$ | 16.80 | 17.40 | 17.10 | 10.60 | 7.46 | 9.03 | 15.20 | 15.86 | 15.53 | 6.73 | 7.53 | 7.13 |
| $KG_{21}$ | 20.60 | 18.86 | 19.73 | 9.20 | 8.93 | 9.06 | 19.06 | 19.73 | 19.40 | 11.40 | 10.67 | 11.00 |
| $KG_{22}$ | 21.67 | 24.00 | 22.83 | 11.33 | 10.33 | 10.83 | 20.33 | 20.60 | 20.46 | 10.80 | 10.67 | 10.73 |
| | | | | | | | | | | | | |
| Mean | 23.95 | 25.05 | 24.50 | 11.52 | 10.64 | 11.08 | 15.96 | 17.29 | 16.62 | 8.03 | 8.26 | 8.14 |
| SE of mean | 1.01 | 1.62 | 1.59 | 0.46 | 0.77 | 0.62 | 0.39 | 0.21 | 0.32 | 0.06 | 0.15 | 0.11 |
| CD (5%) Between genotypes | 1.66 | 2.10 | 1.45 | 1.12 | 1.45 | 0.90 | 1.03 | 0.76 | 0.65 | 0.42 | 0.65 | 0.38 |
| CD (5%) Open x Shade | 0.43 | | | 0.27 | | | 0.19 | | | 0.11 | | |
| CD (5%) Genotype x Condition | 2.05 | | | 1.27 | | | 0.91 | | | 0.54 | | |

partially shaded conditions. The genotypes showed significant difference under both the conditions. Under open condition the genotype $KG_{12}$ (20.66g) with maximum fresh weight differed significantly from other genotypes and the genotype $KG_5$ (12.00g) recorded minimum fresh weight was on par with the genotypes such as $KG_4$ (12.73g), $KG_6$ (12.13g) and $KG_{16}$ (12.93g) .Under partial shade the genotype $KG_{12}$ (23.90g) differed significantly from others but the lowest fresh weight was recorded by the genotype $KG_{16}$ (13.60g) which was on par with the genotype $KG_6$ (13.73g). In pooled analysis the genotype $KG_{12}$ (22.83g) was on par with the genotype $KG_1$ (21.73g) and the genotype $KG_5$ (13.16g) which recorded minimum fresh weight differed significantly from other genotypes. The genotypes such as $KG_4$, $KG_5$, $KG_6$, $KG_7$, $KG_9$, $KG_{13}$, $KG_{15}$ and $KG_{16}$ showed significant interaction with the two conditions.

**4.1.10.2. Dry weight of roots:**

There existed a significant difference in the performance of genotypes between open and partially shaded conditions .Under open condition, maximum dry weight was recorded by the genotype $KG_{13}$ (12.10g) which differed significantly from other genotypes and minimum was recorded by genotype $KG_{16}$ (5.13g) which was on par with the genotype $KG_3$ (5.40g) .Under partial shade maximum dry weight was recorded by genotype $KG_{14}$ (11.46g) which differed significantly from other genotypes but minimum was recorded by the genotype $KG_5$ (5.73g) which was on par with genotypes namely $KG_4$ (5.93g), $KG_{17}$ (6.26g) and $KG_{18}$ (6.13g). From pooled analysis, it was revealed that the genotype $KG_{13}$ (11.11g) recorded maximum dry weight of roots which differed significantly from other genotypes and the minimum dry weight was recorded by the genotype KG5 (5.73g) which was on par with the genotypes $KG_4$ (5.76g) and $KG_6$ (6.10g). A significant interaction between the two conditions and the performance of the genotypes such as $KG_1$, $KG_3$, $KG_7$, $KG_{13}$, $KG_{14}$ and $KG_{15}$ for dry weight of roots was present.

Table 10 clearly reveals that the weight of roots both fresh and dry weight was more under partially shaded condition.

**Table.11. Number of suckers per plant of different genotypes of kacholam:**

| Genotypes | Number of suckers per plant | | |
|---|---|---|---|
| | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 8.33 | 7.66 | 8.00 |
| $KG_2$ | 7.26 | 6.00 | 6.63 |
| $KG_3$ | 7.40 | 4.53 | 5.96 |
| $KG_4$ | 6.26 | 4.66 | 5.46 |
| $KG_5$ | 5.46 | 5.46 | 5.46 |
| $KG_6$ | 5.40 | 6.40 | 5.90 |
| $KG_7$ | 9.06 | 4.86 | 6.96 |
| $KG_8$ | 6.66 | 5.80 | 6.23 |
| $KG_9$ | 7.53 | 7.93 | 7.73 |
| $KG_{10}$ | 7.00 | 6.40 | 6.70 |
| $KG_{11}$ | 7.73 | 7.13 | 7.43 |
| $KG_{12}$ | 7.60 | 7.46 | 7.53 |
| $KG_{13}$ | 5.93 | 5.93 | 5.93 |
| $KG_{14}$ | 5.00 | 4.26 | 4.63 |
| $KG_{15}$ | 4.73 | 5.00 | 4.86 |
| $KG_{16}$ | 4.73 | 5.53 | 5.13 |
| $KG_{17}$ | 6.00 | 6.13 | 6.06 |
| $KG_{18}$ | 4.93 | 4.20 | 4.56 |
| $KG_{19}$ | 5.66 | 4.46 | 5.06 |
| $KG_{20}$ | 5.80 | 5.00 | 5.40 |
| $KG_{21}$ | 4.33 | 5.40 | 4.86 |
| $KG_{22}$ | 6.06 | 7.00 | 6.53 |
| | | | |
| Mean | 6.31 | 5.78 | 6.05 |
| SE of mean | 0.19 | 0.28 | 0.24 |
| CD (5%) Between genotypes | 0.56 | 0.80 | 0.49 |
| CD (5%) Open x Shade | 0.14 | | |
| CD (5%) Genotype x Condition | 0.68 | | |

**4.1.11. Variability in number of suckers per plant:**

There existed significant difference between open and partially shaded condition. Under open condition, maximum number of suckers was produced by genotype $KG_7$ (9.06) which differed significantly from other genotypes .Minimum was reported by genotype $KG_{21}$ (4.33) which was on par with genotypes `$KG_{15}$ (4.73) and $KG_{16}$ (4.73). Under partially shaded condition, the genotype $KG_9$ (7.93) recorded maximum number of suckers which differed significantly from other genotypes except three genotypes such as $KG_1$ (7.66), $KG_{11}$ (7.13) and $KG_{12}$ (7.46). Minimum was recorded by genotype $KG_{18}$ (4.2) which was on par with genotypes $KG_7$ (4.86), $KG_{14}$ (4.26), $KG_{15}$ (5.00), $KG_{19}$ (4.46) and $KG_{20}$ (5.00). When the data was pooled over two conditions the genotype $KG_1$ (8.00) produced maximum number of suckers which was on par with genotype $KG_9$ (7.73) and number of sucker was minimum for the genotype $KG_{18}$ (4.56) and it was on par with genotypes such as $KG_{14}$ (4.63), $KG_{15}$ (4.86) and $KG_{21}$ (4.86) (Table 11).There existed interaction between genotypes like $KG_3$, $KG_4$ and $KG_7$ with two conditions with respect to this characters. The crop produced more number of suckers under open condition than under partially shaded condition as revealed in Table 11.

**4.1.12. Variability in flowering characters:**

The various aspects of flowering such as number of days to flowering spread of flowering and numbers of flowers per inflorescence were studied and the observations after statistical analysis are presented in Table 12.

**4.1.12.1. Number of days to flowering:**

The genotypes showed significant difference between open and partially shaded condition. Under open condition, the genotype $KG_{22}$ (38.53) showed maximum number of days to flowering which was on par with all other genotypes except genotype $KG_{18}$ (35.40) which recorded earlier flowering. Under partially shaded condition, the genotype $KG_4$ (44.00) recorded lowest number of days to flowering which was on par with $KG_5$ (44.06), $KG_6$ (44.40), $KG_8$ (45.20), $KG_9$

**Table.12. Flowering characters of kacholam:**

| Genotype | No: of days to flowering | | | Spread of flowering | | | No: of flowers /inflorescence | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Open** | **Shade** | **Pooled** | **Open** | **Shade** | **Pooled** | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 36.53 | 48.06 | 39.79 | 49.40 | 41.06 | 45.23 | 7.33 | 5.73 | 5.53 |
| $KG_2$ | 36.60 | 48.93 | 40.26 | 49.60 | 41.66 | 45.63 | 6.88 | 6.13 | 5.50 |
| $KG_3$ | 36.33 | 48.32 | 39.82 | 53.46 | 41.90 | 46.18 | 8.93 | 5.53 | 5.23 |
| $KG_4$ | 35.73 | 44.00 | 39.86 | 54.26 | 42.26 | 48.26 | 6.20 | 6.33 | 5.76 |
| $KG_5$ | 36.53 | 44.06 | 40.29 | 53.40 | 42.13 | 46.26 | 8.60 | 5.93 | 6.26 |
| $KG_6$ | 35.53 | 44.40 | 39.96 | 48.93 | 42.86 | 45.53 | 8.06 | 5.66 | 5.86 |
| $KG_7$ | 36.13 | 46.86 | 40.49 | 48.33 | 42.66 | 45.49 | 6.70 | 5.40 | 5.55 |
| $KG_8$ | 35.86 | 45.26 | 40.56 | 49.06 | 42.06 | 46.50 | 6.60 | 5.26 | 5.93 |
| $KG_9$ | 36.73 | 45.20 | 40.96 | 53.80 | 43.00 | 46.90 | 5.60 | 6.60 | 6.10 |
| $KG_{10}$ | 37.13 | 46.53 | 40.89 | 52.86 | 43.26 | 48.03 | 8.20 | 6.80 | 6.50 |
| $KG_{11}$ | 37.46 | 48.73 | 40.59 | 49.86 | 42.00 | 46.13 | 8.06 | 6.26 | 6.16 |
| $KG_{12}$ | 37.80 | 46.93 | 41.36 | 49.20 | 42.80 | 46.00 | 6.33 | 5.46 | 5.89 |
| $KG_{13}$ | 36.66 | 46.73 | 41.69 | 49.80 | 43.13 | 46.46 | 7.93 | 5.80 | 5.86 |
| $KG_{14}$ | 38.33 | 46.73 | 42.59 | 49.60 | 42.53 | 46.06 | 6.53 | 5.93 | 6.23 |
| $KG_{15}$ | 36.60 | 47.60 | 41.10 | 54.86 | 42.70 | 47.28 | 7.46 | 5.93 | 6.19 |
| $KG_{16}$ | 36.46 | 45.86 | 41.16 | 53.06 | 42.71 | 47.50 | 8.86 | 5.66 | 6.26 |
| $KG_{17}$ | 36.46 | 48.06 | 41.26 | 58.26 | 50.53 | 47.89 | 8.93 | 5.66 | 6.29 |
| $KG_{18}$ | 35.40 | 48.73 | 41.06 | 54.73 | 43.20 | 47.46 | 8.53 | 5.86 | 6.19 |
| $KG_{19}$ | 37.40 | 47.66 | 41.59 | 53.80 | 42.73 | 46.76 | 6.26 | 5.26 | 5.78 |
| $KG_{20}$ | 37.60 | 47.27 | 41.23 | 54.73 | 42.73 | 47.23 | 7.73 | 5.66 | 5.69 |
| $KG_{21}$ | 37.80 | 46.80 | 41.90 | 52.86 | 43.30 | 48.08 | 7.26 | 5.66 | 5.46 |
| $KG_{22}$ | 38.53 | 48.07 | 40.29 | 54.46 | 42.20 | 48.09 | 6.33 | 5.93 | 5.63 |
| | | | | | | | | | |
| Mean | 36.80 | 46.85 | 40.85 | 52.19 | 42.88 | 46.77 | 7.42 | 5.83 | 5.90 |
| SE of mean | 0.60 | 0.54 | 0.57 | 0.80 | 0.44 | 0.64 | 0.35 | 1.21 | 0.36 |
| CD (5%) Between genotypes | 3.130 | 2.588 | 2.859 | 0.583 | 1.684 | 1.35 | 1.12 | 1.254 | 1.187 |
| CD (5%) Open x Shade | 0.34 | | | 0.38 | | | NS | | |
| CD (5%) Genotype x Condition | 1.31 | | | 1.67 | | | NS | | |

(45.20), and $KG_{16}$ (45.86). Days for flowering was maximum for the genotype $KG_2$ (48.93) and it was on par with all the genotypes except the following genotypes $KG_4$ (44.00), $KG_5$ (44.06), $KG_6$ (44.40), $KG_8$ (45.20), $KG_9$ (45.20), and $KG_{16}$ (45.86). In pooled analysis the genotype $KG_{14}$ (42.59) recorded delayed flowering which was on par with all other genotypes where as the minimum number of days to flowering was recorded by the genotype $KG_1$ (39.79). Between open and partially shaded condition a significant interaction could be observed in the performance of all the genotypes.

**4.1.12.2. Spread of Flowering:**

The two situations under which the crop was raised differed significantly. Under open condition, the genotype $KG_{17}$ (58.26) recorded maximum spread of flowering which differed significantly from other genotypes. The genotype $KG_7$ (48.33) recorded minimum spread of flowering also differed significantly from all other genotypes except genotype $KG_6$ (48.93). Under partially shaded condition, the genotype $KG_{17}$ (50.53) recorded maximum spread of flowering differed significantly from all other genotypes. Minimum spread of flowering was recorded by the genotype $KG_1$ (41.06) which differed significantly from genotypes viz., $KG_6$ (42.86), $KG_9$ (43.00), $KG_{10}$ (43.26), $KG_{12}$ (42.80), $KG_{13}$ (43.13), $KG_{17}$ (50.53), $KG_{18}$ (43.20) and $KG_{21}$ (43.30). In pooled analysis spread of flowering was maximum for the genotype $KG_4$ (48.20) which was on par with the following genotypes namely $KG_9$ (46.90), $KG_{10}$ (48.03), $KG_{15}$ (47.28), $KG_{16}$ (47.50), $KG_{17}$ (47.89), $KG_{18}$ (47.46) and $KG_{20}$ (47.23) and the genotype $KG_1$ (45.23) recorded minimum spread of flowering which differed significantly from all other genotypes. The character spread of flowering showed a significant interaction in its expression with the genotypes, the two situations in which the crop raised and also with the genotypes and the situations.

**4.1.12.3. Number of flowers per inflorescence:**

There was no significant difference between open and partially shaded conditions and there existed no interaction between genotypes and conditions. But

**Variability in mother rhizome character**

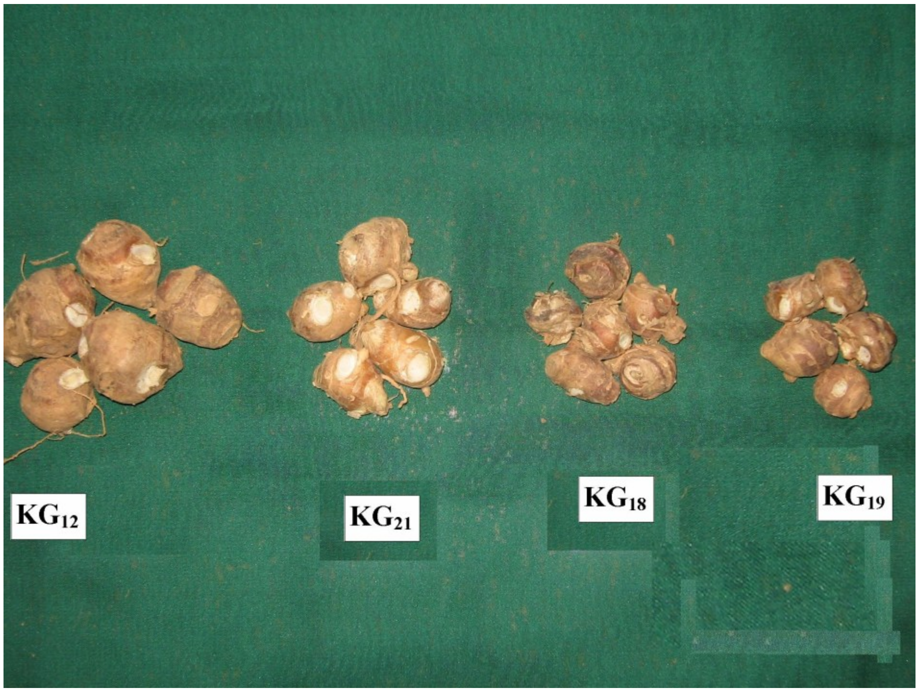



**Plate.10. Girth of mother rhizome**

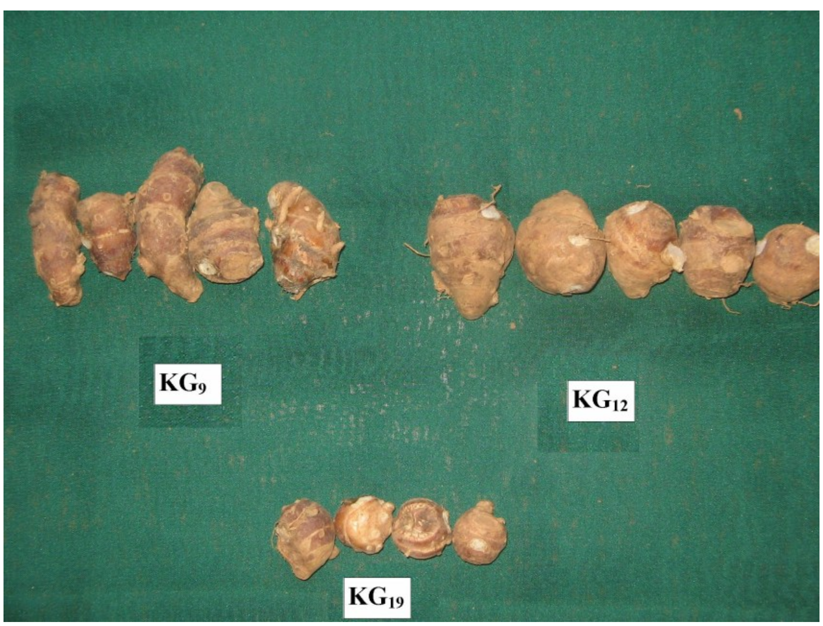



**Plate.11. Length of mother rhizome**

in pooled analysis the number of flowers produced was maximum for the $KG_{10}$ (6.50) which was on par with all the genotypes and the number of flowers produced was minimum for the genotype $KG_3$ (5.23).

### 4.1.13. Variability in characters of mother rhizome:

The data on the length and girth of mother rhizome of different genotypes were statistically analysed and are given in Table 13.

#### 4.1.13.1. Length of mother rhizome:

There existed significant difference between open and partially shaded condition. Mother rhizome attained maximum length under open condition and the genotypes $KG_9$ and $KG_1$ (3.63cm) found to have the longest mother rhizome which was on par with genotypes $KG_{11}$ (3.60cm) and $KG_{12}$ (3.58cm). Shortest rhizome was recorded by the genotype $KG_{19}$ (2.86cm) which was on par with genotype $KG_{20}$ (2.85cm). Under partially shaded condition, the genotype $KG_{12}$ (3.74cm) had the longest mother rhizome which was on par with the genotype $KG_9$ (3.56cm) and the shortest by the genotype $KG_9$ (2.70cm) which was on par with $KG_{16}$ (2.95cm), $KG_{20}$ (2.95cm) and $KG_{22}$ (2.98cm). Maximum length of mother rhizome was recorded by genotypes $KG_{12}$ (3.66cm) which differed from all other genotypes except the genotypes $KG_1$ (3.57cm) and $KG_9$ (2.98cm) under pooled analysis.

#### 4.1.13.2. Girth of mother rhizome:

From Table 13 it was clear that maximum girth was recorded by the genotype $KG_{12}$ in pooled analysis as well as open and partially shaded conditions and minimum by $KG_{21}$. The genotypes differed significantly over both conditions. Under open condition, the genotype $KG_{12}$ (8.12cm) which was followed by $KG_1$ and $KG_{21}$ ((7.8 and 6.38 cm respectively) recorded maximum girth of rhizome which was followed by the genotypes $KG_{16}$ (6.44cm), $KG_{18}$ (6.60cm) and $KG_{19}$ (6.55cm). Under partially shaded condition the genotype, $KG_{12}$ (8.56cm) differed significantly from all other genotypes and the genotype $KG_{21}$ (6.53cm) recorded

**Table.13. Characters of mother rhizome of kacholam under open and partially shaded conditions:**

| Genotypes | Mother rhizome per plant | | | | | |
|---|---|---|---|---|---|---|
| | Length (cm) | | | Girth (cm) | | |
| | **Open** | **Shade** | **Pooled** | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 3.63 | 3.52 | 3.57 | 7.80 | 7.81 | 7.80 |
| $KG_2$ | 3.34 | 3.21 | 3.27 | 6.92 | 7.18 | 7.05 |
| $KG_3$ | 3.24 | 3.00 | 3.12 | 6.93 | 6.78 | 6.85 |
| $KG_4$ | 3.17 | 3.06 | 3.11 | 7.00 | 6.80 | 6.90 |
| $KG_5$ | 3.05 | 3.02 | 3.04 | 7.18 | 7.12 | 7.15 |
| $KG_6$ | 3.03 | 3.15 | 3.09 | 7.16 | 7.52 | 7.34 |
| $KG_7$ | 3.14 | 3.31 | 3.23 | 7.39 | 7.85 | 7.62 |
| $KG_8$ | 3.06 | 3.01 | 3.04 | 7.25 | 7.14 | 7.20 |
| $KG_9$ | 3.63 | 3.56 | 3.60 | 8.06 | 7.91 | 7.99 |
| $KG_{10}$ | 3.10 | 3.08 | 3.09 | 7.43 | 7.29 | 7.36 |
| $KG_{11}$ | 3.60 | 3.33 | 3.46 | 7.58 | 7.55 | 7.56 |
| $KG_{12}$ | 3.58 | 3.74 | 3.66 | 8.12 | 8.56 | 8.34 |
| $KG_{13}$ | 3.13 | 2.91 | 3.02 | 7.23 | 7.37 | 7.30 |
| $KG_{14}$ | 3.14 | 2.75 | 2.94 | 7.15 | 7.03 | 7.09 |
| $KG_{15}$ | 3.22 | 2.70 | 2.96 | 7.10 | 7.56 | 7.33 |
| $KG_{16}$ | 3.14 | 2.95 | 3.04 | 6.44 | 7.58 | 7.01 |
| $KG_{17}$ | 2.98 | 3.01 | 3.00 | 6.89 | 7.42 | 7.15 |
| $KG_{18}$ | 3.01 | 3.12 | 3.06 | 6.60 | 6.80 | 6.70 |
| $KG_{19}$ | 2.80 | 3.16 | 2.98 | 6.55 | 6.72 | 6.64 |
| $KG_{20}$ | 2.85 | 2.95 | 2.90 | 7.06 | 7.16 | 7.11 |
| $KG_{21}$ | 3.05 | 3.02 | 3.04 | 6.38 | 6.53 | 6.46 |
| $KG_{22}$ | 3.33 | 2.98 | 3.15 | 6.91 | 7.40 | 7.15 |
| | | | | | | |
| Mean | 3.19 | 3.11 | 3.15 | 7.14 | 7.32 | 7.23 |
| SE of mean | 0.01 | 0.01 | 0.01 | 0.05 | 0.04 | 0.50 |
| CD (5%) Between genotypes | 0.18 | 0.20 | 0.14 | 0.39 | 0.33 | 0.25 |
| CD (5%) Open x Shade | 0.04 | | | 0.07 | | |
| CD (5%) Genotype x Condition | 0.19 | | | 0.36 | | |

minimum value which was followed by genotypes $KG_{16}$ (6.44cm), $KG_{18}$ (6.60cm) and $KG_{19}$ (6.72cm). In pooled analysis $KG_{12}$ (8.34cm) was significantly different from all other genotypes and $KG_{21}$ (6.46cm) which recorded minimum was on par with the genotypes $KG_{18}$ (6.70cm) and $KG_{19}$ (6.64cm). There existed significant interaction between performance of genotypes and conditions and maximum girth of mother rhizome was recorded under partially shaded condition than under open condition.

**4.1.14. Variability in secondary rhizome character:**

The various characters of secondary rhizomes were statistically analysed and are presented in Table 14.

**4.1.14.1. Number of secondary rhizomes:**

The genotypes differed significantly under open and partially shaded condition. Genotype $KG_{12}$ performed well under open as well as partially shaded condition. Under open condition, the genotype $KG_{12}$ (13.86) significantly differed from other genotypes and $KG_{6}$ (8.86) which produced least number of rhizomes was on par with genotypes such as $KG_{2}$ (9.33) ,$KG_{4}$ (8.93), $KG_{13}$(10), $KG_{14}$ (9.53) $KG_{17}$ (9.53), $KG_{18}$ (10.06, )$KG_{19}$ (9.86) and $KG_{21}$ (9.00).Under partially shaded condition, also $KG_{12}$ (14.23) differed significantly from other genotypes with highest number of rhizome where as genotype $KG_{21}$ which produced least number of secondary rhizome of 8.73 was on par with genotypes $KG_{2}$ (9.73) and $KG_{17}$ (9.66). The number of secondary rhizomes was maximum in the genotype $KG_{12}$ (14.23) which differed significantly from other genotypes where as the minimum was recorded by the genotype $KG_{21}$ (8.86) which was on par with genotypes $KG_{2}$ (9.53)**,** $KG_{16}$ (9.5) and $KG_{17}$ (9.60). The genotype grown under partially shaded condition in coconut gardens produced maximum number of secondary rhizomes. There existed significant interaction between the performance of different genotypes like $KG_{5}$, $KG_{6}$, $KG_{9}$, $KG_{15}$ and $KG_{16}$ with the two conditions.

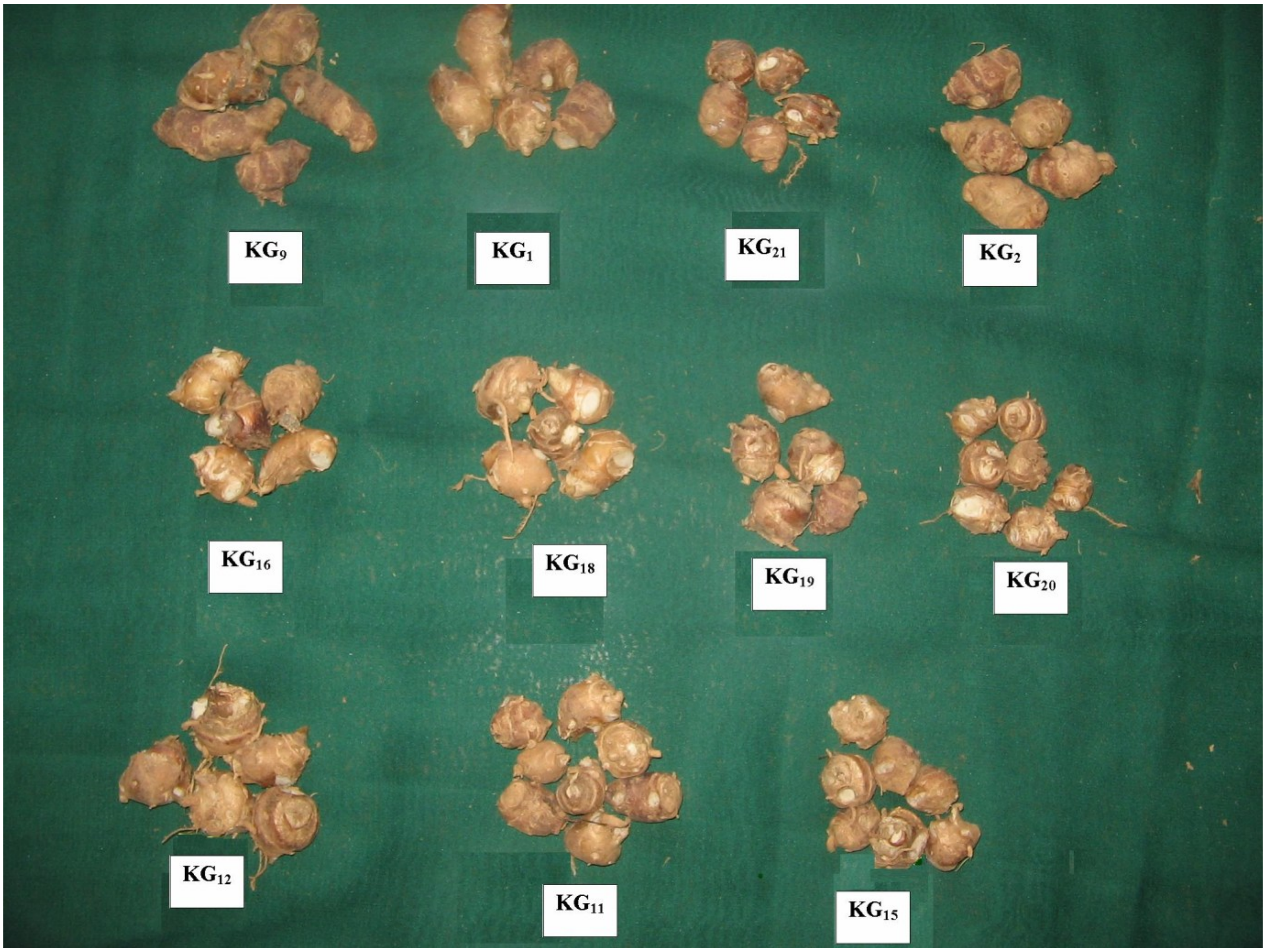



**Plate.12. Variability in mother rhizome shape**

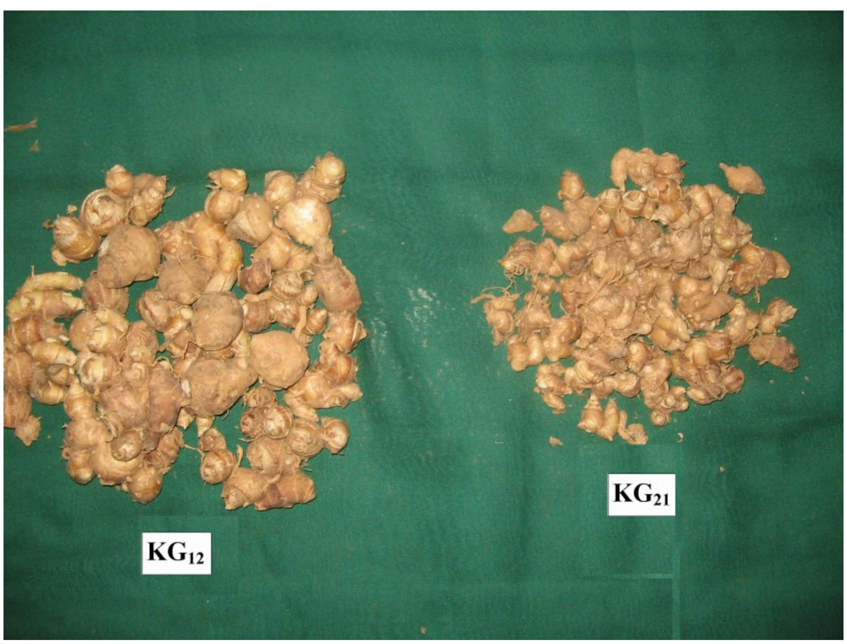



**Plate.13. Variability in girth of secondary rhizomes**

**Table.14. Characters of secondary rhizomes of kacholam under open and partially shaded conditions:**

| Genotypes | Secondary rhizomes per plant | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number | | | Length (cm) | | | Girth (cm) | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 12.20 | 13.66 | 12.93 | 3.39 | 3.54 | 3.46 | 6.10 | 6.24 | 6.17 |
| $KG_2$ | 9.33 | 9.73 | 9.53 | 2.88 | 2.85 | 2.86 | 5.30 | 5.40 | 5.35 |
| $KG_3$ | 11.20 | 11.03 | 11.11 | 2.62 | 2.64 | 2.63 | 5.31 | 5.32 | 5.31 |
| $KG_4$ | 8.93 | 10.60 | 9.76 | 2.78 | 2.64 | 2.71 | 5.57 | 5.24 | 5.40 |
| $KG_5$ | 10.73 | 10.93 | 10.83 | 3.10 | 2.62 | 2.86 | 5.48 | 5.66 | 5.57 |
| $KG_6$ | 8.86 | 10.93 | 9.90 | 3.01 | 2.34 | 2.67 | 5.25 | 5.24 | 5.24 |
| $KG_7$ | 10.93 | 11.73 | 11.33 | 3.40 | 3.34 | 3.37 | 5.51 | 5.30 | 5.41 |
| $KG_8$ | 10.46 | 11.86 | 11.16 | 2.78 | 2.54 | 2.66 | 5.64 | 5.54 | 5.59 |
| $KG_9$ | 11.00 | 13.80 | 12.40 | 3.37 | 3.34 | 3.35 | 6.62 | 6.18 | 6.40 |
| $KG_{10}$ | 11.60 | 11.53 | 11.56 | 3.22 | 3.44 | 3.33 | 5.32 | 5.77 | 5.54 |
| $KG_{11}$ | 10.30 | 10.46 | 10.38 | 3.39 | 3.30 | 3.34 | 5.29 | 5.59 | 5.44 |
| $KG_{12}$ | 13.86 | 14.60 | 14.23 | 3.84 | 4.07 | 3.96 | 6.58 | 6.37 | 6.48 |
| $KG_{13}$ | 10.00 | 11.60 | 10.80 | 2.76 | 2.68 | 2.72 | 5.39 | 5.99 | 5.69 |
| $KG_{14}$ | 9.53 | 10.13 | 9.83 | 2.86 | 2.62 | 2.74 | 5.45 | 5.66 | 5.56 |
| $KG_{15}$ | 11.40 | 8.80 | 10.10 | 2.65 | 2.68 | 2.66 | 5.52 | 5.64 | 5.58 |
| $KG_{16}$ | 10.20 | 8.80 | 9.50 | 2.62 | 2.34 | 2.48 | 5.38 | 5.70 | 5.54 |
| $KG_{17}$ | 9.53 | 9.66 | 9.60 | 2.49 | 2.62 | 2.55 | 5.70 | 5.75 | 5.72 |
| $KG_{18}$ | 10.06 | 11.20 | 10.63 | 3.23 | 2.39 | 2.81 | 5.78 | 5.93 | 5.86 |
| $KG_{19}$ | 9.86 | 10.53 | 10.20 | 2.63 | 2.43 | 2.53 | 5.32 | 5.32 | 5.32 |
| $KG_{20}$ | 11.93 | 11.46 | 11.70 | 2.54 | 2.50 | 2.52 | 5.74 | 5.00 | 5.37 |
| $KG_{21}$ | 9.00 | 8.73 | 8.86 | 2.33 | 2.26 | 2.29 | 5.14 | 5.24 | 5.19 |
| $KG_{22}$ | 10.60 | 11.20 | 10.90 | 3.20 | 2.61 | 2.90 | 6.08 | 6.50 | 6.29 |
| | | | | | | | | | |
| Mean | 10.52 | 11.04 | 10.78 | 2.96 | 2.81 | 2.88 | 5.61 | 5.66 | 5.64 |
| SE of mean | 0.65 | 0.422 | 0.54 | 0.02 | 0.01 | 0.01 | 0.011 | 0.1 | 0.05 |
| CD (5%) Between genotypes | 1.33 | 1.07 | 0.84 | 0.25 | 0.16 | 0.14 | 0.17 | 0.52 | 0.27 |
| CD (5%) Open x Shade | 0.25 | | | 0.13 | | | NS | | |
| CD (5%) Genotype x Condition | 1.19 | | | 0.21 | | | NS | | |

**4.1.14.2. Length of secondary rhizomes:**

There existed difference in performance of genotypes under open and partially shaded condition and length was maximum under open condition. Under open condition, the genotype $KG_{12}$ (3.84cm) which recorded maximum length differed significantly from other genotypes and genotype $KG_{21}$ (2.33cm) which recorded minimum was on par with genotypes $KG_{20}$ and $KG_{17}$ with lengths 2.54 and 2.49 cm respectively. Under partial shade, genotype $KG_{12}$ (4.07cm) differed significantly from other genotypes. The length was minimum for the genotype $KG_{21}$ (2.26cm) which was on par with the genotypes $KG_{18}$ (2.39cm), $KG_{16}$ (2.34cm) and $KG_{6}$ (2.34cm). The maximum length for secondary rhizome was recorded by genotype $KG_{12}$ in pooled analysis and minimum by the genotype $KG_{21}$ (Table 14). In pooled analysis the genotypes $KG_{12}$ (3.96cm) and $KG_{21}$ (2.29cm) differed significantly from other genotypes. A significant interaction was exhibited between the two conditions and performance of the genotypes.

**4.1.14.3. Girth of secondary rhizomes:**

There was no significant difference in performance of genotypes under open and partially shaded condition regarding the girth of mother rhizome. There was no interaction between genotypes and condition. Table 14 reveals that maximum girth was recorded by the genotype $KG_{12}$ (6.48cm) on pooled analysis and it was on par with genotypes $KG_{9}$ (6.40cm) and $KG_{22}$ (6.29cm). Minimum girth was reported by genotype $KG_{21}$ (5.19cm) which was on par with genotypes such as $KG_{2}$ (5.35cm), $KG_{3}$ (5.31cm), $KG_{4}$ (5.40cm), $KG_{6}$ (5.24cm), $KG_{7}$ (5.41cm), $KG_{9}$ (6.40cm), $KG_{11}$ (5.44cm), $KG_{19}$ (5.32cm) and $KG_{20}$ (5.37cm) in pooled analysis. From the result it was seen that shade had no effect on the size of rhizomes.

**4.1.15. Variability in yield characters:**

The different yield characters were statistically analysed and results are given in Table 15.

**Table.15. Yield characters of kacholam**:

| Genotypes | Yield characters | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fresh yield per plant (g) | | | Dry yield per plant (g) | | | Driage (%) | | | Harvest index | | |
| | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled | Open | Shade | Pooled |
| $KG_1$ | 82.66 | 78.40 | 80.53 | 31.06 | 33.53 | 32.30 | 37.58 | 42.79 | 40.19 | 0.57 | 0.61 | 0.59 |
| $KG_2$ | 52.33 | 49.20 | 50.76 | 20.60 | 22.46 | 21.53 | 39.37 | 45.68 | 42.52 | 0.46 | 0.50 | 0.48 |
| $KG_3$ | 50.93 | 48.80 | 49.86 | 22.93 | 21.73 | 22.33 | 45.05 | 44.56 | 44.80 | 0.57 | 0.51 | 0.54 |
| $KG_4$ | 51.46 | 46.40 | 48.93 | 22.20 | 23.66 | 22.93 | 43.18 | 51.00 | 47.09 | 0.57 | 0.62 | 0.6 |
| $KG_5$ | 47.20 | 47.06 | 47.13 | 23.26 | 22.86 | 23.06 | 49.30 | 48.589 | 48.94 | 0.57 | 0.60 | 0.58 |
| $KG_6$ | 46.26 | 45.93 | 46.10 | 22.66 | 28.13 | 25.40 | 48.99 | 61.25 | 55.12 | 0.59 | 0.59 | 0.59 |
| $KG_7$ | 67.13 | 66.26 | 66.70 | 29.53 | 25.06 | 27.30 | 43.99 | 37.83 | 40.91 | 0.56 | 0.57 | 0.57 |
| $KG_8$ | 65.73 | 62.86 | 64.30 | 29.66 | 22.36 | 26.01 | 45.13 | 35.58 | 40.36 | 0.61 | 0.51 | 0.56 |
| $KG_9$ | 75.73 | 75.20 | 75.46 | 31.80 | 31.26 | 31.53 | 41.98 | 41.58 | 41.78 | 0.57 | 0.60 | 0.59 |
| $KG_{10}$ | 65.33 | 64.13 | 64.73 | 32.53 | 30.46 | 31.50 | 49.79 | 47.51 | 48.65 | 0.60 | 0.57 | 0.59 |
| $KG_{11}$ | 76.40 | 71.06 | 73.73 | 33.06 | 29.46 | 31.26 | 43.28 | 41.46 | 42.37 | 0.61 | 0.58 | 0.59 |
| $KG_{12}$ | 81.40 | 75.66 | 78.53 | 36.53 | 30.93 | 33.73 | 44.89 | 40.90 | 42.90 | 0.59 | 0.57 | 0.58 |
| $KG_{13}$ | 54.80 | 53.46 | 54.13 | 25.33 | 25.20 | 25.26 | 46.26 | 47.12 | 46.69 | 0.51 | 0.63 | 0.57 |
| $KG_{14}$ | 45.66 | 43.33 | 44.50 | 21.80 | 24.53 | 23.16 | 47.76 | 56.61 | 52.18 | 0.53 | 0.51 | 0.52 |
| $KG_{15}$ | 45.46 | 44.20 | 44.83 | 21.60 | 21.66 | 21.63 | 47.51 | 49.02 | 48.26 | 0.53 | 0.54 | 0.53 |
| $KG_{16}$ | 43.13 | 41.13 | 42.13 | 18.73 | 22.13 | 20.43 | 43.43 | 53.81 | 48.62 | 0.51 | 0.57 | 0.54 |
| $KG_{17}$ | 52.40 | 49.93 | 51.16 | 22.66 | 22.73 | 22.70 | 43.26 | 45.53 | 44.40 | 0.55 | 0.56 | 0.56 |
| $KG_{18}$ | 43.53 | 41.60 | 42.56 | 21.00 | 22.46 | 21.73 | 48.23 | 54.02 | 51.13 | 0.57 | 0.62 | 0.6 |
| $KG_{19}$ | 43.00 | 40.86 | 41.93 | 20.80 | 20.13 | 20.46 | 48.38 | 49.28 | 48.83 | 0.60 | 0.55 | 0.57 |
| $KG_{20}$ | 42.26 | 42.53 | 42.40 | 22.80 | 20.40 | 21.60 | 53.94 | 47.96 | 50.95 | 0.56 | 0.57 | 0.57 |
| $KG_{21}$ | 42.40 | 41.60 | 42.00 | 22.20 | 19.13 | 20.66 | 52.36 | 46.00 | 49.18 | 0.51 | 0.49 | 0.50 |
| $KG_{22}$ | 54.93 | 55.93 | 55.43 | 23.30 | 26.80 | 25.05 | 42.42 | 47.97 | 45.22 | 0.51 | 0.56 | 0.53 |
| | | | | | | | | | | | | |
| Mean | 55.91 | 53.89 | 54.90 | 25.27 | 24.87 | 25.07 | 45.73 | 47.09 | 46.41 | 0.56 | 0.57 | 0.56 |
| SE of mean | 0.45 | 0.73 | 0.66 | 0.52 | 0.43 | 0.48 | 0.93 | 0.65 | 0.96 | 0.01 | 0.18 | 0.1 |
| CD (5%) Between genotypes | 1.30 | 2.10 | 1.32 | 1.50 | 1.24 | 0.96 | 2.67 | 2.72 | 1.92 | 0.02 | 0.03 | 0.21 |
| CD (5%) Open x Shade | 0.39 | | | 0.29 | | | 0.58 | | | 0.06 | | |
| CD (5%) Genotype x Condition | 1.87 | | | 0.93 | | | 2.72 | | | 0.30 | | |

**4.1.15.1. Fresh yield:**

A significant difference in fresh yield was observed between open and partially shaded condition. Under open condition, the genotype $KG_1$ (82.66g) reported maximum fresh yield per plant was on par with the genotype $KG_{12}$ (81.40g). From this fresh yield per plot and per hectare was worked out (Table.16.) and it was found that the genotype $KG_1$ produced maximum fresh yield per plot and per hectare (2.06 and 13.77 kg respectively). The genotype $KG_{20}$ (42.26g) which recorded minimum fresh yield differed significantly from other genotypes except the genotypes $KG_{16}$ (43.13g), $KG_{18}$ (43.53g), $KG_{19}$ (43.00g) and $KG_{21}$ (42.40g). Under partial shade, maximum fresh yield was observed in genotype $KG_1$ (78.40g) and it differed significantly from other genotypes. Rhizome yield per plot and per hectare under shaded condition was also worked out and presented in Table 17. The minimum yield was observed by the genotype $KG_{19}$ (40.86g) which was on par with the genotypes $KG_{16}$ (41.13g), $KG_{18}$ (41.6g), $KG_{20}$ (42.53g) and $KG_{21}$ (41.60g). The pooled analysis showed that the genotype $KG_1$ (80.53g) differed significantly from other genotypes with respect to fresh yield of rhizomes per plant (Table 15). The minimum yield was reported by the genotype $KG_{19}$ (41.93g) which differed significantly from other genotypes except genotypes $KG_{16}$ (42.13g), $KG_{18}$ (42.56g), $KG_{20}$ (42.40g) and $KG_{21}$ (42.00g) .A significant interaction between the two conditions namely open and partial shade and the performance of the genotypes such as $KG_1$, $KG_2$, $KG_3$, $KG_8$, $KG_{11}$, $KG_{12}$, $KG_{14}$, $KG_{17}$ and $KG_{19}$ was observed (Fig1).

**4.1.15.2. Dry yield:**

Under full sunlight, the genotype $KG_{12}$ (36.53g) recorded maximum dry yield per plant which differed significantly from other genotypes. On calculating per plot and per hectare dry yield from this, the dry yield per plot and per hectare (Table 16) was maximum for the genotype $KG_{12}$ (0.91 and 6.08 kg respectively). The genotype $KG_2$ (20.60g) recorded minimum dry yield which was on par with the genotypes $KG_{14}$ (21.80g), $KG_{15}$ (21.60g), $KG_{18}$ (21.00g) and $KG_{19}$ (20.80g). Under partial shade, maximum dry yield was reported by the genotype $KG_1$

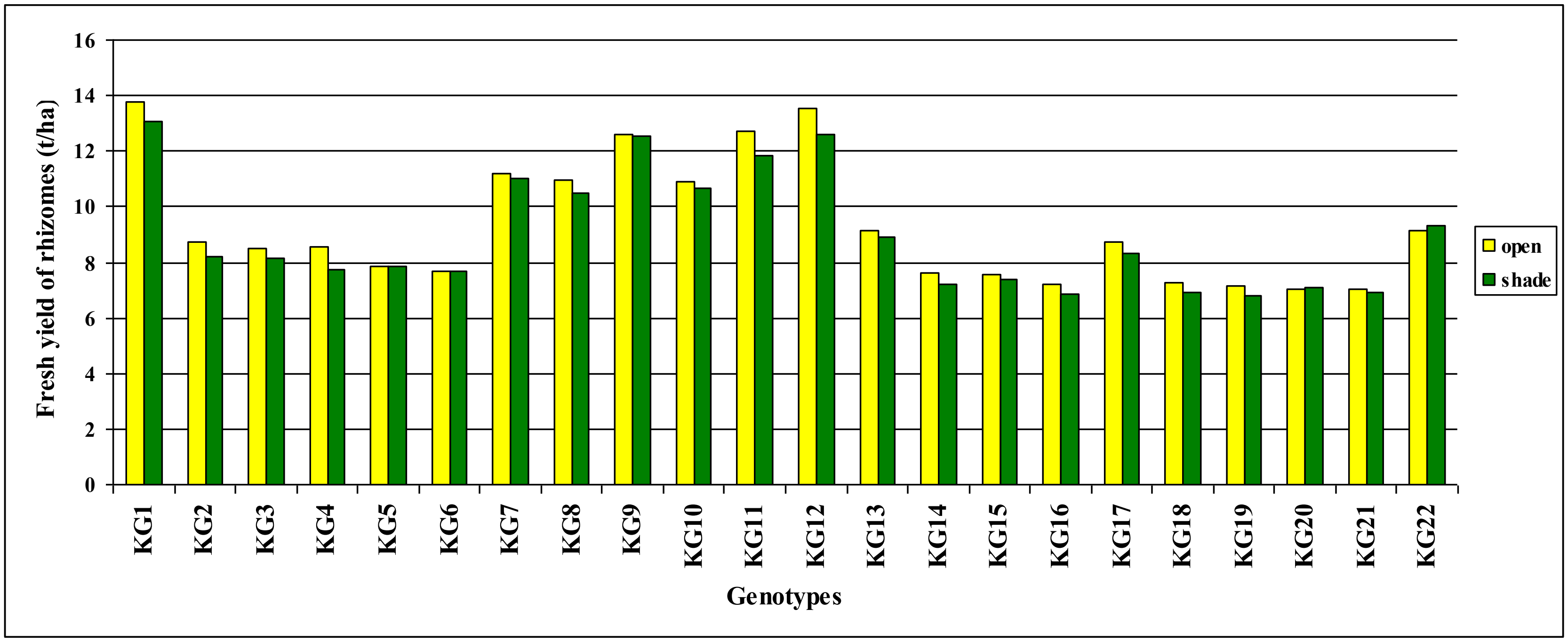
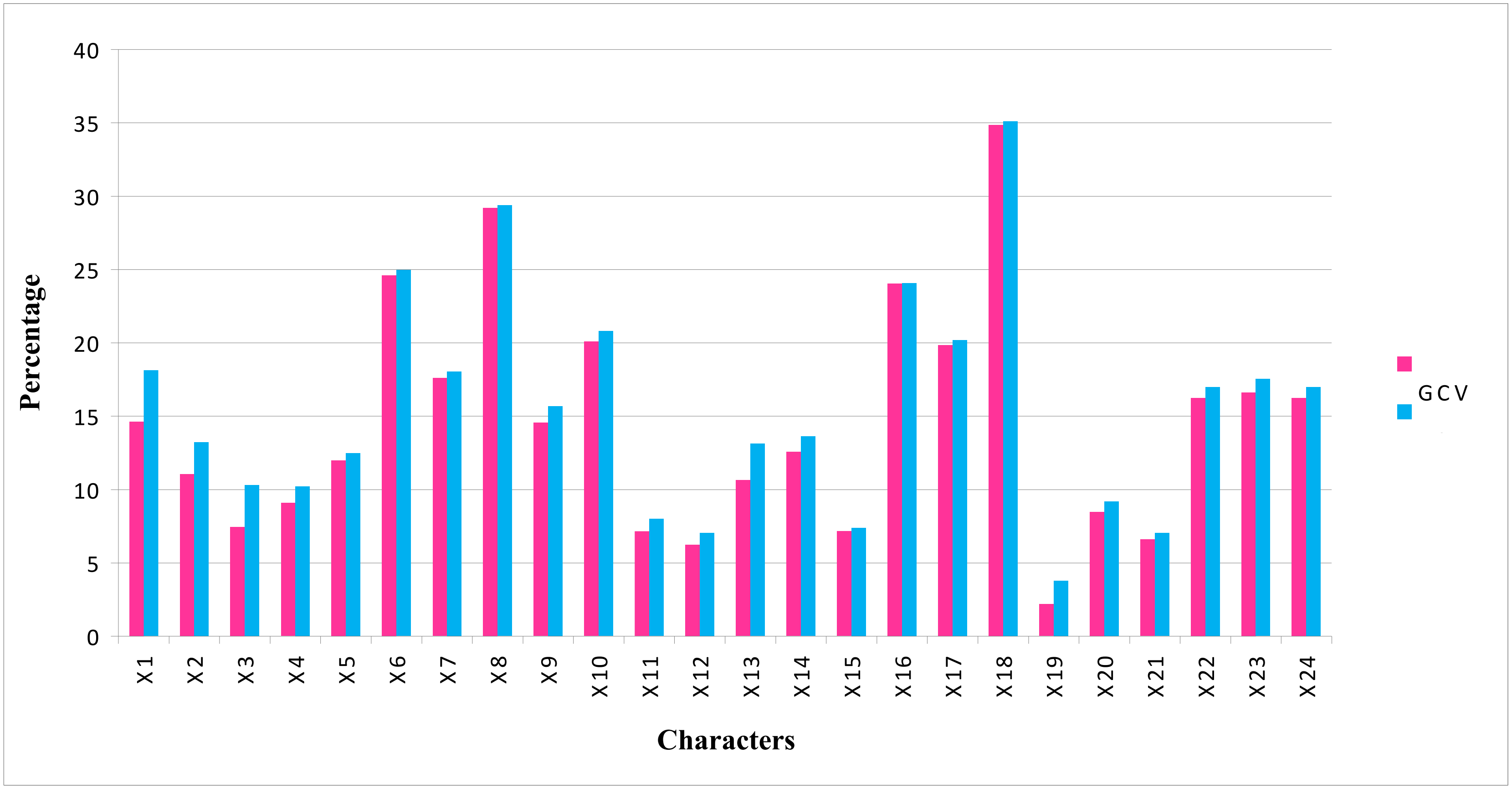



**Fig.1. Dry yield of rhizome under open and partially shaded condition**

**Table.16.Per plot and per hectare fresh and dry yield of rhizome under open condition:**

| Genotypes | Fresh rhizome yield per plot(kg) | Fresh rhizome yield per hectare (t) | Dry rhizome yield per plot(kg) | Dry rhizome yield per hectare (t) |
|---|---|---|---|---|
| $KG_1$ | 2.06 | 13.77 | 0.77 | 5.17 |
| $KG_2$ | 1.30 | 8.718 | 0.51 | 3.43 |
| $KG_3$ | 1.27 | 8.48 | 0.57 | 3.82 |
| $KG_4$ | 1.28 | 8.57 | 0.55 | 3.69 |
| $KG_5$ | 1.18 | 7.86 | 0.58 | 3.87 |
| $KG_6$ | 1.15 | 7.70 | 0.56 | 3.77 |
| $KG_7$ | 1.67 | 11.18 | 0.73 | 4.92 |
| $KG_8$ | 1.64 | 10.95 | 0.74 | 4.94 |
| $KG_9$ | 1.89 | 12.61 | 0.79 | 5.29 |
| $KG_{10}$ | 1.63 | 10.88 | 0.81 | 5.42 |
| $KG_{11}$ | 1.91 | 12.72 | 0.82 | 5.50 |
| $KG_{12}$ | 2.03 | 13.56 | 0.91 | 6.08 |
| $KG_{13}$ | 1.37 | 9.12 | 0.63 | 4.22 |
| $KG_{14}$ | 1.14 | 7.60 | 0.54 | 3.63 |
| $KG_{15}$ | 1.13 | 7.57 | 0.54 | 3.59 |
| $KG_{16}$ | 1.07 | 7.18 | 0.46 | 3.12 |
| $KG_{17}$ | 1.31 | 8.72 | 0.56 | 3.77 |
| $KG_{18}$ | 1.08 | 7.25 | 0.52 | 3.49 |
| $KG_{19}$ | 1.07 | 7.16 | 0.52 | 3.46 |
| $KG_{20}$ | 1.05 | 7.04 | 0.57 | 3.79 |
| $KG_{21}$ | 1.06 | 7.06 | 0.55 | 3.69 |
| $KG_{22}$ | 1.373 | 9.15 | 0.58 | 3.88 |

**Fig.3. Phenotypic and genotypic coefficient of variation for different characters under partially shaded condition**




| | | | | |
|---|---|---|---|---|
| X1- No: of days for sprouting | X6- Fresh weight of leaves per plant, | X11- Length of mother rhizome per plant | X16- Fresh yield of rhizomes/plant | X21- HI |
| X2- No: of leaves per plant, | X7- Fresh weight of roots per plant | X12- Girth of mother rhizome per plant | X17- Dry yield of rhizome/ plant | X22- Leaf Area |
| X3 -Leaf length, | X8-Dry weight of roots per plant | X13- Number secondary rhizomes per plant | X18- Volatile oil | X23- Leaf Area Ratio |
| X4- Leaf breadth | X9-Dry weight of leaves per plant, | X14- Length of secondary rhizomes per plant | X19- Oleoresin | X24- Leaf area index |
| X5-Plant spread | X10-No: of suckers per plant | X15- Girth of secondary rhizome per plant | X20- Driage | |

(33.53g) which differed significantly from other genotypes. The minimum yield was recorded by the genotype $KG_{21}$ (19.13g) which differed significantly from other genotypes except genotype $KG_{19}$ (20.13g). Table 15 revealed that in pooled analysis maximum dry yield of rhizomes was recorded by the genotype $KG_{12}$ (33.73g) which was on par with the genotype $KG_{1}$ (32.30g) where as the minimum dry yield recorded by genotype $KG_{16}$ (20.43g) was on par with genotype $KG_{19}$ (20.46g) (Fig.2). The performance of genotypes and the two conditions had significant interaction between them

Even though the crop gave maximum fresh yield and dry yield under open condition it was comparable with yield under partial shade. In other words, when rhizome yield is taken as the economic yield the crop is suited to grow as a pure crop under full sunlight conditions as well as an intercrop in coconut plantations as well.

**4.1.16. Driage:**

The genotypes differed significantly between open and partially shaded condition and the crop recorded maximum drying per cent under partially shaded condition. Under open condition, the genotype $KG_{20}$ (53.94) recorded maximum drying per cent which was on par with genotype $KG_{21}$ (52.36). The genotype $KG_{3}$ (37.58) recorded minimum drying per cent which was on par with genotypes $KG_{2}$ (39.37). Under partially shaded condition, the genotype $KG_{6}$ (61.25) recorded maximum drying per cent which differed significantly from other genotypes. The genotype $KG_{8}$ (35.58) recorded minimum drying per cent which differed significantly from all other genotypes except genotype $KG_{7}$ (37.83). The pooled analysis showed that maximum drying per cent was recorded by the genotype $KG_{6}$ (55.12) which differed significantly from all other genotypes and minimum drying per cent was observed in genotype $KG_{1}$ (40.19) which was on par with genotypes such as $KG_{7}$ (40.91), $KG_{8}$ (40.36) and $KG_{9}$ (41.78). The percentage of drying of rhizomes had a profound influence on shade and a significant interaction was observed with the performance of genotypes and the two conditions.

**Fig.2. Dry yield of rhizome under open and partially shaded condition.**

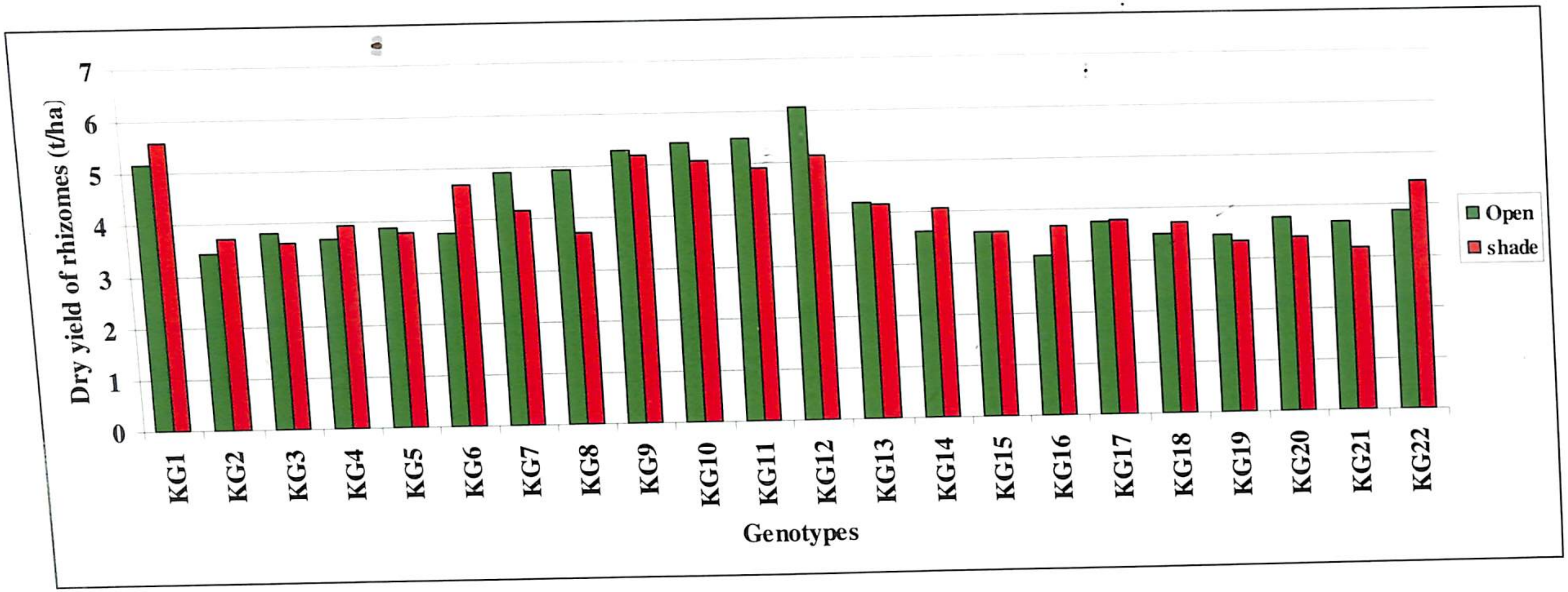


**Table.17. Per plot and per hectare yield of fresh and dry yield of rhizome under shaded condition:**

| Genotypes | Fresh rhizome yield per plot(kg) | Fresh rhizome yield per hectare (t) | Dry rhizome yield per plot(kg) | Dry rhizome yield per hectare (t) |
|---|---|---|---|---|
| $KG_1$ | 1.96 | 13.06 | 0.83 | 5.58 |
| $KG_2$ | 1.23 | 8.19 | 0.56 | 3.74 |
| $KG_3$ | 1.22 | 8.13 | 0.54 | 3.62 |
| $KG_4$ | 1.16 | 7.73 | 0.59 | 3.94 |
| $KG_5$ | 1.17 | 7.84 | 0.57 | 3.80 |
| $KG_6$ | 1.14 | 7.65 | 0.70 | 4.68 |
| $KG_7$ | 1.65 | 11.04 | 0.62 | 4.17 |
| $KG_8$ | 1.57 | 10.47 | 0.55 | 3.72 |
| $KG_9$ | 1.88 | 12.52 | 0.78 | 5.20 |
| $KG_{10}$ | 1.60 | 10.68 | 0.76 | 5.07 |
| $KG_{11}$ | 1.77 | 11.83 | 0.73 | 4.90 |
| $KG_{12}$ | 1.89 | 12.60 | 0.77 | 5.15 |
| $KG_{13}$ | 1.33 | 8.90 | 0.63 | 4.19 |
| $KG_{14}$ | 1.08 | 7.21 | 0.61 | 4.08 |
| $KG_{15}$ | 1.10 | 7.36 | 0.54 | 3.60 |
| $KG_{16}$ | 1.02 | 6.85 | 0.55 | 3.68 |
| $KG_{17}$ | 1.24 | 8.31 | 0.56 | 3.78 |
| $KG_{18}$ | 1.04 | 6.93 | 0.56 | 3.74 |
| $KG_{19}$ | 1.02 | 6.80 | 0.50 | 3.35 |
| $KG_{20}$ | 1.06 | 7.08 | 0.51 | 3.39 |
| $KG_{21}$ | 1.04 | 6.93 | 0.47 | 3.18 |
| $KG_{22}$ | 1.39 | 9.31 | 0.67 | 4.46 |

### 4.1.17. Harvest index:

There was no significant difference between the performance of the genotypes under open and partially shaded condition and also between the performance of the two genotypes and conditions with respect to harvest index. But in pooled analysis the genotypes varied in their performance. The genotype $KG_4$ (0.6) and $KG_{18}$ (0.6) recorded maximum harvest index when data was pooled over the situations (Table .15) which were on par with all the genotypes whereas minimum harvest index was recorded by the genotype $KG_2$ (0.48).

### 4.1.18. Variability in quality parameters:

The data recorded on the yield of oil and oleoresin were statistically analysed and presented in Table 18.

#### 4.1.18.1. Oil:

There existed no significant difference for oil yield of rhizomes under open and partial shade condition and also no significant interaction between genotypes and conditions except for $KG_{10}$ which exhibited a significant interaction with condition. When data was pooled over both conditions the oil extracted from rhizomes was maximum for the genotype $KG_2$ (1.40%) which was on par with the genotype $KG_1$ (1.39%), $KG_{10}$ (1.35%) and $KG_{13}$ (1.33%) where as the minimum oil yield was recorded by the genotype $KG_6$ (0.57%) which was on par with the genotypes such as $KG_3$ (0.67%), $KG_4$ (0.67%), $KG_{15}$ (0.61%), $KG_{18}$ (0.67%) and $KG_{21}$ (0.61%).

#### 4.1.18.2. Oleoresin:

There was no significant difference between open and partially shaded condition and no significant interaction existed between the performance of genotypes and the two conditions except for $KG_{17}$, $KG_{18}$ and $KG_{21}$ which showed interaction with the conditions. The pooled analysis showed maximum oleoresin content for the genotype $KG_{12}$ (4.45%) which was on par with genotypes $KG_1$

**Table.18. Quality parameters of kacholam under open and partially shaded conditions:**

| Genotypes | Oil (%) | | | Oleoresin (%) | | |
|---|---|---|---|---|---|---|
| | **Open** | **Shade** | **pooled** | **Open** | **Shade** | **Pooled** |
| $KG_1$ | 1.39 | 1.38 | 1.39 | 4.26 | 4.33 | 4.30 |
| $KG_2$ | 1.38 | 1.43 | 1.40 | 4.26 | 4.16 | 4.21 |
| $KG_3$ | 0.61 | 0.73 | 0.67 | 4.20 | 4.40 | 4.30 |
| $KG_4$ | 0.65 | 0.70 | 0.67 | 4.23 | 4.20 | 4.21 |
| $KG_5$ | 0.77 | 0.70 | 0.73 | 4.20 | 4.33 | 4.26 |
| $KG_6$ | 0.54 | 0.61 | 0.57 | 4.30 | 4.26 | 4.28 |
| $KG_7$ | 0.74 | 0.71 | 0.72 | 4.16 | 4.26 | 4.21 |
| $KG_8$ | 1.31 | 1.14 | 1.2 | 4.40 | 4.43 | 4.41 |
| $KG_9$ | 0.84 | 0.76 | 0.80 | 4.16 | 4.26 | 4.21 |
| $KG_{10}$ | 1.40 | 1.30 | 1.35 | 4.36 | 4.50 | 4.43 |
| $KG_{11}$ | 1.31 | 1.26 | 1.29 | 4.26 | 4.23 | 4.25 |
| $KG_{12}$ | 1.26 | 1.32 | 1.29 | 4.43 | 4.46 | 4.45 |
| $KG_{13}$ | 1.34 | 1.32 | 1.33 | 4.26 | 4.33 | 4.30 |
| $KG_{14}$ | 0.68 | 0.74 | 0.71 | 4.20 | 4.23 | 4.21 |
| $KG_{15}$ | 0.59 | 0.63 | 0.61 | 4.23 | 4.56 | 4.40 |
| $KG_{16}$ | 0.74 | 0.70 | 0.72 | 4.16 | 4.20 | 4.18 |
| $KG_{17}$ | 0.70 | 0.78 | 0.74 | 4.13 | 4.46 | 4.30 |
| $KG_{18}$ | 0.71 | 0.63 | 0.67 | 4.20 | 4.60 | 4.40 |
| $KG_{19}$ | 0.68 | 0.68 | 0.68 | 4.33 | 4.30 | 4.31 |
| $KG_{20}$ | 0.79 | 0.78 | 0.78 | 4.00 | 4.23 | 4.11 |
| $KG_{21}$ | 0.62 | 0.61 | 0.61 | 3.90 | 4.43 | 4.16 |
| $KG_{22}$ | 0.82 | 0.77 | 0.79 | 4.20 | 4.16 | 4.18 |
| | | | | | | |
| Mean | 0.90 | 0.89 | 0.90 | 4.22 | 4.33 | 4.27 |
| SE of mean | 0.018 | 0.03 | 0.05 | 0.07 | 0.10 | 0.08 |
| CD (5%) Between genotypes | 0.06 | 0.08 | 0.11 | 0.21 | 0.2 | 0.17 |
| CD (5%) Open x Shade | NS | | | NS | | |
| CD (5%) Genotype x Condition | 0.088 | | | NS | | |

**Table.19. Oil yield per hectare under open and partially shaded conditions:**

| Genotypes | Oil content in percentage | | Oil yield per hectare (kg) | |
|---|---|---|---|---|
| | Open | Shade | Open | Shade |
| $KG_1$ | 1.39 | 1.38 | 191.88 | 181.12 |
| $KG_2$ | 1.38 | 1.43 | 120.60 | 117.48 |
| $KG_3$ | 0.61 | 0.73 | 52.04 | 59.61 |
| $KG_4$ | 0.65 | 0.70 | 55.73 | 54.11 |
| $KG_5$ | 0.77 | 0.70 | 60.80 | 54.88 |
| $KG_6$ | 0.54 | 0.61 | 41.62 | 46.93 |
| $KG_7$ | 0.74 | 0.71 | 82.76 | 78.74 |
| $KG_8$ | 1.31 | 1.14 | 143.82 | 120.10 |
| $KG_9$ | 0.84 | 0.76 | 105.98 | 96.05 |
| $KG_{10}$ | 1.40 | 1.30 | 153.11 | 139.61 |
| $KG_{11}$ | 1.31 | 1.26 | 167.16 | 149.97 |
| $KG_{12}$ | 1.26 | 1.32 | 171.78 | 166.40 |
| $KG_{13}$ | 1.34 | 1.32 | 122.33 | 118.17 |
| $KG_{14}$ | 0.68 | 0.74 | 51.734 | 53.90 |
| $KG_{15}$ | 0.59 | 0.63 | 44.94 | 46.63 |
| $KG_{16}$ | 0.74 | 0.70 | 53.65 | 48.42 |
| $KG_{17}$ | 0.70 | 0.78 | 61.10 | 65.44 |
| $KG_{18}$ | 0.71 | 0.63 | 51.73 | 43.89 |
| $KG_{19}$ | 0.68 | 0.68 | 49.19 | 46.75 |
| $KG_{20}$ | 0.79 | 0.78 | 55.86 | 55.27 |
| $KG_{21}$ | 0.62 | 0.61 | 43.79 | 42.50 |
| $KG_{22}$ | 0.82 | 0.77 | 75.04 | 72.05 |

**Table.20. Oleoresin yield per hectare of kacholam under open and partially shaded conditions:**

| Genotypes | Oil content in percentage | | Oil yield per hectare (kg) | |
|---|---|---|---|---|
| | **Open** | **Shade** | **Open** | **Shade** |
| $KG_1$ | 4.26 | 4.33 | 587.62 | 565.99 |
| $KG_2$ | 4.26 | 4.16 | 372.00 | 341.53 |
| $KG_3$ | 4.20 | 4.40 | 356.39 | 357.72 |
| $KG_4$ | 4.23 | 4.20 | 362.97 | 324.67 |
| $KG_5$ | 4.20 | 4.33 | 330.26 | 339.78 |
| $KG_6$ | 4.30 | 4.26 | 331.44 | 326.50 |
| $KG_7$ | 4.16 | 4.26 | 466.02 | 471.04 |
| $KG_8$ | 4.40 | 4.43 | 481.85 | 464.32 |
| $KG_9$ | 4.16 | 4.26 | 525.71 | 534.54 |
| $KG_{10}$ | 4.36 | 4.50 | 475.29 | 480.80 |
| $KG_{11}$ | 4.26 | 4.23 | 543.07 | 501.21 |
| $KG_{12}$ | 4.43 | 4.46 | 601.21 | 563.07 |
| $KG_{13}$ | 4.26 | 4.33 | 389.53 | 385.99 |
| $KG_{14}$ | 4.20 | 4.23 | 319.53 | 305.61 |
| $KG_{15}$ | 4.23 | 4.56 | 320.66 | 336.27 |
| $KG_{16}$ | 4.16 | 4.20 | 299.41 | 287.81 |
| $KG_{17}$ | 4.13 | 4.46 | 360.83 | 371.57 |
| $KG_{18}$ | 4.20 | 4.60 | 304.61 | 318.80 |
| $KG_{19}$ | 4.33 | 4.30 | 310.42 | 292.76 |
| $KG_{20}$ | 4.00 | 4.23 | 281.66 | 299.97 |
| $KG_{21}$ | 3.90 | 4.43 | 275.48 | 307.25 |
| $KG_{22}$ | 4.20 | 4.16 | 384.37 | 388.27 |

(4.3%), $KG_8$ (4.41%), $KG_{10}$ (4.43%), $KG_{11}$ (4.25%), $KG_{15}$ (4.4%), $KG_{17}$ (4.3%), $KG_{18}$ (4.3%) and $KG_{19}$ (4.31%). The minimum oleoresin content was recorded by $KG_{20}$ (4.11%) which was on par with $KG_2$ (4.2%), $KG_4$ (4.21%), $KG_5$ (4.26%), $KG_7$ (4.21%), $KG_9$ (4.21%), $KG_{11}$ (4.25%) $KG_{14}$ (4.21%), $KG_{21}$ (4.16%) and $KG_{22}$ (4.18%).

Oil and oleoresin content showed not much difference when kacholam was grown under open and partially shaded condition. Oil and oleoresin yield on per hectare basis under open and partially shaded condition revealed genotype $KG_1$ gave highest values for both under open and partially shaded conditions (Table 19 and 20).

**4.1.19. Estimation of genetic parameters:**

The different genetic parameters such as range, genotypic and phenotypic coefficients of variation, heritability and genetic advance expressed as percentage of mean are given in Table 21 and 22.

**4.1.19.1. Under open condition:**

A wide range of variations were observed for all the characters under study (Table 21) under open condition. Characters like leaf area (43.03 - 112.66) and fresh yield of rhizomes (41.20 - 83.00) showed wide range of variation. The range of characters like length of mother rhizome (2.72 - 3.70), oleoresin (3.50 - 4.50), leaf area index (0.71 - 1.87) and leaf area ratio (1.00 - 3.07) were low.

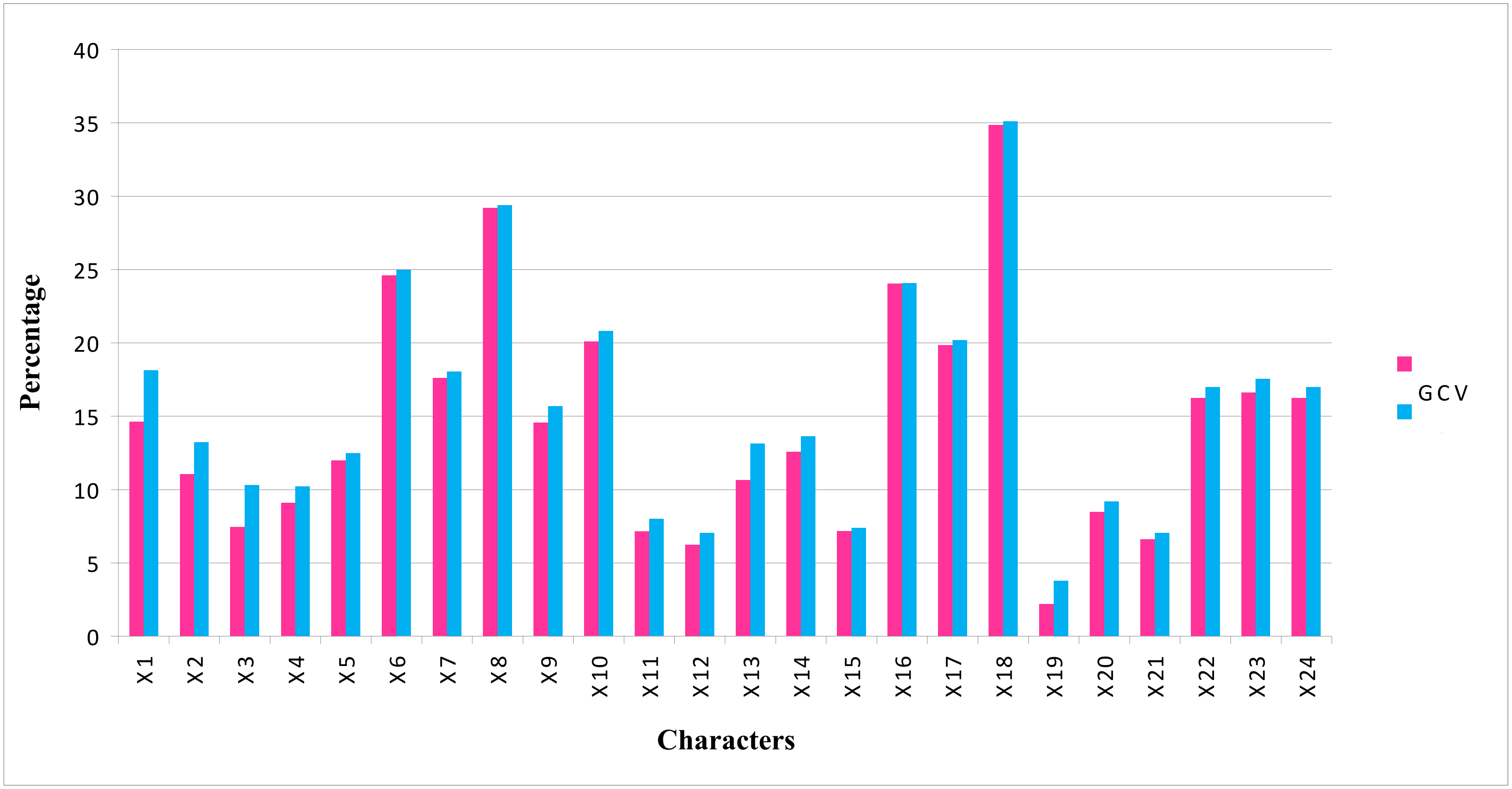
GCV and PCV were highest for volatile oil (34.87 and 35.11) which was followed by dry weight of roots (29.20 and 29.38), fresh weight of leaves(24.60 and 24.95),fresh yield of rhizome per plant (24.03 and 24.07) and number of suckers per plant (20.08 and 20.79) whereas the GCV and PCV were low for characters such as leaf length(7.43 and 10.31) ,leaf breadth (9.07 and 10.21), length(7.15 and 7.99) and girth (6.22 and 7.05) of mother rhizome, girth of secondary rhizomes (7.15 and 7.40), oleoresin (2.17 and 3.78), driage (8.45 and 9.17) and harvest index (6.59 and 7.02) and all other character showed moderate

.

**Table.21.Estimates of genetic parameters for yield and yield attributing traits of kacholam under open condition:**

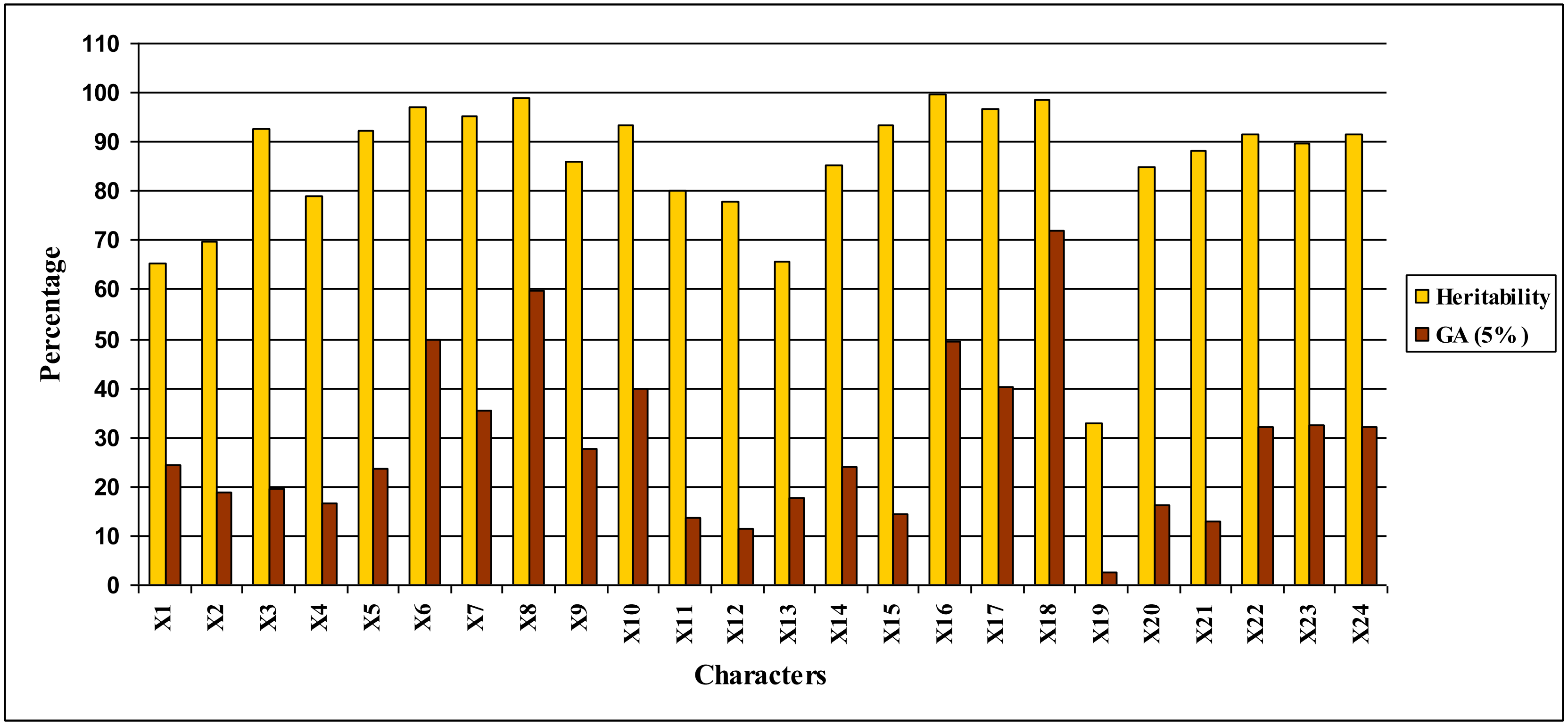
| Characters | Mean | Range | PCV | GCV | Heritability | GA (5%) |
|---|---|---|---|---|---|---|
| No: of days for sprouting | 19.66 | 15.00-29.00 | 18.12 | 14.63 | 65.2 | 24.35 |
| No: of leaves per plant | 12.11 | 7.20- 15.20 | 13.21 | 11.04 | 69.79 | 19.01 |
| Leaf length | 14.68 | 10.0- 17.20 | 10.31 | 7.45 | 92.62 | 19.69 |
| Leaf breadth | 12.26 | 8.80- 14.80 | 10.21 | 9.07 | 78.9 | 16.61 |
| Plant spread | 26.67 | 19.00- 35.10 | 12.47 | 11.98 | 92.29 | 23.72 |
| Fresh weight of leaves per plant | 23.95 | 16.00- 35.80 | 24.95 | 24.60 | 97.17 | 49.96 |
| Fresh weight of roots per plant | 15.96 | 11.00- 21.60 | 18.04 | 17.60 | 95.24 | 35.41 |
| Dry weight of roots per plant | 8.03 | 5.00- 12.70 | 29.37 | 29.20 | 98.8 | 59.81 |
| Dry weight of leaves per plant | 11.52 | 6.40- 15.80 | 15.69 | 14.54 | 85.83 | 27.75 |
| No: of suckers per plant | 6.31 | 4.20- 9.20 | 20.79 | 20.08 | 93.25 | 39.98 |
| Length of mother rhizome per plant | 3.1 | 2.70- 3.70 | 7.99 | 7.15 | 80.17 | 13.61 |
| Girth of mother rhizome per plant | 7.14 | 6.20- 8.20 | 7.05 | 6.22 | 77.77 | 11.32 |
| Number secondary rhizomes per plant | 10.52 | 7.40- 14.60 | 13.11 | 10.62 | 65.66 | 17.75 |
| Length of secondary rhizomes per plant | 2.96 | 2.20- 4.00 | 13.61 | 12.56 | 85.28 | 23.93 |
| Girth of secondary rhizome per plant | 5.61 | 5.08- 6.80 | 7.39 | 7.15 | 93.44 | 14.25 |
| Fresh yield of rhizomes per plant | 55.91 | 41.20 -83.00 | 24.07 | 24.03 | 99.65 | 49.42 |
| Dry yield of rhizome per plant | 25.27 | 18.60- 38.00 | 20.17 | 19.84 | 96.81 | 40.24 |
| Volatile oil | 0.90 | 0.48- 1.42 | 35.11 | 34.87 | 98.64 | 71.8 |
| Oleoresin | 4.22 | 3.50- 4.50 | 3.78 | 2.17 | 33.02 | 2.574 |
| Driage | 45.73 | 36.50 -54.30 | 9.17 | 8.45 | 85.02 | 16.06 |
| Harvest index | 0.56 | 0.45- 0.62 | 7.02 | 6.59 | 88.38 | 12.84 |
| Leaf Area | 88.60 | 43.03- 112.66 | 16.98 | 16.23 | 91.38 | 31.97 |
| Leaf Area Ratio | 2.00 | 1.00- 3.07 | 17.54 | 16.62 | 89.78 | 32.48 |
| Leaf area index | 1.47 | 0.71- 1.87 | 16.98 | 16.23 | 91.38 | 32.12 |

**Fig.3. Phenotypic and genotypic coefficient of variation for different characters under partially shaded condition**




| | | | | |
|---|---|---|---|---|
| X1- No: of days for sprouting | X6- Fresh weight of leaves per plant, | X11- Length of mother rhizome per plant | X16- Fresh yield of rhizomes/plant | X21- HI |
| X2- No: of leaves per plant, | X7- Fresh weight of roots per plant | X12- Girth of mother rhizome per plant | X17- Dry yield of rhizome/ plant | X22- Leaf Area |
| X3 -Leaf length, | X8-Dry weight of roots per plant | X13- Number secondary rhizomes per plant | X18- Volatile oil | X23- Leaf Area Ratio |
| X4- Leaf breadth | X9-Dry weight of leaves per plant, | X14- Length of secondary rhizomes per plant | X19- Oleoresin | X24- Leaf area index |
| X5-Plant spread | X10-No: of suckers per plant | X15- Girth of secondary rhizome per plant | X20- Driage | |

**Fig.5. Heritability and genetic advance of different characters under open condition.**




| | | | | |
|---|---|---|---|---|
| X1- No: of days for sprouting | X6- Fresh weight of leaves per plant, | X11- Length of mother rhizome per plant | X16- Fresh yield of rhizomes/plant | X21- HI |
| X2- No: of leaves per plant, | X7- Fresh weight of roots per plant | X12- Girth of mother rhizome per plant | X17- Dry yield of rhizome/ plant | X22- Leaf Area |
| X3 -Leaf length, | X8-Dry weight of roots per plant | X13- Number secondary rhizomes per plant | X18- Volatile oil | X23- Leaf Area Ratio |
| X4- Leaf breadth | X9-Dry weight of leaves per plant, | X14- Length of secondary rhizomes per plant | X19- Oleoresin | X24- Leaf area index |
| X5-Plant spread | X10-No: of suckers per plant | X15- Girth of secondary rhizome per plant | X20- Driage | |

GCV and PCV. The PCV values were higher than GCV values for all characters studied (Fig .3).

Heritability was high for almost all characters studied except oleoresin. Oleoresin recorded a moderate heritability (33.02%). Highest heritability was shown by fresh yield of rhizome (99.65%) followed by dry weight of roots (98.81%), volatile oil (98.64%), fresh weight of leaves (97.17%) and dry yield of rhizome (96.81%).

Genetic advance (GA) expressed as percentage of mean was highest for volatile oil (71.38%) followed by dry weight of roots (59.78%) and fresh yield of rhizome (49.4%).Very low genetic advance expressed as percentage of mean was recorded by oleoresin (2.57%). The character number of leaves per plant (18.99%), leaf length (19.67%), leaf breadth (16.55%), length of mother rhizome per plant (13.17%), girth of mother rhizome per plant (11.295%), number of secondary rhizomes per plant (17.73%), girth of secondary rhizomes per plant (14.22%), driage (16.06%) and harvest index (12.63%) showed moderate GA and all other characters expressed high genetic advance (Fig 5).

From the Table 21 it is clear that the characters like fresh yield of rhizome per plant, fresh weight of leaves, number of suckers per plant, dry yield of rhizome, leaf area ratio, dry weight of roots and volatile oil recorded high heritability, genetic advance, GCV and PCV which give an indication of the importance of these characters in further selection of genotypes.

**4.1.19.2. Under partial shade:**

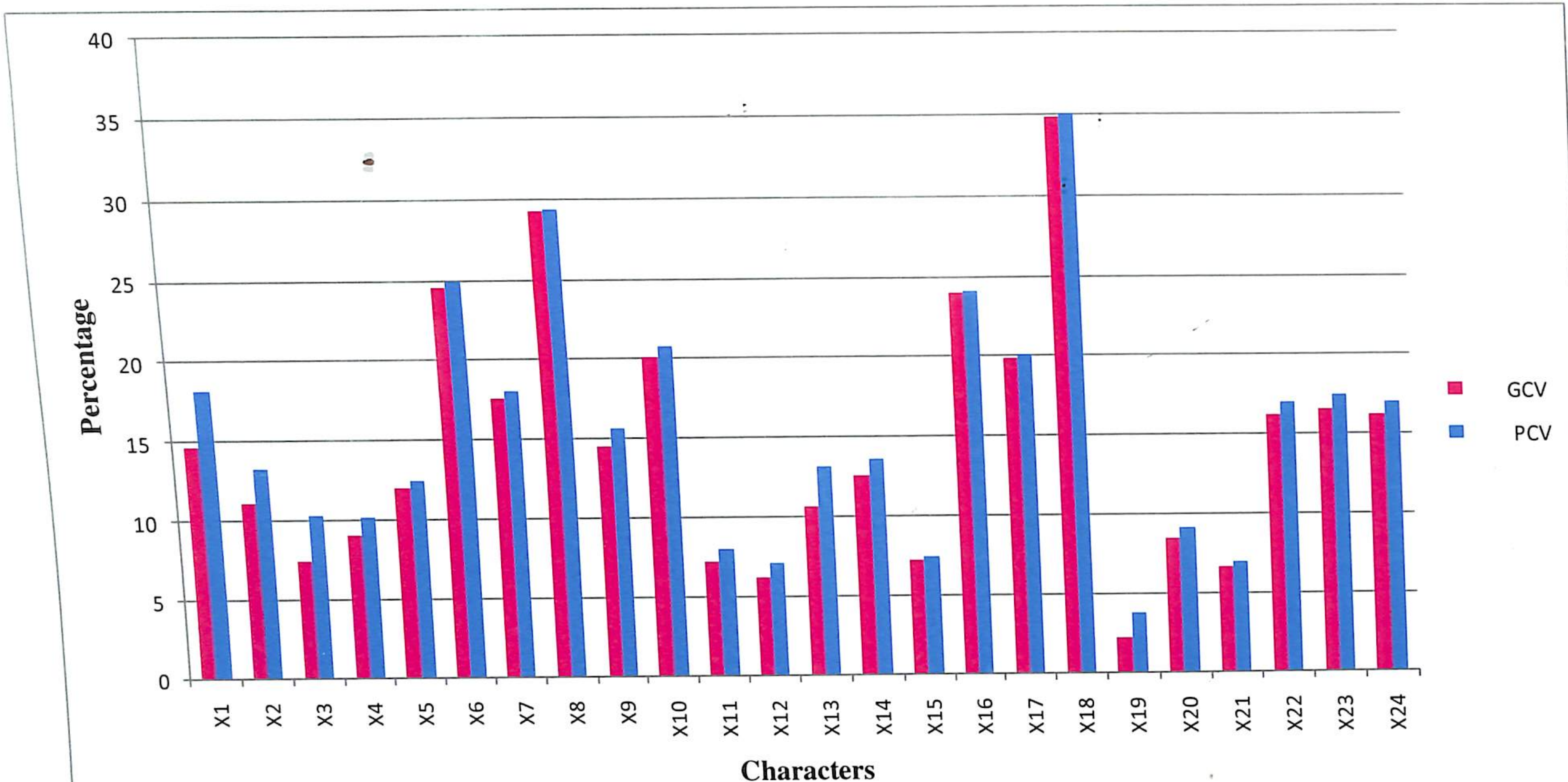
Table 22 revealed that under shaded condition also there existed wide range for characters like leaf area (43.20 - 106.60) and fresh yield of rhizomes (40.00 - 80.60). The range of characters like length of mother rhizome (2.55 - 3.86), oleoresin (4.10 - 4.80), leaf area index (0.72 - 1.77) and leaf area ratio (1.10 - 2.80) was low under shaded condition also. GCV and PCV were highest for volatile oil (32.92 and 33.41) which was followed by fresh weight of leaves (28.29 and 28.89), fresh yield of rhizome per plant (23.45 and 23.56) and dry weight of roots (22.23 and 22.74). The characters leaf breadth (7.41 and

.

**Table.22. Estimates of genetic parameters for yield and yield attributing traits of kacholam under partially shaded conditions:**

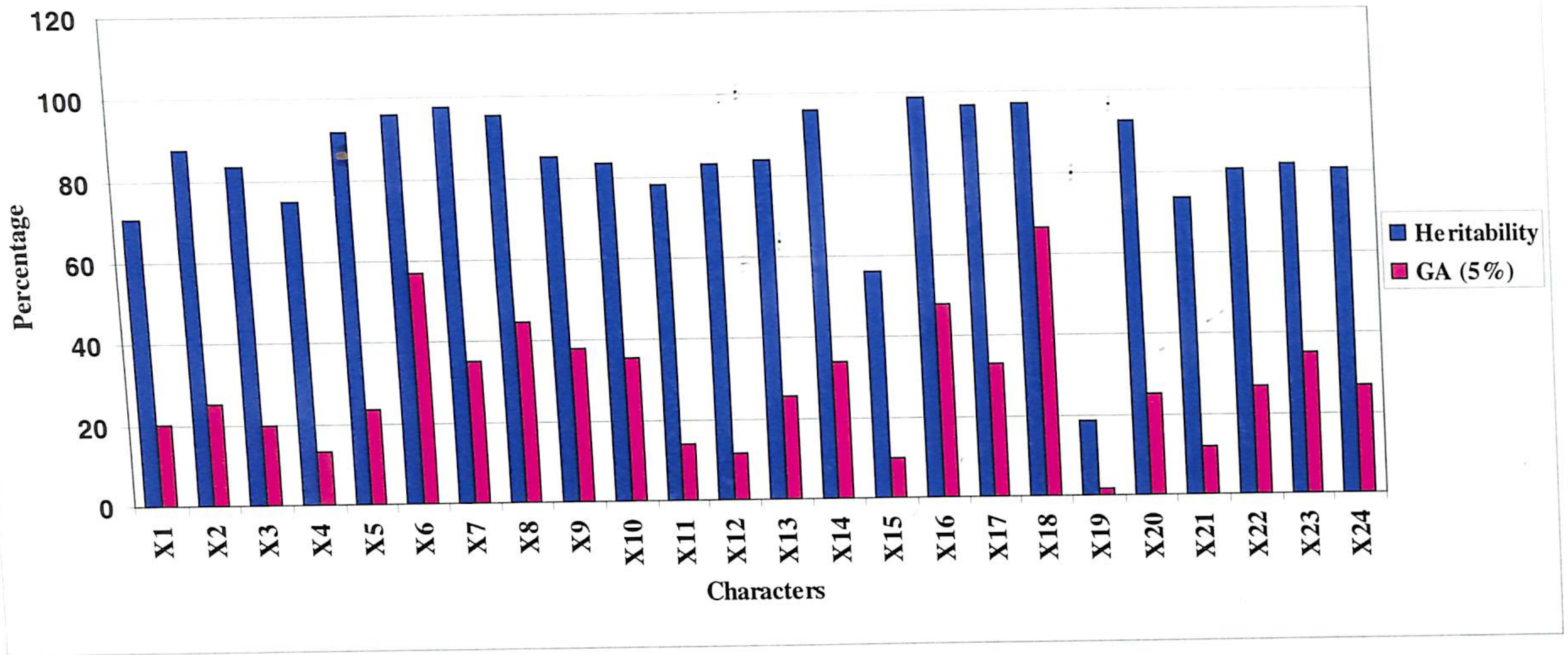
| Characters | Mean | Range | PCV | GCV | Heritability | GA (5%) |
|---|---|---|---|---|---|---|
| No: of days for sprouting | 20.40 | 16.00-26.00 | 13.91 | 11.70 | 70.8 | 20.3 |
| No: of leaves per plant | 14.30 | 9.00-18.00 | 13.89 | 13.00 | 87.7 | 25.1 |
| Leaf length | 14.55 | 9.30-17.20 | 11.64 | 10.64 | 83.59 | 20.04 |
| Leaf breadth | 11.82 | 9.30-13.80 | 8.56 | 7.41 | 75.01 | 13.23 |
| Plant spread | 27.54 | 19.10-32.30 | 12.46 | 11.93 | 91.73 | 23.56 |
| Fresh weight of leaves per plant | 25.05 | 16.40-41.00 | 28.89 | 28.29 | 95.89 | 57.07 |
| Fresh weight of roots per plant | 17.29 | 13.00-24.50 | 17.39 | 17.19 | 97.63 | 34.99 |
| Dry weight of roots per plant | 8.26 | 5.40-11.80 | 22.74 | 22.23 | 95.55 | 44.78 |
| Dry weight of leaves per plant | 10.64 | 6.20-15.60 | 21.59 | 19.94 | 85.32 | 37.95 |
| No: of suckers per plant | 5.78 | 3.80-8.80 | 20.78 | 18.97 | 83.38 | 35.69 |
| Length of mother rhizome per plant | 3.11 | 2.55-3.86 | 8.67 | 7.68 | 78.3 | 14.00 |
| Girth of mother rhizome per plant | 7.32 | 6.34-8.56 | 6.80 | 6.21 | 83.28 | 11.68 |
| Number secondary rhizomes per plant | 11.04 | 7.80-15.00 | 14.73 | 13.50 | 84.08 | 25.52 |
| Length of secondary rhizomes per plant | 2.81 | 2.18-4.12 | 17.21 | 16.86 | 95.94 | 34.02 |
| Girth of secondary rhizome per plant | 5.66 | 4.34-6.80 | 8.45 | 6.34 | 56.39 | 9.821 |
| Fresh yield of rhizomes per plant | 53.89 | 40.00-80.60 | 23.56 | 23.45 | 98.99 | 48.07 |
| Dry yield of rhizome per plant | 24.87 | 18.20-34.80 | 16.61 | 16.33 | 96.66 | 33.08 |
| Volatile oil | 0.89 | 0.54-1.50 | 33.41 | 32.92 | 97.06 | 66.81 |
| Oleoresin | 4.33 | 4.10-4.80 | 4.39 | 1.89 | 18.52 | 1.678 |
| Driage | 47.09 | 35.04-64.19 | 13.09 | 12.62 | 92.87 | 25.06 |
| Harvest index | 0.56 | 0.48-0.72 | 7.91 | 6.79 | 73.84 | 12.03 |
| Leaf Area | 84.46 | 43.20-106.60 | 16.17 | 14.55 | 80.88 | 26.96 |
| Leaf Area Ratio | 1.96 | 1.10-2.80 | 20.68 | 18.73 | 82.07 | 34.97 |
| Leaf area index | 1.40 | 0.72-1.77 | 16.17 | 14.55 | 80.89 | 26.96 |

*Fig.4. Phenotypic and genotypic coefficient of variation for different characters under partially shaded condition.*




| | | | | |
|---|---|---|---|---|
| X1- No: of days for sprouting | X6- Fresh weight of leaves per plant, | X11- Length of mother rhizome per plant | X16- Fresh yield of rhizomes/plant | X21- HI |
| X2- No: of leaves per plant, | X7- Fresh weight of roots per plant | X12- Girth of mother rhizome per plant | X17- Dry yield of rhizome/ plant | X22- Leaf Area |
| X3 -Leaf length, | X8-Dry weight of roots per plant | X13- Number secondary rhizomes per plant | X18- Volatile oil | X23- Leaf Area Ratio |
| X4- Leaf breadth | X9-Dry weight of leaves per plant, | X14- Length of secondary rhizomes per plant | X19- Oleoresin | X24- Leaf area index |
| X5-Plant spread | X10-No: of suckers per plant | X15- Girth of secondary rhizome per plant | X20- Driage | |

**Fig.6. Heritability and genetic advance for various characters under partially shaded condition.**




| | | | | |
|---|---|---|---|---|
| X1- No: of days for sprouting | X6- Fresh weight of leaves per plant, | X11- Length of mother rhizome per plant | X16- Fresh yield of rhizomes/plant | X21- HI |
| X2- No: of leaves per plant, | X7- Fresh weight of roots per plant | X12- Girth of mother rhizome per plant | X17- Dry yield of rhizome/ plant | X22- Leaf Area |
| X3 -Leaf length, | X8-Dry weight of roots per plant | X13- Number secondary rhizomes per plant | X18- Volatile oil | X23- Leaf Area Ratio |
| X4- Leaf breadth | X9-Dry weight of leaves per plant, | X14- Length of secondary rhizomes per plant | X19- Oleoresin | X24- Leaf area index |
| X5-Plant spread | X10-No: of suckers per plant | X15- Girth of secondary rhizome per plant | X20- Driage | |

8.56), length (7.68 and 8.67) and girth (6.21 and 6.80) of mother rhizome, girth of secondary rhizomes (6.34 and 8.45) and oleoresin (1.89 and 4.39) showed lower GCV and PCV and all other character showed moderate GCV and PCV (Fig.4).

Fresh yield of rhizome per plant (98.99%) showed highest heritability followed by fresh weight of root (97.63%), volatile oil (97.05%), dry yield of rhizome (96.67%) length of secondary rhizome (95.94%) and fresh weight of leaves (95.89%). Almost all characters showed high heritability except girth of secondary rhizomes and oleoresin. Girth of secondary rhizomes showed (56.39%) moderate heritability where as oleoresin (18.52%) showed the lowest heritability.

Genetic advance expressed as percentage of mean was high for all characters except length (13.82%) and girth (11.68%) of mother rhizome which showed moderate GA. Lowest genetic advance expressed as percentage of mean was shown by oleoresin (1.61%). Volatile oil recorded highest genetic advance (67.41%) expressed as percentage of mean followed by fresh weight of leaves (57.04%) and fresh yield of rhizomes per plant (48.07%) (Fig 6).

From Table 23 it is clear that fresh weight of leaves, fresh weight of roots, dry weight of roots, length of secondary rhizomes, fresh and dry yield of rhizomes per plant and volatile oil recorded high heritability, genetic advance, GCV and PCV.

Under both conditions, characters such as fresh yield of rhizome, dry yield of rhizomes, fresh weight of leaves, dry weight of roots, length of secondary rhizomes and volatile oil showed high heritability and genetic advance which revealed the importance of these characters during selection .

**4.1.20. Correlation studies:**

The genotypic correlation of different characters with dry yield of rhizomes and between themselves when the crop was grown under open and partially shaded conditions are given in Table 23 and 24.

**4.1.20.1. Under open condition:**

Genotypic correlation with yield was highly positive and significant for characters such as girth of mother rhizome (0.9248), fresh weight of leaves (0.8703), length of secondary rhizome (0.7774), number of suckers per plant (0.7422), number of secondary rhizome (0.6950), length of mother rhizome (0.6608), oil (0.6450), dry weight of leaves (0.6231), oleoresin content (0.5972) leaf area index (0.5928), harvest index (0.5421), girth of secondary rhizome (0.5118), plant spread (0.5011), and dry weight of roots (0.4306) (Table 23). Leaf area ratio was found to be negatively correlated with rhizome yield (-0.3584).

Association between plant spread (0.4697), number of suckers per plant (0.6664), length of secondary rhizomes (0.4539), oil (0.4238) and oleoresin (0.4584) was positive and highly significant with number of leaves per plant.

The character plant spread had positive and high significant correlation with dry weight of leaves (0.5409), number of suckers per plant (0.4091), length of mother rhizome per plant (0.3946), girth of mother rhizome per plant (0.5190), length of secondary rhizomes per plant (0.2174), leaf area index (0.5011), fresh yield of rhizomes per plant (0.7563), dry yield of rhizome per plant (0.5303), oil (0.5424) and oleoresin (0.6732).

Fresh weight of leaves had high positive significant correlation with dry weight of roots(0.4734), dry weight of leaves (0.7606), number of suckers per plant(0.8360), length of mother rhizome per plant (0.7362), girth of mother rhizome per plant(0.8150), number of secondary rhizomes (0.5829), length of secondary rhizomes per plant (0.7174), girth of secondary rhizomes (0.4141), leaf area index (0.3944), fresh yield of rhizomes per plant (0.8957), dry yield of rhizome per plant (0.8703), oil (0.5787) and oleoresin (0.4357).

The character dry weight of roots had high positive significant correlation with number of suckers per plant (0.3752), length of mother rhizome per plant (0.5420), girth of mother rhizome per plant (0.3858), fresh yield of rhizomes per plant (0.5049), dry yield of rhizome per plant (0.4306) and oil (0.5297).

Association between number of suckers per plant (0.5855), length of mother rhizome per plant (0.6510), girth of mother rhizome per plant (0.7158),

## Table.23.Genotypic correlation of yield and yield attributing characters under open condition:

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 | X17 | X18 | X19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1 | | | | | | | | | | | | | | | | | | |
| X2 | 0.4697** | 1 | | | | | | | | | | | | | | | | | |
| X3 | 0.3816* | 0.3533* | 1 | | | | | | | | | | | | | | | | |
| X4 | 0.1974 | 0.2091 | 0.4734** | 1 | | | | | | | | | | | | | | | |
| X5 | 0.2094 | 0.5409** | 0.7606** | 0.1978 | 1 | | | | | | | | | | | | | | |
| X6 | 0.6664** | 0.4091** | 0.836** | 0.3752** | 0.5855** | 1 | | | | | | | | | | | | | |
| X7 | 0.2688 | 0.3946** | 0.7362** | 0.542** | 0.651** | 0.6197** | 1 | | | | | | | | | | | | |
| X8 | 0.3658* | 0.519** | 0.815** | 0.3858** | 0.7158** | 0.7301** | 0.7333** | 1 | | | | | | | | | | | |
| X9 | -0.0706 | 0.2174** | 0.5829** | 0.2767 | 0.4682** | 0.5032** | 0.493** | 0.7081** | 1 | | | | | | | | | | |
| X10 | 0.4539** | 0.5011** | 0.7174** | 0.365* | 0.5032** | 0.6611** | 0.7085** | 0.8164** | 0.5931** | 1 | | | | | | | | | |
| X11 | 0.0348 | 0.3413* | 0.4141** | 0.3586* | 0.335* | 0.3572* | 0.6021** | 0.6823** | 0.6691** | 0.6145** | 1 | | | | | | | | |
| X12 | 0.1309 | 0.1451 | 0.26 | -0.3625 | -0.0109 | 0.3042* | -0.0127 | 0.4397** | 0.3565* | 0.3898** | 0.16 | 1 | | | | | | | |
| X13 | 0.0826 | 0.197 | -0.517 | -0.4671 | -0.3885 | -0.2697 | -0.4076 | -0.2495 | -0.112 | -0.1977 | 0.0174 | 0.179 | 1 | | | | | | |
| X14 | 0.378* | 0.7563** | 0.3944** | 0.2102 | 0.364* | 0.4672** | 0.3777* | 0.6699** | 0.5372** | 0.5297** | 0.5377** | 0.3786* | 0.47** | 1 | | | | | |
| X15 | 0.4389** | 0.5303** | 0.8957** | 0.5049** | 0.6334** | 0.8372** | 0.8294** | 0.9131** | 0.6222** | 0.792** | 0.5834** | 0.4004** | -0.3189 | 0.6174** | 1 | | | | |
| X16 | 0.2829 | 0.5011** | 0.8703** | 0.4306** | 0.6231** | 0.7422** | 0.6608** | 0.9248** | 0.6947** | 0.7774** | 0.5118** | 0.5421** | -0.3584 | 0.5928** | 0.9396** | 1 | | | |
| X17 | -0.5743 | -0.41 | -0.4883 | -0.3461 | -0.4116 | -0.6131 | -0.7477 | -0.3675 | -0.0762 | -0.4072 | -0.3871 | 0.1709 | 0.0211 | -0.3743 | -0.5839 | -0.283 | 1 | | |
| X18 | 0.4238** | 0.5424** | 0.5787** | 0.5297** | 0.5068** | 0.5426** | 0.4949** | 0.5536** | 0.4167** | 0.4714** | 0.1762 | 0.0778 | -0.0863 | 0.6597** | 0.6758** | 0.645** | -0.4016 | 1 | |
| X19 | 0.4584** | 0.6732** | 0.4357** | -0.0323 | 0.3278 | 0.4824** | 0.3551* | 0.6245** | 0.3479* | 0.7053** | 0.2122 | 0.5937** | 0.4552** | 0.8891** | 0.5995** | 0.5972** | -0.4212 | 0.6858** | 1 |

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

X1 Number of leaves
X2 Plant spread
X3 Fresh weight of leaves
X4 Dry weight of roots
X5 Dry weight of leaves
X6 Number of Suckers
X7 Length of mother rhizome
X8 Girth of mother Rhizome
X9 Number of secondary rhizomes
X10 Length of secondary rhizomes
X11 Girth of Secondary rhizomes
X12 Harvest Index
X13 LAR
X14 LAI
X15 Fresh yield of Rhizome
X16 Dry yield of Rhizome
X17 Driage
X18 Oil content
X19 Oleoresin

number of secondary rhizomes (0.4682), length of secondary rhizomes per plant (0.5032), fresh yield of rhizomes per plant (0.3350), dry yield of rhizome per plant (0.6334) and oil content (0.6231) with dry weight of leaves (0.5068) was highly significant and positive.

The character number of suckers per plant had positive and highly significant correlation with length of mother rhizome per plant (0.6197), girth of mother rhizome per plant (0.7301), number of secondary rhizome per plant (0.5032), length of secondary rhizomes per plant (0.6611), leaf area index (0.4672) fresh yield of rhizomes per plant (0.8372), dry yield of rhizome per plant (0.7422), oil (0.5426) and oleoresin (0.4824).

Length of mother rhizome was highly significant and positively correlated with girth of mother rhizome per plant (0.7333), number of secondary rhizomes (0.4930), length of secondary rhizomes per plant (0.7085), girth of secondary rhizomes (0.6021), fresh yield of rhizomes per plant (0.8294), dry yield of rhizome per plant (0.6608) and oil content (0.4949).

Association of girth of mother rhizome with number of secondary rhizomes(0.7081), length of secondary rhizomes per plant (0.8164), girth of secondary rhizomes (0.6823),harvest index (0.4397), leaf area index (0.6699), and fresh yield of rhizomes per plant (0.9131), dry yield of rhizome per plant (0.9248), oil (0.5536) and oleoresin (0.6245) content was highly positive and significant while its association with leaf area ratio (-0.2495) and driage (-0.3675) was negative.

Number of secondary rhizomes had high positive significant relation with length of secondary rhizomes per plant (5931), girth of secondary rhizomes (0.6691), leaf area index (0.5372), fresh yield of rhizomes per plant (0.6222), dry yield of rhizome per plant (0.6947) and oil (0.4167).

Association of length of secondary rhizomes with girth of secondary rhizomes (0.6145), harvest index (0.3898), leaf area index (0.5297), and fresh yield of rhizomes per plant (0.792), dry yield of rhizome per plant (0.7774), oil (0.4714) and oleoresin (0.7053) content was highly positive and significant.

The character girth of secondary rhizome had high positive significant correlation with leaf area index (0.5377), fresh yield of rhizomes per plant (0.5834) and dry yield of rhizome per plant (0.5118).

Harvest index had high significant positive correlation with leaf area index (0.3786), fresh yield of rhizomes per plant (0.4004), dry yield of rhizome per plant (0.5421) and oleoresin (0.5937) while the character leaf area ratio had highly significant positive correlation with leaf area index (0.4700) and oleoresin (0.4552) content. The character leaf area index had highly significant positive correlation with fresh yield of rhizomes per plant (0.6174), dry yield of rhizome per plant (0.5928), oil (0.6597) and oleoresin (0.8891).

Fresh yield of rhizome had high positive significant relation with dry yield of rhizome per plant (0.9396), oil (0.6758) and oleoresin (0.5995) while dry yield of rhizome had high positive significant relation with oil (0.6450) and oleoresin (0.5972) content. Oil and oleoresin content also had high significant positive correlation with each other.

**4.1.20.2. Under partial shade:**

In the case of partially shaded condition, genotypic correlation with yield was highly positive and significant for characters like oil content (0.848), number of suckers per plant (0.8369), length of secondary rhizome per plant (0.8035) number of secondary rhizome per plant (0.7430),fresh weight of leaves (0.7130), girth of mother rhizome per plant (0.7360), length of mother rhizome per plant (0.7071), girth of secondary rhizome per plant (0.6955), dry weight of leaves (0.6845), plant spread (0.6740), harvest index (0.4758), number of leaves per plant(0.4042), and leaf area index (0.3517) (Table .24).

Association between number of leaves produced per plant with dry weight of roots (0.3987), number of suckers per plant (0.4454), girth of secondary rhizomes (0.6386) and dry yield of rhizomes per plant (0.4042) was highly significant and positive.

The character plant spread had positive and highly significant correlation with fresh weight of leaves(0.6273), dry weight of leaves(0.5794), number of

**Table.24.Genotypic correlation of yield and yield attributing characters of kacholam under partially shaded condition:**

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 | X17 | X18 | X19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | 1 | | | | | | | | | | | | | | | | | | |
| X2 | 0.0676 | 1 | | | | | | | | | | | | | | | | | |
| X3 | 0.2313 | 0.6273* | 1 | | | | | | | | | | | | | | | | |
| X4 | 0.3987** | -0.2 | 0.2219 | 1 | | | | | | | | | | | | | | | |
| X5 | 0.1276 | 0.5794** | 0.5814** | 0.0071 | 1 | | | | | | | | | | | | | | |
| X6 | 0.4454** | 0.548** | 0.7241** | 0.1053 | 0.6484** | 1 | | | | | | | | | | | | | |
| X7 | 0.1277 | 0.5175** | 0.6772** | -0.081 | 0.5138** | 0.7094** | 1 | | | | | | | | | | | | |
| X8 | 0.3758* | 0.4581** | 0.7137** | 0.1446 | 0.419** | 0.737** | 0.6582** | 1 | | | | | | | | | | | |
| X9 | -0.0017 | 0.6543** | 0.6893** | -0.009 | 0.4242** | 0.586** | 0.8315** | 0.6233** | 1 | | | | | | | | | | |
| X10 | 0.2109 | 0.5602** | 0.8389** | 0.1889 | 0.5875** | 0.6509** | 0.8053** | 0.7753** | 0.7432** | 1 | | | | | | | | | |
| X11 | 0.6386** | 0.4767** | 0.6328** | 0.309* | 0.2893 | 0.7502** | 0.4429** | 0.6686** | 0.5923** | 0.5574** | 1 | | | | | | | | |
| X12 | 0.1178 | 0.4419** | 0.2244 | -0.557 | -0.153 | 0.2766 | 0.302* | 0.3401* | 0.4615** | 0.2352 | 0.3842** | 1 | | | | | | | |
| X13 | -0.5021 | 0.0906 | -0.233 | -0.522 | -0.412 | -0.361 | -0.247 | -0.2667 | 0.0228 | -0.392 | -0.134 | 0.2943* | 1 | | | | | | |
| X14 | -0.2044 | 0.6525** | 0.3717* | -0.336 | 0.2874 | 0.3146* | 0.255 | 0.2862 | 0.5584** | 0.2207 | 0.412** | 0.3934** | 0.6712** | 1 | | | | | |
| X15 | 0.2697 | 0.7033** | 0.825** | 0.1012 | 0.6852** | 0.8069** | 0.808** | 0.7444** | 0.7938** | 0.8935** | 0.6127** | 0.2637 | -0.358 | 0.3159 | 1 | | | | |
| X16 | 0.4042** | 0.674** | 0.713** | 0.039 | 0.6845** | 0.8369** | 0.7071** | 0.736** | 0.743** | 0.8035** | 0.6955** | 0.4758** | -0.382 | 0.3517* | 0.848** | 1 | | | |
| X17 | 0.0417 | -0.394 | -0.592 | -0.155 | -0.349 | -0.385 | -0.508 | -0.3482 | -0.4431 | -0.568 | -0.208 | 0.163 | 0.14 | -0.123 | -0.6976 | -0.219 | 1 | | |
| X18 | 0.1339 | 0.467** | 0.7073** | 0.2559 | 0.5612** | 0.5788** | 0.4476** | 0.4111** | 0.4446** | 0.6385** | 0.4131** | 0.0575 | -0.276 | 0.166 | 0.6323** | 0.5404** | -0.4756 | 1 | |
| X19 | 0.208 | -0.453 | 0.1466 | -0.016 | -0.014 | -0.302 | -0.084 | -0.0175 | 0.065 | 0.1076 | 0.3634* | -0.052 | 0.0242 | -0.092 | 0.0102 | -0.11 | -0.177 | -0.0189 | 1 |

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

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| | | | |
|---|---|---|---|
| X1 Number of leaves | X7 Length of mother rhizome | X13 LAR | X19 Oleoresin |
| X2 Plant spread | X8 Girth of mother Rhizome | X14 LAI | |
| X3 Fresh weight of leaves | X9 Number of secondary rhizomes | X15 Fresh yield of Rhizome | |
| X4 Dry weight of roots | X10 Length of secondary rhizomes | X16 Dry yield of Rhizome | |
| X5 Dry weight of leaves | X11 Girth of Secondary rhizomes | X17 Driage | |
| X6 Number of Suckers | X12 Harvest Index | X18 Oil content | |

**Characters selected for path analysis:**

| | **Characters** |
|---|---|
| X1 | Number of leaves |
| X2 | Plant Spread |
| X3 | Fresh Weight of Leaves |
| X4 | Dry Weight of Roots |
| X5 | Dry Weigh of Leaves |
| X6 | Suckers |
| X7 | Length of Mother Rhizome |
| X8 | Girth of Mother Rhizome |
| X9 | Number of Secondary Rhizomes |
| X10 | Length of Secondary Rhizomes |
| X11 | Girth of Secondary Rhizomes |
| X12 | Harvest Index |
| X13 | LAR |
| X14 | LAI |
| X15 | Driage |
| X16 | Oil |
| X17 | Oleoresin |

suckers per plant (0.5480), length of mother rhizome per plant (0.5175), girth of mother rhizome per plant (0.4581), number of secondary rhizome per plant (0.6543), length of secondary rhizomes per plant (0.5602), girth of secondary rhizome (0.4767), harvest index (0.4419), leaf area index (0.6625), fresh yield of rhizomes per plant (0.7033), dry yield of rhizome per plant (0.6741)and oil (0.467).

Fresh weight of leaves had high positive significant correlation with dry weight of leaves (0.5814), number of suckers per plant (0.7241), length of mother rhizome per plant (0.6772), girth of mother rhizome per plant (0.7137), number of secondary rhizomes (0.6893), length of secondary rhizomes per plant (0.8389), girth of secondary rhizomes (0.6328), fresh yield of rhizomes per plant(0.825), dry yield of rhizome per plant (0.713) and oil (0.7073) content.

The character dry weight of roots had positive significant correlation only with girth of secondary rhizome (0.3090).

Association between number of suckers per plant (0.6484), length of mother rhizome per plant (0.5138), girth of mother rhizome per plant (0.4190), number of secondary rhizomes (0.4242), length of secondary rhizomes per plant (0.5875), fresh yield of rhizomes per plant (0.6852), dry yield of rhizome per plant (0.6845) and oil content (0.5612) with dry weight of leaves was highly significant and positive.

The character number of suckers per plant had positive and highly significant correlation with length of mother rhizome per plant (0.7094), girth of mother rhizome per plant (0.7370), number of secondary rhizome per plant (0.5860), length of secondary rhizomes per plant (0.6509), girth of secondary rhizomes per plant (0.7502), fresh yield of rhizomes per plant (0.8069), dry yield of rhizome per plant (0.8369) and oil (0.5788) content.

Length of mother rhizome was highly significant and positively correlated with girth of mother rhizome per plant (0.6582), number of secondary rhizomes (0.8315), length of secondary rhizomes per plant (0.8053), girth of secondary rhizomes (0.4429), fresh yield of rhizomes per plant (0.8080), dry yield of rhizome per plant (0.7071) and oil (0.4476).

Association of girth of mother rhizome with number of secondary rhizomes (0.6233), length of secondary rhizomes per plant (0.7753), girth of secondary rhizomes (0.6686), fresh yield of rhizomes per plant (0.7444), dry yield of rhizome per plant (0.7360) and oil content (0.4111) was highly positive and significant

Number of secondary rhizomes had high positive significant relation with length of secondary rhizomes per plant (0.7432), girth of secondary rhizomes (0.5923), harvest index (0.4615), leaf area index (0.5584), fresh yield of rhizomes per plant (0.7938), dry yield of rhizome per plant (0.7430) and oil content (0.4446).

Association of length of secondary rhizomes with girth of secondary rhizomes (0.5574), fresh yield of rhizomes per plant (0.8935), dry yield of rhizome per plant (0.8035), and oil (0.6385) content was highly positive and significant.

The character girth of secondary rhizome had high positive significant correlation with harvest index (0.3842), fresh yield of rhizomes per plant (0.6127) and dry yield of rhizome per plant (0.6955) and oil content (0.4131).

Harvest index had high significant positive correlation with leaf area index (0.3934) and dry yield of rhizome per plant (0.4758) while the character leaf area ratio (0.2943) had significant positive correlation with harvest index. The character leaf area ratio had highly significant positive correlation with leaf area index (0.6712). Leaf area index (0.3517) had positive correlation with dry yield of rhizome per plant.

Fresh yield of rhizome had high positive significant relation with dry yield of rhizome per plant (0.8480) and oil content (0.6323) while dry yield of rhizome (0.5404) had high positive significant relation with oil content. Under partially shaded condition oil and oleoresin content did not show any significant positive correlation with each other.

From the genotypic correlation studies it has been able to highlight that the characters fresh weight of leaves, number of suckers per plant and length of mother rhizome had high positive correlation with rhizome yield under both the conditions.

**4.1.21. Path Analysis:**

Path analysis was done to partition the association of various yield contributing characters into direct and indirect effects. Path analysis was carried out from the data for open condition and results are presented in Table 25 and Fig 7.

The analysis was done by taking 17 yield contributing characters having high correlation coefficient value with yield. The direct and indirect effect of each character on yield is presented in Table 25.

**4.1.21.1. Direct effects:**

From Table 25 it was clear that harvest index (0.6815), dry weight of roots (0.4506) and dry weight of leaves (0.3741) had high direct effect on yield. The characters driage (0.2206) and length of mother rhizome (0.2241) exhibited moderate positive effect on yield while the characters like number of suckers per plant (0.1793) and volatile oil (0.1365) recorded low positive direct effect on yield. Number of leaves per plant (-0.1042), girth of mother rhizome (-0.115) and number of secondary rhizome (-0.1316) had a negative direct effect on yield.

**4.1.21.2. Indirect effects:**

Fresh weight of leaves (0.2133), length of mother rhizome (0.2442) and oil content (0.2390) recorded moderate indirect effect through dry weight of roots while number of suckers per plant (0.1691), girth of mother rhizome (0.1738), number of secondary rhizomes (0.1247), length of secondary rhizomes (0.1645) and girth of secondary rhizomes (0.1616) had low indirect effect through dry weight of roots whereas harvest index (0.1633) and driage (-0.1560) recorded low negative indirect effect on dry weight of roots.

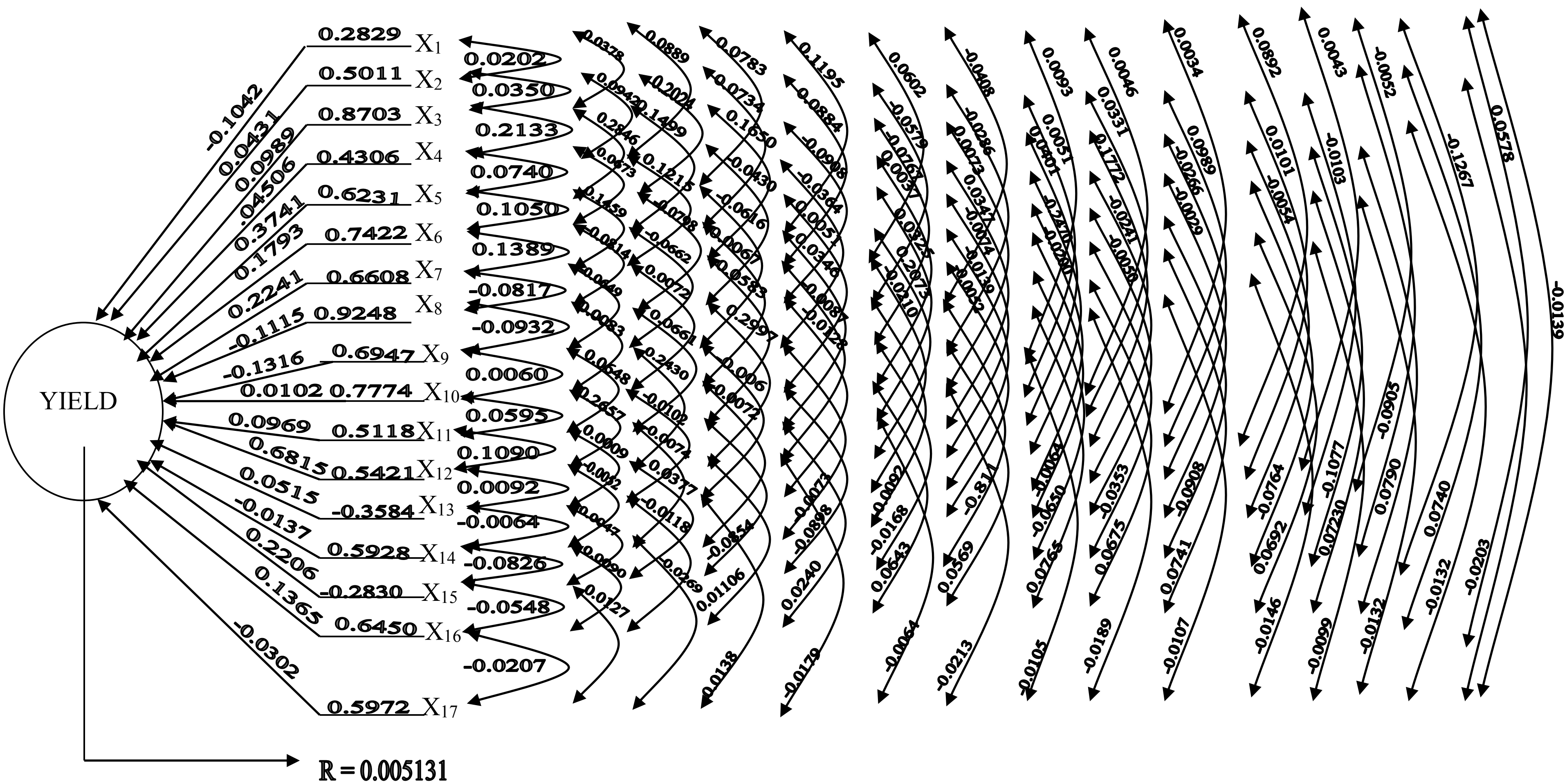
The characters plant spread (0.2024), fresh weight of leaves (0.2846),number of suckers per plant (0.2191), length of mother rhizome (0.2436)

## Table.25. Direct and indirect effects of different characters with yield under open condition:

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 | X16 | X17 | Genotypic correlation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X1 | **-0.1042** | 0.0202 | 0.0378 | 0.0889 | 0.0783 | 0.1195 | 0.0602 | -0.0408 | 0.0093 | 0.0046 | 0.0034 | 0.0892 | 0.0043 | -0.0052 | -0.1267 | 0.0578 | -0.0139 | 0.2829 |
| X2 | -0.0489 | **0.0431** | 0.035 | 0.0942 | 0.2024 | 0.0734 | 0.0884 | -0.0579 | -0.0286 | 0.0051 | 0.0331 | 0.0989 | 0.0101 | -0.0103 | -0.0905 | 0.074 | -0.0203 | 0.5011 |
| X3 | -0.0398 | 0.0152 | **0.0989** | 0.2133 | 0.2846 | 0.1499 | 0.165 | -0.0908 | -0.0767 | 0.0073 | 0.0401 | 0.1772 | -0.0266 | -0.0054 | -0.1077 | 0.079 | -0.0132 | 0.8703 |
| X4 | -0.0206 | 0.009 | 0.0468 | **0.4506** | 0.074 | 0.0673 | 0.1215 | -0.043 | -0.0364 | 0.0037 | 0.0347 | -0.247 | -0.0241 | -0.0029 | -0.0764 | 0.0723 | 0.001 | 0.4306 |
| X5 | -0.0218 | 0.0233 | 0.0753 | 0.0891 | **0.3741** | 0.105 | 0.1459 | -0.0798 | -0.0616 | 0.0051 | 0.0325 | -0.0074 | -0.02 | -0.005 | -0.0908 | 0.0692 | -0.0099 | 0.6231 |
| X6 | -0.0694 | 0.0176 | 0.0827 | 0.1691 | 0.2191 | **0.1793** | 0.1389 | -0.0814 | -0.0662 | 0.0067 | 0.0346 | 0.2073 | -0.0139 | -0.0064 | -0.1353 | 0.0741 | -0.0146 | 0.7422 |
| X7 | -0.028 | 0.017 | 0.0728 | 0.2442 | 0.2436 | 0.1111 | **0.2241** | -0.0817 | -0.0649 | 0.0072 | 0.0583 | -0.0087 | -0.021 | -0.0052 | -0.165 | 0.0675 | -0.0107 | 0.6608 |
| X8 | -0.0381 | 0.0224 | 0.0806 | 0.1738 | 0.2678 | 0.1309 | 0.1643 | **-0.1115** | -0.0932 | 0.0083 | 0.0661 | 0.2997 | -0.0128 | -0.0092 | -0.0811 | 0.0756 | -0.0189 | 0.9248 |
| X9 | 0.0074 | 0.0094 | 0.0577 | 0.1247 | 0.1752 | 0.0902 | 0.1105 | -0.0789 | **-0.1316** | 0.006 | 0.0648 | 0.243 | -0.0058 | -0.0073 | -0.0168 | 0.0569 | -0.0105 | 0.6947 |
| X10 | -0.0473 | 0.0216 | 0.071 | 0.1645 | 0.1883 | 0.1186 | 0.1588 | -0.091 | -0.078 | **0.0102** | 0.0595 | 0.2657 | -0.0102 | -0.0072 | -0.0898 | 0.0643 | -0.0213 | 0.7774 |
| X11 | -0.0036 | 0.0147 | 0.041 | 0.1616 | 0.1253 | 0.0641 | 0.1349 | -0.0761 | -0.088 | 0.0062 | **0.0969** | 0.109 | 0.0009 | -0.0074 | -0.0854 | 0.024 | -0.0064 | 0.5118 |
| X12 | -0.0136 | 0.0063 | 0.0257 | -0.1633 | -0.0041 | 0.0546 | -0.0028 | -0.049 | -0.0469 | 0.004 | 0.0155 | **0.6815** | 0.0092 | -0.0052 | 0.0377 | 0.0106 | -0.0179 | 0.5421 |
| X13 | -0.0086 | 0.0085 | -0.0512 | -0.2105 | -0.1454 | -0.0484 | -0.0913 | 0.0278 | 0.0147 | -0.002 | 0.0017 | 0.122 | **0.0515** | -0.0064 | 0.0047 | -0.0118 | -0.0138 | -0.3584 |
| X14 | -0.0394 | 0.0326 | 0.039 | 0.0947 | 0.1362 | 0.0838 | 0.0846 | -0.0747 | -0.0707 | 0.0054 | 0.0521 | 0.258 | 0.0242 | **-0.0137** | -0.0826 | 0.09 | -0.0269 | 0.5928 |
| X15 | 0.0598 | -0.0177 | -0.0483 | -0.156 | -0.154 | -0.1099 | -0.1675 | 0.041 | 0.01 | -0.0041 | -0.0375 | 0.1165 | 0.0011 | 0.0051 | **0.2206** | -0.0548 | 0.0127 | -0.283 |
| X16 | -0.0442 | 0.0234 | 0.0573 | 0.2387 | 0.1896 | 0.0973 | 0.1109 | -0.0617 | -0.0548 | 0.0048 | 0.0171 | 0.053 | -0.0044 | -0.009 | -0.0886 | **0.1365** | -0.0207 | 0.645 |
| X17 | -0.0478 | 0.029 | 0.0431 | -0.0146 | 0.1226 | 0.0865 | 0.0796 | -0.0696 | -0.0458 | 0.0072 | 0.0206 | 0.4046 | 0.0234 | -0.0122 | -0.0929 | 0.0936 | **-0.0302** | 0.5972 |

R=0.005131

**Fig.7. Path Diagram showing direct and indirect effects of components of yield**




**Direct effects are given in straight lines and indirect effects in curved lines**

| | | |
|---|---|---|
| X1 - Number of Tillers | X7-Length of Mother Rhizome | X13- Leaf area ratio |
| X2 - Plant Spread | X8 -Girth of Mother Rhizome | X14- Leaf area index |
| X3 -Fresh Weight of Leaves | X9 -Number of Secondary Rhizomes | X15- Driage |
| X4 -Dry Weight of Roots | X10-Length of Secondary Rhizomes | X16- Oil |
| X5- Dry Weigh of Leaves | X 11-Girth of Secondary Rhizomes | X17-Oleoresin |

and girth of mother rhizome (0.2678) recorded moderate indirect effect through dry weight of leaves while number of secondary rhizomes (0.1752), length of secondary rhizome(0.1883), girth of secondary rhizome(0.1253), leaf area index (0.1362), oil content (0.1896) and oleoresin content (0.1223) showed low indirect effect through dry weight of leaves and the characters leaf area ratio (-0.1454) and driage (-0.1540) showed negative low indirect effect through dry weight of leaves.

The characters fresh weight of leaves (0.1650), dry weight of roots (0.1215), and dry weight of leaves (0.1459), number of suckers per plant (0.1389), girth of mother rhizome (0.1643), number of secondary rhizome (0.1105), length of secondary rhizome (0.1588), girth of secondary rhizome (0.1349) and oil content (0.1109) showed low indirect effect through length of mother rhizome while driage (-0.1675) recorded low negative indirect effect through length of mother rhizome.

Oleoresin content(0.4046) and girth of mother rhizome (0.2997) showed a high indirect effect on yield through harvest index while the characters number of suckers per plant (0.2073), number of secondary rhizome (0.2430), length of secondary rhizome (0.2657) and leaf area index (0.2580) recorded moderate indirect effect through harvest index and the characters fresh weight of leaves (0.1772), girth of secondary rhizome (0.1090), leaf area ratio (0.1220) and driage (0.1165) recorded low indirect effect on yield through harvest index.

Number of leaves per plant (-0.1267), fresh weight of leaves (-0.1077), number of suckers per plant (-0.1353) and length of mother rhizome (-0.1650) showed low negative indirect effect on yield through driage.

**4.1.22. Genetic divergence analysis:**

The genotypes were subjected to Mahalanobis $D^2$ analysis based on eight most prominent characters such as number of leaves per plant, plant spread, fresh weight of leaves, dry weight of roots, number of secondary rhizomes, girth of secondary rhizomes, driage and yield .The genotypes were grouped into seven

**Table.26.Clustering pattern of different genotypes of kacholam:**

| Cluster number | Genotypes | Number of genotypes |
|---|---|---|
| I | $KG_4$ | 1 |
| II | $KG_7$ | 1 |
| III | $KG_{21}$ | 1 |
| IV | $KG_2$,$KG_{13}$,$KG_{22}$ | 3 |
| V | $KG_8$,$KG_{10}$,$KG_{11}$ | 3 |
| VI | $KG_1$,$KG_9$,$KG_{12}$ | 3 |
| VII | $KG_3$,$KG_5$,$KG_6$,$KG_{14}$,$KG_{15}$,$KG_{16}$,$KG_{17}$,$KG_{18}$ $KG_{19}$,$KG_{20}$ | 10 |
| **Total** | | **22** |

**Table.27.Contribution of each character to divergence:**

| Character | Percentage of contribution |
|---|---|
| Number of leaves per plant | - |
| Plant spread | 2 |
| Fresh weight of leaves per plant | 2 |
| Dry weight of roots per plant | 29 |
| Number of secondary rhizomes per plant | - |
| Girth of secondary rhizomes per plant | 4 |
| Driage | 2 |
| Yield | 61 |
| **Total** | **100** |

**Table.28. Intra and inter cluster D values:**

| Cluster | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| **I** | 0 | | | | | | |
| **II** | 31.44 | 0 | | | | | |
| **III** | 48.27 | 43.18 | | | | | |
| **IV** | 27.00 | 20.14 | 29.87 | 13.42 | | | |
| **V** | 25.86 | 18.73 | 54.43 | 29.16 | 13.17 | | |
| **VI** | 39.93 | 15.87 | 54.07 | 31.09 | 22.10 | 12.19 | |
| **VII** | 16.41 | 32.02 | 35.45 | 21.77 | 33.12 | 42.79 | 10.97 |

clusters using Tochers' method of clustering. The clustering pattern is presented in Table 26 and Fig.8.

Cluster VII had highest number of genotypes (10) followed by clusters IV (3), V (3) and VI (3). Cluster I, II and III had one genotype each. Cluster VII had the genotypes $KG_3$, $KG_5$, $KG_6$ ,$KG_{14}$ ,$KG_{15}$, $KG_{16}$ ,$KG_{17}$ ,$KG_{18}$, $KG_{19}$ and $KG_{20}$.The genotypes $KG_1$, $KG_9$ and $KG_{12}$ are included in cluster VI .The genotypes $KG_8$, $KG_{10}$ and $KG_{11}$ constituted cluster V. Cluster IV had $KG_2$, $KG_{13}$, and $KG_{22}$. The genotypes $KG_4$, $KG_7$ and $KG_{21}$ remained as divergent genotypes that cannot be accommodated by any of the clusters and each remained as a separate cluster.

When the contribution of different characters towards divergence (Table.27) was calculated, yield (61) contributed the maximum percentage for divergence followed by dry weight of roots (29).

The average inter and intra cluster distances were estimated based on the total $D^2$ values. The inter and intra cluster distance (D) of various clusters were worked out and presented in Table 28.The intra cluster distance varied from 0 (cluster I,II and III) to 13.41 (cluster IV).The inter cluster distances varied from 15.87 (between cluster VI and II) to 54.43 (between cluster V and III). Maximum divergence was shown between clusters III and V while minimum between clusters II and VI. The intra cluster distance was highest for the cluster IV

Cluster means were calculated and presented in Table 29 .Cluster means were high in cluster I for the characters like number of days for sprouting, number of leaves, leaf breadth, plant spread, harvest index, leaf area, leaf area ratio and leaf area index. Cluster VI had high cluster means for fresh and dry yield of rhizomes. Cluster means for fresh weight of leaves, the character which contributes 2 percent for divergence was high in cluster VI. Dry weight of roots contributes 29 percent for divergence show maximum cluster means in cluster III.

The cluster means for the character number of secondary rhizomes per plant was high in cluster VI. Girth of secondary rhizomes, the character which had

**Table.29.Cluster means of different yield and yield attributing characters:**

| Characters | Cluster means | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Number of days for sprouting | 23.33 | 19.7 | 16.67 | 20.1 | 17.7 | 20.7 | 19.77 |
| Number of leaves/plant | 13.4 | 12 | 10.07 | 11.8 | 12.6 | 11.8 | 12.23 |
| Leaf length | 16.6 | 13.8 | 10.83 | 15.3 | 15.7 | 16 | 14.08 |
| Leaf breadth | 12.2 | 11.9 | 9 | 12.8 | 13.2 | 13.3 | 11.93 |
| Plant spread | 30.27 | 27.2 | 19.17 | 29.4 | 29.9 | 27.7 | 24.91 |
| Fresh weight of leaves /plant | 19.53 | 33 | 20.6 | 23.2 | 29 | 32.6 | 19.9 |
| Fresh weight of roots /plant | 12.73 | 17.3 | 19.07 | 18.6 | 15.5 | 19.9 | 14.02 |
| Dry weight of roots /plant | 5.6 | 9.67 | 11.4 | 11.2 | 7.47 | 10.7 | 6.2 |
| Dry weight of leaves /plant | 11 | 12.9 | 9.2 | 11.9 | 12.9 | 13 | 10.71 |
| No: of suckers /plant | 6.267 | 9.07 | 4.333 | 6.42 | 7.13 | 7.82 | 5.513 |
| Length of mother rhizome /plant | 3.173 | 3.15 | 3.053 | 3.27 | 3.26 | 3.62 | 3.05 |
| Girth of mother rhizome /plant | 7 | 7.4 | 6.387 | 7.02 | 7.42 | 8 | 6.908 |
| No: of secondary rhizomes /plant | 8.933 | 10.9 | 9 | 9.98 | 10.8 | 12.4 | 10.33 |
| Length of secondary rhizomes /plant | 2.787 | 3.4 | 2.33 | 2.95 | 3.13 | 3.54 | 2.779 |
| Girth of secondary rhizome /plant | 5.57 | 5.51 | 5.14 | 5.59 | 5.42 | 6.44 | 5.497 |
| Fresh yield of rhizomes/ plant | 51.47 | 67.1 | 42.4 | 54 | 69.2 | 79.9 | 45.99 |
| Dry yield of rhizome /plant | 22.2 | 29.5 | 22.2 | 23.1 | 31.8 | 33.1 | 21.83 |
| Volatile oil | 0.65 | 0.74 | 0.62 | 1.18 | 1.34 | 1.17 | 0.684 |
| Oleoresin | 4.233 | 4.17 | 3.9 | 4.24 | 4.34 | 4.29 | 4.197 |
| Driage | 43.18 | 44 | 52.37 | 42.7 | 46.1 | 41.5 | 47.59 |
| Harvest index | 0.572 | 0.57 | 0.519 | 0.5 | 0.61 | 0.58 | 0.564 |
| Leaf Area | 99.01 | 80.1 | 47.73 | 95.5 | 101 | 98.3 | 82.07 |
| Leaf Area Ratio | 2.552 | 1.54 | 1.115 | 2.06 | 1.95 | 2.01 | 2.131 |
| Leaf area index | 1.65 | 1.33 | 0.795 | 1.59 | 1.69 | 1.64 | 1.368 |

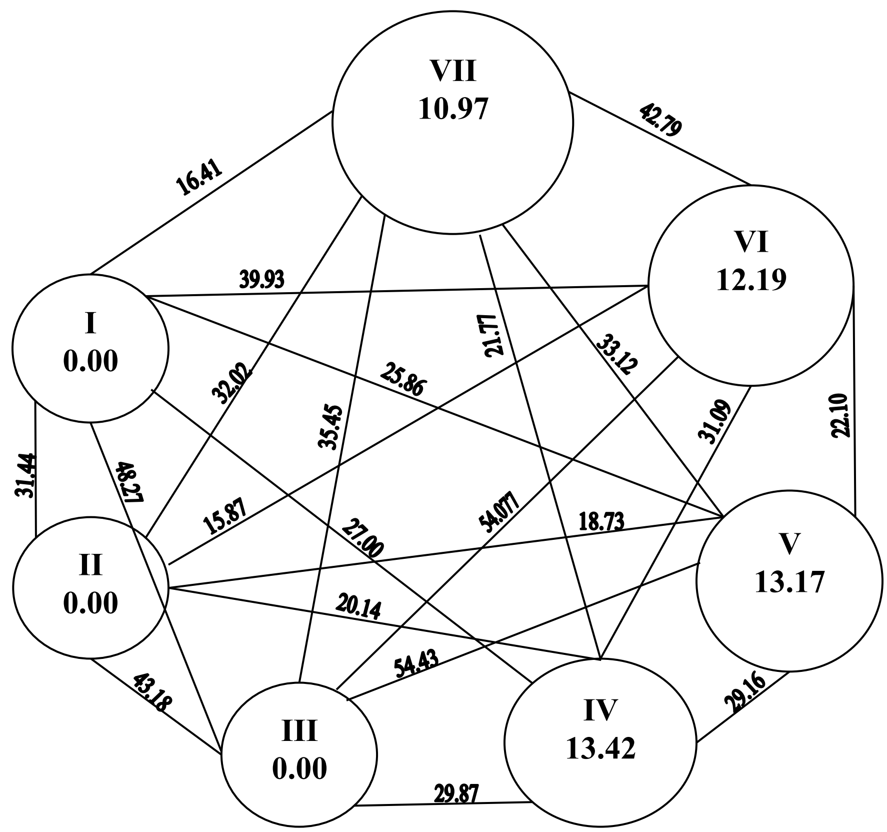
**Table.30.Selection index of different characters:**

| Characters | b coefficients |
|---|---|
| Number of leaves per plant | 6.41 |
| Plant spread | -5.49 |
| Fresh weight of leaves per plant | -3.78 |
| Dry weight of roots per plant | 0.89 |
| Dry weight of leaves per plant | 20.69 |
| Number of suckers per plant | 7.47 |
| Length of mother rhizome per plant | -4.80 |
| Girth of mother rhizome per plant | -10.50 |
| Number of secondary rhizomes per plant | 6.54 |
| Length of secondary rhizomes per plant | 9.78 |
| Girth of secondary rhizomes per plant | -1.09 |
| Harvest Index | 45.33 |
| Leaf Area Index | 4.06 |
| Leaf Area Ratio | 74.45 |
| Driage | -1.68 |
| Oil | -18.82 |
| Oleoresin | -23.66 |
| Yield | -0.10 |

**Table.31.Index score of different genotypes:**

| Genotypes | Score | Rank |
|---|---|---|
| $KG_1$ | 59.8483 | 6 |
| $KG_2$ | 65.60738 | 3 |
| $KG_3$ | 55.35611 | 8 |
| $KG_4$ | 41.43162 | 10 |
| $KG_5$ | 56.07667 | 7 |
| $KG_6$ | -9.84542 | 21 |
| $KG_7$ | 35.29401 | 14 |
| $KG_8$ | 35.29401 | 13 |
| $KG_9$ | 84.76631 | 1 |
| $KG_{10}$ | 62.8382 | 4 |
| $KG_{11}$ | 33.61176 | 15 |
| $KG_{12}$ | 71.35436 | 2 |
| $KG_{13}$ | 28.72618 | 18 |
| $KG_{14}$ | 28.75027 | 17 |
| $KG_{15}$ | 40.32289 | 11 |
| $KG_{16}$ | 62.36578 | 5 |
| $KG_{17}$ | 30.97019 | 16 |
| $KG_{18}$ | 2.452313 | 20 |
| $KG_{19}$ | 8.901761 | 19 |
| $KG_{20}$ | 55.21285 | 9 |
| $KG_{21}$ | -33.8996 | 22 |
| $KG_{22}$ | 37.35593 | 12 |

**Fig: 8. CLUSTER DIAGRAM**




Values in circles indicate intra cluster distance and others indicate inter cluster distance.

a 4 per cent contribution to divergence had its maximum cluster mean value in cluster VI. Cluster means was high in cluster III for driage

Cluster VI had maximum distance from cluster VII followed by cluster III, cluster V, cluster II, cluster IV and cluster I. Cluster VI was at a greatest distance from cluster III followed by cluster VII, cluster I, cluster IV, cluster V, and cluster II. Cluster V was at the maximum distance from cluster III followed by VII, IV, I, VI and II. Cluster VI had maximum distance from cluster IV followed by III, V, VII, II. Cluster III was at maximum distance from V, VI, I, II, VII and IV. Cluster II had maximum distance from cluster I followed by cluster VI, II, IV, V and cluster VII.

**4.1.23. Selection index:**

Selection index for the genotypes were computed based on the 18 characters given in Table 30 using the b coefficient values. Accordingly, selection index values were worked out and presented in Table .31. Based on this genotype $KG_9$ i.e., genotype from Neyyattinkara attained maximum selection index score followed by $KG_{12}$ (Koothattukulam) and $KG_2$ (Madavur) the minimum estimates were recorded for $KG_{21}$ (Alleppey) followed by $KG_6$ (Kasaragod) and $KG_{18}$ (Kozhikode).

The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in $D^2$ analysis. The genotypes in cluster VI ($KG_9$ and $Kg_{12}$) topped the list while the genotype $KG_{21}$ with least index formed a single cluster.

The performance of the genotypes from Neyyattinkara, Kannur, Koothattukulam, Madavur, Ponnukara, Kanyakumari dist, and Ponneyekkad were superior in terms of yield and quality parameters as a pure crop and as an intercrop in coconut plantations when compared to the released varieties. All these accessions can be considered for further improvement programmes. Since the crop is a clonally propagated one, an improvement once made in the specific gene combinations can be preserved for generations and superior clones released as varieties.

# Discussion

# 5. DISCUSSION

Yield components play an important role in any crop breeding programme. Plant breeders aim to improve crop productivity by seeking selection for appropriate yield components. Selection acts as the vital tool in plant breeding and has played an important role in the history of mankind. Ever since the beginning of agriculture consciously or unconsciously man has created genotypes which are more efficient in providing food, fibre and fuel. This is a continuous process and a never ending feature.

Kacholam (*Kaempferia galanga* L) is a high valued medicinal and aromatic annual herb. The rhizomes are used in many Ayurvedic, flavouring and culinary preparations. Kacholam is suited for cultivation in Kerala as a pure crop as well as an intercrop. Two separate field experiments viz., under open condition and under partially shaded condition in coconut gardens were conducted to study the performance of the crop under two growing conditions and extent of genetic variability in different genotypes of kacholam collected from different parts of Kerala and southern district of Tamil Nadu for yield and yield attributing characters. The results on the evaluation of genetic variability of kacholam (*Kaempferia galanga* L.) under open and partially shaded conditions are discussed in this chapter under different headings.

## 5.1. VARIABILITY:

An estimate of the magnitude of variability present in a population is of great importance as it provides basis for effective selection. The observed variability in a population is the total variation arising due to the genotypic and environmental effects. But only the genetic component of total variability contributes to gain under selection. So knowledge on the nature and magnitude of genetic variation governing the inheritance of quantitative characters like yield and its components is essential Allard (1960).

There was significant difference among the twenty two genotypes of kacholam collected from different parts for all the characters in the present study.

**5.1.1. Number of days for sprouting:**

The crop took more number of days for sprouting under partially shaded condition than under open condition. The genotypes from Kozhikode ($KG_{18}$) and Malappuram ($KG_{22}$) districts sprouted much earlier than other genotypes under open condition. Variation in number of days for sprouting between the genotypes observed in the present study was supported by the findings of Nybe (1978) in ginger types.

**5.1.2. Number of leaves:**

From the results it is clear that there existed no variation in number of leaves produced under open and partially shaded condition at two months after planting. The influence of shade on leaf number was quite visible at four months and six months after planting. The leaf number showed an increasing trend under partially shaded condition. In contrast to the results of the present study the number of leaves produced under open condition was higher in kacholam as reported by Latha (1994). But an increase in number of leaves of kacholam under partially shaded condition was also reported from Kerala Agricultural University (KAU, 1999). Similar response to shade was reported by Jessykutty (2003). The influence of environment is not uniform over the genotypes. After six months of planting variety Rajani ($KG_{16}$) showed maximum number of leaves under both the growing conditions. Performance of genotype from Idukki was very poor under both conditions. This indicates that this type is very much sensitive to environment. Significant variability in the number of leaves produced among the different types was noticed in the study. The same result was reported in turmeric by George (1981), Mukhopadhyay et al. (1986) and Menon et al. (1992) and in kacholam by Latha (1994).

**5.1.3. Leaf length:**

Leaf length showed variability only at the early stages of growth ie., two months after planting between the two situations in which crop was raised. At later stages there was no significant difference in leaf length when the two conditions were compared. Significant variation in leaf length was observed between the genotypes under both open condition and partially shaded condition. Similar results were observed indifferent types of kacholam under partially shaded condition by Latha (1994). In ginger types also, Nybe (1978) reported variability in leaf length under open condition. The above studies reveal that there exists variability in the effect of environment on leaf length between accessions.

The present study revealed the maximum length in leaves at 6 months after planting for all the genotypes and the genotypes of Koothattukulam ($KG_{12}$), Kannur($KG_1$), Palakkad and Idukki had the capacity of producing good vegetative growth under full sunlight whereas the genotypes from Wayanad ($KG_{17}$) and Kottayam ($KG_8$) were superior in terms of leaf length. The genotype Alleppey ($KG_{21}$) was with the shortest leaf length among the genotypes at different stages of its growth under both open and partially shaded condition. From the present study it is concluded that there was no much influence of light on length of leaves. The leaves were equally elongated under both conditions of growth.

**5.1.4. Leaf breadth:**

Genotypes differ significantly among themselves under open and partially shaded condition for this character. Mohanty et al (1981) also observed variability in leaf width in ginger ecotypes. Compared to both conditions, plants grown under full sunlight showed maximum leaf breadth. The leaves were narrower in general under partially shaded conditions. The genotype from Kannur ($KG_1$) showed maximum leaf breadth at two months after planting under both conditions. At four months and six months after planting the genotypes from Koothattukulam ($KG_{12}$), Pathanamthitta ($KG_{13}$) and Neyyattinkara ($KG_9$) showed maximum leaf breadth under open conditions. Leaf breadth had significant difference when genotypes were compared over open and partially shaded condition at all stages of growth.

**5.1.5. Leaf area:**

Leaf area showed considerable variability among the genotypes studied under both open and partially shaded condition. Significant variability was noticed in leaf area between the two conditions and leaf area was maximum under open condition than partial shade. The same result was reported by Latha (1994) in kacholam while the leaf area in ginger was not appreciably altered by shading. (Bai,1981). The genotype from Kannur ($KG_1$) show maximum leaf area under both the condition at two months after planting, but at four months after planting genotype Koothattukulam ($KG_{12}$) showed maximum leaf area at both the condition. Genotype from Alleppey ($KG_{21}$) had smaller leaves at all growth stages.

**5.1.6. Leaf area ratio:**

Leaf area ratio varied significantly among genotypes under both conditions of growth. Leaf area ratio was maximum under open condition. These results were supported by the findings of Latha (1994) in Kacholam and Vastrad et al., (2006) in ginger. The genotype Alleppey recorded minimum leaf area ratio over all growth stages under both the conditions. Under open condition, genotype Idukki recorded maximum leaf area ratio.

**5.1.7. Leaf area index:**

There existed no variability in leaf area index among the genotypes which was in accordance with the result of Latha (1994) in kacholam. In the present study even though the leaf area index was found to be higher under open condition there was significant variation in the performance of genotypes and the conditions. The reason can be attributed to the difference in vegetative growth of the types in different environments. Similar findings were reported by Bai (1981) in ginger, turmeric and coleus. Contrary to these, Jessykutty (2003) reported that leaf area index was found to increase with increasing levels of shade. Among types, leaf area was maximum for the genotype Kannur ($KG_1$) and minimum for the genotype Alleppey ($KG_{21}$).

**5.1.8. Plant spread:**

The character plant spread was found to be significantly different among the genotypes both under open and partially shaded condition. The results are in confirmation with those of Latha (1994) in kacholam. Plant spread was found to be high in partially shaded condition than under open. With increased plant spread, the photosynthetic surface is increased and thus photosynthesis. Under controlled condition of light infiltration, the plant extends more to capture more of solar radiation and thereby total spread of the plant is more in shade. The genotype Malappuram ($KG_{22}$) found to have maximum plant spread under open condition but under shade the genotype Neyyattinkara ($KG_9$) and Kanzhangad ($KG_{11}$) was found to perform well over different growth stages.

**5.1.9. Fresh weight of roots and leaves:**

Increased fresh weight of roots and leaves were recorded under partially shaded condition in the present study. This was in accordance with the study of Jessykutty (2003) in kacholam. Under shade the genotype Koothattukulam ($KG_{12}$) recorded maximum fresh weight of leaves and roots.

**5.1.10. Dry weight of roots and leaves:**

Dry weight of leaves was found to be high in open condition than under partial shade. But an increased dry weight of leaves was reported in turmeric under shade by Louis (2000). The genotype Ponneyekkad ($KG_{10}$) was found to have the highest dry weight of leaves under both conditions.

The dry weight of roots was higher under partially shaded condition. This was in accordance with the findings of Louis (2000). The genotype Kollam recorded maximum root dry weight under partially shaded condition.

**5.1.11. Flowering characters:**

From the results it was found that there was significant difference in number of days to flowering between the genotypes of kacholam. Flowering started earlier in the genotypes grown under open condition when compared to the intercrop under partially shaded condition in coconut garden. Similar results were obtained in kacholam by Latha (1994). There was considerable difference in days to flowering for the genotypes between open and partially shaded condition. The genotype from Kozhikode ($KG_{18}$) took minimum number of days for flowering while the genotype from Malappuram ($KG_{22}$) took maximum number of days for flowering under open condition. The number of days taken for flowering was more in partial shade than under open condition whereas the spread of flowering was more under open conditions which was in accordance with the findings of Latha (1994) in kacholam and Maheswarappa et al. (2000) in ginger. Regarding the spread of flowering there was variability among the genotypes. Genotype from Wayanad ($KG_{17}$) had prolonged flowering period where as variety Kasthuri had the shortest period under open condition. There was significant difference between the genotypes under open and partially shaded condition for number of flowers per inflorescence. It was more under open condition than in shade. Similar trend was noticed in kacholam by Latha (1994) and by Maheswarappa et al. (2000) in ginger. The number of flowers was highest in the genotypes from Ponnukara ($KG_3$) and Wayanad ($KG_{17}$) under open condition and lowest in the Neyyatinkara($KG_9$) genotype.

**5.1.12. Number of suckers per plant:**

Significant variability in number of suckers per plant was observed among the genotypes under both conditions. The same result was obtained in kacholam by Latha (1994).Variation in number of tillers was reported in ginger by Nybe (1978) and Mohanty et al., (1981) and in turmeric by Philip (1978) George (1981) and Mukhopadhyay et al., (1986). Number of suckers was more under open condition than under shade and the variety Kasthuri showed maximum number of suckers under open condition.

**5.1.13. Mother rhizome character:**

There existed significant variation in length and girth of mother rhizome among genotypes under open and partially shaded condition. Variability in length and girth of mother rhizome was reported in ginger by Nybe (1978) and in turmeric by George (1981). Length of mother rhizome was highest under open condition than shade and girth was maximum under partial shade. High moisture content in the rhizome can be attributed to the more girth of mother rhizome under partial shade. The genotype Kannur ($KG_1$), Koothattukulam ($KG_{12}$) and Neyyattinkara ($KG_9$) performed better in the case rhizome length under both conditions whereas the genotypes Koothattukulam (KG12) and Neyyattinkara ($KG_9$) gave big rhizomes in size under both conditions.

**5.1.14. Secondary rhizome character**:

High amount of variability was noted in number of secondary rhizomes among genotypes under open and partially shaded condition which is in line with the findings of Latha (1994) in kacholam. Variability in the number of secondary rhizome was reported in turmeric by Philip (1978). Number of secondary rhizome was more in partially shaded condition than under open condition which is in contradiction to the findings of Latha (1994). The genotype Koothattukulam ($KG_{12}$) showed maximum length for mother rhizome and Alleppey ($KG_{21}$) showed minimum under partially shaded condition. Length of secondary rhizome was more in open condition than under partially shaded condition. The genotype Koothattukulam ($KG_{12}$) showed highest length of secondary rhizome under both conditions and Alleppey($KG_{21}$) performed poorer. There existed no significant variation in girth of secondary rhizome among types under both conditions. This was similar to findings of Latha (1994).

**5.1.15. Yield characters:**

The fresh rhizome yield, dry rhizome yield and drying percentage were found to be significantly different for the genotypes under both conditions. The genotype Kannur ($KG_1$) was found to be superior in case of fresh yield and Koothattukulam ($KG_{12}$) found to be superior regarding the dry yield of rhizome. Compared to both conditions fresh and dry yield was more under open condition. The study was in accordance with the study of Jessykutty and Latha (1994) in Kacholam. The same results were reported in turmeric by Ramadasan and Satheesan (1980), Bai (1981), Varughese (1989) and Nair et al (1991). But Kumar et al (2005) reported that the presence or absence of over canopy seemed to have little effect on kacholam (galanga) yield as yield response under no over canopy, single strata and multi strata are similar.

Drying percentage of kacholam was found to be more under shade than under open condition. The result was supported by the findings of Varughese (1989) in turmeric and George (1992) in ginger.

Even though fresh and dry yield of rhizomes were more under open condition, the results showed that the rhizome yield under partially shaded condition was also comparable with that under open condition. This indicates that crop can also be adopted as an intercrop in many plantations .This was in agreement with the reports of Jessykutty (2003) in kacholam.

**5.1.16. Harvest index:**

There was no significant variability in harvest index between the conditions. The harvest index was found to be similar under open and partially shaded condition. The result was in contrary to the reports of Jessykutty (2003) in which she reported high harvest index under open condition.

**5.1.17. Quality Parameters:**

From the results it is clear that the content of volatile oil and oleoresin was found to be similar under open and partially shaded condition and no significant variation existed regarding these parameters. However there was a slight increase in oil content under open condition. This was in accordance with reports of Kurian et al (2000). Jessykutty (2003) also reported that at higher shade intensities the oil content decreased and was equal to that under open condition. The result of present study was in contradictory to the findings of Maheswarappa (1999). Oleoresin content was also found to be similar under both conditions. But this was contrary to the reports of Kurian et al (2000) and Jessykutty (2003) as they reported increased oleoresin content under partially shaded condition.

So the present study on the variability of kacholam genotypes revealed the presence of variability and scope for selection in the yield contributing characters like number of days to sprouting, leaf length and breadth, number of leaves, leaf area, LAI, LAR, plant spread, fresh and dry weight of leaves, all the flowering characters, number of suckers per plant, mother rhizome characters such as number and girth and secondary rhizome characters like number and length. Direct selection based on all the above characters and also yield is found to be effective.

**5.2. GENETIC PARAMETERS:**

Variability is also expressed as coefficients of variation .Coefficients of variation, phenotypic (PCV) and genotypic (GCV) are better indices for comparison of characters with different units of measurements. The GCV provides a valid basis for comparing and assessing the range of genetic variability for quantitative characters and PCV measures the extent of total variation. There was a close relationship between genotypic and phenotypic coefficients of variation for almost all characters. (Table22 and 23) The similarity between PCV and GCV indicated low environment influence and reflected the reliability of influence of selection based on phenotypic performance

In present study GCV ranged from 2.17 to 34.87 under open condition and 1.89 to 32.92 under partially shaded condition .Highest GCV was for volatile oil followed by dry weight of roots under open condition and under partially shaded condition volatile oil record highest GCV followed by fresh weight of leaves. Lowest was for oleoresin under both conditions. GCV and PCV were highest for fresh yield of rhizome per plant. This was in agreement with the study of Mukhopadhayay (1986) in turmeric, Yadav (1999), Singh and Mittal (2003) in ginger .Leaf length, leaf breadth, length and girth of mother rhizome records low to moderate GCV and PCV under both conditions. This result was supported by the findings of Prasad et al (1998) in ginger. High GCV was recorded for fresh yield of rhizome under both the conditions. The result was in agreement with Indiresh et al (1992) who reported high GCV for fresh yield of turmeric indicating high degree of genetic variability for the characters and Ali et al (1994) also reported the same in ginger types.

High heritability and genetic advance expressed as percentage of mean was recorded for the characters like fresh yield of rhizome, dry weight of roots, number of secondary rhizomes, leaf breadth was in agreement with the findings of Mohanty (1979) in turmeric cultivars. Highest heritability and genetic advance was recorded for volatile oil in present study. Heritability was lowest for oleoresin which confirms the findings of Philip and Nair (1986) in turmeric. High heritability of number of suckers per plant in present study was supported by the findings of Mukhopadhayay (1986) in turmeric genotypes.

**5.3. CORRELATION STUDIES:**

Yield is a complex character influenced by many characters either positively or negatively .So selection for yield should take into account related characters as well. Correlation provides information on the nature and extent of relationship between pairs of character. Therefore analysis of yield in terms of genotypic correlation coefficients of component character leads to the identification of character that can form the basis of selection.

In present investigation almost all characters show positive and significant correlation with yield under both conditions. The characters like leaf area index, number of suckers, plant spread, number of secondary rhizomes, girth of primary and secondary rhizomes and number of primary rhizomes show significant positive correlation with yield .Same result was reported in kacholam by Latha (1994) and Kanakamony (1997) and in ginger by Nybe (1978)

Highest positive significant correlation was noticed for girth of mother rhizome (0.913) with yield .This was in accordance with the result of Philip (1978) and Chandra et al. (1999) in turmeric

Length of mother rhizome, number of suckers, length and number of secondary rhizomes are found to be positively and significantly correlated with yield under both conditions. This was similar to the results obtained in turmeric by Yadav et al. (2006), Narayanpur and Hanashetti (2003) and Singh et al. (2003).

**5.4. PATH ANALYSIS:**

Correlation of yield and its components does not give an exact picture of the relative importance of the various yield attributes. Rate of crop improvement is expected to be rapid if differential emphasis is laid on the component characters during selection .Path coefficient analysis helps in partitioning the genotypic correlation coefficient into direct and indirect effect of the component character on yield on the basis of which improvement programme can be devised more effectively.

In the present study rhizome yield per plot had high direct effect and high positive correlation with harvest index followed by dry weight of roots, dry weight of leaves, number of suckers per plant ,length of mother rhizome ,driage and volatile oil

Number of leaves, girth of mother rhizome and number of secondary rhizome show negative direct effects on yield. But this contradicts with the opinion of Geetha (1985) and Tomar et al.( 2005) in turmeric .Girth of secondary rhizome had very low positive direct effect on yield .This was against the opinion of Abraham and Latha(2003) as a high positive direct effect of thickness of secondary rhizome with yield was noticed by them in ginger. A very low residual effects (R=0.0051) was also noticed in the present study.

**5.5. GENETIC DIVERGENCE:**

Mahalnobis $D^2$ statistic (Mahalanobis, 1936) is one of the potent technique of measuring genetic divergence. The technique measures the force of differentiation at the intra cluster and inter cluster levels and thus provides a basis for selection.

Following Mahalanobis $D^2$ statistic, the 22 genotypes were grouped into seven clusters. The clustering pattern is presented in Table.27. Cluster VII had highest number of genotypes (10) followed by clusters IV (3), V (3) and VI (3) .The clusters I, II and III had one genotype each. The inter and intra cluster distance (D) of various clusters were worked out and presented in Table 29.

From Table.29. it was clear that major characters contributing to divergence was yield (61%) followed by dry weight of roots (29%).This result was similar to result obtained by Singh et al (2000) in turmeric.

Intra and inter cluster distance values (Table 29) showed wide genetic divergence among the genotypes and this trend was noticed in turmeric by Rao et al (2005).

The genotypes Ponnukara ($KG_3$), Kanyakumari($KG_5$), Kasargod ($KG_6$), Poojappura($KG_4$), Kollam($KG_{15}$), Wayanad($KG_{17}$), Kozhikode($KG_{18}$), Idukki($KG_{19}$), Ernakulum ($KG_{20}$) and variety RajaniKG16 showed similarity with each other and comes under a single cluster and the genotypes from Palakad ($KG_4$), Alleppey($KG_{21}$) and variety Kasthuri($KG_7$) were the divergent genotypes and formed different clusters with single genotype .This type of clustering was reported in Kasturi turmeric by Alex (2005).

**5.6. SELECTION INDEX:**

Selection of genotypes based on suitable index is highly efficient in any breeding programme. An estimation of discriminant function based on reliable and effective characters is a valuable tool for plant breeders. Superior genotypes can be selected from a collection of genotypes using selection index employing the discriminant function. In the present study, the selection indices for the genotypes were computed on the basis of 18 characters and the leaf area index had the highest b coefficient value (74.45) followed by harvest index (45.33) and dry weight of leaves (20.69) as given in Table.31.

Accordingly selection index were calculated and presented in Table 32. Genotype Neyyatinkara attained maximum selection index followed by Madavur, Koothattukulam, Ponneyakad variety Rajani, Kannur and so on. The efficiency of the technique in identifying high yielding genotypes depends on inclusion of several important yield associated characters.

# *Summary*

# 6. SUMMARY

Kacholam (*Kaempferia galanga* L.) is one of the most important commercially exploited medicinal plant of Kerala. Evaluation of genetic variability existing among different genotypes was carried out in twenty genotypes from Kerala and southern parts of Tamil Nadu along with two released varieties, Kasthuri and Rajani in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2007-2008. The experiment was aimed at studying the extent of variability in morphological, biochemical and yield characters of kacholam. Identification of best genotype in terms of yield and quality parameters for large scale cultivation was also attempted in the study. The study also aimed to compare the performance of genotypes under open condition and as an intercrop in coconut gardens under partial shade. Various studies including variability studies, estimation of genetic parameters like heritability, genetic advance, correlation studies, path coefficient analysis, genetic divergence analysis and selection index were carried out. The salient results of investigation are summarised below:

- Analysis of variance revealed significant difference among the genotypes for all the characters studied and the pooled analysis showed significant difference between genotypes averaged over two conditions for all characters
- The study on variability of *Kaempferia galanga* L. types also revealed the presence of considerable amount of variability in characters and scope for selection of the characters like plant spread, fresh weight of leaves, dry weight of roots, dry weight of leaves, number of suckers per plant, length of mother rhizome, girth of mother rhizome, number of secondary rhizomes, length of secondary rhizomes, girth of secondary rhizomes, harvest index, leaf area index, fresh yield of rhizome, dry yield of rhizome, driage, oil and oleoresin content under both open and partially shaded condition

- Neyyattinkara and Koothattukulam were the best genotype regarding fresh yield of rhizome under open and partially shaded conditions.
- The genotype Koothattukulam and Kanzhangad recorded maximum dry yield of rhizomes under open condition whereas the genotypes Koothattukulam and Neyyattinkara give maximum dry yield of rhizomes under partially shaded conditions.
- Performance of the genotype from Alleppey was poor irrespective of growing situations.
- Regarding oil yield of rhizomes, Kannur genotype was the superior type under both open and partially shaded conditions.
- The study on the comparative performance of the genotypes under open and shaded condition revealed that the characters such as leaf breadth, leaf area, leaf area ratio, leaf area index, dry weight of leaves, spread of flowering, number of flowers per inflorescence, number of suckers per plant, length of mother rhizome, length of secondary rhizome, fresh dry yield of rhizomes were more under open condition.
- The characters such as number of days for sprouting, number of leaves, plant spread, fresh weight of leaves, fresh and dry weight of roots, number of days to flowering, girth of mother rhizome, number of secondary rhizomes and driage were more under partially shaded condition.
- The difference in the characters like leaf length, girth of secondary rhizomes, harvest index, oleoresin and oil content of the various genotypes were non significant between open and partially shaded condition.
- Even though the fresh and dry yield of rhizome of kacholam was lesser under partially shaded condition, the yield was comparable with yield under open condition which indicates that kacholam can be successfully grown as an intercrop in coconut gardens also. Among the twenty two genotypes, the

genotype Kannur, Koothattukulam and Neyyattinkara showed their superiority under partially shaded condition.

- High estimates of heritability (broad sense) were observed for almost all characters studied. Volatile oil, dry yield of rhizomes per plant, fresh yield of rhizome per plant, dry weight of roots, fresh weight of roots had highest heritability and genetic advance under open and partially shaded condition. So selection will be effective for these characters. Direct selection for rhizome yield also will also be reliable
- The characters plant spread, fresh weight of leaves, dry weight of roots, dry weight of leaves, number of suckers per plant, length of mother rhizome, girth of mother rhizome, number of secondary rhizome, length of secondary rhizome, girth of secondary rhizome, harvest index, leaf area index, oil and oleoresin content recorded highly significant positive correlation with yield Leaf area ratio was found to be negatively correlated with rhizome yield.
- In the case of partially shaded condition, the characters like plant spread, fresh weight of leaves, dry weight of leaves, number of suckers per plant, length of mother rhizome per plant, girth of mother rhizome per plant, number of secondary rhizomes per plant, length of secondary rhizome per plant, girth of secondary rhizome per plant, harvest index, leaf area index and oil content was found to be positively and significantly correlated with yield. Leaf area ratio, driage and oleoresin were found to be negatively correlated with yield.
- The characters like plant spread, fresh weight of leaves, dry weight of roots, dry weight of leaves, number of suckers per plant, length of mother rhizome, girth of mother rhizome, number of secondary rhizomes, length of secondary rhizome, leaf area index, fresh yield of rhizomes and dry yield of rhizomes were found to be positively and significantly correlated with oil yield.
- Considering the partially shaded condition the characters such as plant spread, fresh weight of leaves, dry weigh of leaves, number of suckers per plant,

length of mother rhizome, girth of mother rhizome, number of secondary rhizomes, length of secondary rhizome, girth of secondary rhizome fresh yield of rhizomes and dry yield of rhizomes found to be positively and significantly correlated with oil yield.

- The characters like harvest index, dry weight of roots and dry weight of leaves had high correlation and direct effect on yield. So selection based on these characters will also be effective.
- Among the characters selected for genetic divergence analysis dry yield of rhizomes per plant and dry weight of roots contributed more to the divergence.
- Following Mahalanobis $D^2$ statistics the twenty genotypes were grouped into seven clusters. Maximum divergence was shown between clusters III and V while minimum between clusters II and VI. The intra cluster distance was highest for the cluster IV.
- The genotypes such as Palakkad local, Alleppey and the Variety Rajani were divergent genotypes that cannot be accommodated by any of the clusters and so each remained as a separate cluster.
- Selection indices for 22 genotypes were worked out and maximum index values were obtained for genotype Neyyattinkara followed by Koothattukulam. The minimum estimates were recorded by Alleppey followed by Kasaragod.
- The grouping of genotypes by selection indices followed almost the same pattern as their clustering pattern in $D^2$ analysis. The genotypes in cluster VI (Neyyattinkara and Koothattukulam) topped the list while the genotype Alleppey with least index formed a single cluster.

The performance of the genotypes from Kannur, Madavur, Ponnukara, Kanyakumari district, Neyyattinkara, Ponneyekkad and Koothattukulam were superior in terms of yield and quality parameters as a pure crop and as an intercrop in coconut plantations when compared to the released varieties. As being a vegetatively propagated crop, kacholam has the unique advantage of keeping specific gene combinations intact for generations. The performance potential of the above high yielding genotypes may be confirmed through repeated trials and the outstanding cultures may be released as a variety.

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* Original not seen

# Abstract

# GENETIC VARIABILITY IN KACHOLAM (*Kaempferia galanga* L.) UNDER OPEN AND PARTIALLY SHADED CONDITIONS.

DIVYA KRISHNAN

Abstract of the
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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM,695522

## ABSTRACT

A research programme was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2007-08 with the object of assessing the genetic variability in kacholam genotypes for yield and yield attributing characters. Data on the investigations were recorded from two field experiments- one under open and other under partially shaded conditions.

Twenty two genotypes including two released varieties (Kasthuri and Rajani) were evaluated for yield and related characters in field experiments in RBD with three replications under open and partially shaded conditions in coconut garden. Analysis of variance revealed significant difference among the genotypes for all the 37 characters studied.

Genotypic and phenotypic coefficients of variation were highest for volatile oil, dry weight of roots, and fresh weight of leaves and fresh yield of rhizome per plant under both conditions. Under both conditions, characters such as fresh yield of rhizome, dry yield of rhizomes, fresh weight of leaves, dry weight of roots, length of secondary rhizomes and volatile oil showed high heritability coupled with high genetic advance. Rhizome yield showed significant positive correlation with fresh weight of leaves, number of suckers per plant and length of mother rhizome under both the conditions. Leaf area ratio was found to be negatively correlated with rhizome yield under both open and partially shaded conditions. Volatile oil, dry yield of rhizomes per plant, fresh yield of rhizome per plant, dry weight of roots, fresh weight of roots had highest heritability and genetic advance under two conditions viz., open and partially shaded condition.

The characters such as plant spread, fresh weight of leaves, dry weight of leaves, number of suckers per plant, length of mother rhizome, number of secondary rhizomes, length of secondary rhizome, girth of secondary rhizome fresh yield of

rhizomes and dry yield of rhizomes found to be positively and significantly correlated with oil yield under both conditions.

Path analysis revealed that harvest index, dry weight of roots and dry weight of leaves were the primary yield contributing characters due to their high direct effect on rhizome yield.

Mahalanobis $D^2$ analysis clustered the twenty two genotypes into seven clusters. Cluster VII formed the largest cluster with 10 genotypes while clusters I, II and III had one genotype each. The genetic distance was maximum between clusters III and V while minimum divergence was between clusters II and VI. The intra cluster distance was highest for cluster IV. Selection index revealed that the genotypes Neyyattinkara attained maximum selection index value followed by Koothattukulam and minimum estimates were recorded by Alleppey and Kasaragod.

The genotypes from Neyyattinkara, Koothattukulam, Madavur, Ponneyekkad, Kannur, Ponnukara and Kanyakumari district and were superior in terms of yield and quality parameters as pure crop and as an intercrop in coconut plantations. So these genotypes can be considered for further crop improvement programme.