

**EVALUATION OF GINGER (*Zingiber Officinale* ROSC.) GENOTYPES
FOR GROWTH, YIELD AND QUALITY UNDER COCONUT
ECOSYSTEM**

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2011

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*Thesis submitted in part of fulfillment of the requirements for the Degree of
MASTER OF SCIENCE IN HORTICULTURE specialized in Spices and Plantation crops to the
Tamil Nadu Agricultural University, Coimbatore-641 003*

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CERTIFICATE

This is to certify that the thesis entitled **“EVALUATION OF GINGER (*Zingiber Officinale* Rosc.) GENOTYPES FOR GROWTH, YIELD AND QUALITY UNDER COCONUT ECOSYSTEM”** submitted in part of fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN HORTICULTURE** specialized in **SPICES AND PLANTATION CROPS** to the Tamil Nadu Agricultural University, Coimbatore-641003 is a bonafide research work carried out by **Ms.V.DURGAVATHI** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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(Durgavathi. V)

ABSTRACT

EVALUATION OF GINGER (*Zingiber Officinale* Rosc.) GENOTYPES FOR GROWTH, YIELD AND QUALITY UNDER COCONUT ECOSYSTEM

By

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The present investigation on evaluation of ginger genotypes for growth, yield and quality under coconut ecosystem was conducted in a farmer field at Sethumadai near Pollachi in Tamil Nadu during 2010-2011. The experiment was laid out in Randomized Block Design with three replications using eight ginger genotypes viz., Varada, Nadan, Kerala, Malaiinji, Maran, Idukki 1, Idukki 2, and Idukki 3.

Various growth characters were recorded at monthly interval from 30th to 240th days after planting. Observation on growth characters such as number of days taken for sprouting, sprouting percentage, plant height, number of tillers, number of leaves were recorded. The physiological attributes like Leaf Area, Leaf Area Index, Crop Growth Rate, Relative Growth Rate, Net Assimilation Rate and Dry Matter Production were recorded at different growth stages of the crop. The yield components such as number and size of mother, primary, secondary and tertiary rhizomes at 240th days after planting and fresh rhizome yield at 180th and 240th days after

planting were recorded. The quality attributes viz., oleoresin, crude fibre and essential oil were studied and analyzed after harvest.

The present investigation revealed that ginger being a pseophyte (shade loving) showed response to growth, yield and quality parameters under coconut shade condition. Among the eight genotypes, Idukki 2 has recorded higher growth parameters viz., sprouting percentage (91.96 %), plant height (66.13 cm), number of tillers /plant (9.40) and number of leaves/ plant (137) respectively.

The genotype, Idukki 2 has registered higher Leaf Area (4229.59 cm^2) and Leaf Area Index (7.04). The genotypes viz., Idukki 1, Nadan, Varada and Idukki 2 have recorded higher physiological characters viz., Crop Growth Rate ($11.91600 \text{ g m}^{-2} \text{ day}^{-1}$), Relative Growth Rate ($0.0145 \text{ mg g}^{-1} \text{ day}^{-1}$), Net Assimilation Rate ($0.000331 \text{ mg cm}^{-2} \text{ day}^{-1}$) and Dry Matter Production (64.53 g) respectively.

The genotype, Idukki 2 has registered higher mother rhizome characters viz., number (3.06), length (5.05 cm), girth (10.93 cm) and weight (50.33 g). The same genotype has produced well developed primary and secondary rhizomes viz., number (6.50 and 8.23), girth (9.39 and 9.06 cm) and weight (61.83 g and 75.16 g) respectively. With respect to tertiary rhizomes the genotype Idukki 2 has produced well developed tertiary rhizomes viz., length (5.93 cm), girth (7.83cm) and weight (47.50 g) respectively. The genotype, Idukki 2 was found superior in per plant yield (189.50 g), per plot yield (11.37 kg) and estimated yield per hectare (31.58 t ha^{-1}) respectively. Varada recorded higher dry recovery percentage (25.46 %).

The genotypes viz., Nadan has higher oleoresin (9.72 %), Malaiinji has higher crude fibre (5.33 %) and Idukki 1 recorded higher essential oil content (2.08 %) respectively under coconut shade.

The benefit cost ratio was found higher in Idukki 2 (3.25) than other genotypes evaluated under coconut ecosystem.

Hence, considering the overall performance in terms of growth, physiological, yield parameters and economics of cultivation it could be concluded that the genotype, Idukki 2 has recorded better performance under coconut shade.

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CHAPTER I

INTRODUCTION

The spice, ginger (*Zingiber officinale* Rosc.) is an herbaceous tropical perennial crop belonging to the family Zingiberaceae. Among the major spices grown in the country, ginger occupies third position after pepper and chilli. The crop ginger is originated in South-East Asia probably in India (Burkill, 1996; Purseglove *et al.*, 1981). Among the major spices grown in the country, ginger occupies an important place and it is a valuable source of foreign exchange. Apart from its use as a spice, it is regarded as Mahaoushadha (supreme medicine) in Ayurveda and recommended for liver complaints, flatulence, anemia, rheumatism, piles and jaundice in Indian systems of medicine (Ayurveda , Siddha and Unani). Ginger is also believed to absorb and neutralize toxins in stomach. It is also effective in nausea associated with chemotherapy, radiation and motion sickness (Anon, 2009). It is used as an inflammatory, anti - emetic and to treat rheumatic conditions. In western medicine, it is used to prevent motion sickness, dizziness as well as post operative vomiting and vomiting during pregnancy (Grant, 2000). Besides, ginger is an essential ingredient in culinary preparations viz., soups, pickles, curries etc and it is also used as a flavouring agent in several beverages. Ginger in its fresh form (green ginger) is consumed in the domestic market. Only dried ginger, bleached or unbleached ginger is exported (Radhakrishnan and Madhusoodanan, 2009).

The total production of ginger in the world is 1,476,900 tons with the total acreage of 3, 87, 300 ha. India, China, Indonesia and Nepal are the major producers of ginger in the world. India is the largest producer of ginger. In India, during the year 2006-2007, ginger was cultivated in an area of 1,29,014 ha with a production of 7,21,539 tonnes. During 2009-10 India has exported 5000 tonnes of ginger with a value of Rs. 3750 lakhs (Anon, 2011). Although ginger is grown in several parts of India, Karnataka makes significant contribution of 27 per cent with the cultivated area of 20,489 ha and production of 1, 98,180 tonnes. The ginger rhizomes produced in Kerala are superior as they possess better intrinsic quality and hence more acceptable in global markets. In Tamil Nadu, ginger is cultivated in an area of 669 ha with the production of 12,470 tonnes (Anon, 2006-07). Due to the gaining importance of ginger in the domestic and export trade it is very much essential to increase the area and production of ginger in Tamil Nadu and in

India. Still there is a scope to increase the area and production of ginger in Tamil Nadu by way of intercropping the ginger in the existing coconut garden having an age of 15 years and above. Since these coconut gardens offers similar climatic conditions that exist in the sub tropical areas where the ginger is a regular crop.

Coconut with ginger as an intercrop, offers considerable scope for increasing production (20 tonnes/ha) and productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour. It provides additional income to the coconut farmers and serves as food adjunct to flavour the Indian foods. World trade of ginger was 3, 34,433 tonnes during the year 2005, of which India's share was only 3.26 per cent. By means of cultivating ginger as an intercrop in coconut garden, we can enhance India's foreign exchange. Ginger, a shade loving crop, can be grown well under partial shade of coconut without hampering the performance of the main crop (Nampoothiri, 2003). The most profitable combination is coconut and ginger followed by coconut and banana (Ramakrishna *et al.*, 2008).

Coconut in India is primarily a crop of small farmers and about 98 percent of the coconuts holding in the countries are less than 2 ha in size and more than 90 percent of them are less than 1 ha in extent. The income derived from such smallholding is not sufficient to sustain even the small families. Ginger is the important rhizome spice crop commonly intercropped in coconut gardens. Better performance under partially shaded conditions, fair market demand, easy processing and long storage lives are some of the factors that favour the ginger crop to grow as intercrop in the coconut garden (Maheswarappa, 2007).

Practically, it is difficult to increase the area under ginger in the Sub tropical region. By using the existing area of coconut in Tamil Nadu, there is a scope to increase the area and production of ginger. With this background a study was under taken with eight ginger genotypes collected from different sources and evaluated their performance under coconut ecosystems at Coimbatore condition with the following objectives.

- To find out the suitable ginger genotype for the coconut eco system for high fresh and dry rhizome yield.
- To find out the quality performance of the ginger genotypes under coconut eco system
- To work out the cost economics of ginger cultivation under coconut ecosystem.

CHAPTER II

REVIEW OF LITERATURE

Ginger is an important spice crop of India and plays a pivotal role in the national economy. It is one of the oldest spice, known for its aroma and pungency. In recognition of the importance of ginger in the domestic and export trade genotypes and improved technologies were given much impetus among the ginger growers to get high rhizome yield and quality. The present investigation aims on evaluating the ginger genotypes under coconut ecosystem to identify a good ginger genotype for the coconut growers of Tamil Nadu. Published data on different shade conditions, varieties suitable under coconut ecosystem, yield and quality behavior of ginger are reviewed hereunder.

In conjunction with the earlier research carried out, the essentials pertaining to the topics are reviewed under the following headings,

- Effect of Weather parameters on growth, yield and quality of ginger
- Effect of cultural practices on growth, yield and quality of ginger
- Effect of open and shade on growth, yield and quality of ginger

2.1. Effect of Weather parameters on growth, yield and quality of ginger

Kim (1961) established that low night temperature increases tuber weight in sweet potato. Ginger is adapted to varying altitudes from sea level to 1500 meter; the optimum elevation for its successful cultivation is from 300 to 900 meters (Kannan and Nair, 1965).

Tropical root crops are confined to short day conditions of the tropics in which tuberisation occur readily. Evidence of the influence of short days in stimulating tuberisation has been reported for cassava (Bolhuis, 1966). (Minoru and Hori, 1969) stated that ginger can efficiently utilize low light intensities for photochemical reactions. It particularly requires a saturating light intensity of 20K Lux.

Treshow (1970) revealed that relatively cool temperature may influence growth by modified chemical composition of plants. Relatively high carbohydrate level was considered to

result from the slower degradation of carbohydrates caused by decrease in respiration at lower temperature. Spence and Humphries (1972) reported that the tuber development in sweet potato was more rapid at 25°C than at 30°C and no tubers were formed at 10 and 15°C.

Whiley (1974) reported that high temperature and moderate rainfall during the growing season are essential for the successful cultivation of ginger. These two factors create high humidity which is required by the crop. It is also beneficial to have a cooler dry season while the rhizome matures and is being harvested. The growth of ginger does not resume until the soil temperature at 150 mm depth exceeds 20°C. Most favorable growth was obtained at a soil temperature between 25 and 30°C.

Soil temperature for the germination and early growth of ginger is greater than 25°C but less than 30°C, shoot emergence with these temperature requiring 3.5 to 4 weeks. With the normal planting time, crops commonly take six or more weeks to reach full emergence. These observations suggested that low soil temperature and following planting may be an important factor limiting growth in commercial ginger production under Australian condition (Evenson *et al.*, 1978).

Ginger can be grown in non- conventional areas in the plains as an intercrop. Ginger can be intercropped with chillies, okra, maize and tomato (Singh *et al.*, 1981), pigeon pea and castor (Purseglove, 1975), grape vineyard (Ranga Reddy and Satyanarayana, 1972), in orchard trees like mangoes (Randhawa and Mandpuri, 1970) and areca garden (Abdul Kadar, 1982).

2.2. Effect of cultural practices on growth, yield and quality of ginger

Rajan and Singh (1972) reported that oil cakes and saw dust caused significant increase in plant growth and reduction in the incidence of soft rot of ginger caused by *P.aphanidermatum*. Saha (1989) stated that 90 N+60 P+90 K (kg/ha) would be optimum dose of fertilizers when applied in combination of urea+ diammonium phosphate + muriate of potash. Nizam and Jayachandran (1997) recorded that plants raised from 15 g rhizomes had significantly higher Non Volatile Ether Extract (NVEE) than plants rose from 5 or 10 g rhizomes. In open conditions, plants raised from 5 g rhizomes had higher crude fibre contents, but when grown as an intercrop, plants raised from 15 g rhizomes had increased crude fibre contents. The variety

Kuruppampaddy recorded the highest NVEE under open and intercropped conditions. Prasad *et al.* (1997) found that, greater nitrogen contents in the rhizome (1.81%), shoot (1.90%) and root (1.00%) in cv. Nadan. Phosphorous contents of the rhizome (0.44%) and shoot (0.38%) were more in cv. Maran, while the rhizome and shoot of the cultivar Waynad local had higher potassium contents (2.56 and 2.44 %) respectively. The cultivar Nadan removed more nitrogen (150.31 Kg/ha) and potassium (213.31 Kg/ha). The cultivar Maran removed more phosphorous (35.91 Kg/ha) from the soil. Shashidhar *et al.* (1997) reported that, in turmeric the medium spacing (20 x 20 cm) recorded higher number of tillers (14.44) and more leaves.

Sadanandan and Hamza (1998) opined that, in ginger groundnut cake gave higher dry yield (4077 Kg/ha) followed by neem cake, cotton cake and NPK fertilizers + micro nutrients (3946, 3887 and 3853 Kg/ha respectively). Neem cake gave higher oleoresin yield (320 Kg/ha) followed by groundnut cake (302 Kg/ha). Economic analysis showed that NPK fertilizers registered increased benefit cost ratio followed by groundnut cake. Wang shao Hui and Zhang-Zhenxian (1998) observed that the leaf number was more with straw mulch. Mulching has increased the yield (294 t /667 m²) in ginger.

Maheswarappa *et al.* (2000) obtained that, maximum number of tillers and leaves at closer spacing (20 x 10 cm) as compared to wider spacing (20 x 15 cm) in galangal grown as intercrop in coconut. Hore *et al.* (2004) stated that, the maximum plot yield (11.67 kg) of ginger was recorded in closer spacing (20 x 15 cm) as compared to medium (20 x 20 cm) (9.94 kg) and wider spacing (25 x 20 cm) (8.51 kg/plot).

Yamgar *et al.* (2001) found that, in turmeric application of 200:100:100 kg N, P₂O₅ and K₂O/ha recorded higher plant height (109 cm), more number of leaves (9.8/ plant), increased length of leaf (62.8 cm) and yield of green rhizome (0.53 g/plant) (41 tonnes/ha). The same treatment recorded higher net returns (Rs 30, 277/ha) and benefit: cost ratio (1.62).

Ajithkumar and Jayachadran (2002) reported that NPK recommended for ginger for open condition of ginger is insufficient when ginger is intercropped in coconut garden. Increased fertilizer dose (150:100:100 of N, P₂O₅ and K₂O kg / ha) is necessary for getting increased rhizome yield under coconut garden.

Hore *et al.* (2004) reported that, in ginger an increase in the dose of K from 100 to 150 kg/ha increases the number of secondary fingers from 2.86 to 3.17/ plant and yield increased from 9.84 to 10.31 kg/ plot while further increase in the level of K caused a marginal decrease in number of secondary fingers (3.10) and plot yield (9.97kg).

Soil fertility status revealed that in turmeric higher organic matter (5.68 %), nitrogen (69.40 kg/ha) during rhizome formation stage at surface layer has recorded under 10 t mulch/ha. Higher content of organic matter (6.37 %) and phosphorous (76.0 kg/ha) during rhizome formation stage at surface layer has exposed under paddy straw mulch. Nitrogen content was more (73.81 kg/ha) with gliricidia mulch. Potassium content was higher (302.22 kg/ha) at sub-surface layer under paddy straw mulch during rhizome formation stage (Dinesh Kumar, 2006). Roy and Hore (2007) observed that, incorporation of nitrogen with poultry manure (25% N), neem cake (50% N) and groundnut cake (50% N) were found to be the best for getting higher yield in ginger.

As planting material, mother rhizome and primary fingers were significantly better than secondary fingers in respect of plant growth characteristics, size of mother rhizome, primary fingers, secondary finger production and yield / plant. Mother rhizome and primary fingers are vigorous with better productivity as compared to those from secondary fingers (Dhatt *et al.*, 2008).

2.3. Effect of open and shade cultivation on growth, yield and quality of ginger

2.3.1. Growth and yield parameters

Tillering was not affected and reduced number of leaves per tiller was recorded in ginger grown under full sunlight compared to different levels of shade (Aclan and Quisumbing, 1976). In general, the leaves of shaded plants were thinner showing poor development of palisade tissue and spongy-mesophyll cell (Broadman, 1977). In a study on the performance of nine varieties of turmeric in coconut garden, more number of leaves per plant was noted in Chayapasupa (20.11) and Type 1 produced less number of leaves per plant (8.67) (Potty *et al.*, 1979).

Increased leaf area of ginger under decreased light was reported by Ravisankar and Muthuswamy (1986). Rhizomatic species viz., ginger and turmeric are commonly intercropped

in arecanut plantations (Muralidharan, 1990). Though the exact statistics pertaining to the distribution of the area under open and shaded conditions are not available, it is well understood that ginger and turmeric can be grown under partial shade as intercrops. Studies conducted in India and elsewhere revealed that ginger and turmeric are shade loving / tolerant plants (George, 1997).

The growth of ginger plants under full sunlight was found to be shorter compared to shaded condition (Aclan and Quisumbing, 1976). Bai and Nair (1982) reported the positive influence of shading on pseudostem height in ginger. Pushkaran *et al.* (1985) reported that higher yield was recorded by turmeric variety AmruthapaniKothapetta (A) 72 (17.36 t/ha) followed by Subha Chayapa (15.17 t/ha) under coconut garden. Satheesan and Ramadasan (1988) obtained that turmeric cultivar Cls.No.24 was more efficient than the cultivar Cll. 328 Sugandham and Duggirala as an intercrop in coconut garden.

Intercrop under 6-year old arecanut plantation of ginger recorded higher starch content (39.5 %) followed by ginger intercropped under 2-year old arecanut plantation recorded a starch level of 38.8 % at final stage. Starch content was higher under shade condition than in the open condition. In ginger, increased protein content up to 120th day and progressive drop thereafter till the final harvesting was evident. Ginger intercropped under 6-year and 2-year old arecanut plantations was found to be superior in protein content (12.71 % and 12.43 %) over open field condition. In ginger, crude fibre content (10.05 % and 9.50 %) showed an increase up to 240th day generally followed by a drop thereafter at the final harvesting stage. The volatile oil (2.85 % and 2.73 %) and Non Volatile Acetone Extract (NVAE) (6.55 and 6.05 %) contents showed a slow increase up to 180th day in both the shade treatments (intercrop under 6-year old and 2-year arecanut plantations) respectively Ravisankar and Muthuswamy (1987). Peter and Kandiannan (1988) observed that in turmeric the wider internodal length added weightage to the yield. They further reported an yield of 28.8 and 23.3 t/ha in Sudarsana and Suguna respectively.

Sannamarappa and Shivasanker (1998) reported that maximum fresh rhizome yield of 5228 kg/ha of turmeric at 60 % inter crop intensity under areca garden. Satheesan and Ramadasan (1988) observed that turmeric cv. Cls No.24, the higher leaf starch content in the leaf was attained by 22nd weeks under intercropped stands, while in the case of cultivar Cll.328

Sugandham and Duggirala, this was attained by 14th week under intercropped condition. Susan (1989) indicated an increase in height of the plant up to 50 per cent shade both in ginger and turmeric. The decrease in number of tillers and number of leaves was recorded up to 50 per cent shade both in ginger and turmeric. Jayachandran *et al.* (1991) revealed that in ginger cultivar Rio-de-Janeiro grown under 75 per cent shade exhibited increased height of the plant (52.3 cm) and they also stated that there was a direct relation between the intensity of shade and height of the plant.

In turmeric, Sheela (1992) noticed taller plants with 75 per cent shade in initial stages and with 50 per cent shade in later stages. Turmeric plants in open, recorded more number of leaves, while shade influenced this character significantly only at 120 DAP. Jayachandran *et al.* (1992) raised ginger variety Kottarakkara under different shade levels and found that the height of the plant was higher under 50 per cent shade (44.3 cm). Tillering was reduced by 50 per cent at 70 per cent shade. However, the tiller production at 25 per cent shade was on par with that of open condition (3.2).

An increasing trend in plant height and some depressing effect on tillering was noticed in turmeric under shade (Anon, 1992). In a study at Vellanikara under shade, Ancy (1992) observed higher number of leaves in ginger under 25 per cent shade at all growth stages and lower leaf number at 75 per cent shade. Babu (1993) showed increased volatile oil content and decrease in Non Volatile Ether Extract (NVEE) in ginger with increase in shade. The increased volatile oil content was recorded from ginger cv. Rio-de-Janeiro grown as an intercrop in a six year old arecanut plantation followed by those grown in two year old plantation compared to those grown in the open.

Wilson and Althea Ovid (1993) reported that in open condition, the ginger plants were shorter at maturity (30 cm), while at 66 percent saran shaded condition; the ginger plant height was 55 cm. Under shade treatment, number of tillers was only 2, while in 66 percent saran shaded condition, it was 6. While 66 percent saran netting shade and fertilizer applications reported lime induced iron chlorosis, thereby improving crop growth and yield of ginger. Latha *et al.* (1995) observed that among the 15 turmeric cultivars grown under open and partially shaded conditions, the cultivars VK 82 (36.3cm) and Sugandham (48.1 cm) recorded increased

plant height under open and partially shaded conditions respectively. The cultivar Sugandham produced higher number of tillers per plant (6.50) followed by VK 116 (5.05) under the open condition and the least was produced by VK 55 and VK 82 (3.00). Contrary to this in the coconut shade, VK 77 produced higher number of tillers (4.75) and the least by VK 82 (2.75). The number of leaves ranged between 8.00 (VK 55) and 6.00 (VK 116) in open and in shade it was from 5.70 (VK 116) to 7.10 (Chayapasupa) respectively. Sujatha *et al.* (1994) stated that 26 ginger cultivars were grown in 3x1 m plots to be screened as intercrop for coconut. Increased sprouting percentage (100 %) was recorded in cultivars of Earandan and Valluvanad. Ginger plant height at 4 months after planting was greater in cv. Calcutta (76.2 cm). The genotype, PGS 10 had more leaves (27.75) and tillers (23.75) under coconut garden. Higher fresh yields were recorded in ginger cv Kuruppampaddy (356.5 g/ plant) followed by Wynad Mananthody and Earandan under coconut gardens. Increased dry yield was recorded in ginger variety viz., PGS-667 (15.5 t/ha) followed by Kuruppampaddy and SG -55.

John and Ferreira (1997) studied that ginger selection G9 (Taiwan) with high crude fibre content of 6.8 % on dry basis recorded better results in terms of oleoresin (3.06 %) and oil (0.52 %) contents, however the dry ginger recovery was higher with G10 (West Indies) (27.5 %). Ginger G13 (Brazilian) gave better results for early harvesting.

Sathish *et al.* (1998) reported that turmeric cv. Cuddapah recorded maximum height (57.3 cm) followed by Sangli (56.5 cm) and the least PCT- 13 (40.3 cm). The turmeric cv. BSR-1 produced increased number of tillers per clump (4.47), followed by Sangli (3.80) and the least with PCT- 5 (1.33) under coconut garden. Turmeric cv. Sangli produced more number of leaves (20.0) followed by BSR-1 (18.27) and the least was PCT- 5 (5.67). The ACCN. 10/8 had higher LAI (6.15) under coconut. Turmeric cultivars PCT- 5 and PCT-13 were found to be short duration types (203 to 207 days). PCT-8 and PCT- 14 are considered as short duration types, under coconut plantation in Bangalore they matured only at medium durations (230-233 days). All the cultivars took 15-20 days more for maturity under coconut as compared to open conditions. Turmeric cultivar, ACCN. 10/8 recorded higher fresh yield (34.16 t/ha), followed by Rajapuri (31.76 t/ha) and Cuddapah (29.87 t/ha). The yield was lower in PCT- 5 (15.89 t/ha) under coconut. Higher dry matter producing cultivars are: PCT-8 (9.32 t/ha), Cuddapah (9.09 t/ha), Sangli (9.08 t/ha) and ACCN. 10/8 (8.56 t/ha) could be attributed to the increase in growth,

fresh weight and yield of the crop. The least dry matter was obtained in PCT-5 (5.07 t/ha) and PCT-13 (5.07 t/ha) under coconut. Cured rhizome yield was higher in turmeric cv. ACCN. 10/8 (7.32 t/ha), followed by Rajapuri (5.36 t/ha) and Cuddapah (5.0 t/ha). The yield was least in PCT- 5 (4.08 t/ha) and PCT- 13 (3.05 t/ha). The relatively higher yield obtained from ACCN. 10/8 could be attributed to the plant height, highest LAI, highest weight of mother rhizome, primary and secondary fingers, as they had positive and significant correlation with rhizome yield. The cv. PCT- 5 recorded higher curing percentage (25.68 %), followed by PCT-8 (22.07 %) and ACCN. 10/8 (21.40 %). It may be due to the genetic factors rather than the environmental conditions under which they are grown. The genotype PCT-8 recorded increased Curcumin content (8.13 %) followed by PCT- 14 (7.13 %) and PCT -5 (5.25 %). The growth, yield and quality of turmeric cv. ACCN. 10/8, Rajapuri and PCT -8 cultivars were found to be suitable for planting as intercrop in the coconut garden especially in the southern region of Karnataka.

Wang shao Hui and Zhang- Zhenxian (1998) observed that stem height was greater with 80 percent shade and increasing trend in plant height with increasing shade intensity (from 0-80 %) was observed in ginger. Rai *et al.* (1999) observed that higher fresh rhizome yield (462.60 g/plant) was recorded in ginger variety Gorubathaney and the lowest (234.50 g/plant) in Suprava. Higher rhizome yields were highly associated with greater chlorophyll a and carbohydrates and lower polyphenol levels in the leaf. Leaf protein contents showed significant correlation with carbohydrates and chlorophyll a: b ratio. Reduced number of tiller production under higher shade intensity was observed. Leaf production and leaf area was found to be significantly superior under 20 % shade (Sreekala, 1999).

Hegde *et al.* (2000) indicated that ginger cv. Suprabha grown as intercrop was significantly taller than those under open condition (pure crop) when measured at 200 DAP. It showed significantly lower number of functional leaves and tillers per clump. Maheswarappa *et al.* (2000) opined that better growth of arrowroot (*Maranta arundinaceae* L.) under coconut shade was reflected in increased height of the plant (99.7cm), more number of tillers (7.1) and leaves (64.3) indicating its adaptability to partially shaded conditions.

Hore *et al.* (2001) observed an increased fresh rhizome yield of 21-26 t/ha at Suguna. Ajithkumar *et al.* (2002) noted that ginger plants grown at 20 and 40 per cent shade levels produced significantly higher leaf area (6492.56 and 6490.67 cm² respectively) compared to the plants grown in open condition (4521.67 cm²). Vijayalatha (2002) noticed that the turmeric genotype CL-2 (48.56 cm) was taller and the genotype CL-20 (29.05cm) was shorter among 223 turmeric genotypes tested under open conditions.

Jayachandran *et al.* (2004) reported that higher rhizome yield of 28.32 t/ha (first year) and 33.6 t/ha (second year) was recorded by ginger plants grown under 25 per cent shade which was 19.2 per cent more than that in open condition in the first year and 18.6 per cent in the second year. Rhizome yield under low levels of shade (25 per cent) compared to open (where photosynthetic rate was higher) might be mainly due to the enhanced leaf area. There was a decrease in the yield when shade increased to 50 and 75 per cent.

Sit *et al.* (2004) reported that the turmeric cultivar Prova took minimum time (59.50 days) for first emergence of shoot after planting of rhizomes followed by Sudarsana (59.67 days) under areca canopy shade condition. The line CL 24 took minimum time (58 days) for shoot emergence in open condition, where extended time was required for the turmeric variety Suguna in both conditions (79.67 days in shade condition and 78.5 days in open condition), where the plant heights were more in shade condition. The plant height differed significantly and ranged from 126.0 (Suguna) to 184.5 cm (Sudarsana) in arecanut shade and from 114.0 (Suguna) to 162.8 cm (Sudarsana) in open condition. The mean number of leaf production for each plant in turmeric was more or less similar under both open and arecanut shade conditions. Increased mother rhizome weight was recorded (113.00 g) in turmeric cultivar Kasturi and it was followed by CLS-3D and CLS-2A in shade condition. Under shade condition, more number of primary fingers and secondary fingers (8.50 and 19.33) was recorded in turmeric cultivar Prova, while 5.5 number of primary fingers was recorded in cv. Suguna and 10.33 number of secondary fingers was recorded in cv. Prothiva. The cv. Suguna recorded the highest fresh yield of 29.04 t/ha while cv. Prova produced only 21.40 t/ha in shade conditions. It indicated that, maximum internodal distance and mean yield per plant contributed to higher yield in cv. Suguna in shade conditions.

Sreekala and Jayachandran (2004) opined that in ginger volatile oil content was higher during 150 and 180 DAP under heavier shade levels (60 to 80 %) and NVEE was higher under 20 percent shade. At 150 and 180 DAP, plants grown under 20 percent shade recorded 9.13 and 9.11 per cent of NVEE followed by those grown under 40 percent shade (8.47 and 8.32 % respectively). Menon (2007) reported that higher percentage of oleoresin content in the primitive type ginger Kozhikkalan.

The ginger cultivars such as Suruchi (6.8 %), Oman (6.5 %), Pulpally (7.2 %), Thodupuzha-2 (7.5 %), Kottayam (8.0 %), Wyanad Local (6.5 %), Vizagapatnam-1 (4.6 %), were recorded high fibre content; while Kintoki (1.3 %) and Nadia (1.8 %) recorded very less fiber content in open condition (Jaleel and Sasikumar, 2009).

2.3.2. Physiological parameters

Blackman and Wilson (1951), Newton (1963) and Coombe (1996) documented positive correlation in plants between Net Assimilation Rate (NAR) and irradiance. The light compensation point for photosynthesis was found to be higher for plants in open than those under shade (Okali and Owusu, 1975). Increased Dry Matter Production (DMP) of any crop was strongly correlated with amount of light intercepted by its foliage (Monteith, 1977). Ramadasan and Satheesan (1980) expressed higher Crop Growth Rate (CGR), NAR and leaf area in three turmeric cultivars grown under open compared to shade. Bai and Nair (1982) indicated that dry matter production in ginger followed a quadratic pattern with maximum value lying between 25 and 50 per cent shade. Ravisankar and Muthuswamy (1986) recorded an increased level of dry matter production with decreased light intensity and significantly negative correlation for NAR with light intensity in ginger raised in arecanut garden; while the Leaf Area Index (LAI) increased significantly under shaded conditions. This was further confirmed by Susan (1989) who recorded higher DMP at 25 per cent shade in ginger.

Ancy (1992) observed significant variation with DMP among different shade levels (0, 25, 50 and 75 per cent) in ginger. DMP at 25 and 50 per cent shade was found to be on par but significantly superior to 0 and 75 per cent shade both at 135 and 180 days after planting. The extent of decrease being 17.8 and 22.2 percent respectively in open and shaded condition. In

turmeric, DMP increased with increasing shade intensity up to 50 per cent shade and declined thereafter (Sheela, 1992).

NAR and LAI were not affected by shade in turmeric (Anon, 1992). In ginger, Beena *et al.* (1998) documented significant difference in shade levels with respect to CGR, NAR and DMP. Higher value (31.5) for DMP was recorded at 50 per cent shade, which was comparable with that at 25 and 75 per cent shade.

Sreekala (1999) reported that, in ginger increased DMP, CGR and LAI from ginger cv. Rio-de-Janeiro grown under 20 per cent shade followed by open condition during 150 and 180 days after planting. Higher CGR ($39.7 \text{ gm}^{-2} \text{ day}^{-1}$) and LAI (7.287) was recorded in ginger under shade. Sreekala and Jayachandran (2002) noted in ginger that the LAI was more in plants grown under 20 and 40 per cent shade (8.18 and 7.57 respectively) and the least in open condition (6.94).

CHAPTER III

MATERIALS AND METHODS

Ginger is one of the most valuable and important spice and India is the largest producer, consumer and exporter of this crop. It is widely used in food, beverage, confectionary and medicine. The present investigation on “Evaluation of ginger (*Zingiber officinale* Rosc.) genotypes for growth, yield and quality under coconut ecosystem” was conducted in a farmer field at Sethumadai near Pollachi in Tamil Nadu during 2010-2011. The details of the materials used, methods adopted for field study and analytical procedures followed during the present investigation are furnished in this Chapter.

3. 1. Materials

3. 1. 1. Field location

Place	:	Sethumadai , Pollachi in Tamil Nadu
Latitude	:	10° 39' N
Longitude	:	77° 03' E
Altitude	:	340 m MSL
Maximum temperature	:	42.95°C
Minimum temperature	:	28.30°C
Mean annual rainfall	:	3300 mm
Average relative humidity	:	86.75 %

3. 1. 2. Weather data

Meteorological data recorded during the experimental period are presented in Annexure I

3. 1. 3. Soil characteristics

Composite soil samples were collected initially from 15 to 30 cm depth before sowing and analyzed for physical and chemical properties. The soil and water properties of experimental field are furnished in Annexure II.

3.1.4. Crop and Variety

Eight ginger genotypes were collected from different parts of India. They were tested under Pollachi condition. The following are the list of ginger genotypes used and source of seed rhizomes obtained for this study.

S.NO	Genotypes	Source of the seed rhizomes
1	Varada	Collected from Horticultural Research Station, HRS, Pechipaarai.
2	Nadan	Collected from Kanyakumari through HRS, Pechipaarai.
3	Kerala	
4	Malaiinji	
5	Maran	Collected from Gudalur of Nilgiri, through Hybrid Rice Evaluation Center, Gudalur.
6	Idukki 1	Collected from Idukki District of Kerala state.
7	Idukki 2	
8	Idukki 3	

3. 2. Methods

3. 2. 1. Experimental details

Evaluation of ginger (*Zingiber officinale* Rosc.) genotypes for growth, yield and quality under coconut ecosystem

Design : Randomized Block Design

Number of treatments : Eight

Number of replications : Three

Spacing : 30 x 20 cm

Treatments (Ginger Genotypes)

G₁ -Varada

G₂ - Nadan

G₃- Kerala

G₄- Malaiinji

G₅- Maran

G₆ – Idukki ₁

G₇ - Idukki ₂

G₈ - Idukki ₃

3. 2. 2. Land preparation

The land was prepared during the first week of July, 2010. The soil was brought to fine tilth by deep ploughing four times. Weeds, stubbles, roots etc. were removed. At the time of last ploughing, 10 t FYM /ha was applied. After leveling, the raised beds were formed to accommodate the treatments.

The field lay out is shown in the Fig 1 and depicted in Plate 1.

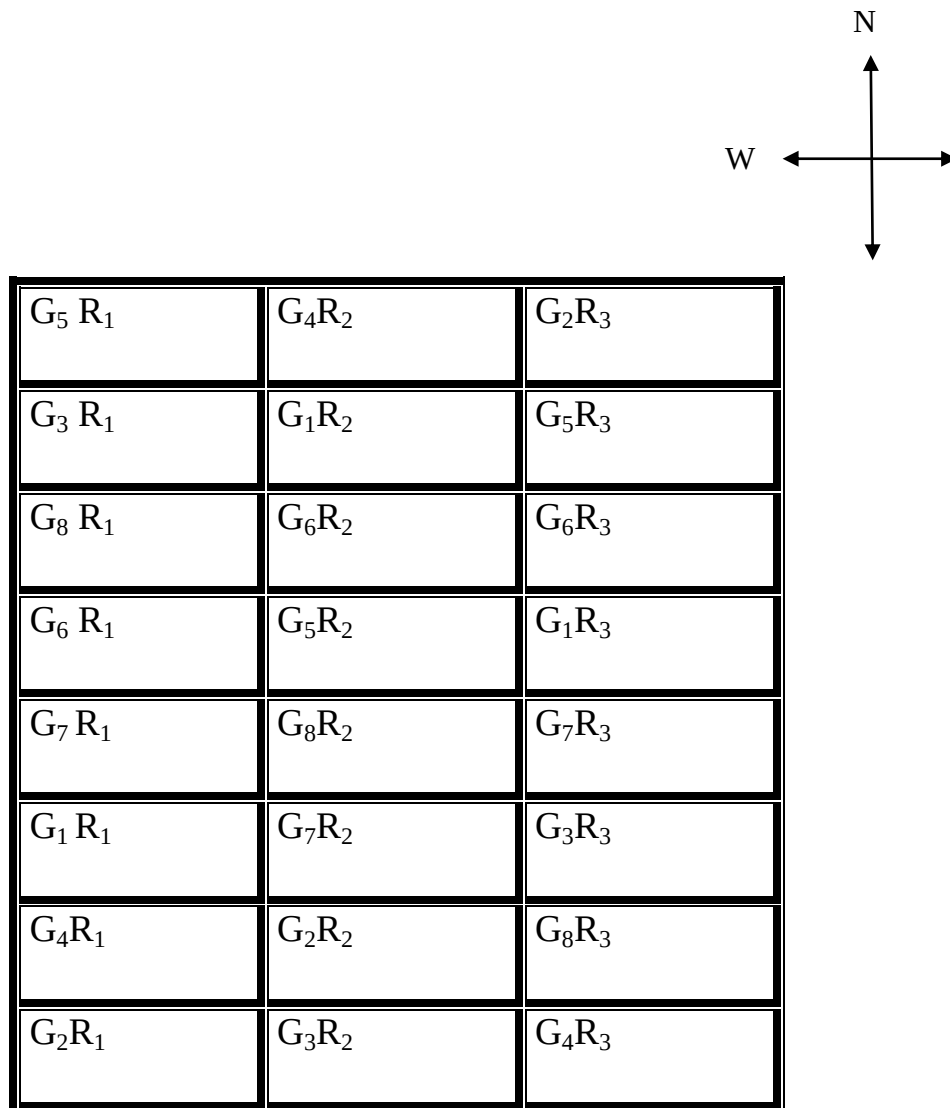


Fig. 1.Field layout of the experiment

3.2.3. Seed Treatment

Healthy and disease free rhizomes weighing about 15-20 grams each were selected and treated with Copper oxy chloride for 20 minutes, shade dried for 30 minutes and used for sowing on 03.07.2010 in the beds at a spacing of 30 x 20 cm.

3.2.4. Method of planting

Bed size of 22m length, 1 m breadth, 20-25cm height were formed and seed rhizome bits of 15-20 g weight, with one or two well-sprouted buds, were planted at a distance of 30 x 20 cm in raised beds, accommodating 60 plants per treatment per bed. The crop was maintained following the regular cultural, manurial and other plant protection operations as per the package of practices given in the crop production manual for Horticultural crops of Tamil Nadu Agricultural University, Coimbatore (Anon, 2004).

3.2.5. Application of fertilizers

Time Period	Full dose (g/ 0.011ha)		
	N (g)	P ₂ O ₅ (g)	K ₂ O (g)
Basal application	-	750	-
45 th day	412.5	-	375
90 th day	412.5	-	375
Total	825	750	750

The beds were earthed up after each top dressing of the fertilizers.

3.2.6. After Cultivation

Manual weeding was done at 30, 60, 90,120 and 150 days after planting.

3.2.7. Harvesting

The crop was harvested for green ginger at 180 DAP when it starts showing signs of maturity viz., yellowing and withering of leaves, appearance of cracks on the soil. The clumps were carefully lifted with spade and yield was calculated for respective treatments. For preparing the dry ginger, the crop was harvested at 240 days after planting (Nybe and Mini Raj, 2007).

3.2.8. Sampling Technique

Five plants in each treatment per replication were tagged randomly for recording the observations on vegetative and rhizome characters and the mean values were subjected to statistical scrutiny.

3. 3. Observations recorded

3.3.1. Morphological Parameters

3. 3. 1. 1. Number of days taken for sprouting of rhizome buds (days)

Number of days required for healthy sprouting was recorded at 20th, 30th and 40th day after planting and the mean value was expressed in days.

3. 3. 1.2. Sprouting percentage (%)

Number of rhizomes that produced healthy sprouts were recorded at 20th, 30th and 40th days after planting and the mean value was expressed in percentage.

3. 3. 1.3. Plant height (cm)

Plant height was measured from the base of the main pseudostem to the top of the plant at monthly intervals (30th, 60th, 90th, 120th and 150th days after planting) and the mean value was expressed in centimeter.

3. 3.1.4. Number of tillers per plant (Number)

Number of aerial shoots that emerged from the rhizome were counted at monthly intervals (30th, 60th, 90th, 120th and 150th days after planting) and the mean value was expressed as number per plant.

3. 3.1.5. Number of leaves per plant (Number)

The total number of fully opened leaves emerged from all the tillers put together were counted at monthly intervals (30th, 60th, 90th, 120th and 150th days after planting) and the mean value was recorded and expressed as number of leaves per plant.

3.3.2 .Physiological Parameters

3. 3. 2.1. Leaf Area (LA) (cm²)

Leaf area was calculated at monthly intervals (30th, 60th, 90th, 120th and 150th days after planting) using the equation $A = 0.6695 \times LB - 0.7608$ (Ancy and Jayachandran, 1994) and mean value was expressed in square centimeter.

3. 3. 2.2. Leaf Area Index (LAI)

The LAI was calculated at monthly intervals (30th, 60th, 90th, 120th and 150th days after planting) using the non-destructive formula suggested by Williams (1946).

$$\text{LAI} = \frac{\text{Total leaf area of the plant (cm}^2\text{)}}{\text{Ground area occupied by the plant (cm}^2\text{)}}$$

3. 3. 2.3. Crop growth rate (CGR) (g m⁻² day⁻¹)

Crop growth rate (CGR) was calculated at four stages of crop growth (30-60, 60-90, 90-120 and 120-150 Days after planting) using the formula suggested by Watson (1952) and expressed as g m⁻² day⁻¹.

$$\text{CGR} = \frac{W_2 - W_1}{P (t_2 - t_1)} \text{ g m}^{-2} \text{ day}^{-1}$$

Where,

W_1 and W_2 are whole plant dry weights at t_1 and t_2 respectively

P- Ground area on which W_1 and W_2 has been estimated

t_1 and t_2 are time in days

3. 3.2.4. Relative growth rate (RGR) (mg g⁻¹ day⁻¹)

Relative growth rate (RGR) was calculated at four stages of crop growth (30-60, 60-90, 90-120 and 120-150 Days after planting) using the formula suggested by Williams (1946) and expressed as $\text{mg g}^{-1} \text{ day}^{-1}$

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{(t_2 - t_1)} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where,

W_1 and W_2 are whole plant dry weights at t_1 and t_2 respectively

t_1 and t_2 are time in days

3. 3.2.5. Net assimilation rate (NAR) ($\text{mg cm}^{-2} \text{ day}^{-1}$)

The net assimilation rate was calculated at four stages of crop growth (30-60, 60-90, 90-120 and 120-150 Days after planting) using the formula suggested by Williams (1946) and expressed as $\text{mg cm}^{-2} \text{ day}^{-1}$.

$$\text{NAR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\text{Log}_e L_2 - \text{Log}_e L_1)}{(L_2 - L_1)} \text{ mg cm}^{-2} \text{ day}^{-1}$$

Where,

W_1 and W_2 are dry weights of whole plant at t_1 and t_2 respectively

L_1 and L_2 are leaf areas at t_1 and t_2 respectively

t_1 and t_2 are time in days

3.3.2.6. Dry Matter Production (g / plant)

Rhizomes were dried in shade for 24 h and then in hot air oven maintained at $70 \pm 1^\circ\text{C}$ till a constant weight arrives. The mean weight was expressed in grams per plant.

3.3.3. Yield Parameters

3.3.3.1. Number of mother rhizomes per plant (number)

The central ovoid mother rhizomes developed at the base of the plant were separated after harvest and counted and expressed as number of mother rhizomes per plant.

3.3.3.2. Length of mother rhizome (cm)

Five mother rhizomes were randomly selected and the length was measured using a scale and the mean was expressed in cm.

3.3.3.3. Girth of mother rhizome (cm)

The girth of mother rhizome was recorded at the middle portion using a non-stretchable string and scale and the mean was worked out for five rhizomes and expressed in cm.

3.3.3.4. Weight of mother rhizome (g per plant)

Fresh weight of mother rhizomes per plant was recorded immediately after the harvest, by separating the mother rhizomes, cleaning of the soil and adhering roots. The weight of mother rhizome was expressed as g per plant.

3.3.3.5. Number of primary rhizomes per plant (number)

The rhizomes originating from the mother rhizomes representing the primary rhizome were separated, counted and expressed as number of primary rhizomes per plant.

3.3.3.6. Length of primary rhizome (cm)

The lengths of five primary rhizomes were measured using a scale and the mean length was expressed in cm.

3.3.3.7. Girth of primary rhizome (cm)

The girths of five primary rhizomes were recorded at the middle portion using a non – stretchable string and scale and the mean value was expressed in cm.

3.3.3.8. Weight of primary rhizome (g per plant)

Fresh weight of the primary rhizomes per plant were recorded after proper cleaning and removal of the roots and expressed as g per plant.

3.3.3.9. Number of secondary rhizomes per plant (number)

The rhizomes arising from the primary rhizomes were separated, counted and recorded as number of secondary rhizomes per plant.

3.3.3.10. Length of secondary rhizome (cm)

Five secondary rhizomes at random were selected and the length was measured using a scale and the mean length was expressed in cm.

3.3.3.11. Girth of secondary rhizome (cm)

The girths of five secondary rhizomes were recorded at the middle part using a non – stretchable string and scale and the mean was worked out for five rhizomes and expressed in cm.

3.3.3.12. Weight of secondary rhizomes (g per plant)

The fresh weights of five separated secondary rhizomes per plant were recorded in five plants and the mean weight was expressed as g per plant after proper cleaning.

3.3.3.13. Number of tertiary rhizomes per plant (number)

The rhizomes arising from the secondary rhizomes were separated, counted and recorded as number of tertiary rhizomes per plant.

3.3.3.14. Length of tertiary rhizomes (cm)

Five tertiary rhizomes at random were selected and the length was measured using a scale and expressed in cm.

3.3.3.15. Girth of tertiary rhizomes (cm)

The girths of five tertiary rhizomes were measured at the middle part using a non – stretchable string and scale and the mean was worked out for five rhizomes and expressed in cm.

3.3.3.16. Weight of tertiary rhizomes (g per plant)

The fresh weights of five separated tertiary rhizomes per plant were recorded in five plants and the mean value was expressed in g per plant after proper cleaning.

3.3.3.17. Fresh rhizome yield per plant (kg)

The fresh weight of rhizomes per plant was recorded immediately after harvest at 180 DAP for green ginger and at 240 DAP for dry ginger by cleaning the soil and roots and the mean yield was expressed as kg per plant.

3.3.3.18. Fresh rhizome yield per plot and estimated yield per hectare (kg per plot and tonnes per ha)

The plot yield and hectare yield of fresh rhizome at 180 DAP was calculated based on the yield obtained per plant and expressed as kg/ plot and t/ ha. The plot yield in each treatment in a replication was calculated by weighing the rhizomes harvested from the entire plot at 240 DAP for dry ginger after cleaning the soil and roots and expressed as kg per plot. The estimated yield of rhizome per hectare was calculated from plot yield obtained in each treatment and expressed as tonnes per hectare.

3.3.3.19. Dry recovery percent (%)

The amount of dry recovery is given on the basis of the weight of water present in the product and is usually expressed in percent (Sahay and Singh, 1994).

$$\text{Dry recovery percent} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.3.4. Quality Attributes

3.3.4.1. Essential oil content (%)

The essential oil content in dry ginger was analyzed from the rhizomes harvested at 240th day after planting and the analytical procedure adopted is given below. The essential oil content was estimated as per the methods suggested by ASTA (1968). A quantity of thirty g of ginger

powder was transferred into the flask with a few glass beads to avoid frothing. The flask was then fitted to an essential oil extraction apparatus (Clevenger's Apparatus). The distillation was made on a thermostatically controlled heating mantle. A temperature of 90°C was maintained till boiling and subsequently at 70°C for 3 hours during the distillation.

The distillate was cooled down to room temperature and allowed to settle till the oil layer was clear. The volume was measured and the oil content was calculated using the formula mentioned below and expressed as percent.

$$\text{Essential oil per cent (V/W)} = \frac{\text{Volume of oil (ml)}}{\text{Weight of sample (mg)}} \times 100$$

3.3.4.2. Crude fibre content

The crude fibre content in dry ginger was analyzed from the rhizomes harvested at 240th day after planting adopting the analytical procedure suggested by Chopra and Kanwar (1976). The rhizome at mature stage was oven dried at 140^o C for 48 hours and pulverized with wooden mallet. The powdered sample was cleaned without stalks or hard pieces. Two gram of prepared moisture free sample was taken in a 500 ml beaker; 200 ml of 1.25 N sulphuric acid was added and boiled for 30 minutes. The volume was maintained constant by replacing the water lost by evaporation. At the end of 30 minutes, the mixture was filtered through a muslin cloth and washed with hot water till it was free of acid. The residue was then transferred to the same beaker and 200 ml of 2.5 N sodium hydroxide was added. The mixture was allowed to boil for 30 minutes keeping the volume constant. The mixture was then filtered through ashless filter paper. The residue was washed with water to remove the alkali. The filter paper with the residue was transferred to a pre-weighed silica crucible (W₁). It was dried overnight at 100±5^o C and weighed (W₂). This was ignited for 30 minutes in a muffle furnace. After cooling, the weight (W₃) was taken. The loss in weight on ignition was worked out and the crude fibre content expressed in percent.

$$\text{Crude fibre (percent)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of the sample}} \times 100$$

3.3.4.3. Oleoresin content (%)

The oleoresin content in dry ginger was analyzed from the rhizomes harvested at 240th day after planting and the analytical procedure adopted is given below. Accurately 10 g of ginger powder was weighed and filled up the column with (3 times weight of powder) acetone or ethylene dichloride. It was allowed to percolate overnight and drained it, into a pre weighed beaker (A). Then the residue was washed once or twice with acetone and the extracts pooled. For evaporation of the solvent, the beaker was kept over a water bath at 80° C until constant weight was obtained (B). The oleoresin content in the sample was calculated and expressed in percentage (Anon, 1975).

$$\text{Oleoresin content (percent)} = \frac{B-A}{10} \times 100$$

Where,

A - Weight of empty beaker

B - Weight of the beaker + residue

3.4. Statistical analysis

The data collected from the experiments were analyzed by adopting the procedure described by Panse and Sukhatme (1985).

3.5. Economics of cultivation

The cost of cultivation was worked out by taking into account various inputs for cultivation during the entire experiment period. Yield was computed per hectare and net income

was calculated by deducting the cost of cultivation from gross return. The benefit cost ratio was worked out by using the formula suggested by Palaniappan (1985).

$$\text{BCR} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

CHAPTER IV

EXPERIMENTAL RESULTS

The performance of certain ginger genotypes were assessed for growth, yield and quality parameters under coconut ecosystem. The mean data pertaining to biometrical, yield and quality parameters were tabulated and their respective interpretations were presented in this Chapter.

4.1. Growth Parameters

4.1.1. Number of days taken for sprouting (Table 1)

Significant variations in the days taken for sprouting were observed (Fig. 1). The days taken for sprouting ranged from 21.00 to 42.66 days. Over all mean was 31.70 days. Earlier sprouting was observed in Idukki 1 (21.00 days). This was followed by Kerala (25.00 days) and Nadan (25.66 days). The genotype Malaiinji took long days for sprouting (42.66 days). This was followed by Maran (40.00 days) and both were on par with each other.

4.1.2. Sprouting percentage (Table 1)

The ginger genotypes differed significantly with respect to sprouting percentage which ranged from 48 to 91.96 %. Over all mean was 73.93 percent. Higher sprouting percentage (91.96 %) was recorded in Idukki 2 followed by Idukki 1 (89.80 %) and Idukki 3 (82.53 %) and all are on par with each other. Sprouting percentage was found low in Varada (48.00 %) which was on par with Maran (49.54%). (Fig. 1).

4.1.3. Plant height (cm) (Table 2)

A progressive increase in plant height as the plant reached its maturity was observed and presented (Fig. 2, Plate 2). Plant height was measured at monthly interval from 30, 60, 90, 120 and 150 DAP. The plant height varied significantly from 24.40 cm to 66.13 cm. At 150 DAP Idukki 2 has recorded higher plant height (66.13 cm) followed by Idukki 1 (65.60 cm) and both are on par with each other. The genotype Varada has recorded a lower plant height at all the stages of crop growth.

4.1.4. Number of tillers (Table 3)

It was found that, different ginger genotypes studied had significant effect on number of tillers during the period of growth (Fig. 3, Plate 3). Number of tillers ranged from 1.22 to 9.40. The genotype, Idukki 2 has recorded higher number of tillers (9.40) per plant followed by Kerala (9.13) and Idukki 3(8.20) at 150 DAP and all are on par with each other. The number of tillers produced was low in Malaiinji (3.8) followed by Varada (4.73) and Idukki 1 (5.06) and all are on par with each other.

4.1.5. Number of leaves (Table 4)

It was observed that different ginger genotypes had significant effect on number of leaves produced during the period of crop growth (Fig. 4, Plate 4).The number of leaves produced varied significantly from 5.22 to 137. Maximum number of leaves (137) was produced by Idukki 2 and found significant with other genotypes. This was followed by Kerala which produced 114.50 numbers of leaves at 150DAP. The leaf number was less in Malaiinji (62.00) at 150 DAP.

4.2. Physiological Parameters

4.2.1. Leaf Area (cm²) (Table 5)

The leaf area varied significantly among the genotypes at all the stages of crop growth and ranged from 148.63 to 4229.59 cm². Larger leaf area per plant was produced by Idukki 2 (4229.59 cm²) at 150 DAP. This was followed by Idukki 3 which produced a leaf area of 3829.38 cm² and found on par with Idukki 2. The least leaf area per plant was noticed in Malaiinji (1795.39 cm²). (Fig. 5)

4.2.2. Leaf Area Index (Table. 6)

Leaf Area Index (LAI) has showed an increasing trend as the plant reached its maturity, but the increasing rate was decreased towards its maturity. It was found that different genotypes of ginger had significant effect on LAI during the period of crop growth (Fig 6). LAI varied significantly from 0.24 to 7.04 at different stages of crop growth. At 150 DAP higher LAI was

recorded by the genotype Idukki 2 (7.04), followed by Idukki 3 (6.38) and Idukki 1 (6.08) and they were on par with each other. Lower LAI was found in Malaiinji (2.32).

4.2.3. Crop Growth Rate (CGR) ($\text{g m}^{-2} \text{ day}^{-1}$) (Table 7)

It was found that different ginger genotypes had significant effect on CGR during the period of crop growth. The CGR had an increasing trend in all ginger genotypes with the advance of the crop growth.

The CGR ranged from $2.25866 \text{ g m}^{-2} \text{ day}^{-1}$ to $11.91600 \text{ g m}^{-2} \text{ day}^{-1}$. Higher CGR value was recorded in Idukki 1 ($11.91600 \text{ g m}^{-2} \text{ day}^{-1}$) at 120-150 DAP. This was followed by the genotype Idukki 2, which recorded a CGR value of $11.80333 \text{ g m}^{-2} \text{ day}^{-1}$ and both were on par with each other. The least CGR value was found in Malaiinji ($6.81633 \text{ g m}^{-2} \text{ day}^{-1}$) at 150 DAP.

4.2.4. Relative Growth Rate (RGR) ($\text{mg g}^{-1} \text{ day}^{-1}$) (Table 8)

The RGR in different genotypes of ginger had significant effect during the period of crop growth. The RGR ranged from 0.0155 to $0.0230 \text{ mg g}^{-1} \text{ day}^{-1}$. Higher RGR value was recorded by Varada ($0.0230 \text{ mg g}^{-1} \text{ day}^{-1}$) at 30-60 DAP. This was followed by the Kerala and Idukki 1 (0.0228 and $0.0227 \text{ mg g}^{-1} \text{ day}^{-1}$) and both were on par with Varada at 30-60 DAP. The least RGR value was observed in Malaiinji ($0.0100 \text{ mg g}^{-1} \text{ day}^{-1}$) at 120-150 DAP. In general the RGR has shown a decreasing trend after 60 DAP in all genotypes.

4.2.5. Net Assimilation Rate (NAR) ($\text{mg cm}^{-2} \text{ day}^{-1}$) (Table 9)

The NAR also registered similar trend as like RGR. The observations at 30-60, and 60-90 DAP exhibited significant differences among the treatments.

The NAR has varied significantly at 60-90 DAP. It ranged from 0.000168 to 0.000331 $\text{mg cm}^{-2} \text{ day}^{-1}$. The genotype Varada recorded highest NAR ($0.000331 \text{ mg cm}^{-2} \text{ day}^{-1}$) followed by Malaiinji ($0.000291 \text{ mg cm}^{-2} \text{ day}^{-1}$) at 60-90 DAP and both are on par with each other. The lowest NAR was recorded by Kerala ($0.000168 \text{ mg cm}^{-2} \text{ day}^{-1}$) followed by Nadan ($0.000186 \text{ mg cm}^{-2} \text{ day}^{-1}$), Idukki 1 ($0.000186 \text{ mg cm}^{-2} \text{ day}^{-1}$), Idukki 3 ($0.000200 \text{ mg cm}^{-2} \text{ day}^{-1}$), Idukki 2 ($0.000209 \text{ mg cm}^{-2} \text{ day}^{-1}$) and Maran ($0.000222 \text{ mg cm}^{-2} \text{ day}^{-1}$) respectively with comparable values.

4.2.6. Dry Matter Production (DMP) (g / plant) (Table 10)

The DMP recorded in all ginger genotypes differed significantly and it has an increasing trend with increase in crop growth (Fig 7). The Dry matter production ranged from 5.43 g to 79.44 g. The dry matter production was found higher in Idukki 2 (79.44 g) at 180 DAP and this genotype differed significantly with all other ginger genotypes with respect to DMP. Idukki 1 had produced a dry matter of 74.83 g and found on par with Idukki 2. The dry matter production was found low in Malaiinji (52.65 g) at 180 DAP.

4.3. Yield Parameters at 180 DAP

4.3.1. Fresh rhizome yield at 180 DAP (Table 11)

The fresh rhizome yield per plant, per plot and the estimated yield per hectare varied significantly among the different ginger genotypes tested at 180 DAP (table 11). The fresh rhizome yield per plant varied from 44.25 g to 188.72 g. Similarly per plot and estimated yield per hectare varied from 2.65 to 11.32 kg and 7.37 to 31.45 tonnes per hectare respectively. Among the eight ginger genotypes tested, the genotype, Idukki 2 had recorded higher per plant yield (188.71 g), plot yield (11.32 kg) and the estimated yield (31.45 t) respectively. This was closely followed by Idukki 1 and this was on par with Idukki 2 for per plant yield (161.44 g), plot yield (9.68 kg) and estimated yield (26.90 t) respectively. The genotype Varada had recorded lower yield of 44.25 g / plant, 2.65 kg / plot and 7.37 tonnes of estimated yield per hectare respectively.

4.4. Yield parameters at 240 DAP

4.4.1. Number and size of mother rhizomes in different ginger genotypes at 240 DAP (Table 12)

Significant difference was observed with respect to number, length, girth and weight of mother rhizome at 240 DAP. The genotype, Idukki 2, had recorded highest value for all mother rhizome parameters viz., number (3.06), length (5.05 cm), girth (10.93 cm) and weight (50.33 g) respectively. This was closely followed by Idukki 1 for number (2.33), length (4.56 cm), girth (10.36 cm) and weight of mother rhizomes (42.33 g) and this genotype was on par with Idukki 2

with respect to all mother rhizome parameters. The genotype, Idukki 3 had recorded lesser number of mother rhizomes (1.36), Varada for length and weight of mother rhizome (5.05 cm and 23.00 g) and Maran for girth of mother rhizome (8.40 cm) respectively.

4.4.2. Number and size of primary rhizomes in different ginger genotypes at 240 DAP (Table 13)

The ginger genotypes tested for various parameters on primary rhizomes at 240 DAP differed significantly. The genotype, Idukki 2 had recorded higher rhizome characters viz., number (6.50), girth (9.39 cm) and weight of primary rhizomes (61.83 g) respectively. This was followed by Nadan for number of primary rhizome (4.00), Idukki 1 for girth and weight of primary rhizome (8.81 cm and 56.33g) and all are on par with Idukki 2 with respect to number, girth and weight of primary rhizome respectively. The genotype, Idukki 1 had produced longest primary rhizome (6.18 cm) was followed by Kerala (6.10 cm) and both are on par with each other for length of primary rhizome. The genotypes Malaiinji, Idukki 3 and Varada have registered lesser value viz., number of primary rhizome (3.16), length of primary rhizome (2.71 cm), girth and weight of primary rhizome (6.70 cm and 20.83 g) respectively.

4.4.3. Number and size of secondary rhizomes in different ginger genotypes at 240 DAP (Table 14)

The result on secondary rhizome parameters revealed that there was a significant difference among the genotypes for secondary rhizome parameters like number, length, girth and weight at 240 DAP. The Idukki 2 had recorded higher number (8.23), girth (9.06 cm) and weight of secondary rhizomes (75.16 g) respectively. This was closely followed by Idukki 1 for number (7.00), girth (8.16 cm) and weight (59.66 g) and all are on par with Idukki 2. The genotype, Idukki 3, produced longest secondary rhizome (7.35 cm) which was followed by Idukki 1 (6.56 cm). The genotypes, Idukki 3 and Varada have produced lesser number of secondary rhizomes (3.66), length, girth and weight of secondary rhizome (2.63 cm, 6.87 cm and 21.66 g) respectively.

4.4.4. Number and size of tertiary rhizomes in different ginger genotypes at 240 DAP (Table 15)

The result on tertiary rhizome parameters indicated that, there was a significant difference among the genotypes for various tertiary rhizome parameters like number, length, girth and weight at 240 DAP. The genotype, Idukki 1 had produced higher number of tertiary rhizomes (6.83) which was followed by Idukki 2 (6.00) and both are on par with each other. The genotype, Idukki 2 has produced well developed tertiary rhizomes viz., length (5.93 cm), girth (7.83 cm) and weight of tertiary rhizomes (47.50 g) respectively. This was closely followed by Idukki 1 for length (5.50 cm), girth (7.50 cm) and weight of tertiary rhizomes (42.66 g) and both genotypes are on par with respect to the size of tertiary rhizomes. The genotype Varada had registered lesser value for number (2.33), and size of tertiary rhizomes viz., length (2.87 cm), girth (5.42 cm) and weight (15.33 g) respectively.

4.4.5. Fresh rhizome yield for dry ginger at 240 DAP (Table 16)

The fresh rhizome yield per plant, per plot and the estimated yield per hectare varied significantly among the different ginger genotypes tested at 240 DAP (Fig. 8, Plate 5). The fresh rhizome yield per plant varied from 54.83 g to 189.50 g. Similarly per plot and estimated yield per hectare varied from 3.29 to 11.37 kg and 9.13 to 31.58 tonnes per hectare respectively. Among the eight ginger genotypes tested, the genotype, Idukki 2 had recorded higher per plant yield (189.50 g), plot yield (11.37 kg) and the estimated yield (31.58 t) respectively. This was closely followed by Idukki 1 which recorded a yield of 173.50 g per plant, 10.41 kg per plot and an estimated yield of 28.91 tonnes per hectare respectively. Both the genotypes are on par with respect to fresh rhizome yield. The genotype, Varada had produced lower yield (54.83 g / plant, 3.29 kg / plot and 9.13 tonnes of estimated yield per hectare respectively).

4.4.6. Dry recovery percentage (%) (Table 16)

Dry recovery percentage varied significantly from 19.43 to 25.46 % with a mean of 22.41 %. Varada had recorded higher dry recovery of 25.46% followed by the genotype Kerala which registered a dry recovery of 24.70 %. The genotype, Maran had produced the lower dry recovery of 19.43%. (Fig. 9)

4.5. Quality characteristics at 240 DAP (Table 17)

The results on quality parameters of eight ginger genotypes found varied significantly at 240 DAP (Fig.10). The genotype, Nadan recorded higher oleoresin content (9.72 %) and this was followed by Kerala (9.23 %), Maran (9.17 %) and all are on par with each other. Lesser oleoresin (5.18 %) was recorded in Malaiinji. Higher crude fibre content (5.33 %) was recorded in Malaiinji followed by Idukki 1(4.48 %) and Varada (4.26 %) respectively. Idukki 3 has recorded lesser crude fibre content of (3.10 %). The genotype, Idukki 1 produced higher essential oil content (2.08 %) followed by Nadan (2.00 %) and both are on par for the essential oil content. The genotype Kerala has recorded a lesser essential oil content (1.55 %).

4.6. Economics of cultivation (Table 18)

The genotype Idukki 2 has registered higher gross returns (Rs. 10,73,720 ha⁻¹), total cost of cultivation of Rs. 3,29,780 ha⁻¹, net returns of Rs. 7,43,940 ha⁻¹ and a higher benefit cost ratio of 3.25 respectively. This was closely followed by the genotype Idukki 1 which exhibited a gross return of (9, 82,940 Rs ha⁻¹), total cost of cultivation (Rs. 3, 29,780 ha⁻¹), net returns of Rs. 6, 53,160 ha⁻¹ and a BCR of 2.98 respectively. While the genotype Varada recorded a lower gross returns (3, 10,420 Rs ha⁻¹), total cost of cultivation (Rs. 3, 29,780 ha⁻¹), net returns of Rs. 19,360 ha⁻¹ and a BCR of 0.94 (Fig.11) respectively.

CHAPTER V

DISCUSSION

Environments, changing spatially and secularly, have enormous influences on crop growth and development resulting in large location to location variation in crop yields. It is evident from the history of agricultural research that, improved genotype played an important role in augmenting the yield of crops. The current study focused on ginger genotypes that were assembled from different ginger producing states of India and evaluated critically about their performance on growth, yield and quality under coconut ecosystem.

It has been known for a long time that plants which occupy shaded habitats are capable of performing efficiently at low light intensities. Since sunlight is the primary source of energy for photosynthesis, the yield of a plant is mainly determined by the factors associated with solar radiation namely its intensity, quality and duration. Light is also a significant factor which has a direct bearing on photosynthesis, photorespiration and translocation of assimilates to the economic parts. When light becomes the limiting factor as encountered under shaded situations, the process of photosynthesis and partitioning of photosynthates into economically important plant parts are partially modified and needs to be investigated in detail.

From the above discussion, it is quite obvious that partial light of a coconut garden shade plays a surmountable role in the yield and quality of ginger. Hence, it is imperative to assess ginger genotypes under coconut shaded condition, for various morphological, physiological, yield and quality characters which ultimately lead to the conclusion of adaptability of ginger in the coconut ecosystem. Therefore, the present investigation on “Evaluation of ginger (*Zingiber officinale* Rosc.) genotypes for growth, yield and quality under coconut ecosystem” was conducted in a farmer field at Sethumadai near Pollachi in Tamil Nadu during 2010-2011. An attempt has been made to enlighten on some of the basic concepts of adaptability of ginger genotypes under coconut shaded condition. The salient findings of the study are discussed in this chapter.

When the mean performance was considered as an index of selection, the genotype with high mean was relatively effective in identifying the superior genotypes Finkner *et al.* (1973).

Growth parameters

The growth and development of the ginger genotypes are highly depends on the climatic conditions and soil factors under which they were grown. Conducive microclimate and soil fertility status are essential. Relative humidity, light intensity and temperature are the important factors which enhance the enzymatic activity involved in plant growth and development. This is mainly due to proper stomatal functioning, enzyme production, photosynthetic efficiency, biochemical reactions and partitioning efficiency from source to sink.

Early sprouting is one of the important trait that decide early emergence and harvesting in ginger. In the present study, the earliest sprouting was noticed in the ginger genotype viz., Idukki 2 (Fig. 1). Generally, provision of shade creates a microclimate with low soil temperature and increased soil moisture which aids the biochemical changes inside the seed rhizomes and thus aids in early sprouting to its maximum score. The result is in conformation with Evenson *et al.* (1978). Thus early sprouting and better germination in case of mother and primary finger rhizomes could be, attributed to their high moisture content and also the aforesaid reasons (Balashanmugam and Vanangamudi, 1998). Thus, early sprouting, in addition to enough vegetative growth in early stages, had also resulted in higher yield from these rhizomes. Regarding sprouting per cent, in the present investigation, the genotype Idukki 2 registered high per cent of sprouting (Fig. 1). This may be due to the atmospheric temperature experienced during this period (23.1 to 32.8°C) as is evident from Annexure1. It was indicated by Ravindran *et al.* (2005) that a temperature range of 25 to 35°C is optimum for sprouting of ginger buds. Sprouting does not occur at less than 10°C or more than 40°C. Therefore temperature of 25 to 30°C is ideal for seedling elongation but does not survive above 40°C.

A significant variation in growth was observed among the genotypes with regard to sprouting, plant height, number of tillers, number of leaves, leaf size. The variation among the ginger genotypes for the morphological attributes might be due to their diversified origin and evolutionization of the particular genotype or morph type in the specific geographic location. This is in confirmation with Cholke (1993), Vijayalatha (2002) and Choudhuri and Hore (2004) in turmeric.

The genotype, Idukki 2 found outstanding in its performance to growth characters indicating its suitability to coconut shade conditions than other genotypes tested. Plant height is an important trait deciding the rhizome growth of ginger. The increase in plant height may be due to the etiolated seedlings, shading caused the plants to grow taller due to increase in concentrations of certain growth promoting substances like auxins and gibberellins. The rate of detoxification of free auxins in the plants might be less leading to the lengthy growth, which is reflected in greater internodal length and height of the plant with thin stem. When auxins are more, the plants are able to absorb and translocate the nutrients to the apical bud, leading to the conclusion that auxins act on some protoplasmic system leading to altered arrangement of cell wall components and hence greater extensibility leading to increased height as observed in the earlier findings by Crookston *et al.* (1975) in beans; Leong and Anderson (1984) in spear scale. The stem elongation could be attributed to the stimulation of cell division in shoot apex, increase in cell wall plasticity and increase in hydrolysis of starch, fructose and sucrose to glucose molecules (Latha *et al.*, 1995; Indires *et al.* 1990; Padmapriya 2004; Vijayalatha 2002; and Vijya 2003) in turmeric.

In the present investigation the genotype Idukki 2 produced more tillers. This might be due to favourable climatic conditions viz., optimum atmospheric and soil temperature and relative humidity that triggers the translocation of stored food in the rhizome to the new sprouts which in turn produced more tillers. This finding is in concordance with Arun Kumar (2003) and Vijayalatha (2002) in turmeric.

Number of leaves produced among the ginger genotypes and cultivars in the present study were differed significantly (Fig 4). In this study the genotype Idukki 2 has produced higher number of leaves under coconut shade. This may be due to that, the leaf production is a direct indication about the performance of particular genotypes and thereby is an important determinant on the final rhizome yield by more assimilates production needed for growth and development of rhizome. The present research findings were in synchrony with the earlier works of Philip and Nair (1983), Jalgaonkar *et al.* (1988), Reddy *et al.* (1989), Choudhuri and Hore (2004), Vijayalatha (2002) and Arunkumar (2003) as reported for turmeric.

In general, ginger plants under shaded condition produced significantly higher leaf area (Fig. 5). The genotype Idukki 2 has recorded larger leaf area and the genotype Malaiinji

registered lesser leaf area. This might be due to the increased leaf area under shade might perhaps be a plant adaptation to expose larger photosynthetic surface under limited illumination (Attridge, 1990). Under low light intensities, reduced irradiation may slow the transpiration and due to higher leaf water potential marked increase in assimilates were effectively translocated to the growing tips which results in increased leaf area. An increased leaf area under reduced light intensity was also reported in ginger by Ravisankar and Muthuswamy (1988), Ancy (1992) and George (1992). Shade level is also an important physiological parameter to increase the leaf dimension, mainly due to the movement of growth hormones as suggested by Ajithkumar *et al.* (2002) and Sreekala and Jayachadran (2002) in ginger and Vijya (2003) and Padmapriya (2004) in turmeric.

The cropping system of particular region depends on crop duration. In the present study, most of the genotypes selected were medium in maturity (*i.e.*, > 170 – 190 days). The genotype Idukki 3 exhibited late maturity (> 200 days) where as Idukki 1, Idukki 2, Malaiinji and Nadan genotypes exhibited medium maturity (170 -180 days) and the genotypes viz., Varada, Maran and Kerala showed early maturity (150 to 165 days). The short duration genotypes showed moderate growth and yield, while the medium duration genotypes excelled in plant and rhizome characters. It could be due to the fact that the optimum cropping period had helped in better partitioning and accumulation of photosynthates as a result of excellent morphological characters exhibited by the medium duration genotypes. This is mainly due to the prevalence of conducive climatological parameters favouring the biological processes viz., physiological and biochemical reactions influenced by the enzyme activities in bulking and maturation of ginger rhizomes under medium duration genotypes. As there was higher leaf area, the total photosynthetic surface on per plant basis was higher which inturn increased the total quantity of photosynthesis. The probable reason for such higher yield in medium duration genotypes could also be ascribed to higher leaf area, less photooxidation and efficient translocation of photosynthates to the developing fingers, as reported by Ajithkumar *et al.* (2002) in ginger, noticing higher yield under shaded condition than open condition. It was also in agreement with Cholke (1993), Sasikumar *et al.* (1994) and Shanmugasundaram (1998) in turmeric. The growth and development of ginger genotypes was highly influenced by temperature, relative humidity, soil and edaphic factors in which they were grown and also most of the genotypes were specific to a particular region. This finding is in concordance with Arun Kumar, 2003.

In the present investigation, the genotype Idukki 1 recorded high Crop Growth Rate at 120-150 DAP. This might be due to higher photosynthetic efficiency obtained from leaves of the middle and lower portion of the ginger plant under shade. Similar results were reported by (Zhao *et al.*, 1991). He further reported a minimum photosynthetic efficiency from apical portion of the plant which received full sunlight.

All genotypes recorded decreased NAR values as the crop growth advances. This result is in agreement with the findings of (Milthroe, (1963) and Okoli and Owasu (1975). Crockson *et al.*, (1975) found a reduction (38 %) in photosynthesis of bean leaves due to shading. Stomatal and mesophyll resistance to diffusion of CO₂ might also be a reason for low rate of NAR under increased shade intensity (Meyer *et al.*, 1973).

Higher DMP was registered in the genotype, Idukki 2 at 150 DAP. This may be due to the effect of partial and uniform shade would greatly impart in the production of photosynthates. A single layer of horizontally placed leaves can intercept the entire light available, but will use it inefficiently, since normal light intensities will greatly exceed the saturation level for photosynthesis. In vertically placed leaves at shade, the light intensity spread over an area, increased the efficiency of light utilization and therefore resulting in greater dry matter production. However the outstanding performance of the genotypes even under partial shade condition is due to the retention of leaves on the tiller for longer durations may be helpful in the full utilization of photosynthetic energy up to the maturity. This finding is in concordance with Arun Kumar, (2003). Increased DMP of ginger in shade condition, the number grana could have increased which may be due to the means of achieving a high density of light harvesting pigment assemblies and hence a more efficient collection of quanta. Ultimately, it could be the probable reason of photosynthates by the ginger plants grown under shade. This finding is in concordance with Padmapriya *et al.* (2008) in turmeric.

Yield parameters

Higher yield of mother rhizome was registered by the genotype Idukki 2 where as the lower number was obtained in genotype Idukki 3. This may be due to the suitability of soil and environmental conditions to the particular genotype (Prabhakaran, 1991). Similar results were reported with the previous work by Satheesan and Ramadasan (1982), Hedge (1992), Cholke (1993) and Vijayalatha (2002) in turmeric. The genotype Idukki 2 found to be vigorous and high

yielder and this is mainly due to the higher response to the inputs, which were highly correlated with yield. The findings also revealed that genotypes Idukki 2, Idukki 1, Maran and Kerala produced better rhizome characteristics. Higher production of tillers and also better growth and vigour in these genotypes, resulted in higher yield. Better rhizome growth was also attributed for better absorption of nutrients from soil (Prabhakaran, 1991).

Significant variation was recorded in the number of primary rhizome among the genotypes evaluated. Higher number of primary rhizome was exerted in the genotypes Idukki 2 and Idukki 1. This may be due to better growth and vigour in these genotypes. The works are in accordance with the findings of Dhandar and Varde (1980), Muthusamy and Shah (1982), Philip and Nair (1983), Jalgaonkar *et al.*, (1988), Indires *et al.*, (1990) and Ushananthinidevi (2004) in turmeric.

The genotype Idukki 2 found high yielding (Fig. 8) as a result of vigorous growth, better rhizome characteristic, which have direct influence on yield. The low yield of genotypes may be due to the fact that the 95 percent of light interception period had finished before that the genotypes had produced the half of the total leaf area. In the high yielding genotypes, the time of 95 percent light interception occur when the vegetative growth decreases and the photosynthates was utilized for rhizome production. According to Minoru and Hori (1969), ginger could efficiently utilize lower light intensities. Under shade conditions, higher values for leaf area, bulking rate, NAR, CGR, were noted indicating better performance of ginger under shaded conditions than in open. The higher yield might be due to higher leaf area exhibited throughout the growth period, increased total photosynthates accumulated. Early bulking with progressive accumulation of photosynthates from the tiller leaves even after the later stages of the plant growth enhances the weight of the rhizomes in proportion to their dimensions of mother, primary, secondary and tertiary fingers. The yielding ability of the genotypes can be improved from knowledge about the optimum morphological and physiological characters of the plant such as plant height, leaf and tiller production, CGR, RGR, NAR and photosynthetically active radiation. This is in accordance with the previous works (Ushanandinidevi, 2004). The yield of ginger rhizome is also predominantly influenced by other rhizome dependant traits viz., number, length, girth and weight of primary and secondary rhizome. Since these traits were reported to

have direct effect on rhizome yield (Philip and Nair, 1983; Pujari *et al.*, 1987; Indires *et al.*, 1990; Chandra *et al.*, 1999; Lynrah and Chakrabarthy, 2000; Vijyalatha, 2002; Vijya (2003).

The yield is an economical and polygeneically inherited trait, which by and large depends on the vigour of the plant as indicated by various growth parameters like height of the plant, number of tillers and number of leaves per plant and rhizome characters. Better growth normally produces higher yield and was influenced by genetic and environmental factors too, under which the crop was grown. Expression of high yield out of exorbitant growth in genotypes frequently influenced both by the genetic potential and environmental factors predominantly; edapic reasons owing to the inherent soil fertility status and crop management practices under which the crop was grown would influence the full expression of genotypes. This is in corroboration with the earlier findings of Radhakrishnan *et al.* (1995) in black pepper, Indires *et al.* (1990), Maurya *et al.* (1998), Shanmugasundaram (1998) and Naidu *et al.* (2000) in turmeric. Average fresh rhizome yield was higher for the genotypes Idukki 2, Idukki 1, Maran and Kerala (Fig 8) due to its positive relationship with optimum growth components like leaf growth, number of tillers/plant and rhizome characters. This is attributed to active photosynthesis favouring accumulation and assimilation in enhancing the yield.

Quality parameters

Synthesis and content of quality parameters are highly influenced by the microclimate viz., leaf temperature, relative humidity and inherent fertility status of the soil. These facts are favourable in influencing the enzyme production and related biochemical reactions. Morphological features namely central cylinder and cortex with more congregations of specialized cells which are the oleoresin bearing cells will be advantageous. The synthesis of oleoresin and essential oil might have been due to the promotive or inhibiting influence at different stages causing physiological and biochemical reactions. This is in concordance with the earlier works of Gupta *et al.* (1982) in costus.

The utilization of ginger oleoresin is gaining momentum in the processed food industry. It is prepared by solvent extraction and subsequent desolvenation to meet the specifications (Sampathu *et al.*, 1990). A significant variation for oleoresin was observed in the present investigation which ranged between 5.60 and 8.62 %. The variation in the oleoresin content

might be due to the genetic potential of genotype and method of extraction (George, 1981). The low oleoresin content might also be due to excess drying and loss while desolvenation process.

In the present study, crude fibre content ranged from 3.10 to 5.33%. The genotype Malaiinji has recorded higher crude fibre content (5.33 %). This might be due to variation in genetic makeup and conducive climatological parameters favouring the biological processes viz., physiological and biochemical reactions influenced by the enzyme activities. The probable reason for such higher crude fibre content could also be ascribed to higher leaf area and efficient translocation of photosynthates to the developing fingers, as reported by Ajithkumar *et al.* (2002) in ginger.

Essential oil of ginger is light to dark brown with harsh odour obtained by steam distillation of ground spice and usually a byproduct from oleoresin industry. In the present study, essential oil content ranged from 1.00 to 2.01 %. Yield of essential oil in ginger ranges from 0.2 to 3.0 %, depending on the origin and state of the rhizome. This is in concordance with the previous works (Ekundayo *et al.*, 1988; Vanbeek *et al.*, 1987) in ginger. Essential oil content is also likely to vary not only due to varietal difference but also due to the origin and method of curing, age at harvest and conductions of distillation (Krishnamurthi *et al.*, 1975) in turmeric. The lower content of Essential oil and oleoresins content might also be due to the stage of harvest. Since the plants harvested at full physiological maturity (6th month after planting in ginger) shown better quality content rather than early or late harvesting. Similar reports were also found in turmeric (Philip *et al.*, 1980) in turmeric and (Radhakrishnan *et al.*, 2002) in black pepper.

Dry recovery percentage also varied significantly, higher range of dry recovery percentage was observed in the genotype Varada. High dry recovery percentage might be due to the production of slender rhizomes, perhaps due to lower moisture retention at harvest. The lower dry recovery percentage was mainly due to the fact that feeder roots are present near the surface soil under irrigated conditions, which absorbs more water and have higher moisture content, as result of which, the rhizome will be plump and after drying the yield get reduced (Philip, 1983; Reddy *et al.*, 1989). This finding is similar in line of work by Rao *et al.* (1975) and Subbarayudu *et al.* (1976) in turmeric. The dry recovery percentage also depends on the cultivars, duration,

soil nutrient management and agro-climatic conditions were reported (Pillai and Nambiar, 1975; Subbarayudu *et al.*, 1976; Reddy *et al.*, 1989).

CHAPTER VI

SUMMARY

The present investigation on “Evaluation of ginger (*Zingiber officinale* Rosc.) genotypes for growth, yield and quality under coconut ecosystem” was conducted in a farmer field at Sethumadi near Pollachi during 2010-2011. The research programme was conducted under coconut shade condition to document the growth, yield and quality characters of eight ginger genotypes. The salient findings in the present investigations are summarized below.

1. All the chosen characters namely sprouting per cent, plant height, number of tillers, number of leaves, number and size of mother rhizomes, primary rhizomes, secondary rhizomes and tertiary rhizomes, yield of rhizomes per plant, per plot, yield of rhizomes per hectare, oleoresin, crude fibre and essential oil contents exhibited significant variation among the eight genotypes evaluated for their per se performance.
2. The earliest sprouting was observed in Idukki 1 (21days). The genotype Malaiinji was late to sprout (42.66 days). Higher sprouting percentage (91.96 %) was recorded in Idukki 2 and lower sprouting percentage was noticed in the genotype Varada (48%). The genotype Idukki 2 produced taller plants (66.13 cm) and the plant height was lesser in Varada (52.26 cm).
3. The genotype, Idukki 2 recorded highest number of tillers (9.40) and maximum leaf number (137) per plant and the tiller number and leaf number were found low (3.8 and 62.00) in Malaiinji respectively.
4. The highest leaf area per plant was possessed by the genotype, Idukki 2 (4229.59 cm²) and the least leaf area (1795.39 cm²) per plant was noticed in Malaiinji. Idukki 2 recorded higher LAI (7.04) and the genotype Malaiinji registered lowest LAI (2.32).
5. Increased CGR value was recorded in Idukki 1 (11.91600 g m⁻² day⁻¹) and the reduction in CGR value was found in Malaiinji (6.81633 g m⁻² day⁻¹). Higher RGR value was recorded in Nadan (0.0145 mg g⁻¹ day⁻¹) and the least RGR value was observed in Malaiinji (0.0100 mg g⁻¹ day⁻¹). The genotype Varada observed higher NAR (0.000331mg cm⁻²day⁻¹) and the lower NAR was in Kerala (0.000168 mg cm⁻² day⁻¹).

Higher dry matter production was found in the genotype Idukki 2 (64.53 g) and lower dry matter production was noticed in Malaiinji (47.56 g).

6. The genotype, Idukki 2 produced higher number (3.06) and size of mother rhizomes viz., length (5.05 cm), girth (10.93 cm) and weight (50.33 g) respectively, whereas the genotypes Idukki 3, Varada, Maran and Varada registered lesser value for number and size of mother rhizomes.
7. The genotype, Idukki 2 produced higher number (6.50) and size of primary rhizomes viz., girth (9.39 cm) and weight (61.83 g) respectively, whereas the genotypes Malaiinji, Idukki 3 and Varada registered lesser value for number and size of primary rhizomes.
8. The genotype, Idukki 2 produced higher number (8.23) and size of secondary rhizomes viz., girth (9.06 cm) and weight (75.16 g) respectively, whereas the genotypes Idukki 3 and Varada recorded lesser value for number and size secondary rhizomes.
9. The genotype, Idukki 2 recorded higher length (5.93 cm), girth (7.83cm) and weight of tertiary rhizome (47.50 g) respectively whereas the genotype Varada registered lower value for number and size of tertiary rhizomes.
10. The genotype, Idukki 2 was found to be superior in per plant yield (189.50 g), yield per plot (11.37 kg) and estimated yield per hectare (31.58 t ha⁻¹) at 240 DAP respectively. The genotype Varada registered lesser value for per plant yield, per plot yield and estimated yield per hectare.
11. Varada recorded higher dry recovery (25.46%) while the genotype Maran registered lower dry recovery (19.43%). Nadan recorded higher oleoresin content (9.72 %) and Malaiinji was found to possess high crude fibre content (5.33 %) and the genotype Idukki 1 has recorded higher essential oil content (2.08 %).
12. The genotype Idukki 2 registered higher gross returns (Rs. 10,73,720 ha⁻¹), with a total cost of cultivation of Rs. 3,29,780 ha⁻¹, net returns of Rs. 7,43,940 ha⁻¹ and a higher benefit cost ratio of 3.25. The genotype Varada recorded lower gross returns (Rs. 3,10,420 ha⁻¹), total cost of cultivation (Rs. 3,29,780 ha⁻¹), net returns of Rs. 19,360 ha⁻¹ and a BCR of 0.94.

Conclusion

From the result obtained in this study it could be concluded that Idukki 2 is most suitable ginger genotype under coconut shade condition. It had significant growth, physiological and yield parameters viz., plant height, number of tillers, number of leaves, Leaf Area, Leaf Area Index, Dry Matter Production, number and size of mother, primary, secondary and tertiary rhizomes, yield per plant, yield per plot and estimated yield per hectare respectively. Idukki 2 also registered higher gross returns of Rs. 10,73,720 ha⁻¹ with a total cost of cultivation of Rs. 3,29,780 ha⁻¹ and net return of Rs. 7,43,940 ha⁻¹ which finally emerged with a benefit cost ratio of 3.25.

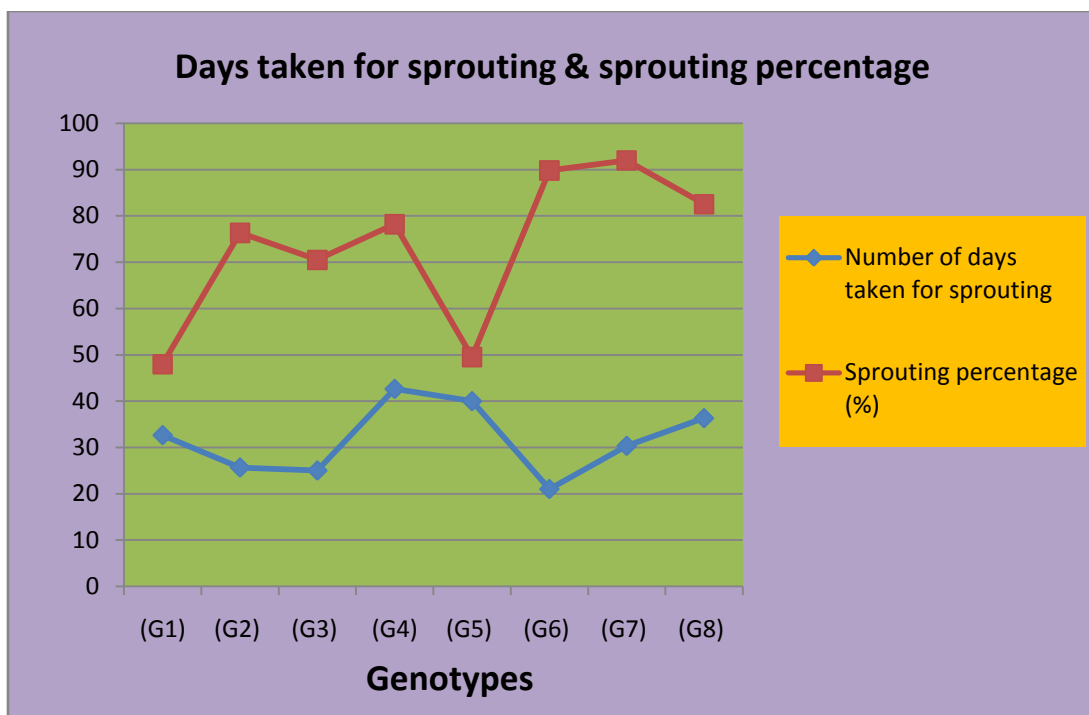


Fig .1 Number of days taken for sprouting and sprouting percentage (%) by different ginger genotypes

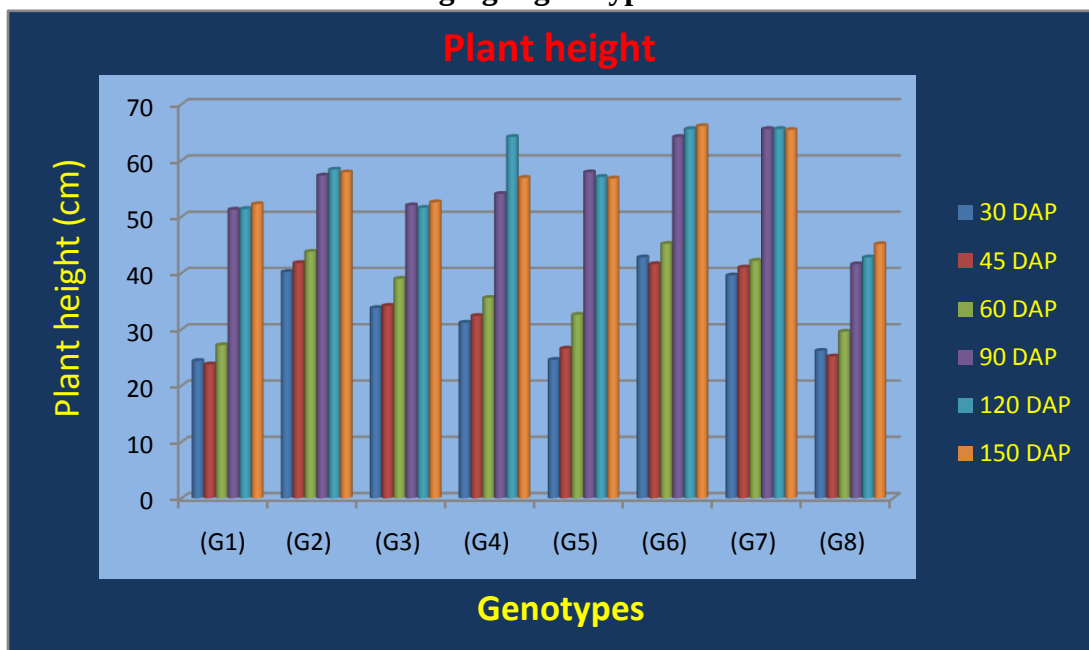


Fig. 2. Plant height (cm) of different ginger genotypes

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

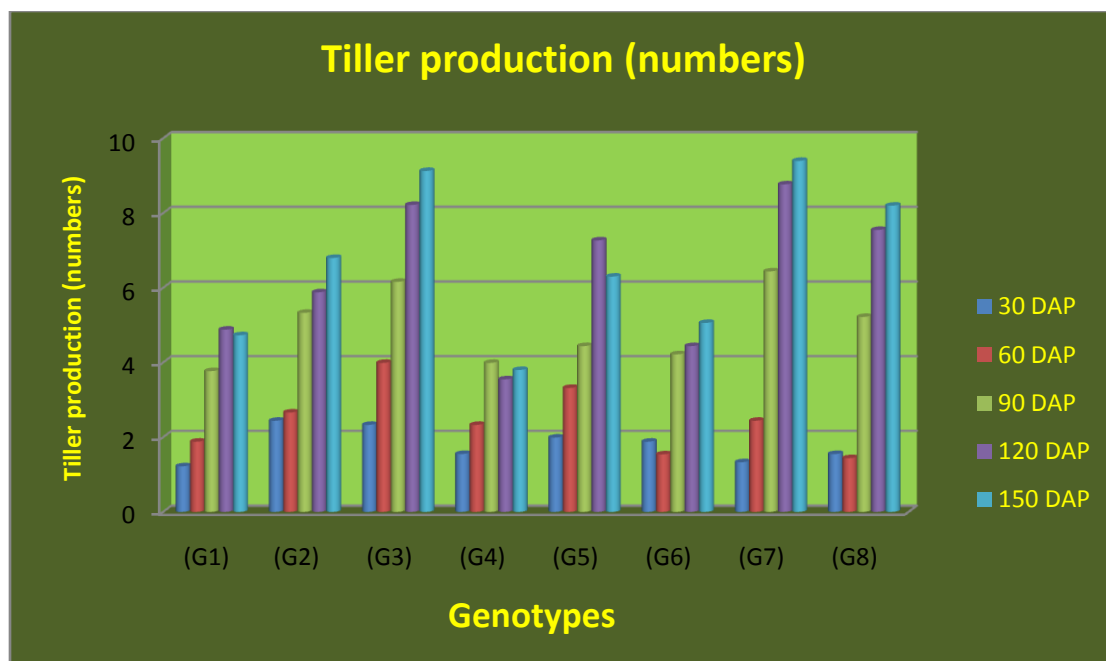


Fig. 3. Tiller production by different ginger genotypes

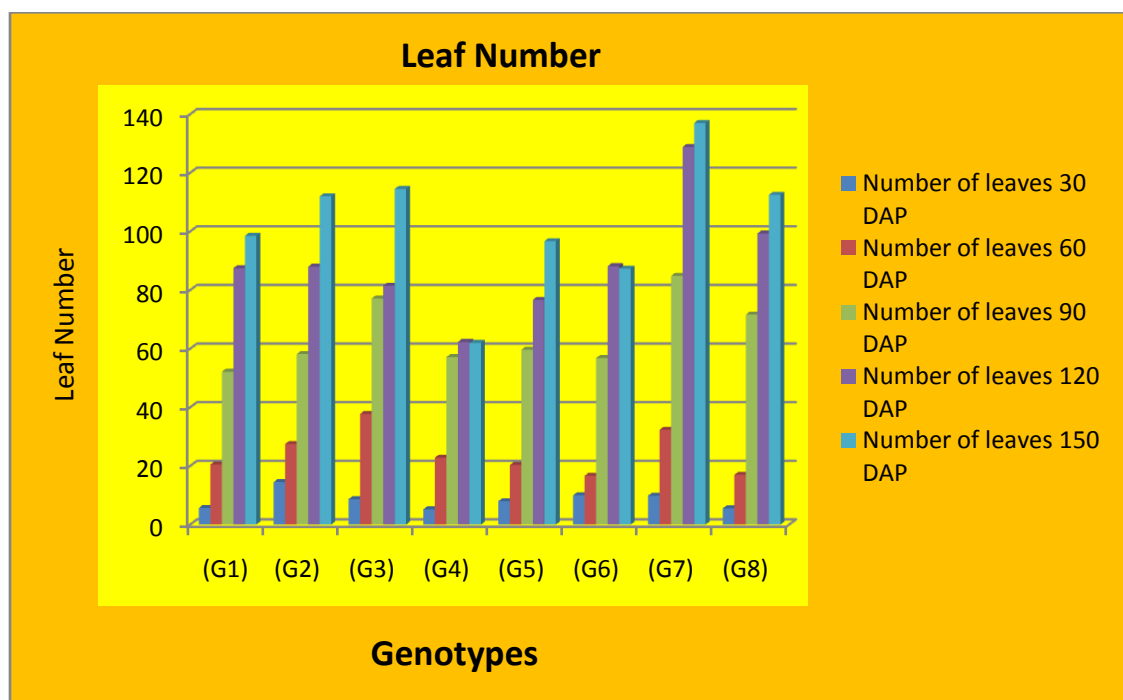


Fig. 4. Number of leaves produced by different ginger genotypes

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

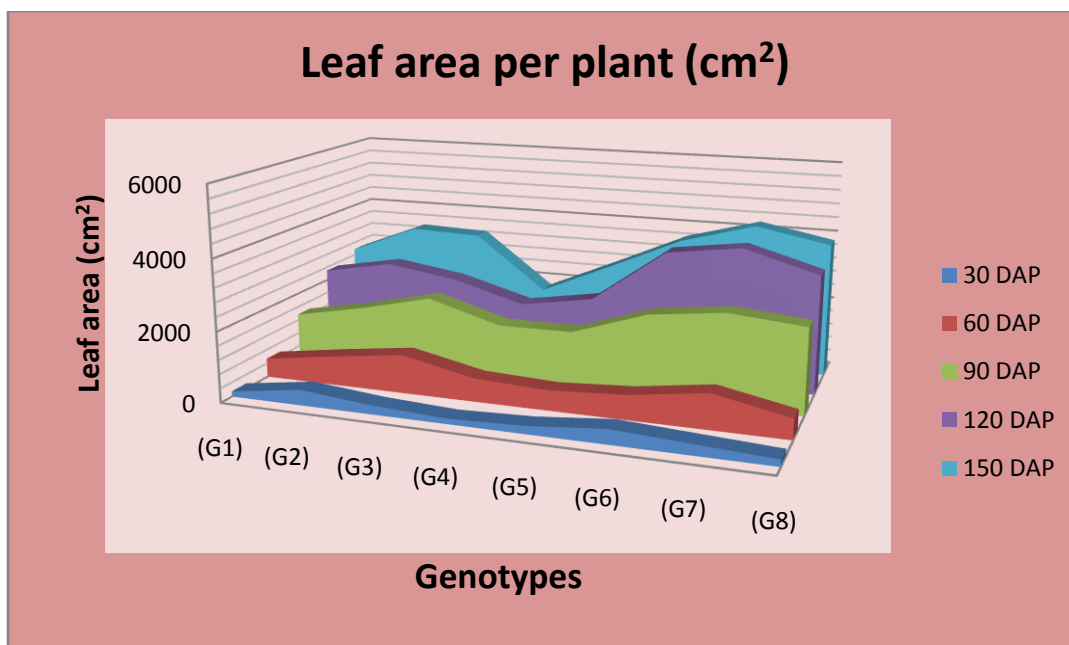


Fig. 5. Leaf area (cm²) produced by different ginger genotypes

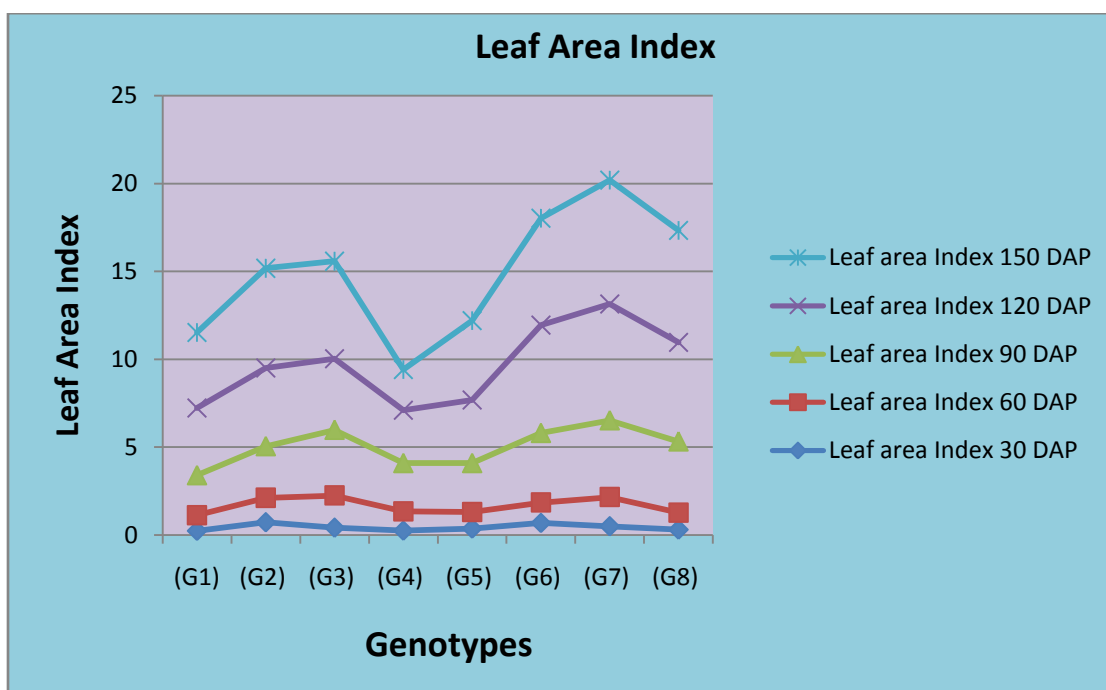


Fig. 6 Leaf Area Index by different ginger genotypes

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ –Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

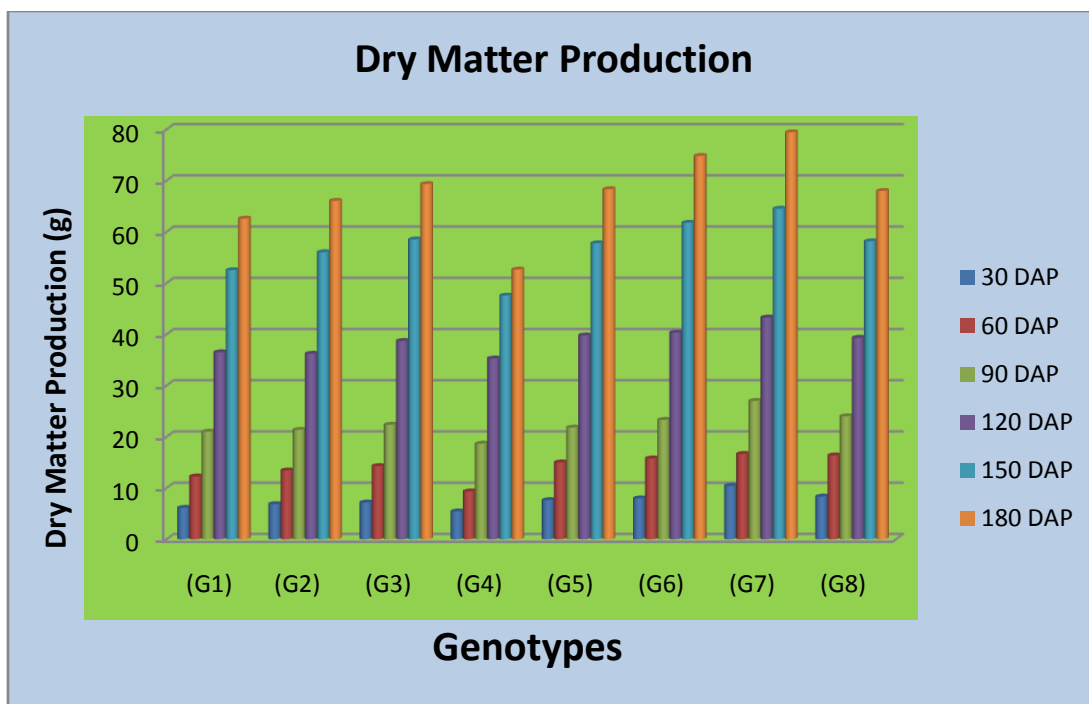


Fig. 7 Dry Matter Production by different ginger genotypes

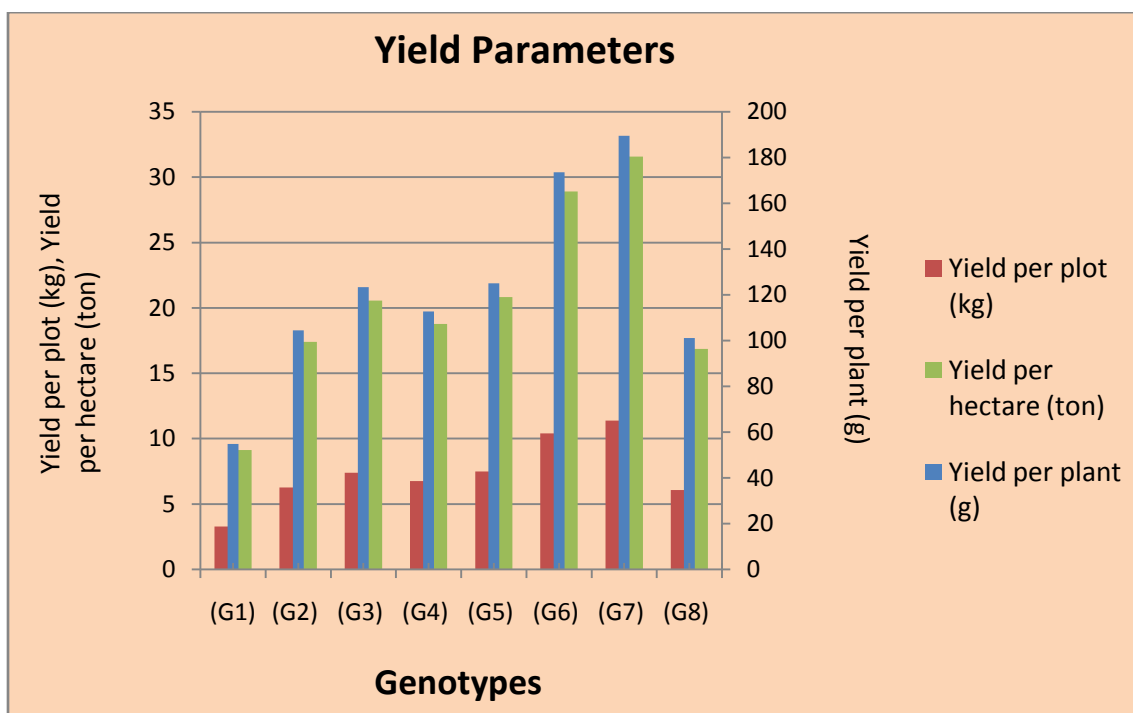


Fig. 8 Fresh rhizome yield of different ginger genotypes at 240 DAP

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

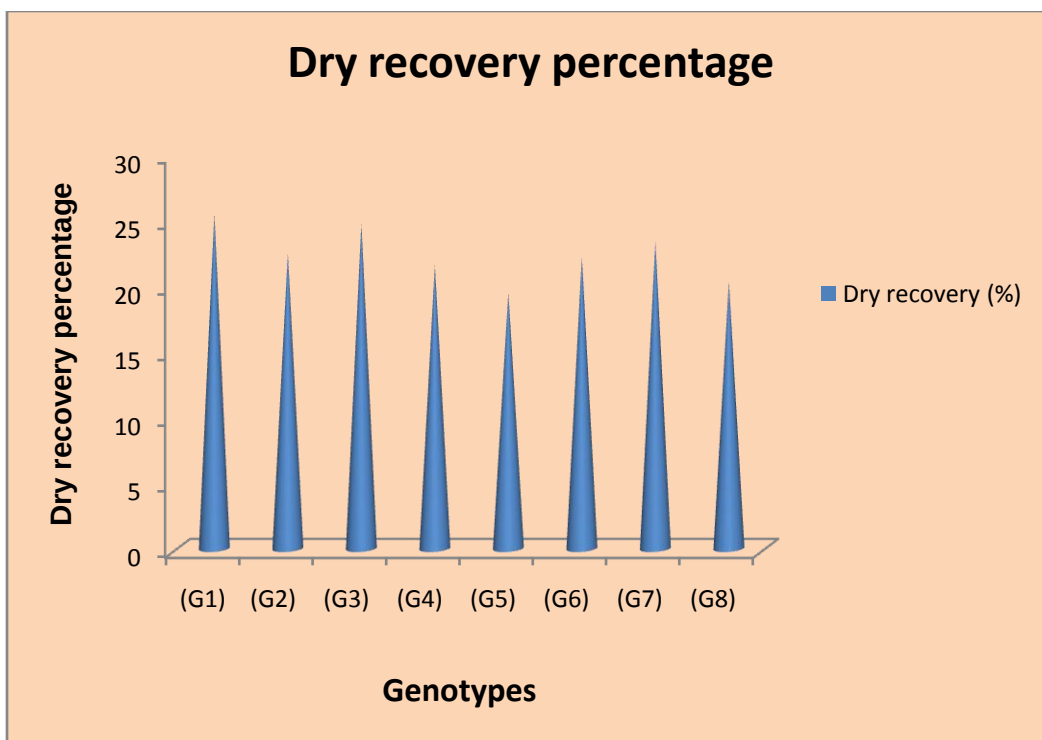


Fig. 9 Dry recovery percentage of rhizomes by different ginger genotypes at 240 DAP

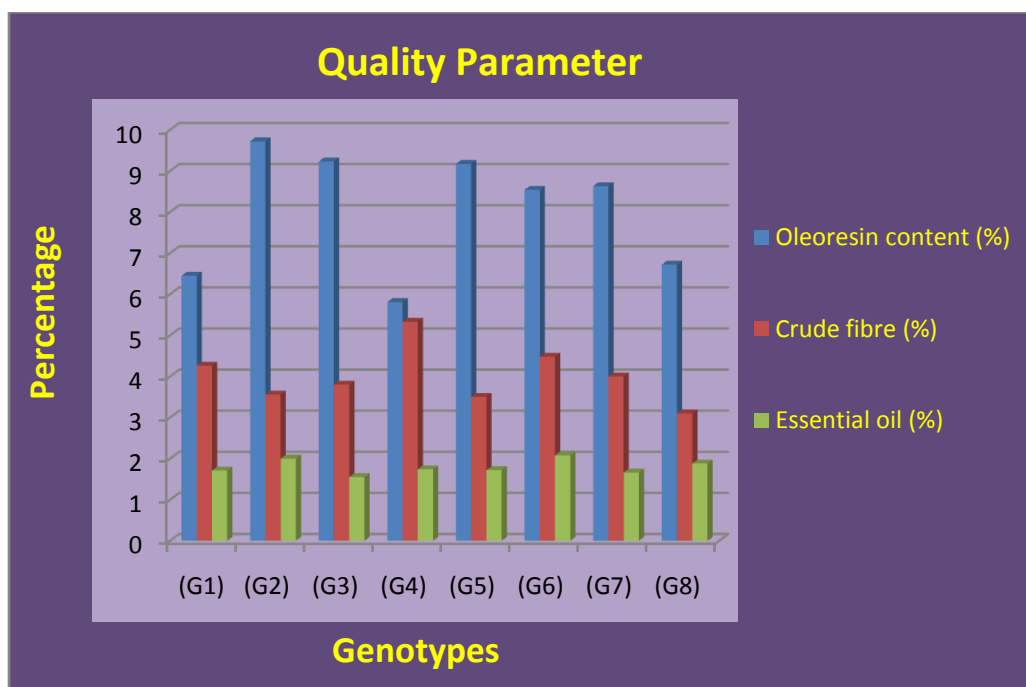


Fig. 10 Oleoresin, Crude fibre and Essential oil contents of different ginger genotypes at 240 DAP

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

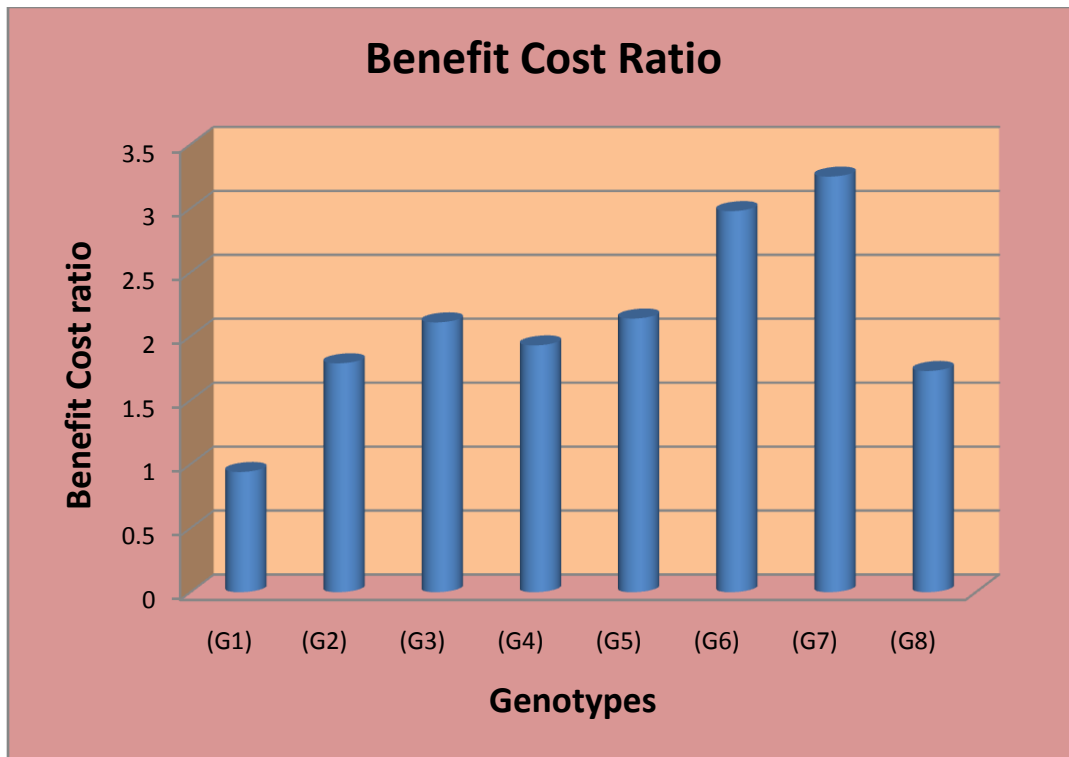


Fig. 11 Economics of cultivation for different ginger genotypes

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3



Plate 1. Field view of the experimental plot



Plate 2. Plant height of promising ginger genotypes

G7- Idukki 2

G8- Idukki 3

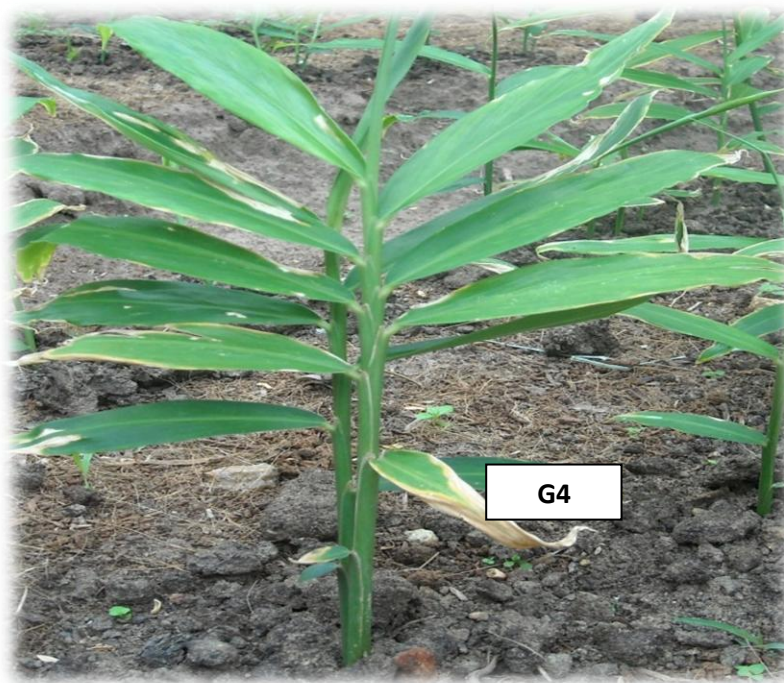


Plate 3. Number of tillers produced by promising ginger genotypes

G7 – Idukki 2

G4- Malaiinji

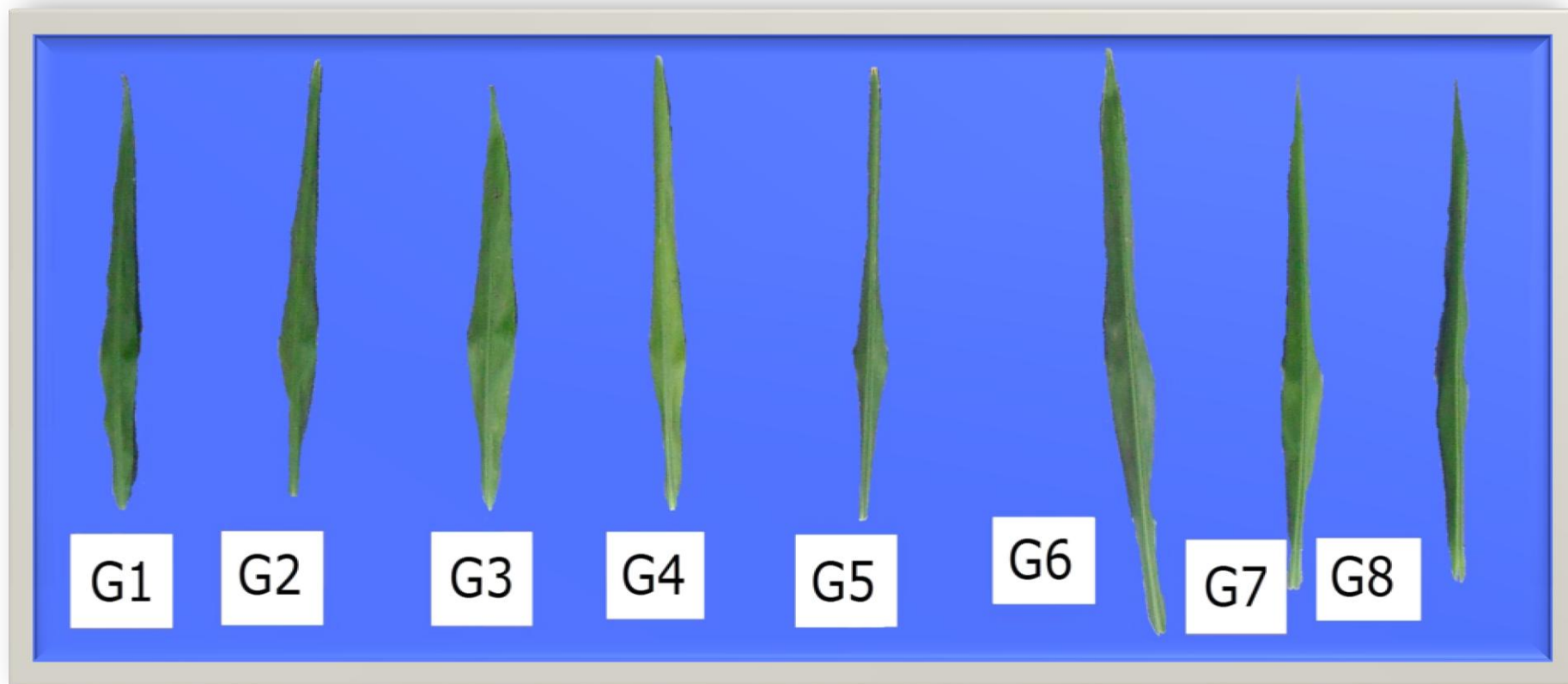


Plate 4. Leaf size produced by different ginger genotypes

G₁- Varada

G₂ - Nadan

G₃ - Kerala

G₄ -Malaiinji

G₅ - Maran

G₆ - Idukki 1

G₇ - Idukki 2

G₈ - Idukki 3

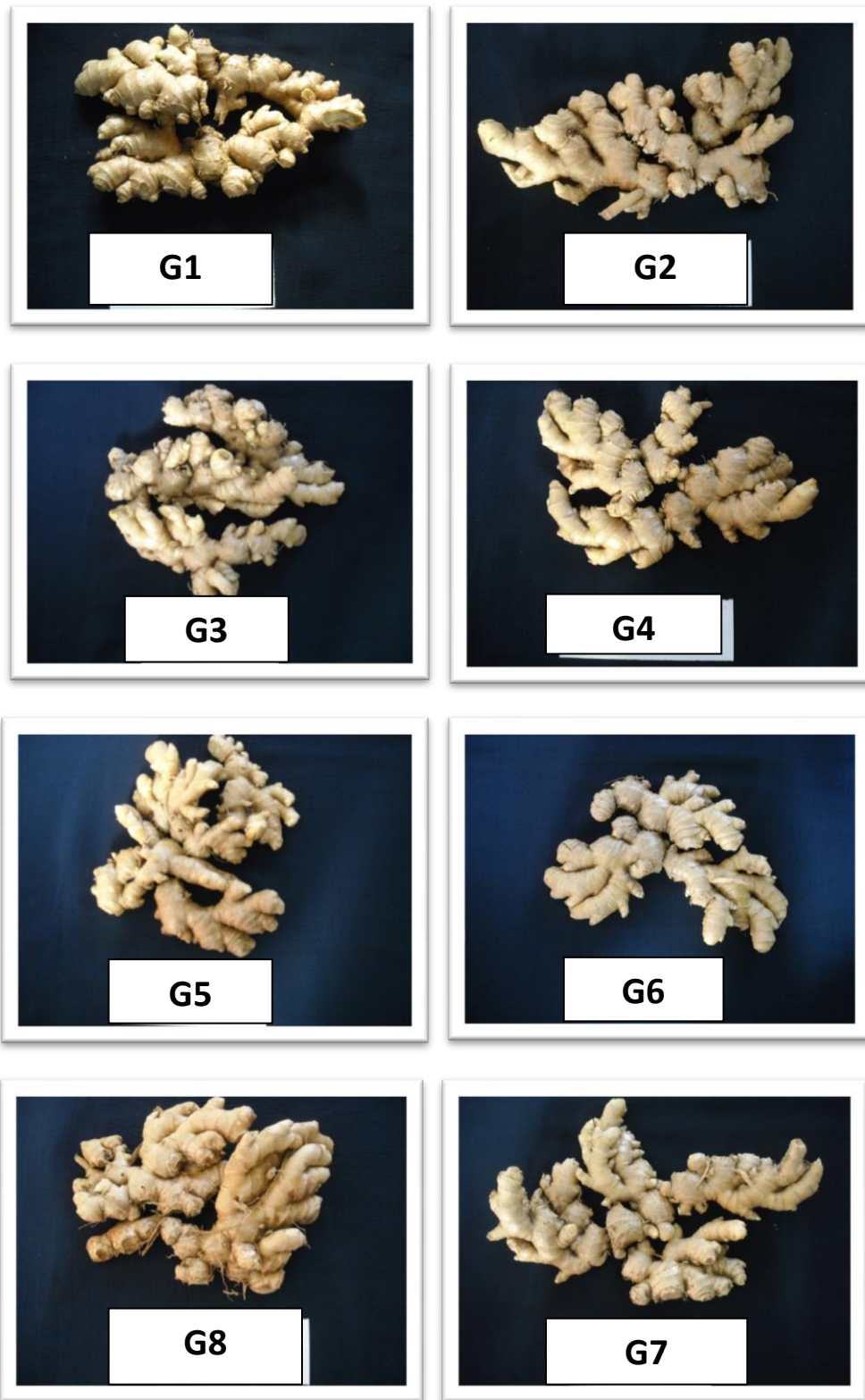


Plate 5. Fresh rhizome yield of different ginger genotypes (240 DAP)

G ₁ - Varada	G ₂ - Nadan	G ₃ - Kerala	G ₄ -Malaiinji
G ₅ - Maran	G ₆ - Idukki 1	G ₇ - Idukki 2	G ₈ - Idukki 3

Table 1. Mean performance of ginger genotypes on days taken for sprouting and sprouting percent (%)

Genotypes	Number of days taken for sprouting	Sprouting percentage (%)
(G₁)Varada	32.66	48.00
(G₂) Nadan	25.66	76.33
(G₃) Kerala	25.00	70.50
(G₄) Malaiinji	42.66	78.20
(G₅) Maran	40.00	49.54
(G₆) Idukki 1	21.00	89.80
(G₇) Idukki 2	30.33	91.96
(G₈) Idukki 3	36.33	82.53
Mean	31.70	73.93
SEd	1.70	4.40
CD at 5%	3.65	9.44

Table 2. Mean performance of ginger genotypes on plant height (cm)

Genotypes	Stages (Days after planting)				
	30	60	90	120	150
(G ₁)Varad	24.	27.2			
a	40	0	51.28	51.40	52.26
(G ₂)	40.	43.8			
Nadan	20	0	57.34	58.40	57.91
(G ₃)	33.	39.0			
Kerala	80	0	52.06	51.60	52.60
(G ₄)	31.	35.6			
Malaiinji	20	0	54.08	64.20	56.93
(G ₅)	24.	32.6			
Maran	60	0	57.92	57.10	56.83
(G ₆)	42.	45.2			
Idukki 1	80	0	64.20	65.60	65.44
(G ₇)	39.	42.2			
Idukki 2	60	0	65.60	65.60	66.13
(G ₈)	26.	29.6			
Idukki 3	20	0	41.58	42.80	45.16
Mean	31.	35.9	55.70	56.18	56.66
	23	0			
SEd	3.4	2.16	1.29	2.35	2.26
	1				
CD at 5%	7.3	4.65	2.78	5.05	4.85
	1				

Table 3. Mean performance of ginger genotypes on number of tillers (number)

Genotypes	Stages (Days after planting)				
	30	60	90	120	150
(G ₁)Varada	1.22	1.88	3.77	4.33	4.73
(G ₂) Nadan	2.44	2.66	5.33	5.88	6.80
(G ₃) Kerala	2.33	3.99	6.16	8.22	9.13
(G ₄) Malaiinji	1.55	2.33	3.99	3.55	3.80
(G ₅) Maran	1.99	3.32	4.44	7.27	6.30
(G ₆) Idukki 1	1.88	1.54	4.22	4.44	5.06
(G ₇) Idukki 2	1.33	2.44	6.44	8.77	9.40
(G ₈) Idukki 3	1.55	1.44	5.22	7.55	8.20
Mean	1.83	2.45	4.94	6.32	6.68
SEd	0.36	0.38	0.64	1.02	0.67
CD at 5%	0.77	0.83	1.37	2.19	1.44
	(NS)				

Table 4. Mean performance of ginger genotypes on number of leaves (number)

Genotypes	Stages (Days after planting)				
	30	60	90	120	150
(G ₁)Varada	5.66	20.50	52.16	87.50	98.50
(G ₂) Nadan	14.50	27.50	58.16	88.00	112.00
(G ₃) Kerala	8.66	37.77	77.11	81.50	114.50
(G ₄) Malaiinji	5.22	22.83	57.16	62.33	62.00
(G ₅) Maran	7.94	20.33	59.66	76.66	96.66
(G ₆) Idukki 1	9.99	16.66	56.83	88.16	87.33
(G ₇) Idukki 2	9.83	32.33	84.83	128.83	137.00
(G ₈) Idukki 3	5.55	17.00	71.66	99.33	112.50
Mean	8.42	24.36	64.70	89.04	102.56
SEd	2.52	2.63	7.74	7.32	6.74
CD at 5%	5.40	5.65	16.61	15.71	14.47

Table 5. Mean performance of ginger genotypes on Leaf Area per plant (cm²)

Genotypes	Stages (Days after planting)				
	30	60	90	120	150
(G ₁)Varada	148.	537.7	1368	2295	2583
	63	1	.33	.12	.65
(G ₂) Nadan	440.	836.0	1768	2675	3404
	80	0	.26	.70	.80
(G ₃) Kerala	252.	1100.	2245	2373	3334
	26	01	.36	.18	.12
(G ₄) Malaiinji	151.	661.2	1655	1805	1795
	16	0	.43	.04	.39
(G ₅) Maran	222.	570.5	1674	2151	2712
	78	3	.18	.19	.37
(G ₆) Idukki 1	418.	696.9	2376	3687	3652
	05	8	.71	.03	.19
(G ₇) Idukki 2	303.	998.2	2624	3977	4229
	48	2	.20	.47	.59
(G ₈) Idukki 3	189.	578.6	2439	3381	3829
	02	6	.46	.20	.38
Mean	265.	747.4	2018	2793	3192
	77	1	.99	.24	.68
SEd	75.8	87.32	243.	226.	199.
	3		02	85	37
CD at 5%	162.	187.3	521.	486.	427.
	66	2	29	60	66

Table.6. Mean performance of ginger genotypes on Leaf Area Index (LAI)

Genotypes	Stages (Days after planting)				
	30	60	90	120	150
(G₁)Varada	0.24	0.89	2.28	3.82	4.30
(G₂) Nadan	0.73	1.39	2.94	4.45	5.67
(G₃) Kerala	0.42	1.83	3.74	4.04	5.55
(G₄) Malaiinji	0.25	1.10	2.75	3.00	2.32
(G₅) Maran	0.37	0.94	2.79	3.58	4.52
(G₆) Idukki 1	0.69	1.16	3.96	6.14	6.08
(G₇) Idukki 2	0.50	1.66	4.37	6.62	7.04
(G₈) Idukki 3	0.31	0.96	4.06	5.63	6.38
Mean	0.44	1.24	3.36	4.66	5.23
SEd	0.12	0.14	0.40	0.37	0.54
CD at 5%	0.27	0.31	0.86	0.81	1.16

Table.7. Mean performance of ginger genotypes on Crop Growth Rate (CGR) ($\text{g m}^{-2} \text{ day}^{-1}$)

Genotypes	Stages (Days after planting)			
	30-60	60-90	90-120	120-150
(G ₁) Varada	3.36986	4.85133	8.61066	8.89200
(G ₂) Nadan	3.64766	4.48100	8.26800	11.01433
(G ₃) Kerala	3.94366	4.49033	8.83066	11.00233
(G ₄) Malaiinji	2.25866	5.09233	9.23466	6.81633
(G ₅) Maran	4.09200	3.76800	9.99033	9.99966
(G ₆) Idukki 1	2.99966	4.17533	9.46233	11.91600
(G ₇) Idukki 2	3.46233	5.74000	9.04600	11.80333
(G ₈) Idukki 3	4.46800	4.23466	8.51766	10.46233
Mean	3.5302	4.6041	8.9950	10.2383
SEd	0.7167	0.5967	0.4206	0.3243
CD at 5%	1.5373	1.2799	0.9021	0.6957
	(NS)	(NS)		

Table.8. Mean performance of ginger genotypes on Relative Growth Rate (RGR)
(mg g⁻¹ day⁻¹)

Genotypes	Stages (Days after planting)			
	30-60	60-90	90-120	120-150
(G ₁)Varada	0.0230	0.0178	0.0184	0.0120
(G ₂) Nadan	0.0224	0.0153	0.0176	0.0145
(G ₃) Kerala	0.0228	0.0149	0.0183	0.0135
(G ₄) Malaiinji	0.0186	0.0225	0.0211	0.0100
(G ₅) Maran	0.0224	0.0124	0.0200	0.0123
(G ₆) Idukki 1	0.0227	0.0130	0.0182	0.0141
(G ₇) Idukki 2	0.0155	0.0159	0.0158	0.0133
(G ₈) Idukki 3	0.0225	0.0126	0.0165	0.0131
Mean	0.0213	0.0156	0.0183	0.0129
SEd	0.0014	0.0018	0.0009	0.0004
CD at 5%	0.0029	0.0038	0.0019	0.0009

Table 9. Mean performance of ginger genotypes on Net Assimilation Rate (NAR)
(mg cm⁻² day¹)

Genotypes	Stages (Days after planting)			
	30-60	60-90	90-120	120-150
(G ₁)Varad	0.00067	0.00033		
a	9	1	0.000293	0.000230
(G ₂)	0.00037	0.00018		
Nadan	6	6	0.000225	0.000220
(G ₃)	0.00042	0.00016		
Kerala	2	8	0.000210	0.000190
(G ₄)	0.00039	0.00029		
Malaiinji	1	1	0.000306	0.000261
(G ₅)	0.00068	0.00022		
Maran	9	2	0.000330	0.000247
(G ₆)	0.00047	0.00018		
Idukki 1	9	6	0.000193	0.000206
(G ₇)	0.00035	0.00020		
Idukki 2	6	9	0.000304	0.000210
(G ₈)	0.00111	0.00020		
Idukki 3	2	0	0.000178	0.000224
Mean	0.0006	0.0002	0.0003	0.0002
SEd	0.0002	0.0000	0.0001	0.0000
CD at 5%	0.0004	0.0001	0.0002(NS	0.0001(NS
			)	)

**Table.10. Mean performance of ginger genotypes on Dry Matter Production (DMP)
(g / plant)**

Genotypes	Stages (Days after planting)					
	30	60	90	120	150	180
(G₁)Varada	6.1	12.	21.	36.	52.	62.
	3	26	00	50	53	59
(G₂)Nadan	6.8	13.	21.	36.	56.	66.
	6	43	36	21	04	06
(G₃)Kerala	7.1	14.	22.	38.	58.	69.
	8	28	36	71	52	32
(G₄)Malaiinji	5.4	9.3	18.	35.	47.	52.
	3	3	66	29	56	65
(G₅)Maran	7.6	15.	21.	39.	57.	68.
	5	01	80	78	78	33
(G₆)Idukki 1	7.9	15.	23.	40.	61.	74.
	8	78	30	33	78	83
(G₇)Idukki 2	10.	16.	27.	43.	64.	79.
	43	66	00	28	53	44
(G₈)Idukki 3	8.3	16.	24.	39.	58.	67.
	3	37	00	33	16	99
Mean	7.5	14.	22.	38.	57.	67.
	0	14	43	68	11	65
SEd	0.2	0.5	0.6	0.3	0.4	0.9
	2	3	6	4	1	1
CD at 5%	0.4	1.1	1.4	0.7	0.8	1.9
	8	5	2	3	8	6

Table.11. Mean performance of ginger genotypes on fresh rhizome yield (180 DAP)

Genotypes	Yield per plant (g)	Yield per plot (kg)	Estimated Yield per hectare (ton)
(G₁)Varada	44.25	2.65	7.37
(G₂) Nadan	94.07	5.64	15.67
(G₃) Kerala	79.56	4.77	13.26
(G₄) Malaiinji	113.33	6.80	18.88
(G₅) Maran	97.70	5.86	16.28
(G₆) Idukki 1	161.44	9.68	26.90
(G₇) Idukki 2	188.72	11.32	31.45
(G₈) Idukki 3	66.25	3.97	11.04
Mean	105.66	6.33	17.61
SEd	29.92	1.11	3.09
CD at 5%	64.17	2.38	6.63

Table .12. Mean performance of ginger genotypes on number and size of mother rhizomes (240 DAP)

Genotypes	No.of mother rhizomes	Length of mother rhizomes (cm)	Girth of mother rhizomes (cm)	Weight of mother rhizomes (g)
(G₁)Varada	1.83	2.56	9.00	23.00
(G₂) Nadan	2.00	3.00	8.73	26.66
(G₃) Kerala	2.23	4.10	9.20	33.00
(G₄) Malaiinji	2.10	4.40	9.33	38.00
(G₅) Maran	1.65	2.60	8.40	26.98
(G₆) Idukki 1	2.33	4.56	10.36	42.33
(G₇) Idukki 2	3.06	5.05	10.93	50.33
(G₈) Idukki 3	1.36	2.63	8.60	24.66
Mean	2.07	3.61	9.32	33.12
SEd	0.30	0.21	0.14	3.22
CD at 5%	0.65	0.45	0.31	6.91

Table .13. Mean performance of ginger genotypes on number and size of primary rhizomes (240 DAP)

Genotypes	No.of primary rhizomes	Length of primary rhizomes (cm)	Girth of primary rhizomes (cm)	Weight of primary rhizomes (g)
(G₁)Varada	3.33	3.41	6.70	20.83
(G₂) Nadan	4.00	4.23	7.59	25.83
(G₃) Kerala	3.66	6.10	7.50	22.16
(G₄) Malaiinji	3.16	4.61	8.10	35.00
(G₅) Maran	3.83	6.00	8.24	35.50
(G₆) Idukki 1	3.66	6.18	8.81	56.33
(G₇) Idukki 2	6.50	3.70	9.39	61.83
(G₈) Idukki 3	3.16	2.71	7.47	28.33
Mean	3.91	4.62	7.97	35.72
SEd	0.73	0.32	0.57	7.31
CD at 5%	1.58	0.70	1.22	15.68

Table .14. Mean performance of ginger genotypes on number and size of secondary rhizomes (240 DAP)

Genotypes	No.of secondar y rhizomes	Length of secondar y rhizomes (cm)	Girth of secondar y rhizomes (cm)	Weight of secondar y rhizomes (g)
(G₁)Varad a	4.16	2.63	6.87	21.66
(G₂) Nadan	6.00	4.23	7.21	37.83
(G₃) Kerala	5.16	4.01	7.40	39.33
(G₄) Malaiinji	5.43	4.96	7.54	46.66
(G₅) Maran	4.50	4.55	7.34	41.50
(G₆) Idukki 1	7.00	6.56	8.16	59.66
(G₇) Idukki 2	8.23	6.50	9.06	75.16
(G₈) Idukki 3	3.66	7.35	6.93	47.50
Mean	5.52	5.10	7.56	46.16
SEd	1.14	0.35	0.45	8.21
CD at 5%	2.45	0.75	0.97	17.61

Table .15. Mean performance of ginger genotypes on number and size of tertiary rhizomes (240 DAP)

Genotypes	No.of tertiary rhizomes	Length of tertiary rhizomes (cm)	Girth of tertiary rhizomes (cm)	Weight of tertiary rhizomes (g)
(G₁)Varada	2.33	2.87	5.42	15.33
(G₂) Nadan	5.33	3.39	6.83	26.00
(G₃) Kerala	4.66	4.05	7.35	32.66
(G₄) Malaiinji	4.00	4.46	7.20	25.83
(G₅) Maran	4.16	4.67	7.22	33.33
(G₆) Idukki 1	6.83	5.50	7.50	42.66
(G₇) Idukki 2	6.00	5.93	7.83	47.50
(G₈) Idukki 3	3.00	3.92	5.90	23.33
Mean	4.54	4.35	6.90	30.83
SEd	0.96	0.47	0.60	4.08
CD at 5%	2.06	1.01	1.29	10.31

Table. 16. Mean performance of ginger genotypes on fresh rhizome yield and dry recovery percentage (240 DAP)

Genotypes	Yield per plant (g)	Yield per plot (kg)	Estimated Yield per hectare (ton)	Dry recovery percentage (%)
(G₁)Varada	54.83	3.29	9.13	25.46
(G₂) Nadan	104.44	6.26	17.40	22.42
(G₃) Kerala	123.33	7.40	20.55	24.70
(G₄) Malaiinji	112.66	6.76	18.77	21.52
(G₅) Maran	125.00	7.50	20.83	19.43
(G₆) Idukki 1	173.50	10.41	28.91	22.17
(G₇) Idukki 2	189.50	11.37	31.58	23.33
(G₈) Idukki 3	101.16	6.07	16.86	20.28
Mean	123.05	7.38	20.50	22.41
SEd	1.95	0.71	1.99	0.18
CD at 5%	25.64	1.53	4.27	0.40

Table. 17. Mean performance of ginger genotypes for Oleoresin, Crude fibre and Essential oil contents (240 DAP)

Genotypes	Essential oil (%)	Crude fibre (%)	Oleoresin content (%)
(G₁)Varada	1.71	4.26	6.45
(G₂) Nadan	2.00	3.56	9.72
(G₃) Kerala	1.55	3.80	9.23
(G₄) Malaiinji	1.74	5.33	5.81
(G₅) Maran	1.72	3.50	9.17
(G₆) Idukki 1	2.08	4.48	8.54
(G₇) Idukki 2	1.66	4.00	8.63
(G₈) Idukki 3	1.88	3.10	6.72
Mean	1.79	4.00	8.03
SEd	0.08	0.19	0.43
CD at 5%	0.18	0.42	0.92

Table 18. Cost of cultivation for different ginger genotypes

Genotypes	Fresh rhizom e Yield (t ha⁻¹)	Gross return (Rs ha⁻¹)	Total Cost of cultivat ion (Rs ha⁻¹)	Net retur ns (Rs ha⁻¹)	B C rat io
(G₁)Var ada	9.13	3,10,4 20	3,29,78 0	19,36 0	0.9 4
(G₂) Nadan	17.40	5,91,6 00	3,29,78 0	2,61,8 20	1.7 9
(G₃) Kerala	20.55	6,98,7 00	3,29,78 0	3,68,9 20	2.1 1
(G₄) Malaiinj i	18.77	6,38,1 80	3,29,78 0	3,08,4 00	1.9 3
(G₅) Maran	20.83	7,08,2 20	3,29,78 0	3,78,4 40	2.1 4
(G₆) Idukki 1	28.91	9,82,9 40	3,29,78 0	6,53,1 60	2.9 8
(G₇) Idukki 2	31.58	10,73, 720	3,29,78 0	7,43,9 40	3.2 5
(G₈) Idukki 3	16.86	5,73,2 40	3,29,78 0	2,43,4 60	1.7 3
Coconut	14,000 Nos	77,000	16 ,950	60,05 0	1.9 6