VARIABILITY IN THE OPEN-POLLINATED PROGENIES OF TURMERIC

Curcuma aromatica. Salisb.

BY

HANZHA GEORGE

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Variability in the open-pollinated progenies of Turmeric *Curcuma aromatica* Salisb." is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

HANZHA GEORGE

Vellanikkara,
15th July, 1981.

CERTIFICATE

Certified that this thesis entitled "Variability in the open-pollinated progenies of Turmeric *Curcuma aromatica* Salisb." is a record of research work done independently by Smt. Mamma George under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. P.C. Sivaraman Nair,
Director of Research

Vellanikkara,
15th July, 1981.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt. Hansha George, a candidate for the degree of Master of Science in Horticulture with major in Horticulture, agree that the thesis entitled "Variability in the open-pollinated progenies of Turmeric Curcuma aromatica Salisb." may be submitted by Smt. Hansha George in partial fulfilment of the requirements for the degree.

Dr. P.C. Sivaraman Nair,
Advisor and Chairman

Dr. N. Mohanakumaran,
Member

Dr. K. Kumaran,
Member

Shri. P.V. Prabhakaran,
Member
(Substituted by Dr. K.C. George)

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HANZHA GEORGE

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INTRODUCTION

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The spice 'turmeric' consists of the cured, dried and polished rhizomes of the herbaceous plant, Curcuma longa L. and Curcuma aromatica. Salisb, grown in India, Bangladesh, Indonesia, Sri Lanka, Taiwan, parts of China and Jamaica. Though the country of origin is not known with certainity, it is presumed to be of South-East Asian origin.

India is by far the largest producer in world, contributing 93.7 per cent of the total world production in turmeric. It occupies about 97.7 thousand hectares of area which is about 6 per cent of the total area under spices and condiments. Andhra Pradesh, Maharashtra, Tamil Nadu, Orissa, Karnataka and Kerala are the important turmeric producing states in India. About 120-150 thousand metric tonnes of cured turmeric are produced annually, of which 92 per cent is consumed internally. The remaining 8 per cent earns foreign exchange to the tune of Re.4.15 to 7.2 crores annually depending upon the world market. The foreign exchange earnings from turmeric ranks fourth among the spices next to black pepper, cardamom and ginger.

The area and production of turmeric in Kerala is only 3.7 per cent (3700 hectares) and 1.8 per cent (3700 tonnes) respectively to that of India. But the export of turmeric is mainly from Kerala because of its higher curcumin content and earns a foreign exchange of 17.9 per cent of the exchange earnings of turmeric.

Turmeric is a versatile commodity with innumerable uses, though outside India, it is known only as a condiment and colouring matter in prepared custard, meat dressings and salads. Turmeric is an important constituent of curry powder, not only to impart colour, and flavour but also for its qualities to preserve. It stimulates appetite as well as aids in digestion of foods. It is also used in Indian medicine in the preparation of medicinal oils, ointments and poultices. It is a stomachic, tonic, blood purifier and antiseptic.

Turmeric contains considerable proportions of an essential oil to which turmeric owes its aromatic taste and flavour and its value as a condiment. Curcumin is the principal colouring constituent which imparts the characteristic yellow colour to turmeric. It is an orange yellow crystalline powder. It has got an inhibitory effect in certain micro-organisms.

Being vegetatively propagated, turmeric have certain inherent advantages than seed propagated crops. Any variability obtained either through the conventional breeding methods or induction, is fixed immediately and true to types could be multiplied through vegetative reproduction.

Although studies on the morphology and anthesis of the turmeric flowers were undertaken, efforts to evolve a suitable technique for controlled pollination had not met with success. The seed set obtained through open pollination in Curcuma aromatica opens out new vista with respect to plant improvement programme. A study was conducted at College of Horticulture, Vellanikkara with the open pollinated seedlings of two types of Curcuma aromatica, namely 'Amalapuram' and 'Dindrigam', since much scope exists in exploitation of the genetical variability in the open pollinated seedlings. The main objectives were (1) to find out the genetical variability with regards to various characters and (2) to select high yielding and high curcumin content and pest and disease tolerant or resistant types of turmeric.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Turmeric is best known in India as a condiment, though the plant has uses in the social and religious life of the people in South East Asia. Though its importance is known from time immemorial and number of turmeric types are being grown in different parts of the country, the research work done on the crop is rather meagre. The work done on the plant improvement and morphological and qualitative studies have been reviewed.

1. CYTOGENETICS AND CROP IMPROVEMENT

Sugiura (1936) was the first to report the chromosome number in Curcuma longa. Chromosome number of 24 species in the family Zingiberaceae including that C. aromatica was reported by Raghavan and Venkatasubban (1943). The chromosome number of 2n=42 for C. longa was reported by Sato (1948) and based on the Karyomorphology, he concluded that the species seems to be an allotetraploid with basic number as x = 8. Cytology of six species of Curcuma and seven cultivars of C. longa was reported by Ramachandran (1961). A chromosome number of 2n = 86 for C. aromatica was also reported by him for the first time and he concluded that the species is a tetraploid. He also studied in detail the mitosis of two species, C. decipiens

(2n = 42) and C. longa (2n = 63) and concluded that the sterility in C. longa is probably due to its auto-triploid nature. Nambiar (1979) reported that all the cultivators of C. aromatica have 2n = 84 and C. longa 2n = 63. He suggested that the earlier reports of chromosome number of 2n = 32, 62 and 64 for C. longa and 42, 63 and 86 for C. aromatica are exceptional cases and the correct chromosome numbers for these species are 2n = 63 and 84 respectively.

Earlier reports indicated that turmeric is a sterile triploid which flowers but fails to set seed (Burkill, 1935; Purseglove, 1975).

In view of this, the plant breeding work has not been undertaken in this crop till recently. Nambiar et al. (1980) reported for the first time that seed set and seedling progenies were obtained in some cultivars of C.aromatica, which opens new vistas in crop improvement programme of this spice crop.

2. VARIETIES

In spite of authoritative works of Valenton (1918); Hooker (1894) and Holttum (1950), the classification of the genus Curcuma remains very confused. The genus consists

of about 70 species of rhizomatous herb, out of which 29 spp. have been described by Hooker (Hooker, 1894).

Aiyer (1954) reported that there were no sharply distinct varieties in the cultivated turmeric."Curcuma" species were very similar in appearance and were likely to be mistaken one for the other and that Curcuma longa was often confused with C. aromatica.

Sankaracharya and Natarajan (1973) reported that there were 50 species under the genus Curcuma of which C. longa, C. aromatica, C. augustifolia, C. amada and C. caesia were the economically important ones and in the family "Zingiberaceae" only C. longa and C. aromatica contained the yellow coloured pigment 'Curcumin'. According to Chaurasia et al. (1974) there were more than 70 spp. of Curcuma, of which nearly thirty had been found to grow in India. They described two varieties of C. longa, one yielding a hard and bright coloured rhizomes and the other a somewhat softer, larger and lighter coloured rhizomes. They noticed camphoraceous odour in C. aromatica type as its distinguishing feature.

Ambekar (1927) also had distinguished two groups of turmeric, one with hard and bright coloured rhizomes and the other with softer, larger and light coloured rhizomes.

Some cultivars producing sweet aroma was described by Rajaratnam (1923). Prathy (1976) reported 30 species under the genus Curcuma of which C. longa was economically the most important accounting for about 96.4% of the total area under turmeric cultivation in India and the remaining 3.6% of the total area were cultivated under C. aromatica.

About 50 commercial cultivars of turmeric belonging to C. longa and C. aromatica are distinguished in this country by the name of localities, where they were extensively cultivated. Some of the popular cultivars are: Armoor, Duggirala, Mydukur, Tekurpetta, Alleppey, Dindrigam and Amalapuram (Rao, Reddy and Subbarayudu, 1975). Cultivars of turmeric have been classified as 'long' duration (9 months) 'medium' duration (8 months) and 'short' duration based on the time taken for the maturity of rhizome (Aiyadurai, 1966). Sarma and Krishnamurthy (1960) reported high percentage of curing for the 'early' duration aromatica type and lowest value for medium duration longa types.

Menon (1975) found that turmeric produced in different localities varied in quality and 'Alleppey' turmeric, 'Rajpuri' turmeric, 'Guntur' turmeric and 'Madras' turmeric

were the popular trade names among Indian turmeric. Sankaracharya and Natarajan (1973) and Pruthy (1976) reported 16 regional varieties of turmeric in the trade mainly based on the commercial qualities.

3. MORPHOLOGICAL STUDIES

According to Sarma and Krishnamurthy (1965) the number of tillers per plant tended to reduce with delay in planting in case of fingers while no such trend was noticed in cut mothers. Pillai and Nambiar (1975) noticed 2 to 3 tillers in 'longa' types. Subbarayudu et al. (1976) observed no significant difference in tiller production among the 'short' duration and 'medium' duration types whereas marginal difference was observed among 'long' duration types. From a study conducted at Vellanikkara, Philip (1978) also found no correlation between tiller production and yield. The variation in tiller production among the types may be due to genetic factors.

The height of the plant was found to vary between 2 to 4 feet in turmeric (Aiyar, 1954); Pary, 1962). According to Pruthy (1976) the height of turmeric was around 60 to 90 cm. Sarma and Krishnamurthy (1965) reported that the height of the plant was greater influenced by the planting time and nature of planting material. They noticed no decrease in height with delayed planting in the case of

mother rhizome while there was a decrease in height by 3 cm for every fortnight delay in planting of finger rhizomes. Pillai and Nambiar (1975) observed a variation of 75 to 81.5 cm in height among C. longa types while Rao et al. (1975) recorded a height of 32-45 cm in 'aromatica' type Dindrigam. According to Philip (1978), the height of the plant showed highly significant differences among the types. The height of the plant is found to be the maximum in the type Chayapasupa (41.09 cm) whereas Dindrigam Co 69 showed the lowest height. Highly significant positive correlation had been noticed between the yield and height of the plant (Philip, 1978).

Purseglove (1975) stated that leaf shoot was 1 M. tall, bearing 6 to 10 leaves, surrounded by bladeless sheaths, the leaf sheaths forming a pseudostem lamina lanceolate, acuminate, thin, usually to 30 cm in length and 7-8 cm wide, rarely over 50 cm long and green in colour. Rao et al. (1975) observed 8-9 leaves in the Dindrigam ('aromatica' type), while Pillai et al. (1975) reported that the 'longa' types produced 9-12 leaves and showed a variation of 38-44 cm in leaf length and 15-17 cm in leaf breadth. Sankaracharya and Nataraj an (1973) observed a variation of 2-3 ft. in leaf length. Philip (1978) observed that the number of leaves both per tiller and per plant

showed significant differences among the types. Comparatively higher rate of leaf production both per plant and per tiller was noticed in the high yielding types like Mannuthy local and Chayapasupa whereas the leaf production was poor in low yielding types. Highly significant and positive correlation was noticed between the yield and the number of leaves per tiller whereas the correlation between the yield and the total number of leaves per plant is found to be non-significant. The number of leaves per tiller was found more important with regard to the yield rather than the total number of leaves per plant (Philip, 1978). He also reported that there is significant and positive correlation between the yield and leaf characters such as petiole length, leaf length, leaf breadth and leaf area index.

Valenton (1918) observed that all the cultivars in Java came to flowering, but the fruit set was observed in only two. Patnaik *et al.* (1960) and Pai (1961) described the floral biology and flowering behaviour of *C. longa*. Aiyer (1954) mentioned that flowering was scarce in turmeric. Aiyadurai (1966) reported that the cultivated varieties of 'longa' types flowered very rarely and viable seeds could be collected from the flowering types. Pillai and Nambiar (1975) noticed flowering and fruit set in nine

'longa' types and eight 'aromatica' types.

Out of the 19 types studied 15 types had flowered under Vellanikkara conditions (Philip, 1978). Maximum flowering is noticed in the types, Dindrigam Ca 69 (95%) and Amalapuram (92.7%). The flowering percentage ranged from 0-17.4 in 'longa' types. Flowering and seed setting in turmeric had been reported by Aiyadurai (1966) and Pillai et al. (1975) - Aiyadurai (1966) also mentioned that the climatic conditions influenced flowering to a great extent.

Under Kasaragod conditions, the flowering period was July to September in C. aromatica and September to December in C. longa (Nambiar et al. 1980). Seed set was noted only in the 'aromatica' types and not in any of the C. longa cultivars.(Nambiar et al. 1980). They also reported that percentage of seed germination varied among cultivars and 90 per cent of the seeds germinated during the first twenty days after sowing. The seedlings produced only roots and root tubers during the first year of growth and normal development of the rhizomes were observed only in the second year.

According to Aiyer (1954) the roots of turmeric grew to a length of 22-30 cm and produced rootlets towards the

tip. He also noted that the number of roots were found to vary depending upon the types. Rendle (1971) described that the roots of turmeric were slender with tuber like ends. According to Philip (1978) both the number and length of roots were found to be higher in high yielding types whereas the number and length of roots were found to be minimum in the low yielding types. Both the character showed significant and positive correlation with the yield.

Rao et al. (1975) and Pillai and Nambiar (1975) noticed variations in thickness, length, internodal length and colour of rhizomes among turmeric types. Aiyer (1954) recorded a length of 10 to 15 cm and a thickness of 2-2.5 cm in secondary fingers of turmeric. Parry (1962) observed deep yellow to orange yellow colour in Alleppey turmeric, Mustard yellow colour in 'Madras turmeric' and dull yellowish brown colour in 'Haiti turmeric'. According to Philip (1978) the turmeric plant produced 4-7 primary and 8-21 secondary rhizomes. The length of rhizomes varied from 8.4 to 12.6 cm in mother rhizomes, 7.5 to 12.1 cm in primary fingers and 4.5 to 8.6 cm in secondary fingers. He also reported that characters such as length, number of nodes and internodal distance were found to be not correlated with the yield whereas the girth at the centre was found to be positively correlated with the yield. The

primary finger characters such as the girth at centre and the internodal length were found to be not correlated with the yield whereas the length of the primary fingers was found to be positively correlated with the yield (Philip, 1978).

4. INCIDENCE OF PESTS AND DISEASES

The most important pest of turmeric was the shoot borer (Dichocrocis punctiferalis) while the green larvae of Udaspes folus Cram (Aiyer, 1954) was of minor importance. Abraham and Pillai (1974) and Dubey et al. (1976) found that none of the turmeric types were tolerant to shoot borer attack. The attack of maggots of dipteran fly Mimegralla sp. on fresh rhizomes of turmeric was noticed by Dubey et al. (1976) for the first time. According to Rao et al. (1975) the 'leaf mites' and 'lace wing bugs' were the important pests of standing crop.

Sarma and Krishnamurthy (1962) found two 'leaf spot' diseases caused by Colletotrichum capsici and Taphrina maculans, and they stated that the 'long duration' types were resistant to Taphrina sp. and medium duration types to Colletotrichum sp. and short duration to both. Aiyer (1954) noted 'leaf spot' diseases caused by Taphrina maculans Butl. in turmeric. Reddy et al. (1963) reported that different turmeric varieties exhibited varying degrees

of resistance to either of the 'leaf spot' disease caused by Colletotrichum and Taphrina sp. and no single variety was infected by both the fungi and no variety was free from either of the leaf spot. Chathopadhayay (1967) observed that 'leaf blotch' was an important disease of turmeric. Sarma and Nambiar (1974) noticed that 'brown rot' of rhizomes affected only 'aromatica' types. This was associated with Fusarium sp. and nematode Pratylenchus sp. They also observed Pythium 'rhizome rot' in 'longa' types. Rao et al. (1975) observed tolerance to 'leaf blotch' disease in 'longa' types viz. Armoor C11 - 324, Duggirala C11-325, Mydukur Ca-326 and Tekurpet Ca-327 whereas the tolerance to both 'leaf spot' and 'leaf blotch' diseases were noticed in aromatica types viz., Dindrigam Ca-69 and Amalapuram Ca-73. Nambiar et al. (1977) noticed maximum incidence of 'leaf blotch' infection during November-December under Kasaragod conditions and reported that both 'longa' and 'aromatica' types were susceptible to the disease.

5. YIELD

Aiyer (1954) recorded an yield of cured turmeric varied between 3.5 to 7 tonnes per hectare and the average was around 2.5 to 3 tonnes per hectare. Pillai and Nambiar (1974) recorded maximum yield in Mydukur C11-326,

Armoor C11-324, Sugandham C11-328, Avanigadda C11-325, Kasturi, Chayapasupa, Amalapuram, Ca-320, Armoor and Sugandham among the 41 types of turmeric. According to Sankaranarayanan (1974) the yield of green turmeric varied from 16.8 tonnes to 22.4 tonnes per hectare under irrigated conditions. Pillai and Nambiar (1975) noticed maximum yield in 'Karhadi local' followed by Kasturi and Tekurpeta among the 42 types of turmeric. In another trial they noticed maximum yield in Nandayal type, followed by Sugandham C11-328, Rajpuri local, Mydukur C11-326, Gorakhpur C11-316, Dindrigam Ca-69 and Kasturi Tanaka. The seedlings were found to perform like biennials producing rhizome only during the second year of their growth. Rao et al. (1975) reported that out of the 100 types of turmeric maximum range of yield was recorded in Mydukur C11-326 and Tekurpeta C11-327, (25-37 tonnes/ha each) followed by Amruthapani Kothapeta C11-317 (25-35 tonnes/ha) Armoor C11-324 and Dindrigam Ca-69 (15-20 tonnes/ha each) and Amalapuram Ca-73 (10-15 tonnes/ha). According to Subbarayadu et al. (1976) the types Dindrigam Ca-69 under short duration group, Amruthapani Kothapetta C11-317 under medium duration group and Duggirala C11-325 followed by Mydukur C11-326 under long duration groups were high yielding and suitable for growing in Cuddapah tract of Andhra Pradesh. (Philip, 1978) observed that the yield of cured

turmeric per hectare was maximum in the type VK.5 (8558.4 kg) and the lowest yield was recorded in VK.19 (1504.1 kg) among the 19 types.

6. PROCESSING

According to Aiyer (1954) turmeric could be dried only after slight boiling and the cells killed. Boiling in cowdung water increased colour of the cured turmeric types yielding a deep dye. Curing of turmeric by boiling with lime water or sodium bicarbonate solution has been standardised (Aiyadurai, 1966; Pruthy, 1976). The boiling of turmeric rhizomes was essential to reduce the drying time and to gelatinise the starch (Natarajan and Sankaracharya, 1974). They also reported that when mechanical driers were used for the drying of spices the drying temperature should be kept within 50-60°C as there was loss in the volatile substances beyond this temperature. The stage at which boiling was to be stopped was very critical for good quality turmeric as the overcooking spoiled the colour and increased the percentage of broken pieces obtained during subsequent polishing.

Stockdale (1925) reported a curing recovery of 20 per cent from the turmeric grown in Ceylon. Desai (1939) described two distinct turmeric varieties of Bombay known

as 'Lokhandi' and 'Seni' with a remarkable variation in their curing quality, the former was reported to cure with shrivelled up and constricted surface and low curing percentage of 10-17, while the latter cured normally with a curing percentage of 21-22. Dhanlal (1944) reported a recovery of about 16 per cent from the types grown in Madhya Pradesh while Sambasiva Rao (1949) observed that the mean proposition of cured produce to raw rhizomes was 1:4 for the Cuddapah and Guntur tracts. Aiyer (1954) noticed a curing percentage of 17-25 in turmeric, depending upon the quality and maturity of rhizomes. The percentage of curing varied with groups of the turmeric types the highest values being rendered by the early duration 'aromatica' types, and the lowest by medium duration types while the long duration 'longa' types recorded medium values (Sarma and Krishna Murthy, 1965; Subbarayadu et al. 1976). According to Sarma and Krishnamurthy (1965) the variation in curing percentage was from 24.9 to 25.3 per cent and 17.6 to 21.7 per cent, respectively, in early and medium duration types of turmeric. While Subbarayudu et al. (1976) recorded that the variation in curing percentage was between 26.4 to 37.4, 18.1 to 20.8 and 15.7 to 23.8 respectively in short, medium and long duration types. Sarma and Krishnamurthy (1965) also observed that the curing

percentage of turmeric tended to decrease with increase in moisture content of the raw rhizomes and there was an appreciable increase in the relative density of green rhizomes on curing. The curing percentage tended to increase with the increasing maturity of rhizomes - the primary mother rhizomes recording the highest and last order of the fingers the least values. The curing of fresh rhizomes within 15 days after harvest gave the maximum out turn of turmeric. According to Rao (1965) and Aiyadurai (1966) curing quality of turmeric was largely varietal character and the curing percentage was found to vary between 14-26.5. Rosengarten (1969) mentioned a curing percentage of 33.3 in turmeric, while Parry (1969) observed a curing percentage of 16.7. Rao et al. (1975) recorded maximum out turn of cured produce when curing of fresh rhizomes was done within 10 days after harvest and that the mother rhizomes required a little longer time for cooking than the fingers. They recorded maximum curing percentage in short duration 'aromatica' types, viz., Amalapuram Ca-73 (35.2%) and Dindrigam Ca-69 (26.7%) and the least in Armoor C11-324 (17.6%).

Mathai (1976) studied on the drying percentage of turmeric at monthly intervals from the third month of planting upto eighth month of maturity in two turmeric

cultivars viz., Kachapudy and G.L. puram. He observed that the drying percentage of turmeric increased steadily with increase in maturity. Philip (1978) also studied on the drying percentage at different periods. He also found that the percentage recovery of dry produce and yield are found to increase with increase in maturity.

7. QUALITY STUDIES

Parry (1969) found that the quality, appearance and colour of the whole turmeric varied according to its source. Rosengarten (1969) found that 'fingers' had the best quality among the grades, 'fingers' 'rounds' and 'splits'. Jain and Mishra (1964) observed that the extract of the rhizomes of Curcuma amada yielded a colourless oil curcumin an unidentified compound, a phytosterol and an azulenogenic oil containing pinene, camphor 1-beta and 1-alpha curcmene and turmone. Lewis (1973) reported distinct differences in quality and quantity of oil and oleoresin in different types of turmeric grown in India. According to Chaurasia et al. (1974) turmeric grown in hills was of better quality than that raised in the plains. According to Pruthy (1976) the quality attributes of the commercial produce were its colour, maturity, bulk density, length and thickness of the finger and aroma.

Kelkar and Rao (1934) noted that the turmeric oil contained Phellandrene (1%), Sabinene (0.6%), Cineole (1%), Borneol (0.5%), Zingiberene (25%) and Turmerone (58%). Parry (1962) reported that oil content in turmeric varied from 1.3 to 5.5 per cent. Krishnamurthy et al. (1972) observed an oil content of 1.5 to 4 per cent in turmeric and 18 to 25 per cent in turmeric oleoresin. Shankaracharya and Natarajan (1973) reported that the volatile oil derived from the tubers of C. longa was an orange yellow, occasionally slightly fluorescent liquid with an odour reminiscent of the tubers. The dried rhizomes gave 5 to 6 per cent essential oil while fresh rhizomes yielded 0.24 per cent. About 58% of the oil was composed of a mixture of sesquiterpene ketones and 90% was composed of tertiary alcohols. The volatile oil C. aromatica consisted chiefly of sesquiterpenes and their alcohols together with small amounts of d-camphene and d-camphor. The rhizomes of C. aromatica yielded oil upto 6.1% which was greenish brown in colour. Lewis et al. (1974) found that the essential oil content in turmeric varied from 1.5 to 4 per cent and the essential oil was composed of oxygenated derivatives (65%), sesquiterpenes (25%) and monoterpenes (10%). Shankaracharya (1974) reported that the dried rhizomes of turmeric contained 5 to 6 per cent of aromatic essential oil while Mathai (1974) observed that

among the 38 turmeric types the essential oil content varied from 2.4% (Tekurpetta C11-327) to 7.2% (Kasturi). Mathai (1975) also found that out of the 6 grades of turmeric, maximum oil content was recorded in Rajamundry Kasturi turmeric (6.3%). Menon (1975) mentioned that turmeric contained 5 to 6% essential oil while Guenther (1975) reported 1.3 to 5.5%. Pillai et al. (1976) reported that 'aromatica' types had more oil content than that of the 'longa' types. Krishnamurthy et al. (1976) observed a variation of 2.5 to 7.2 per cent in oil content among 12 turmeric cultivars commonly grown in India. They also found that the release of oil during distillation was slow because of the presence of high boiling sesquiterpene derivatives (about 85%) and about 4 hours were required to recover 80% of the available turmeric oil. Subbarayudu et al. (1976) reported that the oil content was high in medium duration types, while it was low in long duration types, and moderate in short duration types. They observed a variation of 5.3 to 6.8%, 2.2 to 4.2% and 3.3 to 6% respectively in oil content among medium, long and short duration types.

Curcumin is the principal colouring constituent which imparts the characteristic yellow colour to turmeric. This has the molecular formula $C_{21}H_{20}O_6$ (Narayanan et al., 1980).

According to Lewis (1973) 'Alleppey turmeric' contained about 6.5% 'curcumin' as against 3-4% in other varieties. Shankaracharya (1974) recorded 0.2 to 3.8 per cent of curcumin in dried rhizomes of turmeric. Mathai (1974) reported that among the 38 types of turmeric, curcumin content varied from 3.0-8.1% with the least in Nandyal and maximum in Vonbindatta. Chaurasia et al. (1974) studied the curcumin content of eight commercial varieties of turmeric and found maximum curcumin content in 'Alleppey fingers' (5.2%) and 'Alleppey bulb' (4.8%). The curcumin content varied from variety to variety and it was low in the case of bulbs, compared to fingers, when grown under identical environmental conditions. The agro-climatic conditions were also found to influence the curcumin content. Rao et al. (1975) noticed a variation of 1.24 to 3.87% in curcumin content among the seven turmeric types grown in Andhra Pradesh. Krishnamurthy et al. (1975) observed that the curcumin content of two important turmeric species C. longa and C.aromatica varied from 3.0-3.9 and 1.2 to 1.5% respectively. Krishnamurthy et al. (1976) recorded a variation of 1.2 to 5.4% in curcumin content among 12 turmeric cultivars with the maximum in Alleppey turmeric. Subbarayudu et al. (1976) observed a higher curcumin content among the 'medium' duration types, medium content in 'long' duration and the least content in 'short' duration types. Pillai et al. (1976) recorded a

variation of 8.9 to 14.5 per cent in curcumin content among 15 turmeric types grown under Kasaragod conditions and a higher content of curcumin in 'longa' types than that of 'aromatica' types. Mathai (1976) found that the curcumin content of turmeric varied depending upon maturity. It increased from 4.8 to 6.9 per cent from third to fifth month and decreased to 6.3 per cent in the sixth month and 4.1 in the seventh month and again increased to 6.9 per cent in the eighth month. According to Philip (1978) the curcumin content varied from 2.33 to 6.55 per cent. He also noticed that the uncured turmeric samples had significantly higher content of oleoresin and curcumin than that of the used samples in the same type.

Krishnamurthy et al. (1972) reported that the yield of oleoresin in turmeric varied from 4 to 7.5 per cent and the oleoresin contained about 18 to 25 per cent essential oil and 30 to 47 per cent curcumin. Lewis et al. (1974) reported that turmeric contained 6 to 7 per cent oleoresin and the oleoresin contained 18 to 20 per cent volatile oil and 35 per cent curcumin. Mathai (1975) estimated the oleoresin content of six types of turmeric and found the maximum oleoresin content in 'Alleppey finger' turmeric (24.3%). The bulb of 'Alleppey' turmeric contained only 16.2 per cent oleoresin. Krishnamurthy et al. (1976) tried different extractants and apparatus for oleoresin extraction and found that acetone was superior

to alcohol and ethylene. According to Philip (1978), the oleoresin content varied between 12.1 to 21.1%. The per hectare yield of oleoresin and curcumin was maximum in the type Mannuthy Local. He also noticed that the yield of oleoresin per hectare was maximum on 270th day after planting and the minimum on 165th day in all the 19 types studied.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken at the College of Horticulture, Vellanikkara during the period from June 1979 to May 1981 for two seasons. The topography of area selected for the experiment was fairly level and uniform with good drainage. The soil was red loam.

Open pollinated seeds of two types of turmeric, 'Amalapuram' and 'Dindrigam' (Curcuma aromatica Salisb) were sown and the seedlings were potted in polythene bags in May, 1978. The crop was harvested when the leaves dried up completely. Out of 1500 individual plants, 175 were selected based on the yield taking the yield of Amalapuram and Dindrigam as the basis. These seedling rhizomes were planted in single mounds during May 1979 and harvested in January 1980. Observations on number of roots, total weight of rhizomes, number, length, girth and internodal length of primary fingers and number, length, girth and internodal length of secondary fingers were taken and based on the fresh weight of the rhizomes harvested, selections were made among the plants. Those with a fresh weight of rhizomes having not less than 150 gms. were selected. Twelve selections from Amalapuram and thirty

. A view of the experimental plot

selections from Dindrigam were obtained, which was planted in the main field in May 1980.

The lines selected were numbered as follows:-

SELECTIONS FROM AMALAPURAM TYPE:

1.	A 32	7.	A 78
2.	A 31	8.	A 83
3.	A 53	9.	A 111
4.	A 64	10.	A 104
5.	A 71	11.	A 169
6.	A 76	12.	A 180

AC - Amalapuram control

SELECTIONS FROM DINDRIGAM TYPE:

1.	D 4	11.	D 187	21.	D 211
2.	D 6	12.	D 190	22.	D 214
3.	D 7	13.	D 191	23.	D 217
4.	D 18	14.	D 194	24.	D 220
5.	D 39	15.	D 196	25.	D 229
6.	D 80	16.	D 197	26.	D 304
7.	D 91	17.	D 198	27.	D 310
8.	D 180	18.	D 199	28.	D 311
9.	D 178	19.	D 202	29.	D 314
10.	D 182	20.	D 205	30.	D 320

DC - Dindrigam control

1. EXPERIMENTAL DETAILS

1.1. Cultivation

The land was ploughed well and raised beds of 7 M length and 50 cm width and 25 cm height were taken with a spacing of 30 cm between beds. Seed bits weighing 15 gms each were planted in the beds with one selection in each bed. The plots were given uniform cultural operations. A fertilizer dose at the rate of 60:60:60 kg N, P_2O_5 and K_2O/ha was applied in three split doses in addition to 5 tonnes of cattle manure. Roger (4 ml/lit.) was applied 60 days after planting and the same was repeated on 120th day with Dithane - M. 45 (2 gms/litre).

Final harvesting was done on 230th day after planting when the leaves had dried completely in all the plants. The weight was recorded after proper cleaning.

2. OBSERVATIONS

Observations were made on 100th and 150th day after planting and five plants in each lines selected at random were used for recording observations.

2.1. Germination

The plants germinated in each bed was recorded at weekly intervals and percentage was calculated.

2.2. Height of the plant, number of tillers and number of leaves per plant

The height of the plant was measured in centimetres on 100th and 150th day after planting. The length of the pseudostem, i.e. from the ground level to the point where the petioles clasped tightly, was taken as the height of the plant. The number of tillers per plant and number of leaves on the main plant and tillers were recorded separately.

2.3. Pests and diseases

2.3.1. Incidence of Shoot Borer

The number of plants infected in each bed was recorded and expressed in percentage. Observations were taken on 150th day after planting.

2.3.2. Incidence of leaf diseases

The incidence of leaf diseases was indicated by noting the leaf spots.

2.4. Number of roots

The total number of roots of the selected plants were counted after final harvest and the mean was calculated.

2.5. Rhizome characters

Number of primary and secondary fingers, and length, girth and internodal length of primary and secondary fingers were recorded and the mean was calculated. The length and girth were measured in centimetres using a non-stretchable string and scale. The distance between two consecutive nodes was recorded in millimeters as internodal length.

2.6. Fresh weight of the Rhizomes

The weight of the selected plants were recorded in grams after proper cleaning and the mean was calculated.

2.7. Percentage of dry turmeric

The percentage recovery of cured turmeric was found out taking a known weight of green turmeric and drying after curing.

3. CHEMICAL ANALYSIS

The dried samples of turmeric were ground in a Multiplex grinder and allowed to pass through a sieve of 60 mesh size and was utilised for subsequent analysis.

3.1. Moisture content

Moisture content of dry turmeric samples was

estimated by the Official Analytical Methods of the American Spice Trade Association (1968) using Toluene as reagent.

3.2. Estimation of curcumin

The curcumin content was estimated by the Official Analytical Methods of the American Spice Trade Association (1968) using Methanol. The curcumin content was worked out and expressed in percentage on dry weight basis.

3.3. Estimation of Oleoresin

Oleoresin in turmeric was estimated by the Indian Standard Methods of Sampling and Test for Spices and Condiments (1974). Extraction was done in Soxhlet apparatus using acetone as solvent. The percentage recovery of oleoresin was worked out on dry weight basis.

4. STATISTICAL ANALYSIS

The data on different characters studied were subjected to statistical analysis.

4.1. Analysis of variance

The data on different characters were analysed using the analysis of variance as suggested by Snedecor and Cochran (1967).

4.2. Variability studies

To study the variability of characters, the coefficient of variation was worked out by using the formula,

$$c.v. = \frac{S.D.}{\bar{x}} \times 100, \text{ where}$$

S.D. = Standard deviation

$\bar{x}$ = Mean

To study the reliability of the means of characters, the standard error of means were calculated. The homogenity of different lines with regards to a specific character was tested by using the Bartlett's test (Snedecor and Cochran, 1967). As preliminary test of equality of variance, the F max test was applied (Winesar, 1971). The Bartlett's test were applied only for characters for which the F_{max} test was found to be non-significant as it is more powerful than F_{max} test.

4.3. Correlation studies

The inter relations between various plant characters were studied by using the correlation analysis. The simple correlation coefficients were listed for their significance. In order to assess the relative importance of various characters in contributing to fresh weight of

rhizomes a multiple linear regression equation of the form

$y = b_0 + \sum_{i=1}^{n} b_i x_i$, where

b_0 is ~~the partial regression coefficient of y on y~~ a constant.

b_i is the partial regression coefficient of y on x_i.

x_1 is the value of i^{th} character

y is the expected fresh weight of rhizomes.

The partial regression coefficients were standardised to observe the relative contribution made by each character towards total yield independent of unit measurement. The standard regression co-efficients were worked out by using the relation

$$\beta i = \beta_i \frac{sx_i}{sy}$$ where,

βi = ~~Standardised~~ partial regression coefficient

sy = Standard deviation of yield

sx_i = Standard deviation of the i^{th} variable.

β_i' = standardised regression coefficient.

4.4. Selection of lines for further multiplication

A selection index for identifying superior lines on the basis of various plant characters was developed. It is of the form,

$$y = b_0 + \sum_{i=1}^{n} b_i x_i.$$

Where, n = number of characters, y is the expected fresh weight (index) of the line, b_i is the partial regression coefficient of the fresh weight on the i^{th} character, x_i is the value of the i^{th} character for the line.

The index scores corresponding to each line was found out by substituting the mean values of the character for the line. The best 5% of the lines was considered to be superior as compared to others.

The lines were also ranked according to the curcumin content and dry weight per unit area (
The concordance between the different rankings were measured by calculating the Kendal's concordance coefficient W, given by the formula,

$$W = \frac{12\,S}{m^2(n^3-n)}$$ where,

S = sum of squares of the ranks,

m = number of characters

n = number of lines.

Significance of W was tested by using the Chi-square test. In case 'W' was found to be significant, a "pooled ranking" basing upon the total of the ranks based upon different variables from the lowest to the highest can be attempted (Ostle Bernard, 1960). Basing upon this selection criteria, the best 10% of the lines were recommended for further multiplication.

RESULTS

R E S U L T S

A detailed study of the growth characters and quality aspects of fortytwo lines of open-pollinated progenies of Amalapuram (12 lines) and Dindrigam (30 lines) of turmeric (Curcuma aromatica Salisb) was carried out and the results of the investigations are presented below. The analysis of variance tables for different characters are given in the appendix.

1. GROWTH CHARACTERS

1.1. Germination

It may be seen from the Table 1, that almost all the lines showed 100% germination within two weeks except for the lines A III (90%), D 18 (88.8%), D 39 (90.9%), D 187 (90%), D 194 (84.6%), D 197 (61.5%), D 304 (87.5%), D 310 (75%) and DC (97.7%). Lowest percentage of germination was met with in the case of D 197 (61.5%).

1.2. Morphological Characters

The data on the morphological characters of the open-pollinated lines are presented in the Tables 2 and 3.

1.2.1. Number of tillers per plant

The data showed that the lines were significantly

Table 1. Germination of open-pollinated progenies of Types Amalapuram and Dindrigam (*Curcuma aromatica*)

Sl. No.	Lines	Germination (%)	Sl. No.	Lines	Germination (%)
1	AC	100.0	23	D 178	100.0
2	A 32	100.0	24	D 182	100.0
3	A 31	100.0	25	D 187	90.0
4	A 53	100.0	26	D 190	100.0
5	A 64	100.0	27	D 191	100.0
6	A 71	100.0	28	D 194	84.6
7	A 76	100.0	29	D 196	100.0
8	A 78	100.0	30	D 197	61.5
9	A 83	100.0	31	D 198	100.0
10	A 111	90.0	32	D 199	100.0
11	A 104	100.0	33	D 202	100.0
12	A 169	100.0	34	D 203	100.0
13	A 180	100.0	35	D 211	100.0
14	DC	97.7	36	D 214	100.0
15	D 4	100.0	37	D 217	100.0
16	D 6	100.0	38	D 220	100.0
17	D 7	100.0	39	D 229	100.0
18	D18	88.8	40	D 304	87.5
19	D 39	90.9	41	D 310	75.0
20	D 80	100.0	42	D 311	100.0
21	D 91	100.0	43	D 314	100.0
22	D 180	100.0	44	D 320	100.0

Table 2. Number of tillers and height of the plant of open-pollinated progenies of types Amalapuram and Dindrigam

Lines	Number of tillers/plant		Height of the plant (cm)	
	100th day	150th day	100th day	150th day
AC	1.6 (1.6048)	3.8 (2.1796)	20.8	29.6
A 32	6.3 (2.7074)	8.2 (3.0330)	20.0	28.8
A 31	6.7 (2.7744)	11.0 (3.4708)	25.0	32.2
A 53	2.6 (1.9056)	5.6 (2.5674)	22.0	30.2
A 64	3.2 (2.0408)	4.9 (2.4234)	18.4	26.2
A 71	3.0 (2.0054)	7.8 (2.9662)	20.8	30.6
A 76	2.4 (1.8392)	5.4 (2.5242)	22.0	26.6
A 78	4.9 (2.4268)	5.9 (2.6256)	23.4	28.8
A 85	3.3 (2.0834)	8.5 (3.0842)	23.4	30.0
A 111	3.9 (2.2268)	6.8 (2.7870)	23.2	30.8
A 104	2.5 (1.8654)	5.1 (2.4660)	20.8	30.8
A 169	2.2 (1.7756)	5.4 (2.5370)	21.2	28.2
A 180	4.3 (2.0690)	9.3 (3.2076)	24.6	31.2
DC	2.5 (1.8834)	5.9 (2.6376)	23.4	32.8
D 4	2.7 (1.9190)	7.9 (2.9854)	21.6	27.0
D 6	3.3 (2.0670)	7.7 (2.9530)	24.6	29.6
D 9	3.1 (2.0362)	8.7 (3.1210)	21.6	24.8
D 18	1.7 (1.6408)	6.6 (2.7500)	22.8	30.4
D 39	1.5 (1.5756)	3.6 (2.1416)	17.0	23.4
D 80	2.9 (1.9662)	6.1 (2.6602)	24.0	27.4
D 91	1.5 (1.5756)	5.2 (2.4848)	18.0	29.4
D 180	3.5 (2.1306)	7.4 (2.8926)	23.6	27.8
D 178	3.4 (2.1260)	7.7 (2.9462)	26.8	30.0
D 182	3.1 (2.0362)	6.2 (2.6790)	23.6	26.4
D 187	2.3 (1.8234)	6.4 (2.7132)	23.0	29.0
D 190	1.7 (1.6420)	4.9 (2.4268)	19.6	23.8
D 191	3.5 (2.1196)	8.2 (3.0408)	22.0	25.2
D 194	2.4 (1.8362)	5.5 (2.5446)	20.4	28.2
D 196	3.4 (2.2096)	7.0 (2.8346)	25.8	32.8
D 197	1.8 (1.6764)	6.2 (2.6790)	15.8	26.6
D 198	2.3 (1.8292)	6.7 (2.7764)	22.2	32.0
D 199	3.5 (2.1306)	7.1 (2.8512)	21.6	25.4
D 202	3.8 (2.1870)	9.7 (3.2704)	25.4	33.2
D 203	4.3 (2.3072)	12.6 (3.6826)	25.2	32.2
D 211	2.2 (1.7826)	10.2 (3.3402)	26.0	29.8
D 214	2.9 (1.9936)	7.6 (2.9244)	22.4	28.4
D 217	1.9 (1.7220)	5.6 (2.5658)	22.0	30.0
D 220	3.2 (2.0484)	7.1 (2.8416)	24.6	24.6
D 229	3.0 (2.0054)	6.1 (2.6582)	20.4	24.6
D 304	5.9 (2.6350)	8.3 (3.0474)	21.0	28.8
D 310	3.5 (2.1300)	4.5 (2.3418)	22.2	28.2
D 311	3.5 (2.1196)	7.6 (2.9292)	24.4	30.2
D 314	4.1 (2.2670)	10.9 (3.4602)	24.0	30.2
D 320	5.6 (2.5762)	9.2 (3.2004)	18.0	24.0
CD (P=0.05)	0.5589	0.5141	5.3	3.7

Values in parenthesis indicate $\sqrt{x+1}$ transformed ones

different with regards to the number of tillers per plant.

On hundredth day, the number of tillers per plant varied from 1.5 to 6.7. Ten lines (A 31, A 32, D 304, D 320, A 78, A 180, D 203, A 111, D 196, D 314) were found to differ significantly from others. Line A 31 produced maximum number of tillers per plant (6.7) followed by A 32 (6.3) and D 304 (5.9). The lowest tiller production was noticed in the lines D 39 and D 91 (1.5 each).

The number of tillers per plant varied from 3.6 to 12.6 among lines on 150th day. Maximum number of tillers per plant was recorded in the line D 203 (12.6) followed by line A 31 (11.0), D 314 (10.9) and D 211 (10.2). Lines A 180, D 202 and D 320 are also found to have better tiller production though they did not differ significantly among themselves. The tiller production was poor in the line D 310 (4.5) and D 39 (3.6).

All the progenies of the "Amalapuram" were found to be better than Amalapuram type. Three lines D 39 (3.6), D 310 (4.5) and D 190 (4.9) of Dindrigam showed lower growth than the Dindrigam type.

1.2.2. Height of the plant

The statistical analysis of the data showed that

there were significant differences among the lines with regards to the height of the plants.

On 100th day, the height of the plants varied between 15.8 cm to 26.8 cm. Maximum height was recorded on the line D 178 (26.8 cm) closely followed by lines D 211 (26 cm), D 196 (25.8 cm) and D 202 (25.4 cm). The line D 197 showed the lowest height (15.8 cm).

On 150th day, the height of the plant varied from 24 cm to 33.2 cm. Seventeen lines were found to be significantly taller than the remaining lines and they did not differ significantly among themselves. Maximum height was recorded by the line D 202 (33.2 cm) followed by D 196 (32.8 cm), D 203 (32.2 cm) and A 31 (32.2 cm). Line D 320 was the shortest with a height of 24 cm.

With regards to the progenies of Amalapuram, seven lines (A 31, A 55, A 71, A 76, A 83, A 111, A 104, A 180) were found to be taller than the control plants, but the differences were not significant.

1.2.3. Number of leaves on the main plant

Number of leaves on the main plant showed significant variation among the different lines. Maximum number of leaves on the main plant was noticed on the line D 314 (7.4) followed by D 214 and D 302 (7.2 each). The rate

Table 3. Number of leaves on the open-pollinated progenies of types of Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	On the main plant		On the tillers	
	100th day	150th day	100th day	150th day
AC	6.9 (2.8258)	5.7 (2.5998)	1.7 (1.6568)	19.8
A 32	6.4 (2.7134)	6.7 (2.7784)	20.0 (4.5840)	36.8
A 31	6.4 (2.7160)	6.3 (2.7108)	16.9 (4.1170)	41.4
A 53	6.7 (2.7802)	5.9 (2.6398)	7.4 (2.8972)	22.6
A 64	5.5 (2.5456)	5.9 (2.6376)	15.1 (4.0146)	22.8
A 71	5.9 (2.6346)	5.4 (2.5274)	6.4 (2.7244)	32.6
A 76	6.4 (2.7182)	5.7 (2.5972)	4.9 (2.4288)	28.8
A 78	6.8 (2.7892)	7.2 (2.8582)	12.8 (3.7106)	32.0
A 83	6.7 (2.7844)	5.1 (2.4788)	8.2 (3.0312)	33.2
A 111	5.8 (2.6190)	4.8 (2.4064)	10.6 (3.4022)	26.2
A 104	4.5 (2.3558)	6.2 (2.6768)	3.3 (2.0686)	23.8
A 169	6.3 (2.7134)	4.4 (2.3212)	5.8 (2.6086)	27.2
A 180	6.5 (2.7478)	6.2 (2.6790)	8.0 (3.0070)	28.4
DC	7.2 (2.8602)	7.6 (2.9292)	3.3 (2.0648)	22.8
D 4	5.4 (2.5274)	4.9 (2.4456)	6.9 (2.8092)	31.2
D 6	6.3 (2.7108)	5.2 (2.4848)	10.4 (3.3696)	34.0
D 7	5.6 (2.5640)	5.3 (2.5214)	14.1 (3.8894)	52.8
D 18	4.8 (2.4064)	5.4 (2.5274)	6.8 (2.8000)	30.0
D 39	5.9 (2.6398)	4.9 (2.4456)	3.8 (2.1944)	16.0
D 80	5.4 (2.5248)	6.8 (2.7914)	9.3 (3.2052)	39.8
D 91	6.5 (2.7410)	5.7 (2.5972)	3.1 (2.0188)	34.8
D 180	6.2 (2.6790)	4.7 (2.3844)	8.2 (3.0380)	34.6
D 178	6.1 (2.6694)	6.5 (2.7500)	9.1 (3.1758)	29.8
D 182	6.7 (2.7776)	5.8 (2.6210)	7.9 (2.9870)	25.2
D 187	6.4 (2.7156)	7.4 (2.8968)	5.7 (2.5866)	34.0
D 190	6.7 (2.7844)	5.2 (2.4848)	5.6 (2.5598)	21.0
D 191	5.9 (2.6424)	6.9 (2.8188)	9.4 (3.2230)	31.2
D 194	6.8 (2.7892)	6.4 (2.7134)	8.8 (3.1364)	34.2
D 196	6.2 (2.6768)	8.5 (3.0756)	16.3 (4.1706)	24.0
D 197	2.9 (1.9796)	7.0 (2.8258)	4.9 (2.4482)	29.8
D 198	6.7 (2.7778)	4.7 (2.3840)	3.7 (2.1662)	21.8
D 199	6.2 (2.6816)	5.3 (2.5086)	15.6 (4.0804)	32.0
D 202	5.2 (2.4854)	5.7 (2.5844)	16.4 (4.1736)	33.8
D 203	6.6 (2.7526)	4.7 (2.3890)	13.8 (3.8472)	44.6
D 211	6.6 (2.7526)	6.5 (2.7478)	8.3 (3.0442)	29.6
D 214	7.2 (2.8624)	6.3 (2.6994)	5.6 (2.5838)	34.8
D 217	6.4 (2.7182)	5.8 (2.6058)	5.3 (2.5026)	37.8
D 220	6.8 (2.7892)	7.2 (2.8602)	6.8 (2.7980)	28.4
D 229	7.2 (2.8554)	7.2 (2.8602)	7.6 (2.9414)	26.4
D 304	6.9 (2.8258)	6.8 (2.7866)	17.7 (4.3252)	37.2
D 310	6.8 (2.7870)	5.4 (2.5274)	3.2 (2.0612)	33.0
D 311	6.6 (2.7548)	4.9 (2.4456)	10.2 (3.3504)	36.2
D 314	7.3 (2.8854)	6.1 (2.6682)	11.8 (3.5852)	29.4
D 320	7.2 (2.8602)	4.9 (2.4456)	19.2 (4.4914)	48.0
CD (P=0.05)	0.3439	0.278	1.5525	13.69

Values in parenthesis indicate $\sqrt{x+1}$ transformed ones

of leaf production on the main plant was minimum in the type D 197 (3.6).

From the observations on 150th day, it was seen that the number of leaves on the main plant varied from 4.4 to 8.5. Maximum number of leaves on the main plant was recorded on the line D 196 (8.5) followed by D 187 (7.4), D 220 and D 229 (7.2 each). The lowest number of leaves were recorded by the main plant of the line A 169 (4.4).

In the case of Amalapuram, eight lines (A 32, A 31, A 53, A 64, A 76, A 78, A 104, A 180) were found to produce greater number of leaves on the main plant than the control plants. Line D 196 was found to produce more number of leaves than Dindrigam control.

1.2.4. Number of leaves on the tillers

The data revealed significant differences among the lines with regards to the number of leaves on the tillers.

It was observed that the mean number of leaves on the tillers varied from 1.7 to 20.01 on the 100th day. Twenty lines were found to be superior to the remaining lines, though they were not significantly different among themselves. Line A 32 produced the maximum number of leaves (20.01). It was followed by lines D 320 (19.2). Leaf production was poor in the Amalapuram control (1.7) and D 91 (3.1).

Table 5. Number of roots of open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Number of roots	Lines	Number of roots
AC	64.4	D 178	79.8
A 32	65.6	D 182	72.8
A 31	85.6	D 187	79.2
A 53	86.0	D 190	54.0
A 64	51.0	D 191	60.8
A 71	72.4	D 194	74.2
A 76	64.0	D 196	83.0
A 78	81.6	D 197	72.8
A 83	60.8	D 198	58.6
A 111	71.8	D 199	84.6
A 104	49.6	D 202	69.2
A 169	79.8	D 203	143.6
A 180	82.6	D 211	83.2
DC	62.4	D 214	90.4
D 4	79.0	D 217	53.8
D 6	86.8	D 220	60.0
D 7	91.8	D 229	62.2
D 18	79.8	D 304	79.6
D 39	74.4	D 310	77.0
D 80	80.4	D 311	93.0
D 91	68.8	D 314	82.4
D 180	98.0	D 320	66.4
CD (P=0.05)	29.29		

The number of leaves varied from 16.0 to 52.8 according to the observations taken on 150th day. The lines D 7 (52.8), D 320 (48.0), D 203 (44.6), A 31 (41.4) and D 80 (39.8) were found to be superior to other lines. A poor production of leaves on the tillers was observed in the line D 39 (16) and D 190 (21).

All the lines of the Amalapuram type were found to produce significantly higher number of leaves on the tillers than the control. Except for three lines (D 39, D 190 and D 198), all other lines of the Dindrigam type were also showing more leaf production on the tillers than the control.

2. YIELD AND RHIZOME CHARACTERS

2.1. Number of roots

From the data furnished in the Table 5, it could be seen that the line D 203 produced the maximum number of roots per plant (143) which was significantly higher than that of all other lines. Minimum number of roots of 49.6 was observed in the line A 104.

It was found that the lines A 64, A 76, A 83 and A 104 produced a lesser number of roots than that of the Amalapuram control, while D 229, D 220, D 217, D 198, D 191 and D 190 produced lesser number of roots than the Dindrigam control.

2.2. Primary finger characters

The data are furnished in the Table 5a.

2.2.1. Number of primary fingers per plant

The mean values presented showed that the mean number of primary fingers per plant varied from 4.4 to 14.2 and the differences were statistically significant. The maximum number of primary fingers was observed in the line DC (14.2). It was followed by D 180 (13.6), D 178 (13.2), A 78 (12.6), D 197, D 199 and D 91 (11 each). All these lines were statistically superior to the remaining lines. D 190 was the lowest with regards to the finger production with an average number of 4.4 fingers per plant.

All the progenies of Amalapuram type were found to be superior to their control, with a single exception in A 64. This was not the case with Dindrigam type where the different lines produced leeser number of primary fingers than the control. It was observed that the Dindrigam control produced maximum number of primary fingers.

2.2.2. Length of primary fingers

The variation in length of fingers was significant at one per cent level. Among fortyfour lines D 217 toped the list with an average of 9.75 cm, but not significantly

Table 5a. Primary finger characters of open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Number of fingers	Length of fingers (cm)	Girth of fingers (cm)	Internodal length (cm)
AC	5.6	8.82	7.84	5.70
A 32	9.4	7.16	6.78	6.24
A 31	9.2	7.42	6.04	6.58
A 53	6.4	7.86	7.17	6.10
A 64	4.8	6.92	6.83	5.64
A 71	6.4	7.20	8.12	6.34
A 76	9.2	7.79	8.06	6.08
A 78	12.6	8.10	7.19	6.08
A 83	7.4	9.72	8.14	7.10
A 111	9.8	8.44	6.16	6.14
A 104	6.8	7.44	7.55	6.06
A 169	6.8	9.18	7.06	6.36
A 180	10.0	7.20	6.78	6.92
DC	14.2	8.80	8.10	8.50
D 4	8.6	7.06	7.65	5.60
D 6	7.6	8.35	7.61	6.16
D 7	11.2	7.50	8.10	5.42
D 18	6.6	8.20	8.95	6.46
D 39	6.4	8.50	7.26	6.66
D 80	9.8	7.75	8.10	6.44
D 91	11.0	8.00	7.45	5.84
D 180	13.6	7.70	7.50	5.30
D 178	13.2	8.05	8.15	7.70
D 182	5.8	8.10	8.90	6.64
D 187	9.2	8.15	7.10	6.64
D 190	4.4	7.65	9.00	5.20
D 191	8.0	7.95	7.25	6.46
D 194	8.2	8.80	6.35	7.94
D 196	7.4	8.45	7.90	6.68
D 197	11.0	7.10	6.85	6.02
D 198	6.4	8.55	7.40	7.30
D 199	11.0	8.30	6.75	7.02
D 202	7.8	7.55	7.75	5.08
D 203	10.6	7.05	7.30	5.00
D 211	9.0	7.60	7.35	9.08
D 214	9.0	8.30	8.60	8.42
D 217	8.6	9.75	7.85	9.66
D 220	7.4	7.35	7.15	9.02
D 229	7.8	9.20	7.65	8.16
D 304	7.0	7.45	7.05	8.00
D 310	6.6	8.35	8.30	8.00
D 311	9.4	7.45	6.15	7.00
D 314	8.0	7.60	6.85	7.00
D 320	7.0	7.15	7.80	9.00
CD (P=0.05)	3.29	1.26	1.60	2.17

different from the lines A 83 (9.72 cm), D 229 (9.2 cm), A 169 (9.18 cm), D 194 (8.8 cm), DC and AC (8.8 cm each) and D 39 and D 198 (8.5 cm each). These lines were found to be having longer primary fingers as compared to the rest of the lines. It was also observed that A 64 produced shortest fingers with an average length of 6.92 cm per finger.

The lines A 83 and A 169 were found to be superior to Amalapuram control and D 217 and D 229 were superior to Dindrigam control.

2.2.3. Girth of primary fingers

It may be seen from the Table 5a, that there existed significant variation in girth of rhizomes among lines.

The line D 190 showed maximum girth (9.0 cm) closely followed by D 18 (8.95 cm) and D 182 (8.9 cm). It was seen that on the whole twentyone lines were significantly superior to others but they did not differ significantly among themselves. The line A 31 produced relatively thinner fingers with a mean girth of 6.04 cm per finger.

Only three lines of Amalapuram types (A 71, A 76, A 83) had thicker rhizomes than Amalapuram control. The lines D 18, D 182, D 190, D 214 and D 310 produced thicker

rhizomes than Dindrigam control, while D 7, D 180 and D 178 produced fingers that equalled the line DC in the case of girth of primary fingers.

2.2.4. Internodal length of primary finger

Statistical analysis of the data revealed that the variation among the lines with regards to internodal length was significant. The length of the internode varied from 5.0 mm to 9.66 mm. Maximum length of 9.66 mm was recorded by the line D 217, followed by D 211 (9.08 mm) and D 220 (9.02 mm). Along with them, another eight lines were found to produce fingers with significantly greater internodal length than the rest of the lines. The internodal length was minimum in the line D 205 (5.0 mm).

In the case of Amalapuram lines, all the lines had longer internodes than Amalapuram control except for A 64 which had same length. For Dindrigam, only D 211, D 217, D 220 and D 320 showed longer internodes than Dindrigam control.

2.3. Secondary finger characters

Table 6 contains the data on secondary finger characters.

2.3.1. Number of secondary fingers

The effect of lines on the number of secondary fingers

Table 6. Secondary finger characters of open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Number of fingers	Length of fingers (cm)	Girth of fingers (cm)	Internodal length (mm)
AC	43.6	7.52	5.52	8.02
A 32	64.6	6.97	4.40	6.50
A 31	59.6	8.32	5.52	7.52
A 53	52.0	8.21	4.62	8.20
A 64	42.4	7.44	5.03	7.00
A 71	51.2	6.17	4.94	5.88
A 76	36.8	7.73	5.38	6.58
A 78	57.8	8.25	5.21	6.62
A 83	35.0	7.58	5.28	7.24
A 111	47.6	7.18	5.41	6.44
A 104	48.2	8.30	5.21	7.96
A 169	58.0	8.35	5.13	7.46
A 180	31.2	6.81	4.51	6.56
DC	44.0	8.94	5.22	7.56
D 4	48.6	7.72	4.71	6.74
D 6	34.2	8.00	5.60	7.40
D 7	46.0	6.65	4.85	6.10
D 18	45.2	7.95	4.89	7.46
D 39	44.2	8.50	5.20	7.62
D 80	51.6	8.90	5.20	7.62
D 91	47.8	8.55	5.45	8.42
D 180	81.6	8.20	5.25	7.16
D 178	55.4	7.50	5.25	8.00
D 182	50.4	8.80	6.15	8.62
D 187	57.4	7.75	4.45	8.08
D 190	31.2	7.70	5.55	7.70
D 191	41.8	5.90	5.05	6.38
D 194	79.4	7.60	4.70	7.14
D 196	70.6	8.70	5.00	8.60
D 197	52.0	6.20	5.05	5.14
D 198	40.8	7.15	4.70	8.36
D 199	56.8	7.05	4.85	6.40
D 202	48.2	9.00	4.65	9.40
D 203	66.0	6.20	4.50	7.00
D 211	39.6	6.65	4.90	7.00
D 214	52.6	7.40	5.00	8.00
D 217	41.4	9.00	4.99	10.00
D 220	39.4	6.35	5.05	8.00
D 229	53.0	8.45	5.35	9.32
D 304	49.6	7.25	4.65	9.32
D 310	32.6	7.50	5.15	8.50
D 311	51.8	5.30	4.85	7.32
D 314	52.8	6.80	4.60	7.36
D 320	50.6	6.60	5.60	9.28
CD (P=0.05)	17.17	1.69	0.74	2.20

was found to be significant. The line D 180 produced maximum number (81.6) of secondary fingers followed by D 194 (79.4), D 196 (70.6), D 203 (66.0) and A 32 (64.6). There was no significant difference among the above lines. The least number of 31.2 fingers was observed in line A 180.

Among the Amalapuram lines, eight lines were found to be producing more number of secondary fingers when compared to the control and twentyfive Dindrigam lines were found to produce more number of fingers than control.

2.3.2. Length of secondary fingers

With regards to the length of secondary fingers there was significant variation among lines. The lines 74 was found to be superior to others but on par with themselves. The longest fingers were noticed on the lines D 202 and D 217 (9.0 cm). They were followed by D 80 (8.9 cm) and DC (8.94 cm). The line D 311 produced the shortest fingers (5.3 cm).

Among the Amalapuram, seven lines were found to be having longer fingers than control and among Dindrigam, eleven lines were having longer fingers than Dindrigam control.

2.3.3. Girth of secondary fingers

The mean girth of the secondary fingers varied between 4.4 cm to 6.15 cm and the variation was statistically significant. Maximum girth was recorded by the line D 182 (6.15 cm) followed by D 320 and D 6 (5.6 cm each), D 190 (5.55 cm), A 31 (5.52 cm), AC (5.52 cm), D 91 (5.45 cm) and A 111 (5.41 cm). They were found to have thicker rhizomes than the rest of the lines. The lines A 32 (4.4 cm) and D 187 (4.45 cm) produced fingers with comparatively smaller girth.

A 31 had same girth as that of Amalapuram control and eight Dindrigam lines were found to be thicker than control.

2.3.4. Internodal length of secondary fingers

With regards to the length of internode, the line D 217 (10 mm) produced longest internodes, followed by D 202 (9.4 mm), D 229 and D 304 (9.32 mm each). The line D 197 produced shortest internodes with 5.14 mm. Statistical analysis showed highly significant differences among lines and sixteen lines were found to be producing significantly longer internodes as compared to the rest.

Only the line A 53 is found to have longer internodes

Table 7. Wet weight and curing percentage of rhizomes of open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Wet weight per plant (gms)	Yield per plot (kg)	Curing percentage
AC	516.0	20.64	23.16
A 32	410.2	16.41	29.20
A 31	527.0	21.08	28.10
A 53	383.4	15.32	26.20
A 64	356.2	14.24	22.80
A 71	429.2	17.16	24.70
A 76	388.4	15.54	23.62
A 78	563.2	22.48	26.94
A 83	485.4	19.42	28.30
A 111	653.4	26.14	24.30
A 104	481.0	19.24	19.50
A 169	507.0	20.28	27.13
A 180	316.4	12.65	25.50
DC	494.8	19.79	25.67
D 4	452.8	18.11	25.21
D 6	443.4	17.74	25.86
D 7	413.2	16.53	26.56
D 18	393.8	15.75	28.00
D 39	536.8	21.47	27.81
D 80	517.8	20.71	22.31
D 91	529.0	21.16	23.80
D 180	671.4	26.86	24.68
D 178	431.4	17.26	25.02
D 182	685.4	27.42	21.97
D 187	406.6	16.26	26.19
D 190	383.2	15.33	24.94
D 191	357.4	14.29	31.16
D 194	515.8	20.63	28.09
D 196	486.0	19.44	25.30
D 197	409.8	16.38	25.27
D 198	481.4	19.26	25.01
D 199	693.6	27.74	24.41
D 202	439.2	17.57	28.87
D 205	458.8	18.35	30.24
D 211	381.6	15.26	33.40
D 214	545.0	21.80	29.70
D 217	372.4	14.89	31.84
D 220	439.4	17.58	28.11
D 229	582.4	23.29	26.87
D 304	411.6	16.46	31.95
D 310	356.0	14.24	33.46
D 311	440.6	17.62	33.62
D 314	348.0	13.92	28.56
D 320	445.4	18.22	31.08
CD (P=0.05)	180.18		

(8.2 mm) than Amalapuram control among the Amalapuram lines while fifteen lines showed longer internodes when compared to Dindrigam control among Dindrigam lines.

2.4.1. Fresh weight of the rhizomes per plant

The data on fresh weight of rhizomes per plant is furnished in the Table 7. The yield per unit area (3 m^2) and the curing percentage is also furnished in the same Table.

Observations on yield per plant showed significant difference among lines. The average yield varied from 316.4 gms to 693.6 gms per plant. The line D 199 (693.6 gms) ranked first which was on par with twelve lines (AC, A 31, A 78, A 111, D 39, D 80, D 91, D 180, D 182, D 194, D 214 and D 229). These lines were found to be superior to all other lines. A low yield of 316.4 gms of green turmeric per plant was recorded by the line A 180.

Among the Amalapuram lines, the lines A 31, A 78 and A 111 were found to be higher yielders than control. Nine lines (D 39, D 80, D 91, D 180, D 182, D 194, D 199, D 214 and D 229) were found to produce plants with higher yield than control plants, in the case of Dindrigam lines.

The yield per unit area was also found to be higher

in the line D 199 (27.74 kg), closely followed by D 182 (27.42 kg) and A 111 (26.14 kg). The yield per plot was the lowest in the line A 180 (12.65 kg).

2.4.2. Curing percentage

Maximum recovery of the cured turmeric was recorded by the line D 311 with a curing percentage of 33.62 followed by the lines D 310 (33.46%), D 211 (33.40%), D 304 (31.95%) and D 217 (31.84%). The curing percentage was the minimum in the line A 104 (19.50%).

3. THE IMPORTANT CHEMICAL CONSTITUENTS

The percentage of curcumin and oleoresin and the projected yield of curcumin per unit area are given in Table 8.

3.1. Curcumin

Highly significant differences were noticed in curcumin content among the different lines. The curcumin content varied from 1.14 per cent to 5.37 per cent among the lines. The line A 53 gave 5.37 per cent of curcumin which was maximum and thie line was significantly superior to all other lines. The lines D 18 (4.13%), D 199 (3.99%), D 180 (3.83%), D 311 (3.64%) and A 180 (3.62%) also gave

Table 8. Curcumin and oleoresin in the open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Curcumin on dry weight basis		Oleoresin on dry weight basis (%)
	Percentage	Yield per plot (kg)	
AC	2.28	0.108	11.48
A 32	2.28	0.109	13.58
A 31	2.55	0.151	16.57
A 53	5.37	0.215	19.12
A 64	3.05	0.099	18.39
A 71	2.43	0.103	10.60
A 76	2.53	0.093	16.70
A 78	2.51	0.152	13.64
A 83	1.39	0.076	19.38
A 111	1.18	0.075	19.23
A 104	1.45	0.054	16.26
A 169	1.57	0.086	15.83
A 180	3.62	0.116	16.53
DC	2.43	0.123	14.19
D 4	2.62	0.119	22.11
D 6	3.18	0.146	14.56
D 7	2.77	0.122	16.00
D 18	4.13	0.182	18.16
D 39	1.23	0.073	13.39
D 80	1.34	0.062	15.72
D 91	1.61	0.081	10.75
D 180	3.83	0.254	12.57
D 178	1.84	0.079	13.91
D 182	1.63	0.098	22.60
D 187	1.98	0.084	12.58
D 190	2.59	0.096	18.63
D 191	2.05	0.091	19.57
D 194	2.63	0.152	16.96
D 196	2.94	0.145	13.64
D 197	1.27	0.053	11.74
D 198	2.59	0.125	11.29
D 199	3.99	0.270	16.43
D 202	2.43	0.123	15.69
D 203	1.18	0.065	14.18
D 211	2.54	0.129	15.90
D 214	1.78	0.115	13.87
D 217	2.00	0.095	18.02
D 220	1.14	0.056	14.73
D 229	3.16	0.204	14.20
D 304	2.47	0.129	15.33
D 310	1.58	0.075	15.05
D 311	3.64	0.215	14.89
D 314	2.22	0.122	14.67
D 320	1.38	0.078	12.42
CD (P=0.05)	0.14		1.44

a relatively higher percentage of curcumin. The line D 220 recorded lowest curcumin content of 1.14 per cent.

Among Amalapuram lines, A 31, A 53, A 64, A 71, A 76, A 78 and A 180 showed higher content of curcumin than their control. Among Dindrigam, D 4, D 6, D 7, D 18 D 180, D 190, D 194, D 196, D 198, D 199, D 211, D 229, D 304 and D 311 were better than their control.

The yield of curcumin per plot was found to be maximum in the case of D 199 (0.270 kg) followed by D 180 (0.254 kg) and D 311 (0.215 kg) and it was lowest in the line D 197 (0.053 kg).

3.2. Oleoresin

Analysis of the data on oleoresin percentage revealed that differences among lines were statistically significant. Line D 182 gave 22.60 per cent of oleoresin which was statistically on par with line D 4 (22.11%). These two lines were significantly superior to all the remaining lines, with regards to oleoresin content. Oleoresin recovery was the lowest for the line A 71 (10.60%). Except for A 71, all other lines gave higher oleoresin recovery than Amalapuram control. In the case of Dindrigam lines, 19 lines were found to have higher oleoresin content than control.

Table 4. Variation in the incidence of shoot borer attack

Lines	Percentage	Lines	Percentage
AC	16.66	D 178	20.00
A 32	18.88	D 182	0.00
A 31	10.00	D 187	33.33
A 53	14.28	D 190	33.33
A 64	22.22	D 191	60.00
A 71	25.00	D 194	9.09
A 76	0.00	D 196	25.00
A 78	18.18	D 197	25.00
A 83	0.00	D 198	5.88
A 111	44.44	D 199	0.00
A 104	12.50	D 202	11.11
A 169	16.66	D 203	11.11
A 180	18.18	D 211	10.00
DC	19.99	D 214	10.00
D 4	18.18	D 217	9.09
D 6	12.50	D 220	7.14
D 7	33.33	D 229	11.11
D 18	37.50	D 304	14.28
D 39	0.00	D 310	0.00
D 80	27.27	D 311	0.00
D 91	22.22	D 314	8.33
D 180	0.00	D 320	0.00

. Some lines of Amalapuram type - see the variation

Some lines of Dindrigam type - see the variation

Some lines of Dindrigam type - see the variation

4. INCIDENCE OF PESTS AND DISEASES

No incidence of leaf diseases (Taphrina maculans and Colletotrichum capsici) was noticed during the season.

Incidence of shoot borer (Dichocrosis punctiferalis) attack was found. Lines A 76, A 83, D 39, D 180, D 182, D 199, D 310, D 311 and D 320 were not attacked by the pest whereas D 198 (5.88%), D 220 (7.14%), D 194 (9.09%), D 217 (9.09%), D 211, D 203 and A 31 (10.00% each) showed less occurrence of the attack of shoot borer. Line D 191 (60%), A 111 (44.44%) and D 18 (37.5%) showed maximum incidence of pest attack.

5. VARIABILITY STUDIES

The data on mean, standard error of mean, coefficient of variation (CV) and variance of various characters are furnished in the Tables 9-26.

5.1. Number of tillers

The data indicated that on 100th day, the variability ranged from 17.27 per cent to 100 per cent among lines with respect to number of tillers. The line D 18 showed 100 per cent variability followed by D 187 (95.71%) and A 53 (88.33%). It was the lowest in the case of A 32 (17.27%) and A 111 (20.00%).

Mean, standard error of mean, coefficient of variation and variance (Table 9 to 26)

Table 9. Number of tillers (100th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	1.6	0.25	34.37	0.30
A 32	6.3	0.51	17.27	1.29
A 31	6.7	2.20	66.62	24.30
A 53	2.6	1.18	88.33	7.02
A 64	3.2	0.38	26.25	0.70
A 71	3.0	0.60	60.00	3.68
A 76	2.4	0.25	22.92	0.30
A 78	4.9	0.83	37.40	3.49
A 83	3.3	0.51	33.53	1.29
A 111	3.9	0.45	20.00	1.00
A 104	2.5	0.68	58.46	2.31
A 169	2.2	0.38	38.18	0.70
A 180	4.3	0.75	49.12	2.78
DC	2.5	0.85	68.57	3.68
D 4	2.7	0.86	32.86	2.19
D 6	3.3	0.67	47.50	2.31
D 7	3.1	0.63	28.20	1.98
D 18	1.7	0.89	100.00	4.00
D 39	1.5	0.57	71.25	1.29
D 80	2.9	0.71	52.67	2.49
D 91	2.5	0.51	71.25	1.29
D 180	3.5	0.95	56.05	4.53
D 178	3.5	0.59	37.22	1.79
D 182	3.1	0.49	34.06	1.18
D 187	2.3	1.19	95.71	7.18
D 190	1.7	0.58	72.22	1.69
D 191	3.5	0.68	42.22	2.31
D 194	2.4	0.81	70.00	3.31
D 195	3.9	1.32	70.24	8.70
D 197	1.8	0.71	79.00	2.49
D 198	2.3	0.39	37.08	0.79
D 199	3.5	0.51	31.67	1.29
D 202	3.8	1.19	63.81	7.18
D 205	4.3	0.64	34.55	2.31
D 211	2.2	0.81	75.83	3.31
D 214	2.9	0.32	23.67	0.50
D 217	1.9	0.32	35.50	0.50
D 220	3.2	0.98	64.41	4.79
D 229	3.0	0.86	60.00	3.68
D 304	5.9	1.54	33.75	11.83
D 310	3.5	1.29	84.71	8.29
D 311	3.5	0.68	42.22	2.31
D 314	4.1	1.12	57.05	6.30
D 320	5.6	1.02	39.31	5.19

Mean, standard error of mean, coefficient of variation and variance

Table 10. Number of tillers (150th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	3.8	0.49	28.68	1.18
A 32	8.2	1.29	30.64	8.29
A 31	11.0	1.39	27.77	9.67
A 53	5.6	1.07	41.21	5.71
A 64	4.9	0.89	40.00	4.00
A 71	7.8	1.30	36.50	8.52
A 76	5.4	1.36	54.46	9.30
A 78	5.9	0.83	31.17	3.49
A 83	8.5	0.81	21.16	3.31
A 111	6.8	0.49	60.03	1.18
A 104	5.1	0.86	36.92	3.68
A 169	5.4	1.03	41.07	5.29
A 180	9.3	1.03	25.55	5.29
DC	5.9	0.83	23.38	3.49
D 4	7.9	0.54	20.33	1.48
D 6	7.7	2.83	64.79	40.32
D 7	8.7	0.79	20.34	3.20
D 18	6.6	0.51	17.27	1.29
D 39	3.6	0.25	15.28	0.30
D 80	6.1	0.86	30.97	3.68
D 91	5.2	2.57	110.76	33.17
D 180	7.4	0.51	15.47	1.29
D 178	7.7	1.70	47.63	14.51
D 182	6.2	1.07	36.21	5.71
D 187	6.4	2.08	68.53	21.71
D 190	4.9	0.83	37.40	3.49
D 191	8.2	1.25	33.21	7.78
D 194	5.5	3.62	130.81	65.77
D 196	7.0	1.16	35.97	6.70
D 197	6.2	0.38	13.55	0.70
D 198	6.7	0.79	26.32	3.20
D 199	7.1	0.73	22.78	2.68
D 202	9.7	1.81	40.60	16.48
D 203	12.6	1.91	33.36	18.23
D 211	10.2	0.66	14.51	2.19
D 214	7.6	1.49	42.95	11.22
D 217	5.6	2.29	65.77	26.31
D 220	7.1	0.97	30.14	4.70
D 229	6.1	1.02	36.77	5.19
D 304	8.3	0.98	26.07	4.79
D 310	4.5	0.81	39.57	3.31
D 311	7.6	0.39	11.71	0.79
D 314	10.9	0.54	11.09	1.48
D 320	9.2	1.29	30.64	8.29

Mean, standard error of mean, coefficient of variation and variance

Table 11. Height of the plant (100th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	20.8	1.16	12.45	6.70
A 32	20.0	1.38	15.40	9.48
A 31	25.0	2.29	20.60	26.52
A 53	22.0	2.34	23.82	27.45
A 64	18.4	1.59	19.46	12.81
A 71	20.8	1.39	14.95	9.67
A 76	22.0	1.73	17.59	14.97
A 78	23.4	2.06	19.74	21.34
A 83	23.4	2.48	23.72	30.80
A 111	23.2	3.39	32.72	57.60
A 104	20.8	1.16	12.45	6.70
A 169	21.2	2.08	21.98	21.71
A 180	24.6	1.57	14.27	12.32
DC	23.4	2.01	19.27	20.34
D 4	21.6	1.12	11.62	6.30
D 6	24.6	1.86	16.91	17.30
D 7	21.6	0.92	9.58	4.28
D 18	22.8	1.77	17.36	15.68
D 39	17.0	1.30	17.18	8.52
D 80	24.0	0.98	8.83	4.49
D 91	18.0	2.14	26.61	22.94
D 180	23.6	2.54	24.07	32.26
D 178	26.8	2.43	20.34	29.70
D 182	23.6	0.39	3.77	0.79
D 187	23.0	1.51	14.71	11.49
D 190	19.6	2.16	24.64	23.32
D 191	22.0	1.70	17.32	14.51
D 194	20.4	1.99	21.81	19.80
D 196	25.8	1.93	16.74	18.66
D 197	15.8	3.03	42.97	46.10
D 198	22.2	2.15	21.71	23.23
D 199	21.6	1.69	17.50	14.28
D 202	25.4	1.28	11.34	8.29
D 203	25.2	1.11	9.88	6.20
D 211	26.0	1.00	8.62	5.01
D 214	22.4	1.63	16.29	13.32
D 217	22.0	0.45	4.55	1.00
D 220	24.6	1.48	13.45	10.95
D 229	20.4	2.48	27.21	30.80
D 304	21.0	1.38	14.67	9.48
D 310	22.2	2.13	21.44	22.65
D 311	24.4	1.57	14.38	12.32
D 314	24.0	3.26	30.46	53.43
D 320	18.0	1.41	17.55	9.98

Mean, standard error of mean, coefficient of variation and variance

Table 12. Height of the plant (150th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	29.6	0.98	7.39	4.79
A 32	28.8	0.58	4.51	1.69
A 31	32.2	2.31	1.56	26.72
A 53	30.2	2.17	16.13	23.87
A 64	26.2	1.16	9.88	6.70
A 71	30.6	1.75	12.78	15.91
A 76	26.6	1.17	9.81	6.81
A 78	28.8	1.32	10.24	8.70
A 83	30.0	1.38	10.27	9.48
A 111	30.8	1.32	9.58	8.70
A 104	30.8	1.16	8.41	6.70
A 169	28.2	1.35	10.74	9.18
A 180	31.2	2.64	18.97	35.04
DC	32.8	1.41	11.70	9.98
D 4	27.0	2.57	19.49	33.29
D 6	29.6	1.46	9.97	10.69
D 7	24.8	0.37	3.39	0.70
D 18	30.4	1.39	10.29	9.79
D 39	23.4	1.66	15.85	13.71
D 80	27.4	0.81	6.64	3.31
D 91	29.4	0.68	5.17	2.31
D 180	27.8	0.37	3.07	0.70
D 178	30.0	1.81	13.53	16.48
D 182	26.4	1.08	9.13	5.80
D 187	29.0	0.83	6.45	3.49
D 190	23.8	1.77	16.64	15.68
D 191	25.2	1.07	9.48	5.71
D 194	28.2	2.15	17.09	23.23
D 196	32.8	0.58	3.96	1.69
D 197	26.6	1.12	9.44	6.30
D 198	32.0	0.71	4.94	2.49
D 199	25.4	1.59	14.09	12.81
D 202	33.2	0.92	6.17	4.20
D 205	32.2	1.32	9.16	8.70
D 211	29.8	1.82	13.72	16.72
D 214	28.4	1.03	8.09	5.29
D 217	30.0	1.92	14.33	18.49
D 220	24.6	0.25	2.24	0.30
D 229	24.6	0.31	2.85	0.49
D 304	28.8	0.73	5.69	2.68
D 310	28.2	0.86	6.81	3.68
D 311	30.2	0.70	5.19	2.46
D 314	30.2	2.99	22.15	44.75
D 320	24.0	1.22	11.42	7.50

Mean, standard error of mean, coefficient of variation and variance

Table 13. Number of leaves on the main plant (100th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	6.9	0.32	10.14	0.50
A 32	6.4	0.51	17.81	1.29
A 31	6.4	0.39	13.91	0.79
A 53	6.7	0.73	24.12	2.68
A 64	5.5	0.92	36.96	4.28
A 71	5.9	0.54	20.33	1.48
A 76	6.4	0.25	8.59	0.30
A 78	6.8	0.38	12.35	0.70
A 83	6.7	0.13	19.12	1.69
A 111	5.8	1.24	44.68	7.67
A 104	4.5	0.51	24.78	1.29
A 169	6.3	0.51	17.81	1.29
A 180	6.5	0.59	20.30	1.79
DC	7.2	0.38	11.67	0.70
D 4	5.4	0.25	9.82	0.30
D 6	6.3	0.59	20.94	1.79
D 7	5.6	1.39	55.89	9.79
D 18	4.8	0.20	9.38	0.20
D 39	5.9	0.45	16.67	1.00
D 80	5.4	0.39	16.48	0.79
D 91	6.5	0.81	27.58	3.31
D 180	6.2	0.38	13.55	0.70
D 178	6.1	0.73	26.45	2.68
D 182	6.7	0.81	27.58	3.31
D 187	6.4	0.39	13.91	0.79
D 190	6.7	0.58	19.12	1.69
D 191	5.9	0.32	11.83	0.50
D 194	6.8	0.38	12.35	0.70
D 196	6.2	0.48	17.58	1.18
D 197	2.9	1.57	97.50	12.32
D 198	6.7	0.58	19.12	1.69
D 199	6.2	0.20	7.25	0.20
D 202	5.2	0.33	12.76	0.54
D 203	6.6	0.39	13.48	0.79
D 211	6.6	0.51	17.27	1.29
D 214	7.2	0.20	6.25	0.20
D 217	6.4	0.25	8.59	0.30
D 220	6.8	0.38	12.35	0.70
D 229	7.2	0.58	18.05	1.69
D 304	6.9	0.32	10.14	0.50
D 310	6.8	1.08	33.47	5.80
D 311	6.6	0.25	8.33	0.30
D 314	7.3	0.51	15.41	1.29
D 320	7.2	0.38	11.67	0.70

Mean, standard error of mean, coefficient of variation and variance

Table 14. Number of leaves on the main plant (150th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	5.7	0.49	18.79	1.18
A 32	6.7	0.73	24.12	2.69
A 31	6.3	0.59	20.94	1.79
A 53	5.9	0.45	16.67	1.00
A 64	5.9	0.54	20.33	1.48
A 71	5.4	0.25	10.19	0.30
A 76	5.7	0.66	35.24	2.19
A 78	7.2	0.37	13.55	0.71
A 83	5.1	0.49	15.14	1.18
A 111	4.8	0.58	25.00	1.69
A 104	6.2	0.20	9.37	0.20
A 169	4.4	0.49	17.58	1.18
A 180	6.2	0.25	12.50	0.30
DC	7.6	0.37	13.55	0.71
D 4	4.9	1.61	47.50	13.03
D 6	5.2	0.32	14.20	0.50
D 7	5.3	0.37	16.15	0.71
D 18	5.4	0.51	21.11	1.29
D 39	4.9	0.25	10.19	0.30
D 80	6.8	0.32	14.20	0.50
D 91	5.7	0.20	6.62	0.20
D 180	4.7	0.58	22.41	1.69
D 178	6.5	0.79	37.29	3.20
D 182	5.8	0.51	17.27	1.29
D 187	7.4	0.89	33.33	4.00
D 190	5.2	0.25	7.43	0.30
D 191	6.9	0.37	16.15	0.71
D 194	6.4	0.63	20.14	1.98
D 196	8.5	0.51	17.81	1.29
D 197	7.0	0.25	5.73	0.30
D 198	4.7	0.32	10.14	0.50
D 199	5.3	0.73	34.17	2.68
D 202	5.7	0.81	33.70	3.31
D 203	4.7	0.86	33.10	3.68
D 211	6.5	0.73	34.16	2.68
D 214	6.3	0.59	20.30	1.79
D 217	5.8	0.75	26.09	2.78
D 220	7.2	0.20	7.76	0.20
D 229	7.2	0.38	11.67	0.71
D 304	6.8	1.75	54.31	15.28
D 310	5.4	0.49	16.03	1.18
D 311	4.9	1.32	52.68	8.70
D 314	6.1	0.32	14.20	0.50
D 320	4.9	0.73	26.45	2.68

Mean, standard error of mean, coefficient of variation and variance

Table 15. Number of leaves on the tillers (100th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	1.74	1.28	130.00	8.17
A 32	20.01	2.89	31.72	41.86
A 31	16.94	4.54	59.19	103.63
A 53	7.39	4.50	109.57	101.60
A 64	15.11	2.11	62.11	22.27
A 71	6.42	1.88	58.47	17.72
A 76	4.89	1.80	72.14	16.32
A 78	12.76	3.26	53.68	53.29
A 83	8.18	2.01	52.44	20.34
A 111	10.57	2.92	58.30	42.64
A 104	3.27	1.53	55.16	11.69
A 169	5.80	1,65	59.68	13.69
A 180	8.04	1.80	48.09	16.32
DC	3.26	2.03	108.33	20.70
D 4	6.89	1.35	42.08	9.18
D 6	10.35	3.29	65.98	54.61
D 7	14.12	1.02	16.06	5.19
D 18	6.80	2.37	68.08	28.19
D 39	3.80	1.96	95.43	19.27
D 80	9.27	2.35	53.67	27.66
D 91	3.07	1.03	67.65	5.29
D 180	8.20	3.51	112.28	61.77
D 178	9.10	3.12	71.22	48.72
D 182	7.90	0.77	21.63	2.99
D 187	5.70	5.75	149.88	166.15
D 190	5.60	4.92	141.41	121.66
D 191	9.40	1.44	30.96	10.36
D 194	8.80	4.22	89.15	89.30
D 196	16.30	9.48	98.28	450.71
D 197	4.90	1.10	47.69	6.15
D 198	3.70	0.95	53.00	4.49
D 199	15.60	6.72	81.85	226.80
D 202	16.40	6.71	75.15	225.90
D 203	13.80	6.67	94.55	223.20
D 211	8.30	8.11	84.07	329.78
D 214	5.60	2.54	88.75	32.26
D 217	5.30	0.92	36.96	4.28
D 220	6.80	4.15	108.02	86.30
D 229	7.60	5.06	118.13	128.59
D 304	17.70	7.62	86.16	291.04
D 310	3.20	2.17	115.95	23.71
D 311	10.20	4.82	89.91	116.42
D 314	11.80	2.15	39.51	23.23
D 320	19.20	4.22	47.30	89.49

Mean, standard error of mean, coefficient of variation and variance

Table 16. Number of leaves on the tillers (150th day)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	19.8	3.82	43.23	73.27
A 32	36.8	5.83	35.52	170.82
A 31	41.4	4.81	26.04	116.20
A 53	22.6	3.37	33.36	56.85
A 64	22.8	1.98	19.47	19.71
A 71	32.6	3.38	23.22	57.30
A 76	28.8	7.94	61.77	316.48
A 78	32.0	4.03	28.22	81.54
A 83	33.2	3.81	26.69	72.76
A 111	26.2	3.67	31.41	67.73
A 104	23.8	4.54	42.77	103.63
A 169	27.2	3.29	27.17	54.61
A 180	28.4	3.00	23.53	45.29
DC	22.8	3.36	33.03	56.70
D 4	31.2	2.51	18.16	31.69
D 6	34.0	3.57	23.53	64.00
D 7	52.8	5.88	24.96	173.71
D 18	30.0	4.62	64.63	106.91
D 39	16.0	2.07	29.00	21.52
D 80	39.8	3.42	19.19	58.67
D 91	34.8	6.63	42.67	220.85
D 180	34.6	3.56	23.06	63.68
D 178	29.8	5.61	42.01	157.75
D 182	25.2	1.65	14.68	13.69
D 187	34.0	10.34	68.15	536.84
D 190	21.0	3.43	36.57	58.98
D 191	31.2	3.09	22.24	48.16
D 194	34.2	6.00	39.29	179.82
D 196	24.0	3.07	22.98	47.19
D 197	29.8	4.58	42.71	105.06
D 198	21.8	3.70	38.03	68.72
D 199	32.0	5.62	39.31	158.25
D 202	33.8	4.90	32.48	120.56
D 203	44.6	5.09	25.58	130.18
D 211	29.6	2.63	19.96	34.69
D 214	34.8	6.22	40.06	194.32
D 217	37.8	7.96	47.19	318.26
D 220	28.4	4.22	33.27	89.30
D 229	26.4	6.84	58.03	234.70
D 304	37.2	3.96	23.84	78.67
D 310	33.0	8.78	59.58	386.51
D 311	36.2	6.24	38.59	195.16
D 314	29.4	4.65	35.41	108.36
D 320	48.0	3.74	17.44	70.05

On 150th day, it was seen that there was a wide variability from 11.09 per cent to 130.81 per cent. Variability was maximum in the case of line D 194 (130.81%), followed by D 91 (110.76%) while D 314 (11.09%) and D 311 (11.71%) ranked the lowest.

5.2. Height of the plant

With regards to the height of the plant on 100th day, variability ranged from 4.55 per cent to 42.97 per cent. Line D 197 had the maximum variability with 42.97 per cent and line D 217 had the lowest variability (4.55%).

The height of the plant on 150th day recorded a variability ranging from 1.56 per cent to 22.15 per cent. Maximum variability was met with in line D 314 (22.15%) followed by line D 4 (19.49%) and A 31 showed minimum variability (1.56%).

5.3. Number of leaves on the main plant

With regards to the number of leaves produced on the main plant on 100th day, a variability range of 6.25 per cent to 97.5 per cent was recorded. Line D 197 recorded maximum variability of 97.5 per cent while line D 214 showed minimum variability of 6.25 per cent.

Mean, standard error of mean, coefficient of variation and variance

Table 17. Number of roots

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	64.4	21.03	73.15	2219.35
A 32	65.6	9.07	30.96	412.49
A 31	85.6	9.92	25.95	493.28
A 53	86.0	15.59	40.62	1220.10
A 64	51.0	11.95	52.47	716.09
A 71	72.4	6.98	21.59	244.29
A 76	64.0	9.77	34.20	479.17
A 78	81.6	9.90	27.18	491.95
A 83	60.6	10.28	37.86	529.92
A 111	71.8	10.95	34.16	601.72
A 104	49.6	10.23	46.19	524.86
A 169	79.8	9.66	27.12	468.28
A 180	82.6	14.07	38.16	993.51
DC	62.4	4.96	17.79	123.21
D 4	79.0	10.33	26.66	535.45
D 6	86.8	14.54	37.53	1061.45
D 7	91.8	12.15	29.65	740.92
D 18	79.8	13.49	37.86	912.64
D 39	74.4	11.46	34.52	659.46
D 80	80.4	5.56	15.49	155.25
D 91	68.8	8.61	28.04	372.10
D 180	98.0	10.42	23.79	545.22
D 178	79.8	7.94	22.29	316.48
D 182	72.8	4.04	12.42	81.72
D 187	79.2	10.80	30.55	585.64
D 190	54.0	12.78	53.02	819.67
D 191	60.8	9.21	33.93	425.59
D 194	74.2	7.05	21.28	249.32
D 196	83.0	8.92	24.07	399.20
D 197	72.8	9.30	28.94	434.30
D 198	58.6	6.37	24.35	203.63
D 199	84.6	11.91	31.52	711.28
D 202	69.2	11.78	38.12	695.90
D 203	143.6	12.07	18.82	730.62
D 211	83.2	9.18	24.72	423.12
D 214	90.4	8.33	0.21	347.82
D 217	53.8	7.38	30.71	272.91
D 220	60.0	7.10	26.52	253.12
D 229	62.2	11.99	43.18	721.45
D 304	79.6	4.68	13.17	109.83
D 310	77.0	15.06	43.81	1137.71
D 311	93.0	11.11	26.76	619.51
D 314	82.4	7.92	21.54	315.06
D 320	66.4	5.27	17.74	139.24

Mean, standard error of mean, coefficient of variation and variance

Table 18. Fresh weight of the rhizome (gms)

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	516.0	36.49	15.84	6679.79
A 32	410.2	29.39	16.16	4393.03
A 31	527.0	98.80	41.99	48982.54
A 53	383.4	57.82	33.78	16772.84
A 64	356.2	98.52	61.95	48699.66
A 71	429.2	78.04	40.73	30558.53
A 76	388.4	33.72	19.45	5704.78
A 78	563.2	94.16	37.45	44483.02
A 83	485.4	36.67	16.92	6745.33
A 111	653.4	179.49	61.54	161660.28
A 104	481.0	64.31	29.95	20753.28
A 169	507.0	35.65	15.75	6376.02
A 180	316.4	53.81	38.09	14529.89
DC	494.8	73.46	33.25	27079.99
D 4	452.8	53.53	26.48	14378.40
D 6	443.4	72.89	36.82	26663.62
D 7	413.2	30.52	16.54	4673.08
D 18	393.8	49.00	27.87	12047.25
D 39	536.8	51.74	21.59	13430.49
D 80	517.8	51.68	22.36	13402.69
D 91	529.0	42.72	18.09	9158.49
D 180	671.4	68.86	22.97	23793.06
D 178	431.4	65.14	33.82	21292.64
D 182	685.4	31.92	10.43	5110.82
D 187	406.6	32.64	17.98	5346.53
D 190	383.2	39.16	22.89	7694.79
D 191	357.4	53.01	33.60	14421.60
D 194	515.8	100.96	43.85	51148.34
D 196	486.0	107.29	49.45	57753.70
D 197	409.8	78.66	43.02	31042.91
D 198	481.4	34.69	16.14	6038.84
D 199	693.6	61.97	20.01	19268.21
D 202	439.2	50.72	25.87	12909.50
D 203	458.8	38.99	19.04	7630.02
D 211	381.6	32.34	18.98	5247.55
D 214	545.0	60.48	24.86	18357.54
D 217	372.4	29.85	17.95	4470.25
D 220	439.4	56.09	28.59	15787.92
D 229	582.4	62.96	24.22	19892.28
D 304	411.6	42.80	23.29	9192.97
D 310	356.0	57.29	36.05	16468.58
D 311	440.6	75.13	38.19	28321.52
D 314	348.0	37.74	24.29	7147.01
D 320	455.4	27.33	13.44	3746.66

According to the observations on 150th day, the maximum variability was found in the line D 304 (54.3%) followed by line D 311 (52.68%) and line 197 showed minimum variability (5.73%).

5.4. Number of leaves on the tillers

The data showed that the variability ranged from 16.06 per cent to 149.88 per cent with regards to the number of leaves produced on the tillers hundred days after planting. The maximum variability was noticed in the line D 187 (149.88%) followed by D 190 (141.41%) and the line D 7 (16.06%) showed the lowest variability.

On 150th day, the variability ranged from 14.68 per cent to 68.15 per cent. The line D 187 recorded maximum variability with a coefficient of variation 68.15 per cent followed by D 18 (64.63%) and A 76 (61.77%). The line D 182 (14.68%) indicated the lowest variability with regards to the number of leaves on the tillers on 150th day.

5.5. Number of roots

The variability exhibited in the case of number of roots produced, ranged from 0.21 per cent to 73.15 per cent among the lines. The Amalapuram control ranked first with

Mean, standard error of mean, coefficient of variation and variance

Table 19. Number of primary rhizomes

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	5.6	0.68	27.10	2.31
A 32	9.4	0.39	94.61	0.79
A 31	9.2	0.66	20.55	2.19
A 53	6.4	1.43	50.15	10.30
A 64	4.8	0.66	30.83	2.19
A 71	6.4	1.12	39.06	6.25
A 76	9.2	1.65	40.21	13.69
A 78	12.6	1.25	22.14	7.79
A 83	7.4	0.51	15.41	1.29
A 111	9.8	0.79	18.16	3.16
A 104	6.8	1.14	37.50	6.50
A 169	6.8	0.86	28.24	3.68
A 180	10.0	1.13	25.40	6.45
DC	14.2	0.67	10.63	2.28
D 4	8.6	0.75	19.42	2.78
D 6	7.6	1.68	49.74	14.28
D 7	11.2	1.06	21.25	5.66
D 18	6.6	0.92	31.36	4.28
D 39	6.4	1.03	35.94	5.29
D 80	9.8	0.91	20.82	4.16
D 91	11.0	1.41	28.73	9.98
D 180	13.6	1.50	24.71	11.28
D 178	13.2	1.93	32.73	18.66
D 182	5.8	0.66	25.52	2.19
D 187	9.2	1.31	31.96	8.64
D 190	4.4	0.51	25.91	1.29
D 191	8.0	0.63	17.63	1.98
D 194	8.2	1.88	51.22	17.68
D 196	7.4	1.32	40.00	8.76
D 197	11.0	1.51	30.82	11.49
D 198	6.4	0.81	28.28	3.27
D 199	11.0	1.29	26.45	8.46
D 202	7.8	1.90	54.61	18.14
D 203	10.6	1.07	22.64	5.76
D 211	9.0	2.06	66.00	21.34
D 214	9.0	1.29	32.33	8.46
D 217	8.6	0.92	24.07	4.28
D 220	7.4	0.59	18.11	1.79
D 229	7.8	1.49	42.82	11.15
D 304	7.0	1.59	51.14	12.81
D 310	6.6	1.21	40.91	7.29
D 311	9.4	0.67	16.06	2.28
D 314	8.0	0.83	23.38	3.49
D 320	7.0	0.71	22.57	2.49

Mean, standard error of mean, coefficient of variation and variance

Table 20. Length of primary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	8.82	0.40	10.20	0.81
A 32	7.16	0.25	7.68	0.30
A 31	7.42	0.25	7.41	0.30
A 53	7.86	0.19	5.47	0.18
A 64	6.92	0.75	24.28	2.82
A 71	7.20	0.76	23.75	2.92
A 76	7.79	0.24	6.94	0.29
A 78	8.10	0.81	22.35	3.27
A 83	9.72	0.55	12.65	1.51
A 111	8.44	0.39	10.55	0.79
A 104	7.44	0.18	5.17	0.16
A 169	9.18	0.50	12.42	1.27
A 180	7.20	0.41	12.64	0.82
DC	8.80	0.29	7.61	0.44
D 4	7.06	0.34	10.76	0.57
D 6	8.35	0.43	11.49	0.92
D 7	7.50	0.27	8.13	0.37
D 18	8.20	0.29	8.17	0.44
D 39	8.50	0.33	8.82	0.56
D 80	7.75	0.16	4.52	0.12
D 91	8.00	0.30	8.50	0.46
D 180	7.70	0.29	8.44	0.42
D 178	8.05	0.71	19.88	2.56
D 182	8.10	0.49	13.45	1.18
D 187	8.15	0.47	12.88	1.10
D 190	7.65	0.25	7.45	0.32
D 191	7.95	0.35	9.81	0.60
D 194	8.80	0.73	18.52	2.65
D 196	8.45	0.46	12.07	1.04
D 197	7.10	0.39	12.25	0.75
D 198	8.55	0.62	16.24	1.90
D 199	8.30	0.17	4.46	0.13
D 202	7.55	0.42	12.45	0.88
D 203	7.05	0.29	9.22	0.42
D 211	7.60	0.51	15.13	1.32
D 214	8.30	0.35	9.52	0.62
D 217	9.75	0.41	9.44	0.84
D 220	7.35	0.55	16.73	1.51
D 229	9.20	0.66	15.98	2.16
D 304	7.45	0.39	11.95	0.79
D 310	8.35	0.68	18.35	2.34
D 311	7.45	0.62	18.52	1.90
D 314	7.60	0.56	16.58	1.58
D 320	7.15	0.17	5.31	0.14

Mean, standard error of mean, coefficient of variation and variance

Table 21. Girth of the primary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	7.84	0.64	18.37	2.07
A 32	6.78	0.32	10.03	0.46
A 31	6.04	1.42	52.81	10.17
A 53	7.17	0.96	30.13	4.66
A 64	6.83	0.45	14.79	1.02
A 71	8.12	0.71	19.58	2.52
A 76	8.05	0.49	13.54	1.18
A 78	7.19	0.94	29.21	4.41
A 83	8.14	0.69	18.92	2.37
A 111	6.16	0.55	19.97	1.51
A 104	7.54	1.05	31.29	5.56
A 169	7.06	0.29	9.21	0.42
A 180	6.78	0.42	13.72	0.86
DC	8.10	0.51	14.19	1.32
D 4	7.65	0.60	17.67	1.82
D 6	7.61	0.72	21.15	2.59
D 7	8.10	0.33	9.14	0.54
D 18	8.95	0.34	8.49	0.57
D 39	7.26	0.60	18.62	1.82
D 80	8.10	0.52	14.44	1.36
D 91	7.45	0.56	16.91	1.58
D 180	7.50	0.41	12.27	0.84
D 178	8.15	0.62	17.05	1.93
D 182	8.90	0.75	18.76	2.78
D 187	7.10	0.51	16.19	1.32
D 190	9.00	0.26	6.44	0.33
D 191	7.25	0.57	17.65	1.63
D 194	6.35	0.66	23.31	2.19
D 196	7.90	0.43	12.15	0.92
D 197	6.85	0.76	24.96	2.92
D 198	7.40	0.20	6.08	0.20
D 199	6.75	0.59	17.03	1.74
D 202	7.75	0.86	24.90	3.72
D 205	7.30	0.48	14.79	1.16
D 211	7.35	0.54	16.46	1.46
D 214	8.60	0.49	12.67	1.18
D 217	7.85	0.71	20.38	2.56
D 220	7.15	0.65	20.42	2.13
D 229	7.65	0.82	23.92	3.34
D 304	7.05	0.26	8.37	0.34
D 310	8.30	0.34	9.16	0.57
D 311	6.15	0.65	20.86	2.10
D 314	6.85	0.53	17.23	1.39
D 320	7.80	0.33	9.49	0.54

Mean, standard error of mean, coefficient of variation and variance

Table 22. Internodal length of primary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	5.70	0.61	24.04	1.87
A 32	6.24	0.35	12.66	0.62
A 31	6.58	0.46	15.65	1.06
A 53	6.10	0.15	5.57	0.11
A 64	5.64	0.41	16.13	0.82
A 71	6.34	0.24	8.52	0.29
A 76	6.08	0.45	16.45	1.00
A 78	6.08	0.34	12.50	0.57
A 83	7.10	0.43	13.66	0.94
A 111	6.14	0.62	22.47	1.90
A 104	6.06	0.33	12.00	0.53
A 169	6.36	0.37	13.05	0.68
A 180	6.92	0.46	14.74	1.04
DC	8.50	0.83	21.88	3.45
D 4	5.60	0.28	11.25	0.39
D 6	6.16	0.66	22.56	2.19
D 7	5.42	0.42	17.34	0.88
D 18	6.46	0.68	23.53	2.31
D 39	6.66	0.38	12.67	0.70
D 80	6.44	0.21	7.29	0.22
D 91	5.84	0.26	9.93	0.33
D 180	5.30	0.29	12.64	0.44
D 178	7.70	0.35	10.25	0.62
D 182	6.64	0.19	6.63	0.19
D 187	6.64	0.32	10.84	0.51
D 190	5.20	0.20	8.65	0.20
D 191	6.46	0.58	19.97	1.66
D 194	7.94	0.48	13.60	1.16
D 196	6.68	0.52	17.51	1.16
D 197	6.02	0.62	23.08	1.93
D 198	7.30	0.71	21.92	2.56
D 199	7.02	0.31	9.83	0.47
D 202	5.08	0.15	6.69	0.11
D 203	5.00	0.00	0.00	0.00
D 211	9.08	1.02	25.11	5.19
D 214	8.42	1.45	38.48	10.49
D 217	9.66	1.58	36.75	12.60
D 220	9.02	1.87	46.45	17.55
D 229	8.16	1.20	33.07	7.23
D 304	8.00	1.22	34.25	7.50
D 310	8.00	1.22	34.25	7.50
D 311	7.00	1.22	34.14	7.50
D 314	7.00	1.22	39.14	7.50
D 320	9.00	1.87	46.44	17.47

73.15 per cent and D 214 ranked last with 0.21 per cent variability.

5.6. Fresh weight of the rhizomes

The data indicated that the variability ranged between 10.43 per cent to 61.95 per cent among the lines with respect to the weight of the rhizomes. Line A 64 (61.95%) showed maximum variability closely followed by A 111 (61.54%). Least variability was showed by the line D 182 (10.43%).

5.7. Primary finger characters

With regards to the number of primary fingers, the variability was maximum in the line A 32 (94.6%), followed by D 211 (66%) and D 194 (51.22%). It was minimum in the case of line DC (10.63%).

The length of the primary fingers showed a lesser range of variability among lines, from 4.52 per cent to 24.28 per cent. Maximum variability was recorded by the line A 64 (24.28%), followed by A 71 (23.75%) and A 78 (22.35%). D 80 had the minimum variability (4.52%).

In the case of girth of the primary fingers, the variability ranged from 6.08 per cent to 52.81 per cent.

Mean, standard error of mean, coefficient of variation and variance

Table 23. Number of secondary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	43.6	2.79	14.38	39.31
A 32	64.6	2.83	9.83	40.32
A 31	59.6	3.96	14.89	78.85
A 53	52.0	6.18	21.63	191.54
A 64	42.4	11.51	60.80	664.60
A 71	51.2	6.02	26.33	181.71
A 76	36.8	3.79	23.07	72.08
A 78	57.8	7.09	27.49	252.49
A 83	35.0	3.68	23.57	68.06
A 111	47.6	3.46	16.30	60.21
A 104	48.2	4.72	21.93	111.72
A 169	58.0	4.02	15.60	81.90
A 180	31.2	5.41	38.81	146.65
DC	44.0	7.26	36.95	264.38
D 4	48.6	6.55	30.81	215.20
D 6	34.2	9.05	59.29	411.27
D 7	46.0	2.88	14.00	41.47
D 18	45.2	8.57	43.47	368.64
D 39	44.2	5.19	26.31	135.25
D 80	51.6	2.12	9.65	24.80
D 91	47.8	1.98	9.29	19.71
D 180	81.6	8.28	22.73	344.10
D 178	55.4	7.36	16.48	83.35
D 182	50.4	2.25	9.98	25.30
D 187	57.4	9.52	37.16	454.96
D 190	31.2	4.11	29.48	84.64
D 191	41.8	6.72	36.03	226.80
D 194	79.4	7.68	28.97	296.18
D 196	70.6	12.71	40.33	810.54
D 197	52.0	12.32	53.06	761.20
D 198	40.8	4.78	26.25	114.70
D 199	56.8	8.86	34.93	393.62
D 202	48.2	5.64	26.22	159.76
D 203	66.0	1.05	3.56	5.52
D 211	39.6	3.70	20.93	68.72
D 214	52.6	3.74	20.93	70.22
D 217	41.4	2.83	15.34	40.32
D 220	39.4	5.02	28.53	126.33
D 229	53.0	4.03	17.04	81.54
D 304	49.6	7.23	32.64	262.11
D 310	32.6	4.33	29.79	94.28
D 311	51.8	8.19	35.42	336.72
D 314	52.8	6.70	28.43	225.30
D 320	50.6	3.35	14.82	56.25

Mean, standard error of mean, coefficient of variation and variance

Table 24. Length of secondary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	7.5	1.12	33.92	6.30
A 32	6.9	0.15	4.87	0.11
A 31	8.3	0.16	4.33	0.12
A 53	8.2	0.79	21.56	3.13
A 64	7.4	0.93	28.09	4.36
A 71	6.1	0.38	13.77	0.72
A 76	7.7	0.78	22.64	3.06
A 78	8.2	0.94	25.61	4.45
A 83	7.5	0.58	17.15	1.69
A 111	7.1	0.58	17.99	1.71
A 104	8.3	0.67	17.95	2.22
A 169	8.3	0.62	16.51	1.90
A 180	6.8	0.68	22.32	2.31
DC	8.9	0.73	18.23	2.65
D 4	7.7	0.55	16.06	1.53
D 6	8.0	0.34	9.63	0.59
D 7	6.6	0.83	28.57	3.61
D 18	7.9	0.54	15.09	1.44
D 39	8.5	0.33	8.58	0.53
D 80	8.9	0.77	19.33	2.95
D 91	8.5	0.43	11.35	0.94
D 180	8.2	0.76	20.99	2.89
D 178	7.5	0.47	14.00	1.10
D 182	8.8	0.54	13.64	1.44
D 187	7.7	0.73	21.16	2.68
D 190	7.7	0.21	8.33	0.23
D 191	5.9	0.29	11.02	0.42
D 194	7.6	0.39	11.58	0.77
D 196	8.7	0.60	15.52	1.82
D 197	6.2	0.51	18.55	1.32
D 198	7.1	0.69	21.68	2.40
D 199	7.0	0.62	19.72	1.93
D 202	9.0	0.90	22.78	4.20
D 203	6.2	0.49	17.90	1.23
D 211	6.6	1.47	49.62	10.89
D 214	7.4	0.80	24.46	3.27
D 217	7.0	0.73	18.11	2.65
D 220	6.3	0.23	8.19	0.27
D 229	8.4	0.66	17.51	2.19
D 304	7.2	0.70	21.66	2.46
D 310	7.5	0.30	15.07	1.27
D 311	5.3	0.42	17.55	0.86
D 314	6.8	0.67	22.06	2.25
D 320	6.6	0.43	14.55	0.92

Mean, standard error of mean, coefficient of variation and variance

Table 25. Girth of secondary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	5.52	0.12	4.74	0.06
A 32	4.40	0.11	5.68	0.06
A 31	5.52	0.51	20.83	1.32
A 53	4.61	0.21	10.61	0.24
A 64	5.03	0.29	12.92	0.42
A 71	4.94	0.21	9.72	0.23
A 76	5.38	0.29	12.08	0.42
A 78	5.21	0.32	13.32	0.71
A 83	5.27	0.43	18.41	0.94
A 111	5.41	0.35	14.60	0.62
A 104	5.21	1.16	50.29	6.86
A 169	5.13	0.14	6.24	0.10
A 180	4.15	0.29	14.63	0.43
DC	5.22	0.33	14.23	0.54
D 4	4.71	0.19	9.34	0.19
D 6	5.60	0.23	9.28	0.27
D 7	4.85	0.37	16.91	0.67
D 18	4.89	0.16	6.88	0.12
D 39	5.20	1.04	44.81	5.42
D 80	5.20	0.18	7.88	0.16
D 91	5.45	0.53	21.83	1.41
D 180	5.25	0.28	12.19	0.40
D 178	5.25	0.16	6.66	0.12
D 182	6.15	0.66	24.06	2.19
D 187	4.45	0.33	15.51	0.47
D 190	5.55	0.23	9.19	0.26
D 191	5.05	0.37	16.24	0.67
D 194	4.70	0.37	17.25	0.67
D 196	5.00	0.21	9.40	0.22
D 197	5.05	0.20	8.91	0.20
D 198	4.85	0.20	9.27	0.20
D 199	4.85	0.15	7.01	0.11
D 202	4.65	0.27	12.90	0.36
D 203	4.50	0.26	13.11	0.34
D 211	4.90	0.17	7.76	0.14
D 214	5.00	0.17	7.80	0.15
D 217	4.99	1.16	52.20	6.81
D 220	5.05	0.05	2.18	0.01
D 229	5.35	0.08	3.36	0.03
D 304	4.65	0.25	12.26	0.32
D 310	5.15	0.23	10.09	0.27
D 311	4.85	0.26	11.96	0.33
D 314	4.60	0.23	11.30	0.27
D 320	5.60	0.13	5.00	0.07

Mean, standard error of mean, coefficient of variation and variance

Table 26. Internodal length of secondary fingers

Lines	Mean	± S.E.(d)	C.V.(%)	Variance
AC	8.02	0.79	22.07	3.13
A 32	6.50	0.24	8.15	0.28
A 31	7.52	0.10	3.06	0.05
A 53	8.20	0.82	22.32	3.34
A 64	7.00	0.83	26.43	3.42
A 71	5.88	0.46	17.52	1.04
A 76	6.58	1.56	27.61	11.83
A 78	6.62	0.64	21.67	2.04
A 83	7.24	0.48	14.78	1.14
A 111	6.44	0.28	9.78	0.39
A 104	7.96	0.59	16.58	1.74
A 169	7.46	0.67	20.11	2.25
A 180	6.56	0.80	27.44	3.24
DC	7.56	0.96	28.44	4.62
D 4	6.74	0.80	26.71	3.24
D 6	7.40	0.79	24.19	3.20
D 7	6.10	0.48	17.70	1.16
D 18	7.46	0.34	10.18	0.57
D 39	7.62	0.48	14.04	1.14
D 80	7.62	0.47	13.78	1.10
D 91	8.42	0.41	10.93	0.84
D 180	7.16	0.83	25.84	3.42
D 178	8.00	0.46	12.88	1.06
D 182	8.62	0.84	21.93	3.57
D 187	8.08	0.55	15.22	1.51
D 190	7.70	0.75	21.82	2.82
D 191	6.38	0.61	21.47	1.87
D 194	7.14	0.72	22.69	2.62
D 196	8.60	0.87	22.67	3.80
D 197	5.14	0.09	4.09	0.04
D 198	8.36	0.35	9.33	0.60
D 199	6.40	0.75	26.25	2.82
D 202	9.40	0.53	12.66	1.41
D 203	7.00	1.22	39.00	7.45
D 211	7.00	1.22	39.00	7.45
D 214	8.00	1.22	34.25	7.50
D 217	10.00	0.00	0.00	0.00
D 220	8.00	1.22	34.25	7.50
D 229	9.32	0.83	20.06	3.49
D 304	9.32	0.88	21.14	3.88
D 310	8.50	1.08	28.59	5.90
D 311	7.32	1.11	34.02	6.20
D 314	7.36	2.16	75.39	23.42
D 320	9.28	1.81	43.75	16.48

The line A 31 recorded maximum variability (52.81%) followed by A 104 (31.29%) and A 53 (30.13%). Line D 198 (6.08%) showed lowest variability.

The internodal length of primary finger indicated a variability ranging from 5.57 per cent to 46.45 per cent. Maximum variability was recorded by the line D 220 (46.45%) closely followed by line D 320 (46.44%) and D 311 and D 314 (39.14% each). Line A 53 showed the minimum variability with a coefficient of variation (5.57%).

5.8. Secondary finger characters

The variability with regards to the number of secondary fingers produced by the different lines ranged from 3.56 per cent to 60.80 per cent. The maximum variability was exhibited by the line A 64 (60.80%) followed by D6 (59.29%) and D 18 (43.47%). Minimum variability was recorded by the line D 203 (3.56%).

Variability with regards to the length of the secondary fingers ranged from 4.33 per cent to 49.62 per cent. Line D 211 exhibited maximum variability (49.62%) and line A 31 showed minimum variability (4.33%).

The girth of the secondary fingers recorded a variability ranging from 2.18 per cent to 52.20 per cent.

Maximum variability was noticed in line D 217 (52.20%) followed by A 104 (50.29%) and D 39 (44.81%). Line D 220 showed minimum variability.

Maximum variability with regards to the internodal length of secondary fingers was recorded by the line D 314 (75.39%) followed by D 320 (43.75%), D 203 and D 211 (39% each). Line A 31 (3.06%) recorded the minimum variability. The variability ranged from 3.06 per cent to 75.39 per cent.

In general, it could be seen that, the lines were homogenous in the case of characters such as height of the plant on 100th day, number of leaves on the tillers on 150th day, number of roots, number of primary fingers, length and girth of primary fingers. It was also found that with regards to the characters such as number of tillers on 100th and 150th day, height of the plant on 150th day, number of leaves on the main plant on 100th and 150th day, number of leaves on the tillers on 100th day, fresh weight of rhizomes, internodal length of primary fingers, and number, length, girth and internodal length of secondary fingers, lines were heterogenous.

6. CORRELATION STUDIES

The correlation coefficients between yield and

various morphological characters studied were worked out and were furnished in Table 27 and 28.

6.1. Simple correlation analysis

Length of the primary fingers, length of the secondary finger and girth of the secondary finger showed significant positive correlation with yield. Results were furnished in the Table 27. No significant linear relationship could be observed between yield and characters such as number of roots, number of primary fingers, and number of secondary fingers. The correlation between yield and characters such as height of the plant, number of tillers, girth of primary fingers, internodal length of primary fingers, internodal length of secondary fingers and number of leaves were found to be negative and non-significant.

6.2. Multiple correlation analysis

In order to assess the relationship of different plant characters on the yield of the crop, a multiple regression equation was fitted. The regression equation (selection index) was derived from the data which was of the form

$$y = -189.677 - 9.914\,x_1 - 2.42\,x_2 + 1.633\,x_3 + 26.345\,x_4 + 0.372\,x_5 - 17.046\,x_6 - 41.741\,x_7 + 104.479\,x_8 + 82.648\,x_9 + 108.850\,x_{10} - 14.875\,x_{11} - 2.534\,x_{12},$$

Where y = selection index and $x_1, x_2 \ldots x_{12}$ = mean value of the characters.

Table 28. Partial regression coefficients of various plant characters

Variables		Partial regression coefficients	Standardised partial regression coefficients
Height of the plant	(x_1)	-9.9419	-1.004
Number of tillers	(x_2)	-2.2428	-0.183
Number of roots	(x_3)	+1.6338	+1.183
Number of primary fingers	(x_4)	+26.3458	+2.766
Number of secondary fingers	(x_5)	+0.3728	+0.194
Length of primary fingers	(x_6)	-17.0462	-0.542
Girth of primary fingers	(x_7)	-41.7411	-1.314
Internodal length of primary fingers	(x_8)	+10.4791	+0.544
Length of secondary fingers	(x_9)	+82.6488	+10.909
Girth of secondary fingers	(x_{10})	+108.8506	+1.741
Internodal length of secondary fingers	(x_{11})	-14.8750	-0.847
Number of leaves	(x_{12})	-2.5340	-1.044

About 73.3% of the total variation in yield could be explained by the above multiple regression equation. The multiple correlation coefficient was found to be 0.8561. The significance of the regression equation was tested by using F test and it was found to be highly significant. The standardised regression coefficients of the various plant characters were calculated and are presented in Table 28.

It could be seen that length of secondary finger was the major factor contributing to yield of rhizome in turmeric. The standardised partial regression coefficients of length of secondary finger on yield was found to be 10.909. This indicated that a one per cent increase in length of secondary finger could be on the average followed by a 10.91 per cent increase in the yield of the crop. The standard regression coefficients of number of primary rhizomes was found to be 2.766 i.e. for each additional primary rhizome observed in the plant, will contribute to about 2.7 gms in yield.

The direct effects of height of the plant, number of tillers, length of primary rhizomes, girth of primary rhizomes, internodal length of secondary rhizomes and number of leaves on the yield of the plant were negative.

Table 29. Ranking of different lines of open-pollinated progenies of types Amalapuram and Dindrigam (*Curcuma aromatica*) based on yield, curcumin and selection index

Lines	Dry weight per unit area (kg)	Rank	Curcumin per unit area (kg)	Rank	Selection index	Rank	Pooled rank
A 32	4.79	23	0.109	17	413.0	29	69
A 31	5.92	9	0.151	7	514.0	19	35
A 53	4.01	36	0.215	3	447.3	24	63
A 64	3.25	40	0.099	19	405.7	30	89
A 71	4.24	34	0.105	18	263.0	41	93
A 76	3.67	39	0.093	22	438.5	25	86
A 78*	6.05	6	0.152	6	688.8	3	15
A 83	5.49	14	0.076	29	359.3	36	79
A 111	6.35	4	0.075	30	560.7	15	49
A 104	3.75	38	0.054	36	648.9	6	80
A 169	5.50	13	0.086	24	517.9	18	55
A 180	3.23	41	0.116	15	427.6	28	84
D 4	4.57	28	0.119	14	658.7	5	37
D 6	4.59	27	0.146	8	519.3	17	52
D 7	4.39	31	0.122	13	447.8	23.	67
D 18	4.41	30	0.182	5	379.2	34	69
D 39	5.97	8	0.073	32	600.6	10	50
D 80	4.62	26	0.062	34	604.1	9	69
D 91	5.04	19	0.081	26	609.3	8	53
D 180*	6.63	2	0.254	2	713.2	2	6
D 178	4.32	32	0.079	27	580.3	12	71
D 182	6.02	7	0.098	20	571.5	13	40
D 187	4.26	33	0.084	25	437.3	26	84
D 190	3.82	37	0.098	20	375.1	35	92
D 191	4.45	29	0.091	23	346.2	38	90
D 194	5.79	10	0.152	6	472.5	21	37
D 196	4.92	21	0.145	9	464.4	22	52
D 197	4.14	35	0.053	37	500.3	20	92
D 198	4.82	22	0.125	11	300.9	40	73
D 199*	6.77	1	0.270	1	563.2	14	16
D 202	5.07	18	0.123	12	640.6	7	37
D 203	5.55	12	0.165	33	395.6	32	77
D 211	5.09	17	0.129	10	544.5	16	43
D 214	6.47	3	0.115	16	434.5	27	46
D 217	4.74	25	0.095	21	225.1	42	88
D 220	4.94	20	0.056	35	396.8	31	86
D 229*	6.26	5	0.204	4	766.0	1	10
D 304	5.26	16	0.129	10	354.9	37	63
D 310	4.76	24	0.075	31	591.1	11	66
D 311	5.92	9	0.215	3	320.5	39	51
D 314	5.48	15	0.122	13	666.6	4	32
D 320	5.66	11	0.078	28	389.1	33	72

* Selected lines for further studies

7. SELECTION OF LINES BY RANKING

Based on the yield of curcumin per unit area, the lines were ranked. It was found that the line D 199 ranked first followed by line D 180, and line D 311 and A 53.

According to the dry yield of turmeric per unit area, the line D 199 ranked first followed by line D 180, D 214, A 111 and D 229.

From the selection index calculated we could select lines D 229, D 180, A 78, D 314 and D 4 which were found to be superior.

A composite (pooled) ranking was possible since 'W' was found to be significant. From the pooled ranking, selection was made and the lines D 180, D 229, A 78 and D 199 were recommended for further detailed study.

Table 30. Yield data of open-pollinated lines of Amalapuram and Dindrigam (*Curcuma aromatica*)

Lines	Weight of the rhizomes (g) First season (1978)	Weight of the rhizomes (g) Second season (1979)	Weight of the rhizomes (g) Third season (1980)
A 32	2.050	218.4	410.2
A 31	3.950	230.5	527.0
A 53	2.650	165.5	383.4
A 64	13.500	192.8	356.2
A 71	4.550	167.3	429.2
A 76	2.600	168.1	388.2
A 78*	5.800	235.4	563.2
A 83	1.100	178.5	485.4
A 111	1.600	219.9	653.4
A 104	3.100	158.0	481.0
A 169	7.700	150.2	507.0
A 180	6.900	215.3	316.4
D 4	3.350	240.9	452.8
D 6	4.800	197.8	443.4
D 7	7.100	347.4	413.2
D 18	23.750	184.2	393.8
D 39	7.850	230.8	536.8
D 80	4.000	243.6	517.8
D 91	6.500	180.6	529.0
D 180*	5.750	150.5	671.4
D 178	10.050	173.8	431.4
D 182	3.600	274.6	685.4
D 187	7.100	236.5	406.6
D 190	8.000	185.2	383.2
D 191	5.900	212.5	357.4
D 194	11.100	267.1	515.8
D 196	4.000	372.2	486.0
D 197	5.500	338.3	409.6
D 198	2.100	338.3	481.4
D 199*	11.150	166.5	693.6
D 202	11.150	189.8	439.2
D 203	3.100	184.6	458.8
D 211	3.250	229.7	381.6
D 214	2.650	202.6	545.0
D 217	2.000	275.5	372.4
D 220	2.300	276.1	439.4
D 229*	3.850	195.0	582.4
D 304	4.800	194.0	411.6
D 310	4.100	196.4	356.0
D 311	5.400	262.3	440.6
D 314	2.450	176.2	348.0
D 320	3.600	193.5	455.4

* Selected lines for further studies

DISCUSSION

D I S C U S S I O N

Open-pollinated seeds of two types of turmeric (Curcuma aromatica) namely, Amalapuram and Dindrigam were collected and sown in the nursery in December, 1977. Out of the 1500 individual plants, 175 plants were selected based on the yield taking the yield of Amalapuram and Dindrigam as the basis. The rhizomes of the above lines were planted in May, 1979 and harvested in January, 1980. Further 42 selections were made on the basis of the above criteria and planted in the field in May, 1980 and the result of which is discussed in this chapter.

1. GROWTH CHARACTERS

1.1. With regards to the growth characters, the lines varied significantly in the case of number of tillers, height of the plant, and number of leaves. This variation is quite reasonable as the Amalapuram and Dindrigam types are tetraploids (2n=84) and highly heterozygous. The heterozygous nature will definitely produce wide variability in the progenies which will be available for selection for economical characters.

1.2. Significant variation was found in the present study among the lines with regards to the tiller production

which do not agree with the result of Philip (1978) and Subbarayudu et al. (1976) who were studying vegetatively propagated materials while the present study related to open pollinated seedling progenies. But Pillai (1973a) and Nybe (1978) got similar results in ginger grown vegetatively. However, tiller production was not correlated with yield and this is in confirmity with the findings of Philip (1978) in turmeric and Nybe (1978) in ginger.

1.3. Height of the plant was found to have no correlation with the yield. This result disagreed with the findings of Philip (1978) who found that height was positively correlated with yield. From the present study, it was noticed that the line D 202 with tallest plants (33.2 cm), yielded only 439.2 gms. of rhizomes, whereas the shortest plant D 320 with 24 cm height yielded more with a fresh weight of 445.4 gms. The lines showed significant difference in height among the lines which is in confirmity with findings of Philip (1978). Pillai (1973) and Nybe (1978) noticed similar variation in ginger.

1.4. With regards to the number of leaves both per plant and per tiller differed significantly among lines. The variation in leaf production among the lines may be due to genetic factors under uniform environmental conditions.

It is quite natural that when the total number of tillers increases, the total number of leaves per plant also increases. No significant correlation was found between yield and number of leaves. This confirms the result of Nybe (1978) in the case of ginger, but disagreed with the result of Philip (1978) in the case of turmeric who noticed positive significant correlation with yield. The yield will be a combined effect of height, tiller count, number of leaves and their orientation. An optimum condition of these factors are likely to contribute for higher yield which of course require confirmation supported by sufficient data.

2. RHIZOME CHARACTERS

2.1. The number of roots had got no significant correlation with yield though the character showed significant variation among lines. An optimum number of roots may help in better absorption of nutrients which may increase yield. Hence an optimum number of root production may be preferred rather than maximum.

2.2. Significant variation was noticed in number, length, girth and internodal length of primary fingers and secondary fingers, among lines. Length of the primary finger, length and girth of secondary finger was found to be significant and positively correlated to yield. According

to Philip (1978), the length of primary fingers was found to be positively correlated to yield. Increase in length of primary fingers, naturally will increase the production of secondary fingers and hence an increase in yield.

It can be seen that the number, length and girth of fingers contribute to the higher yield which may be more of a genetical character rather than environmental because all lines were grown under identical conditions.

3. YIELD CHARACTERS

3.1. The fresh weight of rhizomes per plant varied significantly among lines. The maximum was reported in line D 199 (693.6 gms.) and minimum in line A 180 (316.4 gms). Wide differences in yield of turmeric (green and cured) among the types had been noticed by several workers (Aiyadurai, 1966; Pillai et al., 1974 and 1975; Shankaracharya, 1974; Rao et al., 1975; Subbarayudu et al., 1976 and Philip, 1978). The yield was found to be positively correlated with characters like length of the primary fingers, length and girth of secondary fingers. The variation in yield among lines may be due to genetical and morphological characters.

3.2. Maximum recovery of the cured turmeric was recorded by the line D 311 (33.62%) and it was the minimum

in A 104 (10.54%). The lines varied among themselves with regards to curing percentage. The variation may be attributed to the differences in size of the rhizome.

4. QUALITATIVE CHARACTERS

4.1. It may be seen from Table 8 that the lines differ significantly for curcumin content. Lewis (1973); Mathai (1974); Chaurasia et al. (1974); Rao et al. (1975); Krishnamurthy et al. (1976); Pillai et al. (1976); Subbarayudu et al. (1976) and Philip (1978) have reported distinct differences in curcumin content in turmeric. Philip (1978) recorded 2.61 per cent of curcumin for Amalapuram and 3.61 per cent for Dindrigam. In the present study, it varied from 1.18 to 5.37 per cent among Amalapuram lines and 1.14 to 4.13 per cent among Dindrigam. Line A 53 showed maximum curcumin content of 5.37 per cent and line D 220 (1.14%) showed the minimum.

The overall value of turmeric depends on the curcumin content and is more important than the oleoresin. The variation in curcumin content among lines may be due to genetic factors.

4.2. There existed highly significant variation in oleoresin percentage among lines. Distinct differences

in oleoresin content among turmeric types had been reported by Lewis (1973), Krishnamurthy et al. (1972 and 1976), Mathai (1975) and Philip (1978). Philip (1978) recorded 13.69 per cent of oleoresin for Dindrigam and 14.22 per cent for Amalapuram. But in the present study, the percentage of oleoresin varied from 10.75 per cent to 22.6 per cent for Dindrigam and 10.6 per cent to 19.38 per cent for Amalapuram.

The genetic make up will definitely have an impact on the yield of oleoresin and curcumin which may be the reason for the difference in the yield of oleoresin and curcumin among lines.

5. INCIDENCE OF PEST AND DISEASES

No incidence of leaf-disease attack was noticed dur the season. Unless the experiment is continued for another two years, it cannot be claimed that these lines are tolerant or resistant to leaf diseases as the control was also free from these diseases.

The incidence of shoot borer attack varied from zero to 60 per cent among lines.

6. VARIABILITY STUDIES

The success in genetic improvement of crop depends

upon the extent of genetic variability present. In the present study, the range of variability for all the characters studied is large with regards to the characters such as number of tillers, number of leaves both on the main plant and tillers, number of roots, and number of primary fingers. This means that there is scope for selection within the available lines for these characters. In the case of characters such as height of the plant, fresh weight of rhizomes, length, girth and internodal length of primary fingers and number, length, girth and internodal length of secondary fingers, range of variability was found to be medium where there is very little scope for selection.

Variance estimates have shown that variation in almost all of the characters are mainly due to genetic causes rather than environmental reasons.

6.1. The variability with regards to the number of tillers on 150th day varied from 11.09 per cent to 130.81 per cent. Variability was maximum in the case of D 194 (130.81%) followed by D 91 (110.76%) and minimum in D 314 (11.09%). In the case of height of the plant, the variability ranged from 1.56 per cent to 22.15 per cent in which maximum variability was exhibited by D 314 (22.15%) and

minimum in A 31 (1.56%). With regards to the number of leaves on main plant, the variability ranged from 5.73 per cent (D 197) to 54.3 per cent (D 304). The variability was maximum in the line D 187 (68.15%) in the case of number of leaves in tillers and it was minimum in D 182 (14.68%). The variability exhibited in the case of number of roots produced, ranged from 0.21 per cent (D 214) to 73.15 per cent (AC).

6.2. The data indicated that the coefficient of variation with regards to the fresh weight of rhizomes ranged between 10.43% to 61.95 per cent, the maximum being exhibited by A 64 (61.95%) and the least by D 182 (10.43%). In the case of the number of primary fingers, the coefficient of variation was maximum in the line A 32 (94.6%) and minimum in DC (10.63%). The length of primary finger showed lesser range of variability among lines from 4.52 per cent (D 80) to 24.28 per cent (A 64). The girth of the primary finger showed a variability ranging from 6.08 per cent (D 198) to 52.81 per cent (A 31). A variability range of 5.57 per cent (A 53) to 46.45 per cent (D 220) was exhibited by the lines in the case of internodal length of primary fingers. The variability with regards to the number of secondary fingers produced by different lines ranged from 3.56 per cent (D 203) to

60.8 per cent (A 64). It was ranging from 4.33 per cent to 49.62 per cent in the case of length of secondary fingers. The girth of secondary fingers recorded a range of 2.18 per cent to 52.2 per cent. Maximum variability with regards to the internodal length of secondary fingers was recorded by line D 314 (75.39%) and minimum by line A 31 (3.06%). The variability exhibited by the lines with regards to the various characters may be due to genetic factors.

6.3. In general, it was seen that the lines were homogenous in the case of characters such as height of the plant on 100th day, number of leaves on the tillers on 150th day, number of roots, number, length and girth of primary finger. With regards to the characters such as number of tillers on 100th and 150th day, height on 150th day, number of leaves on main plant on 100th and 150th day, number of leaves on tiller on 100th day, fresh weight of rhizomes, internodal length of primary fingers, number, length, girth and internodal length of secondary fingers, the lines were heterogenous.

7. CORRELATION STUDIES

7.1. From the present study, it has been noticed that length of the primary finger and length and girth of

secondary finger were significantly and positively correlated with yield. Number, girth and internodal length of primary fingers and number and internodal length of secondary fingers were not correlated with yield. Philip (1978) obtained positive and significant correlation of length of the primary finger with yield. Increase in length of primary finger, naturally will increase the production of secondary fingers and roots, and hence an increase in yield. Production of tiller was not correlated with yield confirming the findings of Philip (1978). The height of the plant was not correlated with yield and this disagrees with the result of Philip (1978). Number of leaves produced had showed no correlation with yield confirming the result of Nybe (1978) in ginger.

7.2. It was found that length of secondary finger was the major factor contributing to yield of rhizome. It was found from the standardised partial regression coefficient that a one per cent increase in length of secondary finger could, on an average, increase the yield by 10.91 per cent. This may be due to the fact that the increase in the length of the secondary fingers will contribute to the increase in weight of the rhizomes. It was also seen that a unit increase in the number of primary and secondary fingers will increase the yield by 2.76 gms and

0.194 gms. respectively. Increase in number of roots, internodal length of primary finger and girth of secondary fingers will also contribute to the yield.

8. SELECTION OF LINES BY RANKING

From the composite ranking based on the yield of curcumin, dry yield of rhizomes and selection index, four lines (D 180, D 229, A 78 and D 199) were suggested for further selection.

8.1. Line D 180 ranked second in all the three characters. Line D 229 ranked first in selection index, fourth in curcumin yield and fifth in dry yield of rhizomes. A 78 ranked third in selection index and sixth in both curcumin and dry weight. D 199 ranked first in both dry yield and curcumin content, but the selection index derived from various other characters remained only 14th in the ranklist. The line ranked fourth in the pooled ranking.

8.2. Line D 180 was on an average 27.4 cm tall with 7.4 tillers and 40.4 leaves. The line produced 98 roots and 13.6 primary fingers on which 51.6 secondary fingers were produced. The primary finger was 7.7 cm long with 7.5 cm girth with an average internodal length of 5.3 mm. The secondary fingers were 8.1 cm long, 5.25 cm thick and

with 7.16 mm of internodal length. The average green yield per plant of the line was 671.4 gms. with 3.83 per cent curcumin content and 12.57 per cent oleoresin. The curing percentage was 24.68 per cent. No disease and pest attack was noticed.

8.3. Line D 229 was shorter with 24.6 cm height with 6.2 tillers and lesser number leaves, 33.6. It produced 62.2 roots and 7.8 primary fingers and 53 secondary fingers. The primary fingers were longer than D 180 with 9.2 cm of length and girth of 7.65 cm and internodal length of 8.14 mm. The secondary fingers were 8.45 cm. long, 5.35 cm thick and with 9.8 mm long internodes. The green weight was 582.4 gms with a curing percentage of 26.87 and oleoresin content of 14.2 per cent and curcumin of 3.16 per cent. No disease was seen. Incidence of shoot borer was 11.11 per cent.

8.4. The line A 78 was 28.8 cm tall with 6 tillers and 38.2 leaves. The number of roots produced were 81.6. The line produced 12.6 primary fingers and 57.8 secondary fingers which was more than the other three lines. The primary fingers was 8.1 cm long, 7.19 cm thick with internode of 6.06 mm long. The secondary finger was 8.24 cm long, 5.33 cm thick and with 6.66 mm long internodes. The average green weight was 563.2 gms with a curing percentage

of 26.94 and oleoresin content of 13.64 per cent and curcumin content of 2.51 per cent. Incidence of shoot borer was 18.18 per cent and there was no incidence of leaf diseases.

8.5. Line D 199 was 25.4 cm high, with 7.2 tillers and 36.8 leaves. It produced 84.6 roots and 11 primary fingers with 56.8 secondary fingers. The primary fingers were 8.3 cm long, 6.75 cm thick and the nodes are 7.02 mm apart. The secondary finger was 7.05 cm long and 4.85 cm girth and the nodes were 9.8 mm apart. Green weight of the rhizomes recorded 693.6 gms with a driage of 24.41 per cent. The curcumin content was 3.99 per cent and oleoresin 16.43 per cent. No pest and disease incidence was noticed in the line.

Based on the above characters the four lines D 180, D 229, D 199 and A 78 are found to be promising and they are suggested for further detailed studies.

SUMMARY

S U M M A R Y

Open-pollinated seeds of two types of turmeric (Curcuma aromatica) namely, Amalapuram and Dindrigam were collected and sown in the nursery in December 1977. Out of the 1500 individual plants, 175 plants were selected based on the yield, taking the yield of Amalapuram and Dindrigam as the basis. The rhizomes of the above lines were planted in May, 1979 and harvested in January, 1980. Further selections were made on the basis of above criteria and fortytwo such selections were planted in the field in May, 1980 and detailed study was conducted with the objective of (1) finding out variability with regards to various characters and (2) to select high yielding and high curcumin content and pest and disease tolerant or resistant lines of turmeric. The present study was conducted at the College of Horticulture for a period of two years from May, 1979.

1. Morphological characters such as number of tillers, height of the plant, number of leaves both on the main plant and tillers, number of roots and number, length, girth and internodal length of primary and secondary fingers were found to differ significantly among lines.

2. The length of primary fingers and the length and girth of secondary fingers were found to be positively correlated with yield.

3. Leaf diseases were not found to attack the lines.

4. Incidence of shoot-borer was noticed, but lines A 76, A 83, D 39, D 180, D 182, D 199, D 310, D 311 and D 320 were free from the shoot-borer attack.

5. Wide variability among the lines was exhibited with regards to the characters like number of tillers, number of leaves, number of roots and number of primary fingers and the variability was medium in the case of height of the plant, fresh weight of rhizomes, primary and secondary finger characters.

6. There was highly significant difference in yield among lines. The maximum average fresh weight was recorded by line D 199 (693.6 gms) followed by D 182 (685.4 gms) and D 180 (671.4 gms).

7. Curing percentage was maximum in the line D 311 (33.67%) followed by D 310 (33.46%) and D 211 (33.4%).

8. Highly significant variation was noticed among the lines with regards to the percentage recovery of oleoresin

and curcumin. The oleoresin content varied between 10.6 per cent to 22.6 per cent and the variation in curcumin content was from 1.14 per cent to 5.37 per cent. The yield of curcumin per plot was maximum in the case of D 199 (0.27 kg) followed by D 180 (0.254 kg).

9. From the findings of the present investigation, the lines D 180, D 229, A 78 and D 199 are selected for further detailed study, based on the dry yield of rhizomes, yield of curcumin and selection index.

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APPENDIX I

ANALYSIS OF VARIANCE

Sl. No.	Characters	Mean square values	
		Treatments df=43	Error df=176
1.a	Number of tillers (100th day)	0.419	0.203
b	Number of tillers (150th day)	0.577	0.172
2.a	Height of the plant (100th day)	30.210	18.520
b	Height of the plant (150th day)	34.731	9.256
3	Number of leaves on the main plant		
a	On 100th day	0.132	0.076
b	On 150th day	0.152	0.056
4	Number of leaves on the tillers		
a	On 100th day	2.764	1.568
b	On 150th day	270.857	122.063
5	Primary finger characters		
a	Number of fingers	26.085	7.073
b	Length of fingers	2.472	1.037
c	Girth of fingers	2.606	1.672
d	Internodal length of fingers	6.808	3.074
6	Secondary finger characters		
a	Number of fingers	635.936	191.925
b	Length of fingers	4.253	1.863
c	Girth of fingers	0.676	0.359
d	Internodal length	5.301	3.175
7	Number of roots	1256.706	558.500
8	Wet weight of rhizomes	42397.650	21129.380

APPENDIX II

ANALYSIS OF VARIANCE

Sl. No.	Characters	Mean square values	
		Treatments df-43	Error df=88
1	Percentage of curcumin	2.5667	0.0075
2	Percentage of oleoresin	23.8215	0.7891

VARIABILITY IN THE OPEN-POLLINATED PROGENIES OF TURMERIC

Curcuma aromatica. Salisb.

BY

HANZHA GEORGE

ABSTRACT OF A THESIS

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requirements for the degree of

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Department of Horticulture (Plantation Crops)
COLLEGE OF HORTICULTURE
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A B S T R A C T

Studies were undertaken with 42 selected lines of open-pollinated progenies of two types of turmeric, Amalapuram and Dindrigam, at the College of Horticulture for a period of two years from May, 1979. The main objectives of the study were

1. To find out the genetical variability with regard to various characters, and

2. To select pest and disease tolerant/resistant lines of turmeric having high yield and curcumin content.

The results have shown that the differences between the lines were highly significant for all the characters studied.

The estimates of variance components and coefficients of variation have indicated that the major portion of total variability in most of the characters was due to genetic causes.

Yield per plant was found to be highly associated with length of primary fingers and length and girth of secondary fingers. The correlation coefficients of these yield components were found to be positive and significant.

Incidence of leaf diseases were not noticed in the lines. Attack of shoot-borer was noticed, but lines A 76, A 83, D 39, D 180, D 182, D 199, D 310, D 311 and D 320 were free from the attack.

Yield varied significantly among lines with a maximum recorded by the line D 199 (693.6 gms per plant). Curing percentage was maximum in the line D 311 (33.67%) and the percentage varied between oleoresin content varied from 16.6 per cent to 22.6 per cent and variation in curcumin content was from 1.14 per cent to 5.37 per cent.

From the present investigation, the lines D 180, D 229, A 78 and D 199 are selected for further detailed study based on the dry yield of rhizome, yield of curcumin and selection index.