MORPHOLOGICAL STUDIES
AND
QUALITY EVALUATION
OF TURMERIC (*Curcuma longa* L.) TYPES

By

JOSEPH PHILIP

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Horticulture (Plantation Crops)

COLLEGE OF HORTICULTURE

VELLANIKKARA, TRICHUR

1978

DECLARATION

I hereby declare that this thesis entitled "Morphological studies and quality evaluation of turmeric (*Curcuma longa* L.) types" 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.

Vellanikkara,
25th September, 1978.

(JOSEPH PHILIP)

CERTIFICATE

Certified that this thesis entitled "Morphological studies and quality evaluation of turmeric (*Curcuma longa* L.) types" is a record of research work done independently by Shri Joseph Philip under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara,
25th September, 1978.

Dr.P.C.Sivaraman Nair,
Associate Dean.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Shri Joseph Philip, a candidate for the degree of Master of Science in Horticulture with major in Horticulture agree that the thesis entitled "Morphological studies and quality evaluation of turmeric (*Curcuma longa* L.) types" may be submitted by Shri Joseph Philip in partial fulfilment of the requirements for the degree.

(DR. P.C. SIVARAMAN NAIR) 25/9/78
ADVISOR AND CHAIRMAN

(DR. M.ARAVINDAKSHAN)
MEMBER

(DR. A.I.JOSE)
MEMBER

(DR.K.M.N.NAMBOODIRI)
MEMBER

C O N T E N T S

---oOo---

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

The turmeric of commerce is mainly the dried rhizomes of Curcuma longa L. and to a smaller extent it also includes the rhizomes of Curcuma aromatica Salisb. In India it is mainly valued for use as spices and medicines and smaller quantities are being used for the preparation of Asiatic cosmetics. In foreign countries the demand is mainly for curcumin for use as colouring material in food and to a smaller extent for colouring wool, silk and cotton. Since the synthetic dyes are found to be injurious to health when added to food stuffs the Western countries are gradually switching over towards the plant dyes. It is also found to be much in demand from Middle East and Japan in addition to the demand from U.S.A., England and other European countries.

The estimated world production of turmeric is around 1.6 lakh tonnes of which contribution of India is about 93.7 per cent (1.5 lakh tonnes). In India turmeric occupies about 77,400 hectares which is about 6 per cent of the total area under spices and condiments. Andhra Pradesh, Tamil Nadu, Bihar, Orissa and Kerala are the important turmeric producing states in India.

Out of 1.5 lakh tonnes of production in India about 92 per cent is consumed within the country and the remaining 8 per cent earns a foreign exchange to the tune of Rs. 4.44 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. Although there was an increase in foreign exchange earnings from Rs. 4.4 to 7.2 crores from 1976 to 1978, the actual quantity exported decreased from 11,796 tonnes to 9,319 tonnes during the period. This is mainly due to higher demand from foreign countries and due to the acute shortage of the marketable surplus.

The area under turmeric in Kerala is only about 5.6 per cent (4,300 ha) of the area in India and the production is only 2.8 per cent (4,300 tonnes) of that of India. Nearly half of the turmeric produced in Kerala is exported and 'Alleppey turmeric' is famous all over the world for its quality. Kerala contributes about 15.1 per cent of the export of India under turmeric and earns around 76 lakhs of rupees annually which is around 17.9 per cent of India's foreign exchange earnings of turmeric.

The quality of turmeric especially the curcumin content is very important in the export market. Turmeric types yielding lemon-yellow orange or orange yellow powder having five or more per cent of curcumin are preferred in the international market. But most of the Indian turmeric contains less than five per cent of curcumin.

Turmeric can tolerate shade to certain extent and as such it can be grown as an intercrop in coconut gardens. Due to the great demand in the international market and due to the possibilities of growing as intercrop in homesteads, it is possible to increase the production and productivity of turmeric in Kerala.

In any crop improvement programme involving increased production and productivity, the necessity of selecting suitable high yielding quality planting material need no over emphasis. This is true with regards to turmeric also. Though several types are being grown under different names no attempt has been made in Kerala to distinguish different types based on morphological characters and also to screen out suitable types for different agroclimatic zones of Kerala. The quality

evaluation and the actual period of harvest for the higher curcumin content have also not been worked out. Therefore, a trial was conducted at the Research Station and Instructional Farm, Vellanikkara with 19 promising types of turmeric selected from the existing germplasm collection with the following objectives.

(i) To find out the possibility of distinguishing different types based on morphological parameters.

(ii) To screen out types with high yield, high oleoresin and high curcumin content.

(iii) To evaluate their relative susceptibility or tolerance to different pests and diseases.

(iv) To evaluate the yield and quality at different periods of maturity in the case of four types viz., VK4 (G.L.Puram-II), VK5 (Manmuthy Local), VK11 (Ventimitta) and VK17 (Armoor Cll-324).

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Though the importance of turmeric as a spice and medicinal plant is well known to Indians from time immemorial and number of turmeric types are being grown in different parts of the country not much research work has been undertaken on the morphological and quality aspects for the improvement of this crop. In this chapter an attempt is being made to trace the available research information on these lines of work.

1. Varieties

According to Aiyer (1954) 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 Curcuma aromatica. Shankaracharya and Natarajan (1973) reported that there were 30 species under the genus 'Curcuma' of which Curcuma longa, C. aromatica, C. angustifolia, 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'. Chaurasia et al. (1974) opined that there were more than 70 species of 'Curcuma', of which nearly 30 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. Pruthy (1976) reported 30 species under the genus 'Curcuma' of which C. longa was economically the most important accounting for about 96.4 per cent of the total area under turmeric cultivation in India and the remaining 3.6 per cent of the total area were cultivated under C. aromatica.

Aiyadurai (1966) classified turmeric types into three broad groups based on the time taken for harvest such as 'early' duration, 'medium' duration and 'long' duration 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. Shankaracharya and Natarajan (1973) and Pruthy (1976) reported 16 regional varieties of turmeric in the trade mainly based on the commercial qualities.

2. Morphological studies

Aiyer (1954) recorded a length of 10 to 15 cm

and a thickness of 2 to 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'. (Rao et al. (1975) and Pillai and Nambiar (1975) noticed variations in thickness, length, internodal length and colour of rhizomes among turmeric types.)

(According to Aiyer (1954) the roots of turmeric grew to a length of 22 to 30 cm and produced root lets 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.

Sarma and Krishnamurthy (1965) reported that delayed planting of fingers produced comparatively less number of leaves than cut mothers and the leaf size did not vary much in cut mother while the variation in finger was considerably wide. Rao et al. (1975) observed 8 to 9 leaves in the Dindrigam ('aromatic' type). While Pillai et al. (1975) reported that the 'longa' types produced 9 to 12 leaves and showed a variation of

38 to 44 cm in leaf length and 15 to 17 cm in leaf breadth. Shankaracharya and Natarajan (1973) observed a variation of 2 to 3 feet in leaf length.

Sarma and Krishnamurthy (1965) found that 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.

The height of plant was found to vary between two to four feet in turmeric (Aiyer, 1954; Parry,1962). Sarma and Krishnamurthy (1965) reported that the height of plant was greatly influenced by the planting time and nature of planting material. They noticed no decrease in height with delayed planting in 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 to 45 cm in 'aromatica' type - Dindrigam.

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 fruits set in nine 'longa' types and eight 'aromatica' types.

3. 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. was of minor importance (Aiyer, 1954). Abraham and Pillai (1974) and Dubey et al. (1976) found that none of the turmeric types were tolerant to shoot borer attack. Dubey et al.(1976) also noticed the attack of maggots of dipteran fly Mimegralla sp. on fresh rhizomes of turmeric for the first time. According to Rao et al. (1975) the 'leaf mites' and 'lace wing bugs' were the important pests of standing crop.

Aiyer (1954) noted 'leaf spot' disease caused by Taphrina maculans Butl. in turmeric. Sarma and Krishnamurthy (1962) found two 'leaf spot' diseases caused by Colletotrichum capsici and Taphrina maculans,

and they have stated that the 'long duration' types were resistant to Taphrina sp. and medium duration types to Collectotrichum sp. and short duration types to both. Reddy et al. (1963) reported that different turmeric varieties exhibited varying degrees of resistance to either of the 'leaf spot' diseases caused by Colletotrichum sp. and Taphrina sp. and no single variety was infected by both the fungi and no variety was free from either of the 'leaf spots'. Aiyadurai (1966) reported that there was remarkable variation in the degree of resistance to the 'leaf spot' diseases in different varieties and that an optimum spacing of 9" x 9" was the best for reducing the incidence of 'leaf spot'. Chattopadhyay (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) noticed tolerance to 'leaf blotch' disease in 'longa' types Viz., Armoor C11-324, Duggirala C11-325, Mydukur C11-326 and Tekurpet C11-327 whereas the tolerance to both 'leaf spot' and 'leaf blotch' diseases were noticed in 'aromatica' types, viz.,

Dindrigam Ca-69 and Amalapuram Ca-73. Subbarayudu et al. (1976) noted no significant differences among 'short duration' types, while significant differences existed among the 'medium duration' types in the intensity of leaf diseases infection. 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.

3. Yield

According to Aiyer (1954) the 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 Cll-326, Armoor Cll-324, Sugandham Cll-328, Avanigadda Cll-323, Kasturi, Chayapasupa, Amalapuram Cll-320, Armoor and Sugandham among the 41 types of turmeric. Shankaranarayana (1974) recorded that the yield of green turmeric varied from 16.8 tonnes to 22.4 tonnes per hectare under irrigated conditions. Rao et al. (1975) reported that out of the 100 types of turmeric maximum range of yield was recorded in Mydukur Cll-326, and Tekurpeta Cll-327, (25-37 tonnes/ha each) followed by Amruthapani Kothapeta Cll-317 (25-35

tonnes/ha), Duggirala Cll-325 (20-25 tonnes/ha), Armoor Cll-324 and Dindrigam Ca-69 (15-20 tonnes/ha each) and Amalapuram Ca-73 (10-15 tonnes/ha). 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 Nandyal type, followed by Sugandham Cll-328, Rajpuri local, Mydukur Cll-326, Gorakhpur Cll-316, Dindrigam Ca-69, and Kasturi Tamuka. The seedlings were found to perform like biennials producing rhizome only during the second year of their growth. Subbarayudu et al. (1976) reported that the types Dindrigam Ca-69 under short duration group, Amruthapani Kothapeta Cll-317 under medium duration group and Duggirala Cll-325 followed by Mydukur Cll-326 under long duration groups were high yielding and suitable for growing in Cuddapah tract of Andhra Pradesh.

4. Processing

Aiyer (1954) mentioned that turmeric could be dried only after slight boiling and the cells killed. Boiling in cowdung water heightened colour of the cured turmeric types yielding a deep dye cured much harder on drying. The Central Food Technological Research

Institute, Mysore had standardised the curing of turmeric by boiling with lime water or sodium bicarbonate solution (Aiyadurai, 1966; Pruthy, 1976). According to Natarajan and Shankaracharya (1974) the boiling of turmeric rhizomes was essential to reduce the drying time and to gelatinise the starch. 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 volatile substances beyond this temperature. The stage at which boiling was to be stopped was very critical for good quality turmeric as the obvercooking spoiled the colour and increased 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 'Soni' 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 16 to 17, while the latter cured normally with a curing percentage of 21 to 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 proportion of cured produce to raw rhizomes was 1:4 for the Cuddapah and Guntur tracts. Aiyer (1954) noted a curing a percentage of 17 to 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 recorded by the early duration 'aromatica' types, and the lowest by medium duration types while the long duration 'longa' types recorded medium values (Sarma and Krishnamurthy, 1965; Subbarayudu 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 a varietal character and the curing percentage was found to vary between 14 to 26.5. Rosengarten (1969) mentioned a curing percentage of 33.3 in turmeric, while Parry (1969) observed a curing percentage of 16.7. Pillai and Nambiar (1975) noted maximum curing percentage in the types Vontimitta, Kodur, Dangi Ca-68, Jobedi Ca-67, Dindrigam Ca-69 and Amalapuram Ca-73 among 29 turmeric types they studied. 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., Kuchupudy and G.L.Puram. He found that the drying percentage of turmeric increased steadily with increase in maturity. A steady increase in percentage recovery of dry produce was noticed upto seventh month in Kuchupudy whereas it was upto sixth month in G.L.puram. A slight decrease was noticed in the eighth month in Kuchupudy while it was in the seventh month in G.L.Puram and thereafter a steep increase was noticed with the maximum in the eighth month of matufity.

5. Quality studies

Rosengarten (1969) found that 'fingers' had the best quality among the grades, 'fingers' 'rounds' and 'splits'. Parry (1969) found that the quality, appearance and colour of whole turmeric varied according to its source. Lewis (1973) reported distinct differences in quality and quantity of oil and oleoresin in different types of turmeric grown in India. Chaurasia et al. (1974) mentioned that 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 per cent of the oil was composed of a mixture of sesquiterpene ketones and 9 per cent was composed of teritiary alcohols. The volatile oil of Curcuma aromatica consisted chiefly of sesquiterpenes and their alcohols together with small amounts of d-comphene and d-camphor. The rhizomes of C.aromatica yielded oil upto 6.1 per cent 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 per cent (Kasturi). Mathai (1975) also found that out of the 6 grades of turmeric, maximum oil content was recorded in Rajumundry Kasturi turmeric (6.3%) followed by Kodur turmeric (4.5%), Alleppey finger turmeric and Alleppey turmeric bulbs (3.4% each), Duggirala (2.9%) and Harithode unpolished (1.4%). Menon (1975) mentioned that turmeric contained 5 to 6 per cent essential oil while Guenther (1975) reported 1.3 to 5.5 per cent. Pillai et al. (1976) reported that 'aromatica' types had more oil content than that of the 'longa' types. The oil content varied from 3 to 7 per cent with the maximum in the 'aromatica' types, viz., Kasturi and Kasturi Tamuka among the 15 types of turmeric grown under Kasaragod conditions. 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 per cent) and about 4 hours were required to recover 80 per cent of the available turmeric oil. Out of the 12 cultivars

of turmeric maximum oil content was recorded in the cultivar 'Saigon' (7.2%). 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 per cent, 2.2 to 4.2 per cent and 3.3 to 6 per cent respectively in oil content among medium, long and short duration types.

'Alleppey turmeric' contained about 6.5 per cent 'curcumin' as against 3 to 4 per cent in other varieties (Lewis, 1973). 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 to 8.1 per cent with the least in Nandyal type and the maximum in Vontimitta. 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%). They also noted that 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 per cent in curcumin content among the seven turmeric types grown in Andhra Pradesh. Krishnamurthy et al. (1976) recorded a variation of 1.8 to 5.4 per cent 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 in the sixth month and 4.1 in the seventh month and again increased to 6.9 per cent in the eighth month. In the case of G.L.Puram the maximum curcumin content was in the seventh month (6.3%) and it decreased to 6 per cent in the eighth month.

According to Krishnamurthy et al. (1972) 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 dichloride. In the case of coarse powder (30 mesh size) Soxhlet method was found to be better while percolation and soxhlet methods were equally efficient in case of fine powder (60 mesh size). Among 12 turmeric cultivars they noticed a variation of 5.5 to 10 per cent in oleoresin content in the case of fine powder (60 mesh size) by Soxhlet method. The oleoresin content was the maximum in 'Gadhvi' and the least in 'Tekurpeta'.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken at the College of Horticulture, Vellanikkara during the period from April 1977 to June 1978. The topography of the area selected for the experiment was fairly level and uniform with good drainage. The soil was red loam.

Nineteen promising turmeric types from the existing germplasm collection maintained at the Horticultural College, Vellanikkara were used for the trial. The types were as follows:

VK1 (Chayapasupa)

VK2 (Kuchupudi)

VK3 (Kodur 1

VK4 (G.L.Puram-II)

VK5 (Manmuthy Local)

VK6 (Nandyal)

VK7 (Amruthapani Kothapeta)

VK8 (Armoor)

VK9 (Duggirala)

VK10 (Amalapuram Ca-73)

VK11 (Vontimitta)

VK12 (Kasturi Tamuka)

VK13 (Amruthapani Kothapeta C11-317)

VK14 (Dindrigam Ca-69)

VK15 (Duggirala C11-325)

VK16 (Rajpuri)

VK17 (Armoor C11-324)

VK18 (G.L.Puram-I)

VK19 (Tekurpeta C11-327)

1. Experimental details

1.1 Lay out

The experiment was laid out in Randomised Block Design with four replications and 19 treatments. Four turmeric types were also grown separately in replicated plots to evaluate their yield and quality at different periods of maturity. The plots had a gross area of 3.6 x 1.6 m (5.76 m^2) and net size of 3 x 1 m (3 m^2). A spacing of 25 x 25 cm was adopted for planting.

1.2 Cultivation

The land was ploughed well and raised beds of 3 x 1 m with 25 cm height were formed with 30 cm wide channels around each plot. Forty-eight seed bits with

one or two buds in each bit were sown in each bed at the rate of one seed bit per pit. The plots were given uniform cultural operations. A fertilizer dose of 60 : 60 : 120 kg N, P_2O_5 and K_2O per hectare was applied in addition to 30 tonnes of cattle manure. As plant protection measures Dimecron (0.5 ml/litre) and Cumman (3 ml/litre) were sprayed 60 days after planting followed by spraying again with Dimecron and Dithane Z-78 (2 g/litre) on 120th day after planting.

Final harvesting was done on 270th day after planting when the leaves had dried completely in most of the plants. The selected plants from each plot were lifted individually for recording the various observations. Then the remaining plants were harvested and weight recorded after proper cleaning.

2. Observations

The entire population in the plot was taken for recording the germination percentage, yield of green rhizomes per bed and percentage of flowering plants per bed. Ten plants in each bed were selected at random for recording the characteristics of leaf, tiller, inflorescence, root, rhizome, height of plant, yield of

green rhizomes per plant, intensity of shoot borer infection and 'leaf spot ' diseases. The main plant in the clump was taken for recording the height and leaf characters.

Samples comprising of four plants were harvested at fortnightly intervals commencing from 18.10.1977 (165th day of planting) till the final harvest of the crop on 31.1.1978 (270th day of planting) in the case of four turmeric types, viz., VK4 (G.L.Puram-II), VK5 (Manmathy Local), VK11 (Vontimitta) and VK17 (Armoor C11-324) for evaluation of yield and quality at different periods of maturity.

2.1 Germination

The number of plants germinated out of the 48 rhizome bits planted in each plot were recorded and gap was filled up with the same age sprouts on 45th day of planting.

2.2 Height, number of tillers and leaves per plant

The height of the plant was measured in cm on 150th day after planting. The measurement was taken from the ground level to the point where the petioles clasped tightly. The number of tillers per plant and number of

leaves of all the tillers were recorded in selected plants in each plot.

2.3 Length, breadth and leaf area index

The length of leaf was measured in cm from the proximal to the distal end of the lamina and the width was measured at the middle of the leaves. The leaf area index was calculated by multiplying the length by breadth. The length of petiole was measured from the clasping point of the leaf sheath to the base of leaf lamina.

2.4 Flowering

The number of plants flowered and the number of tillers flowered per plant in each plot were recorded on 150th and 200th day of planting and percentage was worked out. The characteristics of inflorescence produced in the mother plant viz., the length of inflorescence, inflorescence stalk and the number of flowers produced per inflorescence were recorded. The length of the inflorescence stalk was measured in cm from the top of the rhizomes upto the basal portion of the inflorescence.

2.5 Pest and diseases

2.5.1 Incidence of shoot borer

The number of tillers infected and the total

number of tillers in each observation plant was recorded and expressed in percentage. Observations were taken on 150th and 190th day of planting.

2.5.2 Incidence of leaf diseases

The intensity of 'leaf spot' (Colletotrichum capsici) and 'leaf blotch' (Taphrina maculans) diseases were recorded on 170th day of planting. The number of leaf spots in each leaf was counted and the plants were categorised as follows:

Sl.No.	Score given for analysis	Categories	Details of infection
1.	0	Nil	When the plant had no leaf spots.
2.	1	Light	When the number of leaf spots were less than five.
3.	2	Medium	When the number of leaf spots was between 5 and 20.
4.	3	Heavy	When the number of leaf spots was between 21 and 40 and the spots coalesced at the tip and margins of the leaves.
5.	4	Very Heavy	When the number of leaf spot was more than 41 and the leaves dried up completely.

2.6 Number and length of root

The number of roots and mean length of roots were recorded after the final harvest. Ten randomly

selected roots from each selected plant were used for recording the length of roots and the length of 100 roots from 10 selected plants were recorded and the mean was calculated.

2.7 Mother rhizome characters

2.7.1 Length and girth

The length and girth of mother rhizome was measured in cm using a non-stretchable string. The girth was measured at the centre of the mother rhizome.

2.7.2 Number of nodes and internodal length

The nodes could be easily identified by noting the markings and the number in each rhizome was recorded and also the distance between two consecutive nodes was recorded in cm as internodal length.

2.8 Finger characters

The number of primary and secondary fingers and the number of nodes, internodal length and girth of the primary and secondary fingers (at middle) were recorded and the mean was calculated.

2.9 Yield of green turmeric

The total net yield per plot ($3m^2$) was recorded

in kgs by weighing the entire produce of the plot. The projected net yield per plot ($3m^2$) was calculated in case of maturity studies by harvesting four plants at random per plot. The gross yield per hectare was calculated taking into account of the interspaces, channels and footpaths.

2.10 Percentage of dry turmeric

The percentage recovery of cured turmeric was found out by taking a known weight of (5 kg) green turmeric and drying after curing. The percentage recovery of dry turmeric was found out without curing in case of maturity studies.

2.11 Yield of cured produce

The yield of cured dry turmeric per hectare was calculated by multiplying the gross yield of green turmeric per hectare with the percentage recovery of cured turmeric.

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 the same 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 moisture free 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 pure as solvent. The percentage recovery of oleoresin was worked out on moisture free basis and was recorded. The yield of oleoresin per hectare was calculated by multiplying the gross yield of dry produce per hectare with the percentage recovery of oleoresin.

4. Statistical analysis

The results were analysed statistically following

the methods of Snedecor and Cochran (1967). The percentage values of shoot borer infected tillers per plant were transformed to the corresponding angular values and the score value of 'x' denoting the intensity of 'leaf spot' disease in 10 selected plants of each plot were transformed to $\sqrt{x+1}$ values for increasing the efficiency of the analysis.

Correlation coefficients between the yield per plot and different growth characters, yield per plot and intensity of shoot borer and leaf diseases infection were worked out using the standard statistical formula.

RESULTS

RESULTS

A detailed investigation on the morphological characters and quality evaluation of 19 turmeric types was undertaken and the results are furnished in Tables 1 to 20. The analysis of variance Tables for different characters are furnished in Appendices from I to III.

1. Growth characters

1.1 Germination

The data on germination percentage furnished in Table 2 indicated significant differences among the types.

The type VK4 with 91.1 per cent ranked first in germination, followed by VK3 (90.11%), VK18 (89.25%), VK14 (89.23%) and VK1 (89.06%). Germination percentage recorded in VK4 was significantly higher than that of VK17, VK16, VK13, VK19 and VK9. It was comparatively poor in the types VK9 and VK19 which recorded 77.82 and 78.17 per cent respectively.

1.2 Morphological characters

The data on the morphological and yield characters of 19 turmeric types are presented in Table 1.

Table 1. Morphological and yield characters of turmeric types

Types	Height of plant (cm)		No.of tillers per plant	
	Range	Mean	Range	Mean
VK1 (Chayapasupa)	39.5-42.6	41.09	2.4-3.3	2.85
VK2 (Kuchupudi)	38.7-40.8	39.75	2.0-4.4	3.08
VK3 (Kodur)	29.5-41.2	37.56	1.3-2.7	2.15
VK4 (G.L.Puram-II)	35.0-41.5	39.30	1.4-3.5	2.30
VK5 (Mannuthy Local)	36.1-40.5	38.15	2.8-4.8	3.70
VK6 (Nandyal)	36.1-43.6	40.21	1.8-3.7	2.95
VK7 (Amruthapani-Kothapeta)	32.4-42.4	37.46	2.0-3.3	2.45
VK8 (Armoor)	32.1-42.4	39.67	2.0-2.4	2.25
VK9 (Duggirala)	38.3-41.6	39.11	2.3-5.3	2.93
VK10 (Amalapuram)	18.7-30.6	23.48	1.8-2.7	2.25
VK11 (Vontimitta)	23.5-28.6	26.16	1.6-3.8	2.08
VK12 (Kasturi Tanuka)	31.5-47.5	36.82	1.8-3.4	2.53
VK13 (Amruthapani-Kothapeta C11-317)	34.6-39.8	37.16	1.6-3.9	2.73
VK14 (Dindrigam Ca-69)	18.4-26.5	22.05	1.7-2.2	2.00
VK15 (Duggirala C11-325)	26.8-34.0	31.23	1.6-3.8	2.80
VK16 (Rajpuri)	32.2-38.9	35.55	1.4-4.2	2.65
VK17 (Armoor C11-324)	24.5-26.0	25.24	2.9-3.3	3.10
VK18 (G.L.Puram-I)	29.3-33.6	30.84	2.0-2.9	2.53
VK19 (Tekurpeta)	26.1-33.4	29.73	2.5-3.3	2.90

(Contd...)

Types		No.of leaves per tiller per plant		No.of leaves per plant	
		Range	Mean	Range	Mean
VK1	(Chayapasupa)	6.2-6.5	6.36	14.9-21.5	18.13
VK2	(Kuchupudi)	5.4-6.6	5.87	10.8-29.0	18.08
VK3	(Kodur)	5.4-7.2	6.31	10.8-19.4	13.57
VK4	(G.L.Puram-II)	5.8-8.0	6.93	8.1-28.0	15.94
VK5	(Manmuthy Local)	5.5-5.9	5.58	15.4-28.3	20.65
VK6	(Nandyal)	5.7-7.8	6.37	10.3-28.9	18.79
VK7	(Amruthapani-Kothapeta)	5.8-7.3	6.32	11.6-24.1	15.48
VK8	(Armoor)	4.7-6.9	5.92	9.4-16.6	13.32
VK9	(Duggirala)	5.0-7.3	5.90	11.5-38.7	17.29
VK10	(Amalapuram)	4.9-5.1	5.00	8.8-13.8	11.25
VK11	(Vontimitta)	5.2-5.9	5.55	8.3-22.4	11.54
VK12	(Kasturi Tanuka)	4.3-6.7	5.48	7.7-22.8	13.86
VK13	(Amruthapani-Kothapeta Cll-317)	5.4-7.0	6.08	8.6-27.3	16.60
VK14	(Dindrigam Ca-69)	5.1-5.8	5.60	8.7-12.8	11.20
VK15	(Duggirala Cll-325)	4.7-5.8	5.40	7.5-22.0	14.85
VK16	(Rajpuri)	5.8-4.8	5.42	8.1-20.2	14.36
VK17	(Armoor Cll-324)	4.5-4.2	4.33	13.1-13.9	13.42
VK18	(G.L.Puram-I)	4.6-5.3	4.92	9.2-15.4	12.45
VK19	(Takurpeta)	4.7-4.8	4.70	11.8-15.8	13.66

(Contd...)

Types		Length of petiole (cm)		Length of leaf (cm)	
		Range	Mean	Range	Mean
VK1	(Chayapasupa)	31.5-36.8	33.93	66.7-71.4	68.45
VK2	(Kuchupudi)	31.5-35.3	33.58	62.7-69.6	66.62
VK3	(Kodur)	28.3-35.3	33.05	59.9-68.5	65.76
VK4	(G.L.Puram-II)	27.8-37.9	33.58	62.8-68.9	66.67
VK5	(Manmuthy Local)	36.6-41.0	38.84	63.5-67.5	66.05
VK6	(Nandyal)	25.3-39.1	31.87	62.8-74.4	67.16
VK7	(Amruthapani-Kothapeta)	39.5-28.5	33.97	63.8-73.8	70.34
VK8	(Armoor)	37.3-25.0	32.97	55.9-71.6	66.14
VK9	(Duggirala)	27.3-36.1	32.47	63.6-69.5	65.49
VK10	(Amalapuram)	20.9-23.8	22.52	56.6-65.4	60.27
VK11	(Vontimitta)	21.5-28.7	24.93	53.5-70.4	62.36
VK12	(Kasturi Tanuka)	18.3-38.9	29.32	45.4-64.6	58.00
VK13	(Amruthapani-Kothapeta C11-317)	28.4-32.1	30.61	59.9-67.8	62.94
VK14	(Dindrigam Ca-69)	20.5-24.5	21.75	62.2-56.4	60.13
VK15	(Duggirala C11-3[illegible]5)	23.2-35.2	30.79	48.5-64.2	56.95
VK16	(Rajpuri)	22.5-35.7	28.48	60.3-65.2	63.34
VK17	(Armoor C11-324)	24.5-26.0	25.23	48.7-51.7	50.19
VK18	(G.L.Puram-I)	21.9-33.8	29.15	54.0-57.6	55.63
VK19	(Tekurpeta)	22.6-30.1	26.30	49.6-59.0	53.62

(Contd...)

Types		Breadth of leaf (cm)		Leaf area index	
		Range	Mean	Range	Mean
VK1	(Chayapasupa)	16.4-16.9	16.75	1045.8-1206.6	1127.8
VK2	(Kuchupudi)	16.1-18.2	17.01	1009.7-1264.1	1134.8
VK3	(Kodur)	15.1-17.5	16.61	1009.3-1177.3	1091.0
VK4	(G.L.Puram-II)	15.1-17.5	16.66	991.0-1202.3	1094.5
VK5	(Mannuthy Local)	15.1-15.8	15.36	972.7-1054.6	1014.7
VK6	(Nandyal)	16.9-18.3	17.44	1070.1-1255.0	1169.8
VK7	(Amruthapani-Kothapeta)	16.1-18.2	17.23	1027.3-1295.0	1214.3
VK8	(Armoor)	14.9-18.2	16.42	832.5-1303.1	1091.6
VK9	(Duggirala)	16.3-17.6	16.87	1056.1-1132.9	1103.6
VK10	(Amalapuram)	14.9-16.8	15.28	796.4-1095.5	923.6
VK11	(Vontimitta)	14.8-18.2	17.05	934.1-1241.9	1106.0
VK12	(Kasturi Tanuka)	14.1-16.5	15.90	640.1-1066.0	929.4
VK13	(Amruthapani-Kothapeta C11-317)	15.5-19.6	17.49	1330.3- 934.3	1104.5
VK14	(Dindrigam Ca-69)	13.9-15.3	14.56	786.1- 951.0	876.0
VK15	(Duggirala C11-325)	13.7-17.2	15.67	713.3-1104.2	898.5
VK16	(Rajpuri)	15.7-16.8	16.44	998.0-1091.3	1040.9
VK17	(Armoor C11-324)	13.3-14.5	13.87	646.2- 750.7	696.6
VK18	(G.L.Puram-I)	12.7-17.6	15.77	708.2- 972.4	881.7
VK19	(Tekurpeta)	15.5-16.6	16.03	766.5-976. 5	860.7

(Contd ...)

Types		No.of roots per plant		Length of root (cm)	
		Range	Mean	Range	Mean
VK1	(Chayapasupu)	80.9-104.3	93.85	12.8-16.5	14.41
VK2	(Kuchupudi)	81.3-95.3	89.43	10.5-14.4	12.30
VK3	(Kodur)	75.4-89.5	86.67	11.5-15.4	13.35
VK4	(G.L.Puram-II)	70.4-92.3	85.80	10.6-15.3	12.52
VK5	(Mannuthy Local)	88.2-110.8	97.47	13.2-16.2	14.45
VK6	(Nandyal)	74.4-95.6	80.24	12.3-15.8	13.82
VK7	(Amruthapani-Kothapeta)	67.2-82.4	75.22	13.1-16.8	15.20
VK8	(Armoor)	63.1-86.6	75.93	10.7-12.6	11.95
VK9	(Duggirala)	81.4-97.6	88.85	11.3-13.1	12.45
VK10	(Amalapuram)	45.6-70.2	53.40	12.2-15.1	13.51
VK11	(Vontimitta)	60.5-78.5	66.70	12.7-14.4	13.70
VK12	(Kasturi Tanuka)	35.6-47.4	43.74	9.5-11.3	10.31
VK13	(Amruthapani-Kothapeta C11-317)	55.4-78.8	67.84	12.5-13.5	13.07
VK14	(Dindrigam Ca-69)	44.4-67.8	58.38	12.1-13.5	12.88
VK15	(Duggirala C11-325)	66.4-82.2	71.00	9.9-14.5	11.70
VK16	(Rajpuri)	38.5-54.5	44.93	8.9-10.3	9.57
VK17	(Armoor C11-324)	48.3-57.6	53.22	11.1-12.0	11.51
VK18	(G.L.Puram-I)	40.6-56.6	47.84	9.3-12.3	10.55
VK19	(Tekurpeta)	42.1-53.8	47.07	10.1-11.2	10.57

(Contd...)

Types	Length of mother rhizome (cm)		Girth of mother rhizome at centre (cm)	
	Range	Mean	Range	Mean
VK1 (Chayapasupa)	10.3-13.4	12.19	15.6-17.6	16.82
VK2 (Kuchupudi)	11.5-13.3	12.06	16.6-18.1	17.09
VK3 (Kodur)	10.6-13.5	11.89	16.6-19.0	17.25
VK4 (G.L.Puram-II)	9.4-12.6	11.25	15.0-17.4	16.11
VK5 (Manmuthy Local)	9.7-11.5	10.53	14.3-15.7	14.79
VK6 (Nandyal)	9.2-11.9	10.45	12.6-17.4	14.93
VK7 (Amruthapani-Kothapeta)	10.1-12.3	11.62	13.3-15.7	14.61
VK8 (Armoor)	10.2-10.6	10.64	15.0-17.5	15.96
VK9 (Duggirala)	11.2-12.1	11.57	15.9-17.1	16.56
VK10 (Asalapuram)	8.3-9.1	8.81	12.9-13.6	13.21
VK11 (Vontimitta)	9.6-12.6	10.77	13.6-16.4	15.31
VK12 (Kasturi Tanuka)	10.5-12.8	12.12	16.5-17.9	17.17
VK13 (Amruthapani-Kothapeta C11-317)	10.7-14.7	12.46	15.0-17.5	16.66
VK14 (Dindrigam Ca-69)	7.9-9.0	8.40	11.7-12.9	12.26
VK15 (Duggirala C11-325)	9.7-11.1	9.83	13.4-14.5	14.11
VK16 (Rajpuri)	8.3-15.5	12.56	14.0-19.6	16.63
VK17 (Armoor C11-324)	9.3-10.7	9.84	11.4-11.6	11.48
VK18 (G.L.Puram-I)	9.0-10.4	9.69	12.5-14.0	13.28
VK19 (Tekurpeta)	10.0-11.1	10.54	12.2-13.0	12.58

(Contd ..)

Types	No.of primary fingers per plant		Length of primary finger (cm)	
	Range	Mean	Range	Mean
VK1 (Chayapasupa)	4.3-6.2	5.34	11.4-12.5	12.10
VK2 (Kuchupudi)	5.0-6.4	5.79	11.5-12.3	11.78
VK3 (Kodur)	4.6-6.1	5.74	8.3-13.5	11.30
VK4 (G.L.Puram-II)	4.4-6.1	5.49	8.8-12.8	10.81
VK5 (Mannuthy Local)	6.6-7.8	7.24	9.3-10.5	9.90
VK6 (Nandyal)	5.0-7.3	5.95	9.0-13.2	11.00
VK7 (Amruthapani-Kothapeta)	4.0-6.1	5.20	10.5-11.8	11.06
VK8 (Armoor)	6.0-7.2	6.39	10.5-12.4	11.14
VK9 (Duggirala)	5.5-6.6	6.10	11.2-12.4	11.69
VK10(Amalapuram)	4.4-6.3	5.03	8.7-11.7	10.69
VK11(Vontimitta)	4.9-5.9	5.13	9.5-11.7	11.00
VK12(Kasturi Tanuka)	4.5-4.8	4.67	10.5-10.8	10.81
VK13(Amruthapani-Kothapeta C11-317)	4.3-5.7	4.76	8.1-10.9	9.27
VK14(Dindrigam Ca-69)	3.0-5.5	4.61	10.6-12.1	11.16
VK15(Duggirala C11-325)	4.4-6.8	5.67	6. 1- 9.9	7.85
VK16(Rajpuri)	4.2-4.6	4.42	10.1-10.4	10.27
VK17(Armoor C11-324)	4.3-4.7	4.50	8.0-8.1	8.09
VK18(G.L.Puram-I)	3.3-5.3	4.40	6.5-8.6	7.45
VK19(Tekurpeta)	3.7-4.6	4.22	9.5-10.5	10.05

(Contd ...)

Types	No.of secondary fingers per plant		Length of secondary finger (cm)	
	Range	Mean	Range	Mean
VK1 (Chayapasupa)	18.8-21.0	19.84	5.5-7.1	6.10
VK2 (Kuchupudi)	13.5-21.8	19.83	7.4-10.1	8.64
VK3 (Kodur)	10.0-21.4	16.96	3.6-7.4	5.92
VK4 (G.L.Puram-II)	4.6-25.4	15.81	4.1-8.0	5.92
VK5 (Mannuthy Local)	3.0-26.3	20.89	6.0-7.8	7.16
VK6 (Nandyal)	22.5-15.4	19.55	6.0-6.9	6.58
VK7 (Amruthapani-Kothapeta)	8.7-19.0	15.76	5.7-7.8	6.70
VK8 (Armoor)	11.4-25.8	19.83	7.8-8.9	8.25
VK9 (Duggirala)	10.5-21.8	18.00	5.8-6.8	6.37
VK10(Amalapuram)	11.5-31.8	18.86	4.7-7.4	6.17
VK11(Vontimitta)	15.7-18.1	16.77	5.3-8.8	6.64
VK12(Kasturi Tanuka)	8.8-13.2	10.71	5.2-5.7	5.41
VK13(Amruthapani-Kothapeta C11-317)	8.3-14.7	10.71	5.3-6.1	5.71
VK14(Dindrigam Ca-69)	11.8-20.8	16.25	8.4-5.6	7.41
VK15(Duggirala C11-325)	4.6-17.3	12.15	4.9-6.6	5.81
VK16(Rajpuri)	7.1-16.4	11.70	4.2-4.7	4.53
VK17(Armoor C11-324)	6.7-9.2	7.86	4.9-5.2	5.06
VK18(G.L.Puram-I)	6.0-10.6	8.27	3.8-6.1	4.94
VK19(Tekurpeta)	8.8-9.3	9.16	5.4-6.2	5.80

(Contd ...)

Types	Girth of primary finger (cm)		Girth of secondary finger (cm)	
	Range	Mean	Range	Mean
VK1 (Chayapasupa)	9.2-12.3	10.54	6.7-7.1	6.83
VK2 (Kuchupudi)	8.4-12.5	10.34	7.0-7.7	7.40
VK3 (Kodur)	8.1-10.9	9.71	5.3-7.1	6.41
VK4 (G.L.Puram-II)	8.5-9.9	9.28	6.4-6.9	6.76
VK5 (Mannuthy Local)	7.2-8.5	7.86	5.2-5.9	5.52
VK6 (Nandyal)	8.0-10.7	9.36	6.5-7.2	6.75
VK7 (Amruthapani-Kothapeta)	8.3-9.3	8.94	6.3-7.5	6.79
VK8 (Armoor)	8.9-10.7	9.67	6.7-7.6	7.00
VK9 (Duggirala)	9.2-10.4	9.76	6.2-6.7	6.50
VK10 (Amalapuram)	6.6-8.3	7.53	4.8-5.3	5.10
VK11 (Vontimitta)	8.8-10.1	9.42	6.0-7.3	6.28
VK12 (Kasturi Tanuka)	8.9-10.8	9.42	6.6-6.7	6.66
VK13 (Amruthapani-Kothapeta C11-317)	9.1-10.9	10.27	6.2-6.9	6.47
VK14 (Dindrigam Ca-69)	6.6- 7.5	7.07	4.9-5.8	5.40
VK15 (Duggirala C11-325)	7.6-10.7	9.40	6.4-8.8	6.97
VK16 (Rajpuri)	8.9-9.2	9.04	6.2-6.7	6.34
VK17 (Armoor C11-324)	7.9-8.2	8.06	6.0-6.3	6.15
VK18 (G.L.Puram-I)	7.3-9.8	8.76	5.3-7.7	6.53
VK19 (Tekurpeta)	9.1-9.4	9.23	6.4-6.7	6.59

(Contd ..)

Types	Yield of green turmeric per hectare (kg)	
	Range	Mean
VK1 (Chayapasupa)	44010-55295	50086.8
VK2 (Kuchupudi)	33316-47361	41371.5
VK3 (Kodur)	18628-53038	41753.5
VK4 (G.L.Puram-II)	14878-56076	39166.7
VK5 (Mannuthy Local)	37222-39010	38173.2
VK6 (Nandyal)	20521-54375	35989.6
VK7 (Amruthapani-Kothapeta)	18264-47101	32847.2
VK8 (Armoor)	7934 -49115	33854.2
VK9 (Duggirala)	13212-41962	28663.2
VK10(Amalapuram)	16753-32118	25312.5
VK11(Vontimitta)	13194-46094	27882.0
VK12(Kasturi Tanuka)	7969-37813	22916.7
VK13(Amruthapani-Kothapeta C11-317)	12014-22899	18316.0
VK14(Dindrigam Ca-69)	14028-19601	16319.5
VK15(Duggirala C11-325)	7188-31421	16145.8
VK16(Rajpuri)	8108-18542	13854.2
VK17(Armoor C11-324)	10972-12066	11510.4
VK18(G.L.Puram-I)	5417-14080	9687. 5
VK19(Tekurpeta)	3872- 9427	6632.0

The roots were smooth and fleshy with tuber like ends. The number of roots per plant ranged from 44 to 97 and the length from 9.6 to 15.5 cm.

The underground rhizomes were elongated, thick, branched and were of deep yellow to orange yellow in colour. They were divided along their length by means of circular scaly ring like nodes. The central ovoid corms developed at the base of the plant is known as the mother rhizome. From the mother rhizome primary fingers and from the primary, secondary fingers were developed. Teritiary fingers were also often produced from the secondary fingers depending on the types. Each plant produced 4 to 7 primary and 8 to 21 secondary fingers. The length of rhizomes varied from 8.4 to 12.6 cm in mother rhizome, 7.5 to 12.1 cm in primary fingers and 4.5 to 8.6 cm in secondary fingers.

The leafy aerial shoots which developed from the terminal bud of rhizomes were covered by successive leaf sheaths and grew to a height of 22 to 41 cm.

The leaves were simple, large, broadly lanceolate, bright green in colour, smooth on both sides and acute at both ends. The leaf petiole was of 22 to 39 cm long whereas the length and breadth varied from 50 to 70 cm and 13.5 to 17.5 cm respectively. Four to seven leaves were produced

in a tiller.

The yellowish white flowers were borne on a compound spike which arose terminally on the leafy shoot. The bracts were large sized, greenish white, the uppermost tinged with pink and were spirally arranged. The inflorescences were of 9.8 to 17 cm long and the lower bracts enclosed 18 to 41 flowers which opened in succession. The length of inflorescence stalk varied from 8 to 38 cm.

The flowers were hermaphrodite, bracteate and bracteolate, Calyx tubular and short, dividing above into three short teeth; corolla tube funnel shaped having three ovate or oblong lobes; stamens epipetalous arising from the throat of the corolla tube of six in two whorls. Of the three stamens in the outerwhorl, one was suppressed and the other two were reduced to staminodes. Of the inner whorl, the posterior stamen was fertile, and had a prominent two lobed anther having broad connectives projected beyond the anther. The other two were sterile, petaloid and fused together to form a 'labellum', the most conspicuous part of the flower. Ovary was inferior trilocular with axile placenta. Style was elongated and slender lying in the channel

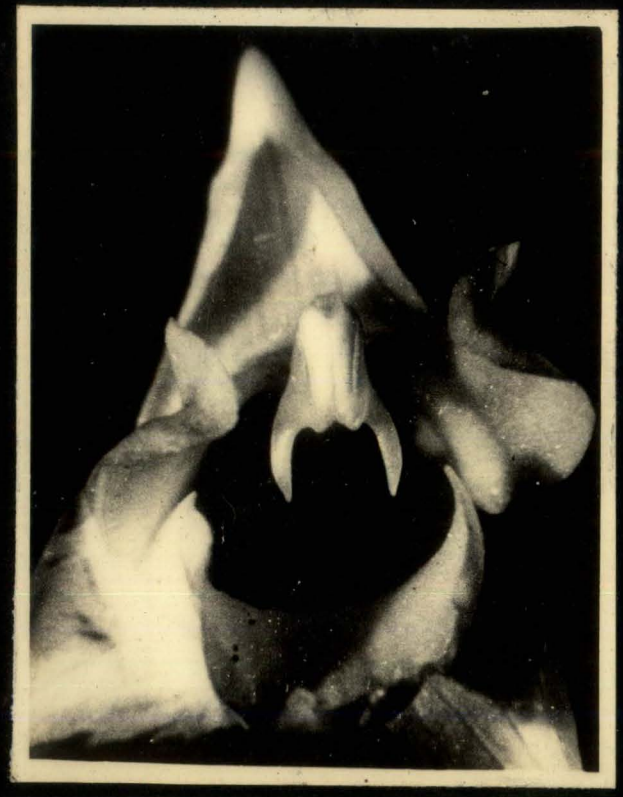
PLATE - III Flower of turmeric developing from the inflorescence

PLATE - V. T.S. of ovary showing placentation

PLATE - IV Turmeric flower - see the two stamens reduced to staminodes and axile placentation.

PLATE - VII. An aerial view of turmeric flower - see the fertile stamen and the two anther lobes and broad connectives, stigma projecting above the anther.

PLATE - VI. Part of turmeric flower showing the style fertile stamen and stigma.



of the fertile stamen and sigma was projected above the anther and two lipped. Fruit was a capsule with numerous and arillate seeds.

1.2.1 Height of plant

The data on height of plant showed highly significant differences among the types (Table 2). Of the 19 types, VK1, VK6, VK2 and VK8 with 41.1, 40.21, 39.75 and 39.67 cm respectively recorded significantly higher height than that of VK16, VK15, VK18, VK19, VK11, VK17, VK10 and VK14. The height was least in the type VK14 (22.05 cm), followed by VK10 (23.48 cm) and VK17 (25.24 cm). The type VK5 with a height of 38.15 cm ranked seventh among the types.

1.2.2 Number of tillers per plant

The data on number of tillers per plant showed no significant differences among the types (Table 2). Of the 19 types, VK5 with 3.7 tillers per plant ranked first and it was followed by VK2 (3.08) and VK1 (2.85). Tiller production was comparatively poor in the types VK14 and VK8 which recorded an average of 2 and 2.08 tillers per plant respectively.

Table 2. Growth characters of turmeric types
(Mean values)

Types	Germination percentage	Height of plant (cm)	No.of tillers per plant	No.of roots per plant	Length of root (cm)
VK1 (Chayapasupa)	89.06	41.09	2.85	93.85	14.41
VK2 (Kuchupudi)	85.38	39.75	3.08	89.43	12.30
VK3 (Kodur)	90.11	37.56	2.15	86.67	13.35
VK4 (G.L.Puram-II)	91.12	39.30	2.30	85.80	12.52
VK5 (Mannuthy Local)	85.70	38.15	3.70	97.47	14.45
VK6 (Nandyal)	84.64	40.21	2.95	80.24	13.82
VK7 (Amruthapani-Kothapeta)	88.62	37.46	2.45	75.22	15.20
VK8 (Armoor)	84.13	39.67	2.25	75.93	11.95
VK9 (Duggirala)	77.82	39.11	2.93	88.85	15.45
VK10 (Amalapuram)	88.02	23.48	2.25	53.40	13.51
VK11 (Vontimitta)	84.52	26.16	2.08	66.70	13.70
VK12 (Kasturi Tamuka)	85.19	36.82	2.53	43.74	10.31
VK13 (Amruthapani-Kothapeta C11-317)	80.86	37.16	2.73	67.84	13.07
VK14 (Dindrigam Ca-69)	89.23	22.05	2.00	58.38	12.88
VK15 (Duggirala C11-325)	87.50	31.23	2.75	71.00	11.70
VK16 (Rajpuri)	80.96	35.55	2.65	44.93	9.57
VK17 (Armoor C11-324)	81.13	25.24	2.10	53.22	11.51
VK18 (G.L.Puram-I)	89.25	30.84	2.53	47.84	10.55
VK19 (Tekurpeta)	78.17	29.73	2.90	47.07	10.57
'F' value	2.8**	10.38**	1.02NS	3.28**	5.22**
C.D. (P = 0.05)	9.29	5.45	-	27.60	2.08

** Significant at 1% level
NS Not significant

1.2.3 Number and length of roots

The data on number and length of roots furnished in Table 2 indicated highly significant differences among the types.

Maximum number of roots per plant was produced in the type VK5 (97.47), followed by VK1, VK2, VK9, VK6, VK8 and VK15 with 93.85, 89.43, 88.85, 80.24, 75.93 and 71.00 roots respectively. The above types were on par with each other and the type VK5 recorded significantly more number of roots than the rest of the types. Root production was comparatively poor in the types VK12 (43.74) and VK16 (44.93).

The type VK9 with 15.45 cm ranked first in root length and it was followed by VK7, VK5, VK1, VK6, VK11 and VK10 with 15.20, 14.45, 14.41, 13.82, 13.70 and 13.51 cm respectively. They were on par with each other and the type VK9 produced significantly longer roots than the rest of the types. The type VK16 produced shortest roots (9.57 cm) among the types.

1.2.4 Leaf characters

1.2.4.1 Number of leaves per tiller

The data on leaf production per tiller and per plant presented in Table 3 showed highly significant

differences among the types. The number of leaves per tiller was maximum in the type VK4 (6.93), followed by VK6 and VK1 (6.36 each), VK7 (6.32) and VK3 (6.31). They were on par with each other. The type VK4 produced significantly more number of leaves per tiller than the rest of the types. The leaf production in tillers was poor in the types VK17 (4.33) and VK19 (4.71). The types VK2 and VK5 had 5.87 and 5.58 leaves per tiller respectively.

1.2.4.2 Number of leaves per plant

The type VK5 with an average of 20.65 leaves per plant ranked first and was significantly superior to the rest of the types. This was closely followed by the types VK6 (18.79), VK1 (18.13) and VK2 (18.08) which were on par with each other and the type VK6 produced significantly more number of leaves than the rest of the types. The number of leaves produced per plant was minimum in VK14 (11.20), followed by VK10 (11.25) and VK11 (11.54).

1.2.4.3 Length of petiole

The length of petiole was maximum in the type VK5 (38.84 cm) and it was followed by VK7 (33.97 cm) VK1 (33.93 cm), VK2 and VK4 (33.58 cm each), VK3(33.05 cm)

Table 3. Leaf characters of turmeric types
(Mean values)

Types	No.of leaves per tiller	No.of leaves per plant	Length of petiole (cm)	Length of leaf (cm)	Breadth (cm)	Leaf area index (l x b)
VK1 (Chayapasupa)	6.36	18.13	33.93	68.45	16.75	1127.8
VK2 (Kuchupudi)	5.87	18.08	33.58	66.62	17.01	1134.8
VK3 (Kodur)	6.31	13.57	33.05	65.76	16.61	1091.0
VK4 (G.L.Puram-II)	6.93	15.94	33.58	66.67	16.66	1094.5
VK5 (Mamuthy Local)	5.58	20.65	38.84	66.05	15.36	1014.7
VK6 (Nandyal)	6.36	18.79	31.87	67.16	17.44	1169.8
VK7 (Amruthapani Kothapeta)	6.32	15.48	33.97	70.34	17.23	1214.3
VK8 (Armoor)	5.92	13.32	32.97	66.14	16.42	1091.6
VK9 (Dugirala)	5.90	17.29	32.47	65.49	16.87	1103.6
VK10 (Amalapuram)	5.00	11.25	22.52	60.27	15.28	923.6
VK11 (Vontimitta)	5.55	11.54	24.93	62.36	17.05	1106.0

(Contd ...)

Types	No.of leaves per tiller	No.of leaves per plant	Length of petiole (cm)	Length of leaf (cm)	Breadth (cm)	Leaf area index (l x b)
VK12 (Kasturi Tamuka)	5.48	13.86	29.32	58.00	15.90	929.4
VK13 (Amruthapani Kothapeta C11-317)	6.08	16.60	30.61	62.94	17.49	1104.5
VK14 (Dindrigan Ca-69)	5.60	11.20	21.75	60.13	14.56	876.0
VK15 (Duggirala C11-325)	5.40	14.85	30.79	56.95	15.67	898.5
VK16 (Rajpuri)	5.42	14.36	28.48	63.34	16.44	1040.9
VK17 (Armoor C11-324)	4.33	13.42	25.23	50.19	13.87	696.6
VK18 (G.L.Puram-I)	4.92	12.45	29.15	55.63	15.77	881.7
VK19 (Tekurpeta)	4.71	13.66	26.30	53.62	16.03	860.7
'F' value	5.63**	5.68**	4.39**	6.04**	3.2**	5.24**
C.D. (P = 0.05)	0.78	0.94	5.98	6.25	1.54	165.90

** Significant at 1% level

and VK8 (32.97 cm). The above types were on par with each other and the type VK5 recorded significantly greater petiole length than the rest of the types. Leaves having comparatively shorter petioles of 21.75 and 22.52 cm were produced in the types VK14 and VK10 respectively.

1.2.4.4 Length of leaf

The length of leaf was maximum in the type VK7 (70.34 cm) followed by VK1 (68.45 cm) and VK6 (67.16 cm) and they were on par with each other. The type VK7 produced significantly longer leaves than that of VK16, VK13, VK11, VK10, VK14, VK12, VK15, VK18, VK19 and VK17. The type VK17 produced the shortest leaves (50.19 cm) among the types. The type VK2 and VK5 recorded a leaf length of 66.62 and 66.05 cm respectively.

1.2.4.5 Breadth of leaf

Leaves having maximum breadth were produced in the type VK13 (17.49 cm), followed by VK6 (17.44 cm), VK7 (17.23 cm), VK11 (17.05 cm) and VK2 (17.01 cm). They were on par with each other and the type VK13 produced significantly broader leaves than that of VK12, VK18, VK15, VK5, VK10, VK14 and VK17. The breadth

of leaf was least in the types VK17 (13.87 cm) followed by VK14 (14.56 cm).

1.2.4.6 Leaf area index

The type VK7 with a leaf area index of 1214.3 was significantly superior to VK16, VK5, VK12, VK10, VK15, VK18, VK14, VK19 and VK17. This was followed by the types VK6 (1169.78), VK2 (1134.8), VK1 (1127.8), VK11 (1106), VK13 (1104.5) and VK9 (1103) which were on par with each other. Smaller leaves were produced in the types VK17 (696.6) and VK19 (860.7).

1.2.5 Flowering

The data on flowering characters are furnished in Table 4. The data were not subjected to statistical analysis as few types had not flowered.

Among the 15 flowered types, the percentage of flowering varied from 95.28 to 1.2 per cent with the maximum in VK14 and the minimum in VK16.

The tillers were found to flower only in the case of two types viz., VK10 and VK14. The length of inflorescence stalk varied widely from 8 to 38 cm with the maximum in VK13 and the minimum in VK9.

VK18 with 17 cm ranked first in inflorescence length and it was followed by VK16 (15 cm) and VK19(14.5cm).

Table 4. Flowering characters of turmeric types
(Mean values)

Types	Length of inflo-rescence stalk (cm)	Length of inflo-rescence (cm)	No. of flowers per in-flores-cence	Percen-tage of flower-ing tillers	Percen-tage of flow-ering
VK1 (Chayapasupa)	30.50	14.00	26.00	N	2.5
VK2 (Kuchupudi)	NF	NF	NF	NF	NF
VK3 (Kodur)	26.20	10.00	28.50	N	12.5
VK4 (G.L.Puram-II)	NF	NF	NF	NF	NF
VK5 (Mannuthy Local)	30.00	9.80	28.00	N	3.6
VK6 (Nandyal)	25.00	13.20	22.00	N	2.9
VK7 (Amruthapani-Kothapeta)	25.00	12.00	31.00	N	2.8
VK8 (Armoor)	NF	NF	NF	NF	NF
VK9 (Duggirala)	38.00	13.80	32.00	N	3.3
VK10(Amalapuram)	27.30	12.10	19.70	72.4	92.7
VK11(Vontimitta)	27.40	11.60	18.00	N	17.4
VK12(Kasturi Tamuka)	34.00	13.00	22.00	N	1.6
VK13(Amruthapani-Kothapeta C11-317)	8.00	11.00	42.00	N	2.3
VK14(Dindrigam Ca-69)	27.81	12.80	19.70	69.6	95.3
VK15(Duggirala C11-325)	21.50	12.50	34.00	N	1.9
VK16(Rajpuri)	18.00	15.00	26.00	N	1.2
VK17(Armoor C11-324)	NF	NF	NF	NF	NF
VK18(G.L.Puram-I)	21.00	17.00	41.00	N	4.3
VK19(Tekurpeta)	20.50	14.50	34.00	N	6.1

NF Plants not flowered

N Tillers not flowered

Shortest inflorescence was produced in VK5 (9.8 cm).

The number of flowers per inflorescence varied from 18 to 42 with the maximum in VK13 and the minimum in VK11.

1.2.6 Rhizome characters

1.2.6.1 Mother rhizome

The data on mother rhizome characters are presented in Table 5. Significant variations were noticed with regards to the length, girth and number of nodes and internodal length of mother rhizome among the types.

The type VK16 (12.56 cm), followed by VK13 (12.46 cm) recorded the maximum length and were significantly superior to all the other types except VK1, VK12, VK2, VK3, VK7, VK9 and VK4. The length of mother rhizome was least in the type VK14 (8.4 cm). The type VK5 (10.53 cm) ranked 12th among the types.

Of the 19 types VK2 and VK13 with an average of 15.24 and 15.23 nodes respectively recorded the maximum number of nodes and they were significantly superior to VK6, VK17, VK7, VK5, VK11, VK14 and VK10. Minimum number of nodes was produced in the type

Table 5. Mother rhizome characters of turmeric types (Mean values)

Types		Length (cm)	No.of nodes	Internodal distance (cm)	Girth at centre (cm)
VK1	(Chayapasupa)	12.19	14.48	0.84	16.82
VK2	(Kuchmpudi)	12.06	15.24	0.80	17.09
VK3	(Kodur)	11.89	14.12	0.84	17.25
VK4	(G.L.Puram-II)	11.25	13.82	0.84	16.11
VK5	(Mannuthy Local)	10.53	12.82	0.81	14.79
VK6	(Nandyal)	10.45	13.26	0.78	14.93
VK7	(Amruthapani-Kothapeta)	11.62	12.84	0.91	14.61
VK8	(Armoor)	10.64	14.44	0.72	15.96
VK9	(Duggirala)	11.57	14.21	0.82	16.56
VK10	(Amalapuram)	8.81	11.28	0.79	13.21
VK11	(Vontimitta)	10.77	12.69	0.85	15.31
VK12	(Kasturi Tamuka)	12.12	13.58	0.87	17.17
VK13	(Amruthapani-Kothapeta Cll-317)	12.46	15.23	0.81	16.66
VK14	(Dindrigam Ca-69)	8.40	12.11	0.70	12.26
VK15	(Duggirala Cll-325)	9.83	14.61	0.68	14.11
VK16	(Rajpuri)	12.56	14.23	0.85	16.63
VK17	(Armoor Cll-324)	9.84	13.21	0.76	11.48
VK18	(G.L.Puram-I)	9.69	14.17	0.71	13.28
VK19	(Tekurpeta)	10.54	14.13	0.77	12.58
'F' value		5.63**	2.61**	2.13*	11.2**
C.D. (P = 0.05)		1.45	1.81	0.12	1.54

** Significant at 1% level

* Significant at 5% level

VK10 (11.28), followed by VK14 (12.11). The type VK1 with 14.48 nodes ranked fourth among the types.

The internodal length of mother rhizome varied from 0.68 to 0.91 cm with the minimum in VK15 and maximum in VK7. The type VK7 recorded significantly longer internode than that of VK6, VK10, VK19, VK17, VK8, VK16, VK14 and VK15. The types VK1, VK3 and VK4 with an internodal length of 0.84 cm ranked fifth while VK5 with 0.81 cm ranked seventh among the types.

The maximum girth was noticed in the type VK3 (17.25 cm), followed by VK12 (17.17 cm) and VK2 (17.1cm). They were on par with each other and were significantly superior to all the other types except VK1, VK13, VK16, VK9, VK4 and VK8. The girth of mother rhizome was least in VK17 (11.48 cm) followed by VK14 (12.26 cm). The type VK5 (14.79 cm) ranked 12th among the types.

1.2.6.2 Finger characters

1.2.6.2.1 Primary fingers

The data furnished in Table 6 showed highly significant differences among the types with regard to the number of fingers, number of nodes, length, internodal distance and girth of fingers.

Among the types VK5 with an average of 7.24 primary fingers ranked first among the types, and it

Table 6. Characters of rhizome (Finger-primary)
(Mean values)

Types	No.of fingers per plant	No.of nodes per finger	Length (cm)	Inter-nodal distance (cm)	Girth at middle (cm)
VK1 (Chayapasupa)	5.34	11.51	12.10	1.05	10.54
VK2 (Kuchupudi)	5.79	11.90	11.78	1.04	10.34
VK3 (Kodur)	5.74	10.11	11.30	1.11	9.71
VK4 (G.L.Puram-II)	5.49	10.95	10.81	0.98	9.28
VK5 (Mannuthy Local)	7.24	11.34	9.90	0.88	7.86
VK6 (Nandyal)	5.95	10.45	11.00	1.01	9.36
VK7 (Amruthapani-Kothapeta)	5.20	10.24	11.06	1.08	8.94
VK8 (Armoor)	6.39	11.52	11.14	0.96	9.67
VK9 (Duggirala)	6.10	10.95	11.69	1.05	9.76
VK10 (Amalapuram)	5.03	9.78	10.69	1.09	7.53
VK11 (Vontimitta)	5.13	10.74	11.00	1.02	9.42
VK12 (Kasturi Tanuka)	4.67	10.77	10.81	1.01	9.42
VK13 (Amruthapani-Kothapeta C11-317)	4.76	9.87	9.27	0.94	10.27
VK14 (Dindrigam Ca-69)	4.61	10.15	11.16	1.09	7.07
VK15 (Duggirala C11-325)	5.67	9.90	7.85	0.79	9.40
VK16 (Rajpuri)	4.42	9.10	10.27	1.08	9.04
VK17 (Armoor C11-324)	4.50	9.19	8.09	0.89	8.06
VK18 (G.L.Puram-I)	4.40	9.18	7.45	0.82	8.76
VK19 (Tekurpeta)	4.22	10.07	10.05	0.98	9.23
'F' value	2.55**	4.66**	6.26**	6.81**	3.91**
C.D. (P = 0.05)	1.41	1.08	1.51	0.10	1.33

** Significant at 1% level

was closely followed by VK8 (6.39), VK9 (6.1) and VK6 (5.94). They were on par with each other and type VK5 had significantly more number of primary fingers than rest of the types. The number of primary fingers was least in the type VK19 (4.22), followed by VK18 (4.39) and VK16 (4.43). The types VK2 (5.8), VK3 (5.73), VK4 (5.49) and VK1 (5.34) ranked firth, sixth, eighth and nineth respectively among the types.

The number of nodes in primary fingers varied from 9.1 to 11.9 with the minimum in VK16 and maximum in VK2. The type VK2 was significantly superior to all the other types except VK8, VK1, VK5, VK4 and VK9 which recorded an average of 11.52, 11.51, 11.34, 10.95 and 10.95 nodes respectively.

The length of primary fingers varied from 7.45 to 12.1 cm among the types with the maximum in VK1 and the minimum in VK18. The type VK1 produced significantly longer fingers than that of VK16, VK19, VK5, VK13, VK17, VK15, and VK18. The types VK2(11.78 cm) VK9 (11.69 cm) and VK3 (11.3 cm) ranked second, third and fourth respectively among the types.

Maximum internodal distance was noticed in the type VK3 (1.11 cm), followed by VK14 (1.1 cm),

VK10 (1.09 cm), VK16 and VK7 (1.08 cm each). They were on par with each other and VK3 was significantly superior to VK19, VK4, VK8, VK13, VK17, VK5, VK18 and VK15. Primary fingers with closer internodes were produced in VK15 (0.79 cm), VK18 (0.85 cm) and VK5 (0.88 cm). The types VK1 and VK2 with an internodal length of 1.05 and 1.03 cm ranked fifth and sixth respectively among the types.

Maximum girth was noticed in the type VK1 (10.54 cm) and it was followed by VK2 (10.35 cm) and VK13 (10.27 cm). They were on par with each other and recorded significantly more girth than that of VK7, VK18, CK17, VK5, VK10 and VK14. The girth was least in the type VK14 (7.07 cm) followed by VK10 (7.53 cm) and VK5 (7.86 cm).

1.2.6.2.2 Secondary fingers

The data on secondary finger characters are furnished in Table 7. The data showed that the types differed significantly with regards to the number of fingers, number of nodes per finger, length, internodal distance and girth of fingers.

Maximum number of secondary fingers was produced in the type VK5 (20.89), followed by VK1 (19.83), VK2

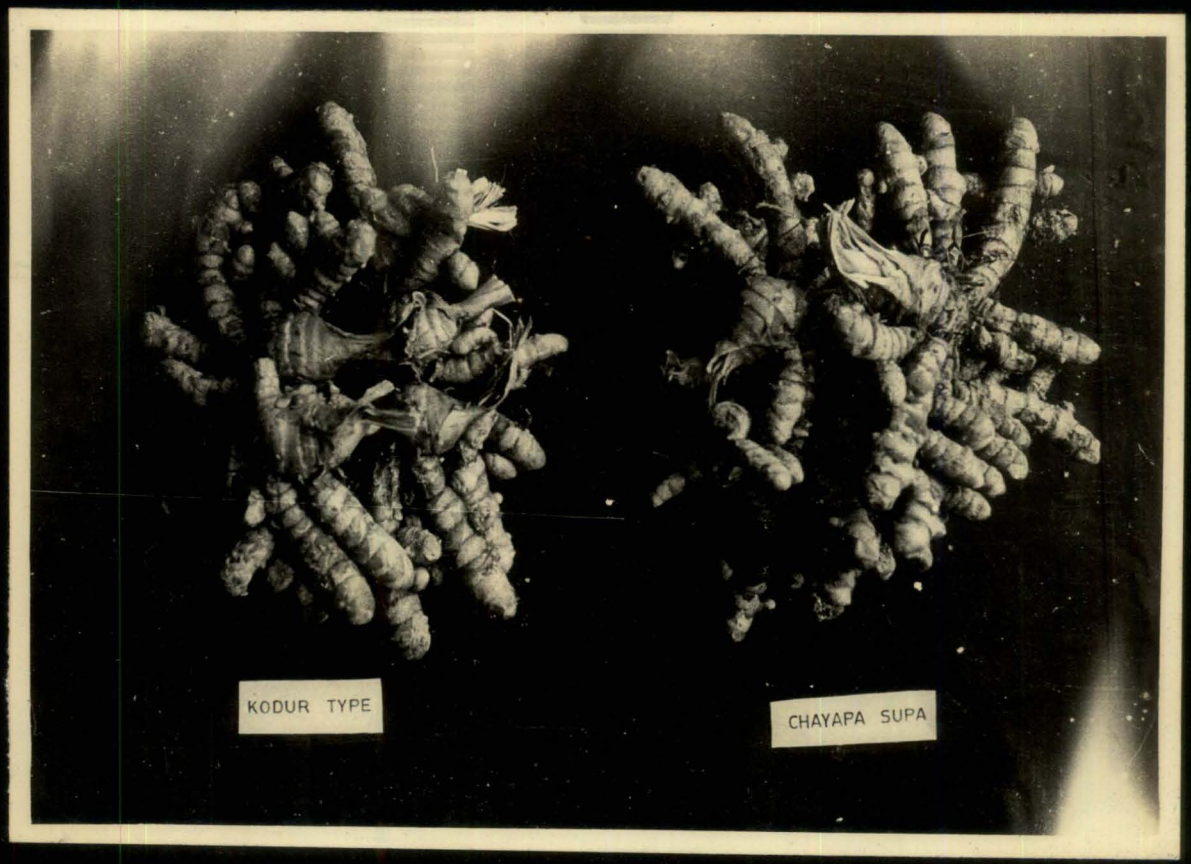
Table 7. Characters of rhizome (Finger-secondary)
(Mean values)

Types	No.of fingers per plant	No.of nodes per finger	Length (cm)	Inter-nodal distance (cm)	Girth at middle (cm)
VK1 (Chayapasupa)	19.84	6.16	6.10	0.99	6.83
VK2 (Kuchupudi)	19.83	8.61	8.64	1.01	7.40
VK3 (Kodur)	16.96	6.11	5.92	0.96	6.41
VK4 (G.L.Puram-II)	15.81	6.80	5.92	0.86	6.76
VK5 (Mannuthy Local)	20.89	8.44	7.16	0.85	5.52
VK6 (Nandyal)	19.55	6.90	6.58	0.87	6.75
VK7 (Amruthapani-Kothapeta)	15.76	6.58	6.70	1.01	6.79
VK8 (Armoor)	19.83	8.67	8.25	0.95	7.00
VK9 (Duggirala)	18.00	6.60	6.37	0.98	6.50
VK10 (Amalapuram)	18.86	6.44	6.17	0.95	5.10
VK11 (Vontimitta)	16.77	6.74	6.64	0.98	6.28
VK12 (Kasturi Tanuka)	10.71	5.24	5.41	1.02	6.66
VK13 (Amruthapani-Kothapeta Cll-317)	10.71	6.34	5.71	0.89	6.47
VK14 (Dindrigam Ca-69)	16.25	7.80	7.41	1.11	5.40
VK15 (Duggirala Cll-325)	12.15	7.06	5.81	0.83	6.97
VK16 (Rajpuri)	11.70	4.52	4.53	1.01	6.34
VK17 (Armoor Cll-324)	7.86	6.27	5.06	0.81	6.15
VK18 (G.L.Puram-I)	8.27	6.74	4.94	0.73	6.53
VK19 (Tekurpeta)	9.16	6.52	5.81	0.89	6.59
'F' value	2.49**	7.21**	4.82**	4.82**	4.15**
C.D. (P = 0.05)	7.84	1.11	1.36	0.18	0.76

** Significant at 1% level

PLATE - VIII Rhizome characters of the types - Kodur and Chayapasupa

PLATE - IX Rhizome characters of the types - Nandyal and G.L.Puram-II.


KODUR TYPE
CHAYAPA SUPA

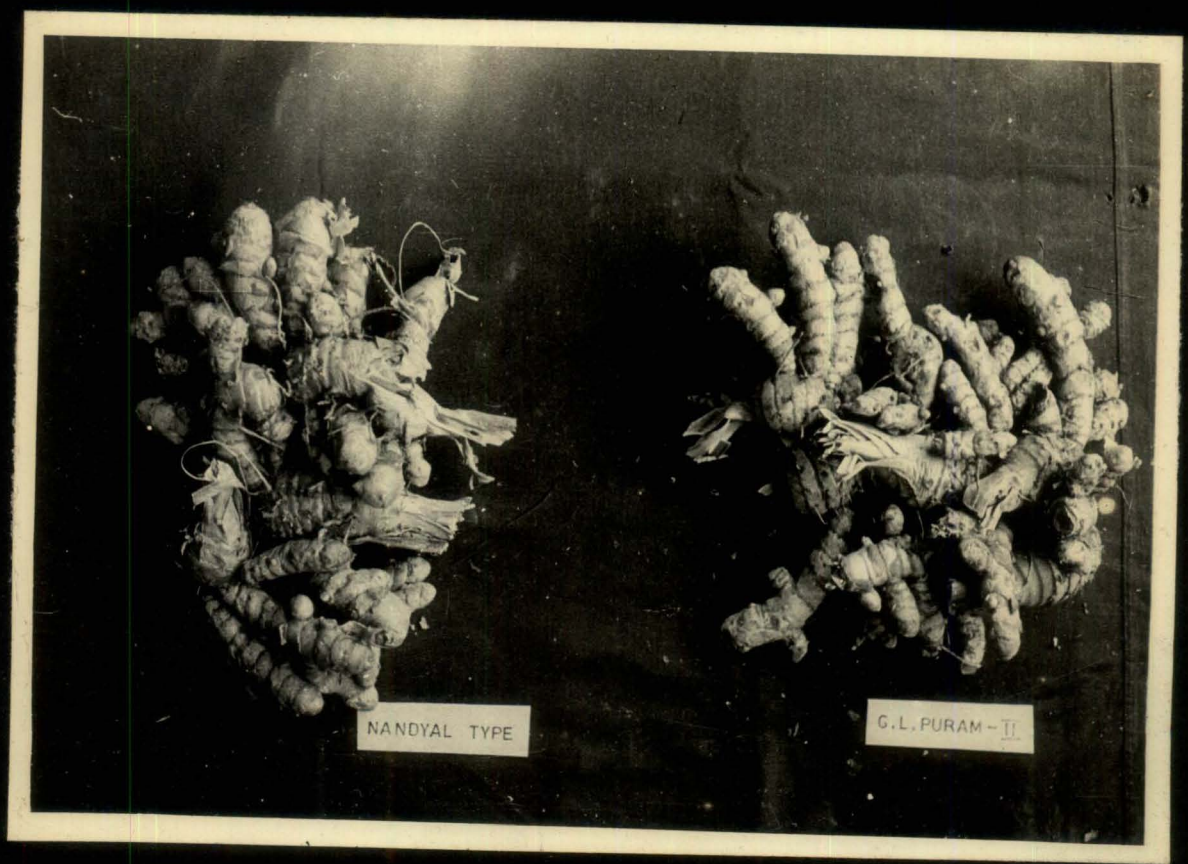
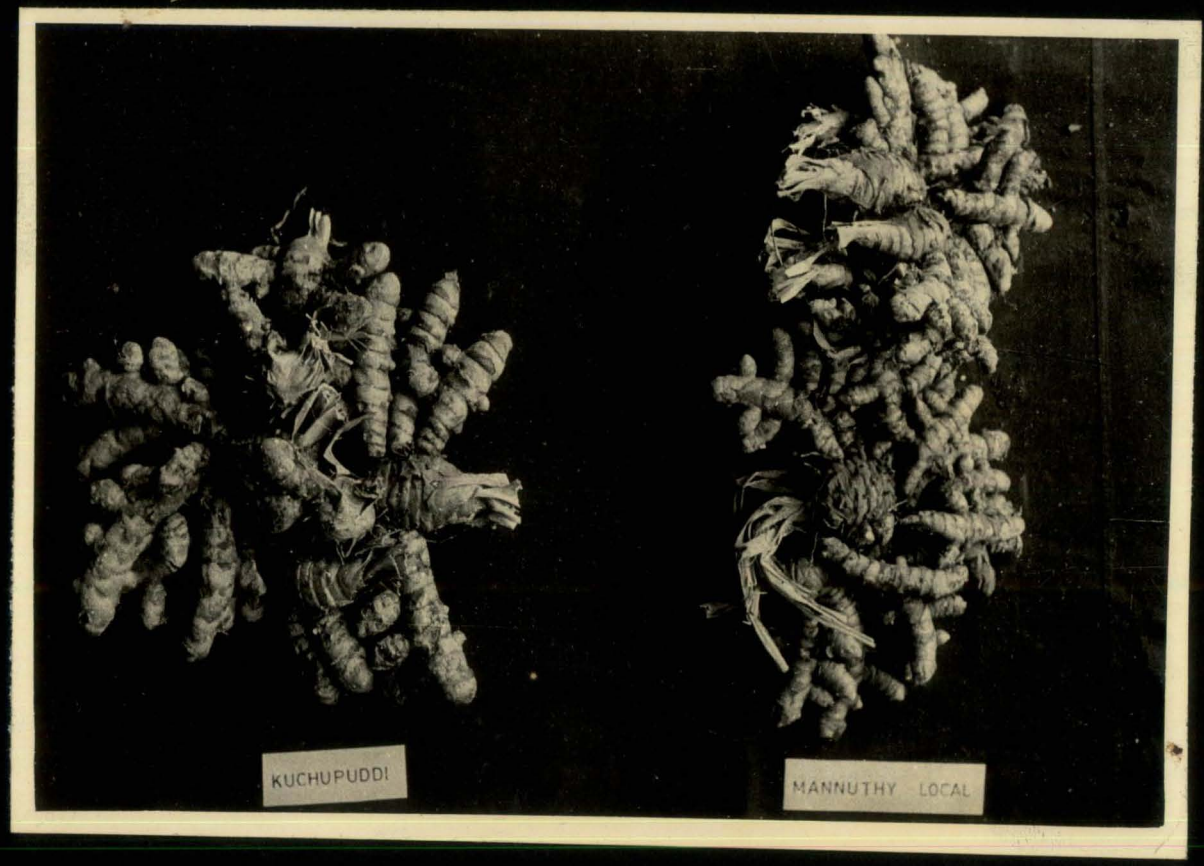

NANDYAL TYPE
G.L.PURAM - II

PLATE - X Rhizome characters of the types - Kuchupudi and Manmuthy Local.


KUCHUPUDDI
MANNUTHY LOCAL

and VK8 (19.82 each). They were on par with each other and VK5 was significantly superior to VK15, VK16, VK12, VK13, VK19, VK18 and VK17. The number of secondary fingers was minimum in the types VK17 (7.86), followed by VK18 (8.26).

The maximum number of nodes was recorded in the type VK8 (8.67) among the types and it was followed by VK2 (8.61), VK5 (8.44) and VK14 (7.8). The above types were on par with each other and VK8 had significantly more number of nodes than the rest of the types. The type VK16 (4.57) had the least number of nodes.

The length of secondary finger was maximum in the type VK2 (8.64 cm), followed by VK8 (8.24 cm), VK14 (7.41 cm) and VK5 (7.15 cm). They were on par with each other and VK2 was significantly superior to all the other types except VK8 and VK14. The length was least in the type VK16 (4.53 cm). The types VK1 and VK3 recorded a length of 6.1 cm and 5.92 cm respectively.

The internodal distance varied from 0.74 to 1.1 cm with the maximum in VK14 and minimum in VK18. The type VK14, was significantly superior to VK13,

VK19, VK6, VK4, VK5, VK15, VK17 and VK18. The types VK2 (1.01 cm) and VK1 (0.99 cm) ranked third and fourth among the types.

A maximum girth was noticed in the type VK2 (7.4 cm) and it was followed by VK8 (7.0), VK1(6.83 cm), VK7 (6.79 cm), VK6 (6.75 cm). They were on par with each other and type VK2 was significantly superior to rest of the types except VK8, VK15, VK1, VK7, VK4, VK6 and VK12. The girth of secondary fingers was least in the types VK10 (5.1 cm), followed by VK14 (5.4 cm) and VK5 (5.52 cm).

2. Incidence of pest and diseases

The data presented in Table 8 showed significant differences among the types with regard to the incidence of shoot borer, 'leaf spot' and 'leaf blotch'. None of the types were found to be resistant or tolerant to shoot borer and leaf diseases infection.

Minimum incidence of shoot borer infection was noticed in the type VK5 (18.1%), followed by VK1 (32.7%) and VK2 (34.9%). They were on par with each other and VK5 showed significantly lower incidence to shoot borer attack than the rest of the types. Shoot borer infection was maximum in the type VK18 (84.5%) followed by VK17 (75.6%) and VK16 (72.6%).

Table 8. Incidence of pests and diseases
(Mean values)

Types		Percentage of shoot borer infected tillers per plant+	Intensity of leaf disease infection++	
			Leaf spot	Leaf blotch
VK1	(Chayapasupa)	32.7 (34.88)	2.62	2.39
VK2	(Kuchupudi)	34.9 (36.21)	2.16	1.29
VK3	(Kodur)	36.5 (37.17)	1.79	1.37
VK4	(G.L.Puram-II)	40.6 (39.58)	2.06	1.21
VK5	(Mannuthy Local)	18.1 (25.18)	1.54	1.16
VK6	(Nandyal)	41.4 (40.05)	2.05	2.51
VK7	(Amruthapani-Kothapeta)	49.5 (44.70)	2.16	1.66
VK8	(Armoor)	37.1 (37.51)	3.35	1.29
VK9	(Duggirala)	43.5 (41.28)	2.38	1.39
VK10	(Amalapuram)	47.6 (43.64)	2.76	1.41
VK11	(Vontimitta)	49.5 (44.70)	3.53	1.49
VK12	(Kasturi Tamuka)	58.9 (50.12)	3.84	1.71
VK13	(Amruthapani-Kothapeta C11-317)	54.5 (47.59)	2.65	1.49
VK14	(Dindrigam Ca-69)	43.7 (41.41)	2.88	1.21
VK15	(Duggirala C11-325)	61.6 (51.72)	2.86	3.62
VK16	(Rajpuri)	72.6 (58.41)	4.07	1.68
VK17	(Armoor C11-324)	75.6 (60.37)	1.72	5.27
VK18	(G.L.Puram-I)	84.5 (66.78)	2.57	3.69
VK19	(Tekurpeta)	59.9 (50.70)	1.57	5.04
	'F' value	1.91*	2.99**	21.22**
	C.D. ($P = 0.05$)	17.8	1.22	0.80

\+ Transformed values within the brackets are obtained after effecting the arc sine transformation.

++ Mean values obtained after applying $\sqrt{x+1}$ transformation

** Significant at 1% level

* Significant at 5% level

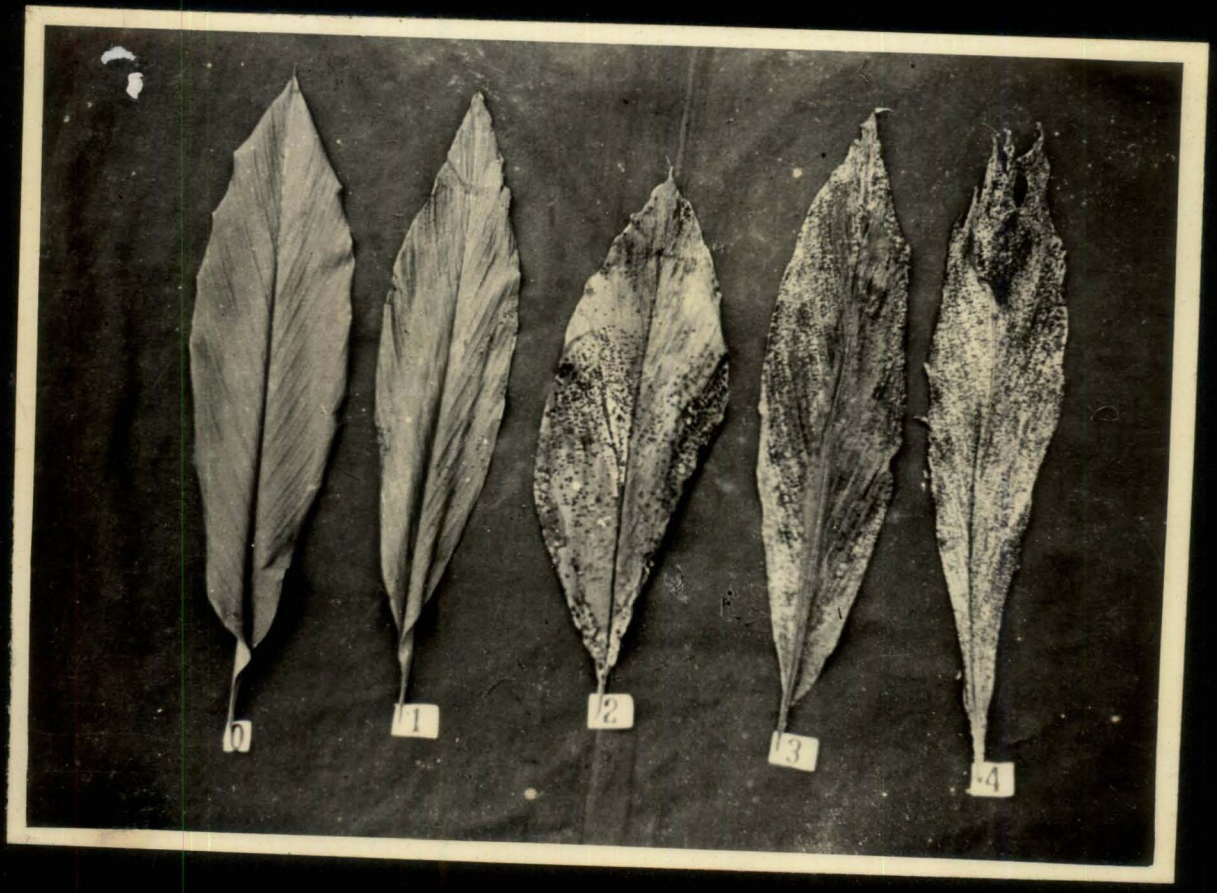
PLATE - XI Range of intensity of leaf spot (*Colletotrichum capsici*)

0 - Nil
1 - Light
2 - Medium
3 - Heavy
4 - Very heavy

PLATE - XII Range of intensity of leaf blotch (*Taphrina maculans*)

0 - Nil
1 - Light
2 - Medium
3 - Heavy
4 - Very heavy


0
1
2
3
4


0
1
2
3
4

The minimum incidence of 'leaf spot' disease was noticed in VK5 (1.54) and it was followed by VK19 (1.57). They were on par with each other and were significantly superior to VK15, VK14, VK8, VK11, VK12 and VK16. The incidence of 'leaf spot' was maximum in the type VK16 (4.07) followed by VK12 (3.84) and VK11 (3.53).

The incidence of 'leaf blotch' disease was minimum in the type VK4 (1.16) and it was followed by VK5 and VK14 (1.21 each). They were on par with each other and recorded significantly lower incidence than the types VK1, VK6, VK15, VK18, VK19 and VK17. The maximum incidence was noticed in the type VK17 (5.27), followed by VK19 (5.04).

3. Yield characters

3.1 Green turmeric

3.1.1 Yield per plot

The data on yield per plot furnished in Table 9 indicated highly significant differences among the types.

The type VK1 with an yield of 28.86 kg ranked first and it was followed by VK3 (24.06 kg), VK2 (23.84 kg) VK4 (22.56 kg), VK5 (21.99 kg) and VK6 (20.73 kg). They were on par with each other and VK1 was significantly

Table 9. Yield characters of turmeric types
(Mean values)

	Types	Net yield of green turmeric per plot (kg)	Curing percentage	Projected gross yield per ha.in kg	
				Green turmeric	Cured turmeric
VK1	(Chayapasupa)	28.86	15.84	50086.8	7933.8
VK2	(Kuchupudi)	23.84	17.23	41371.5	7128.3
VK3	(Kodur)	24.06	15.87	41753.5	6626.3
VK4	(G.L.Puram-II)	22.56	14.63	39166.7	5730.1
VK5	(Mamuthy Local)	21.99	22.42	38173.2	8558.4
VK6	(Nandyal)	20.73	14.06	35989.6	5060.1
VK7	(Amruthapani-Kothapeta)	18.93	15.18	32847.2	4986.2
VK8	(Armoor)	19.51	20.17	33854.2	6828.4
VK9	(Duggirala)	16.51	15.21	28663.2	4359.7
VK10	(Amalapuram)	14.45	27.87	25312.5	7054.6
VK11	(Vontimitta)	16.06	18.66	27882.0	5502.8
VK12	(Kasturi Tamuka)	13.20	17.08	22916.7	3914.2
VK13	(Amruthapani-Kothapeta C11-317)	10.55	16.02	18316.0	2934.2
VK14	(Dindrigam Ca-69)	9.40	28.17	16319.5	4597.2
VK15	(Duggirala C11-325)	9.30	20.08	16145.8	3242.1
VK16	(Rajpuri)	7.99	22.93	13854.2	3176.8
VK17	(Armoor C11-324)	6.64	19.12	11510.4	2200.8
VK18	(G.L.Puram-I)	5.60	20.47	9687.5	1983.0
VK19	(Tekurpeta)	3.83	22.68	6632.0	1504.1
	'F' value	5.41**	338.8**	--	--
	C.D. (P = 0.05)	8.81	0.65	--	--

** Significant at 1% level

superior to the rest of the types. The yield per plot was least in the type VK19 (3.83 kg), followed by VK18 (5.59 kg) and VK17 (6.64 kg).

3.1.2 Yield per hectare

The yield of green turmeric per hectare was maximum in the type VK1 (50086.8 kg), followed by VK3 (41753.5 kg), VK2 (41371.5 kg), VK4 (39160.7 kg) and VK5 (38173.2 kg). The lowest yield was recorded in VK19 (6632.0 kg) among the types.

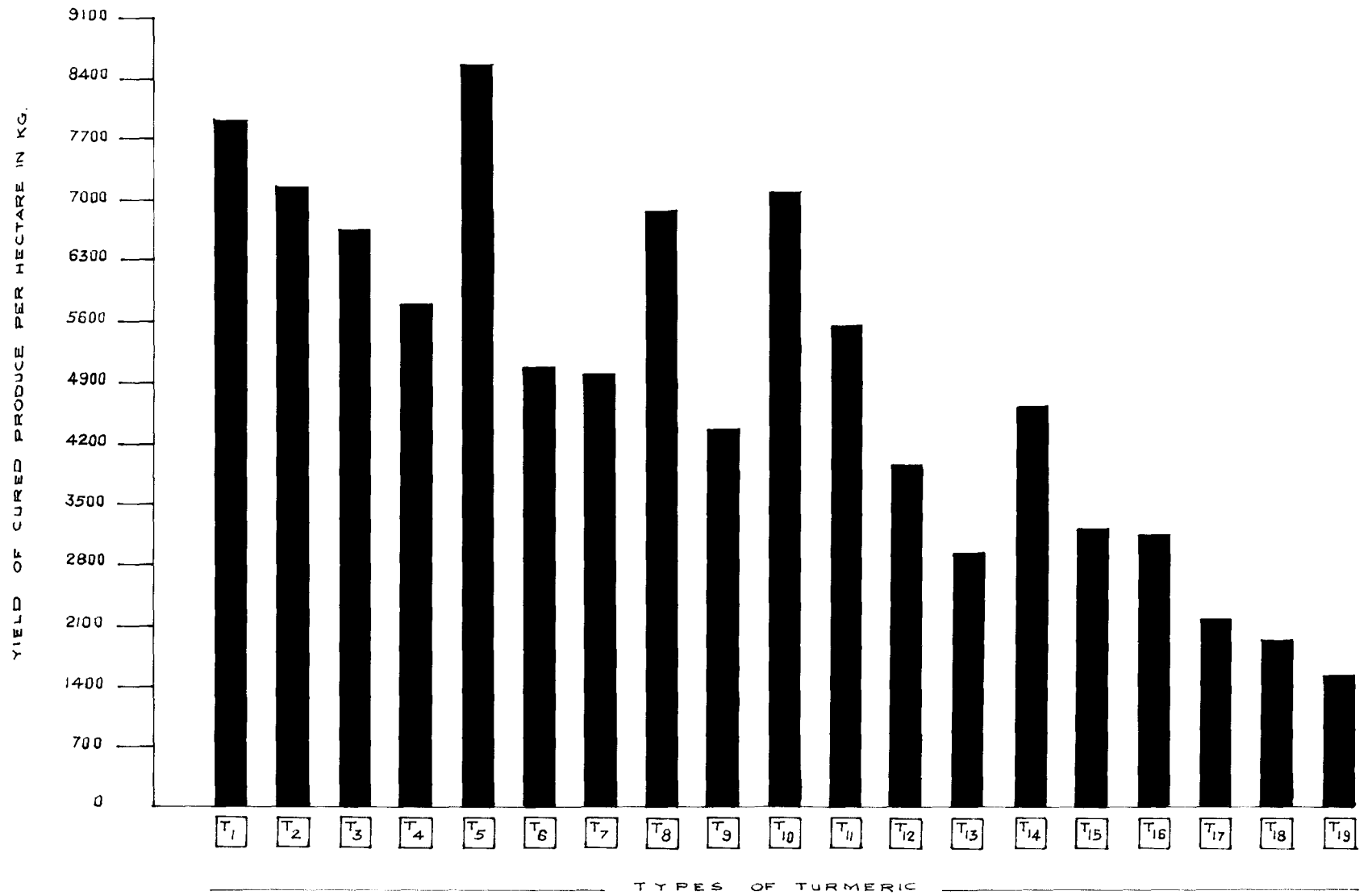
3.2 Cured turmeric

3.2.1 Curing percentage

Highly significant variation was noticed among the types with regards to the percentage recovery of cured turmeric (Table 8).

Maximum curing percentage was recorded in the type VK14 (28.17%), followed by VK10 (27.87%), VK16 (22.93%), VK19 (22.68%) and VK5 (22.42%). Of the above types VK14 and VK10 were on par with each other and were significantly superior to the rest. The curing percentage was least in VK6 (14.06%) followed by VK4 (14.63%), VK7 (15.13%) and VK9 (15.21%).

FIG. . COMPARISON OF THE YIELD OF CURED PRODUCE PER HECTARE IN DIFFERENT TURMERIC TYPES.



3.2.2 Yield per hectare

A comparison of yield of cured produce per hectare among the 19 types is presented in Fig.1. Maximum yield of cured turmeric per hectare was recorded in the type VK5 (8558.4 kg) followed by VK1 (7933.8 kg), VK2 (7128.3 kg), VK10 (7054.6 kg) and VK8 (6828.4 kg). The yield of cured turmeric per hectare was least in the type VK19 (1504.1 kg), followed by VK18 (1983 kg) and VK17 (2200.8 kg).

4. Chemical constituents

Data presented in Table 10 and 11 showed highly significant variation in oleoresin and curcumin content among the types and also among the cured and uncured samples. A comparison of yield of oleoresin per hectare among the 19 types is shown in Fig.2.

4.1 Oleoresin

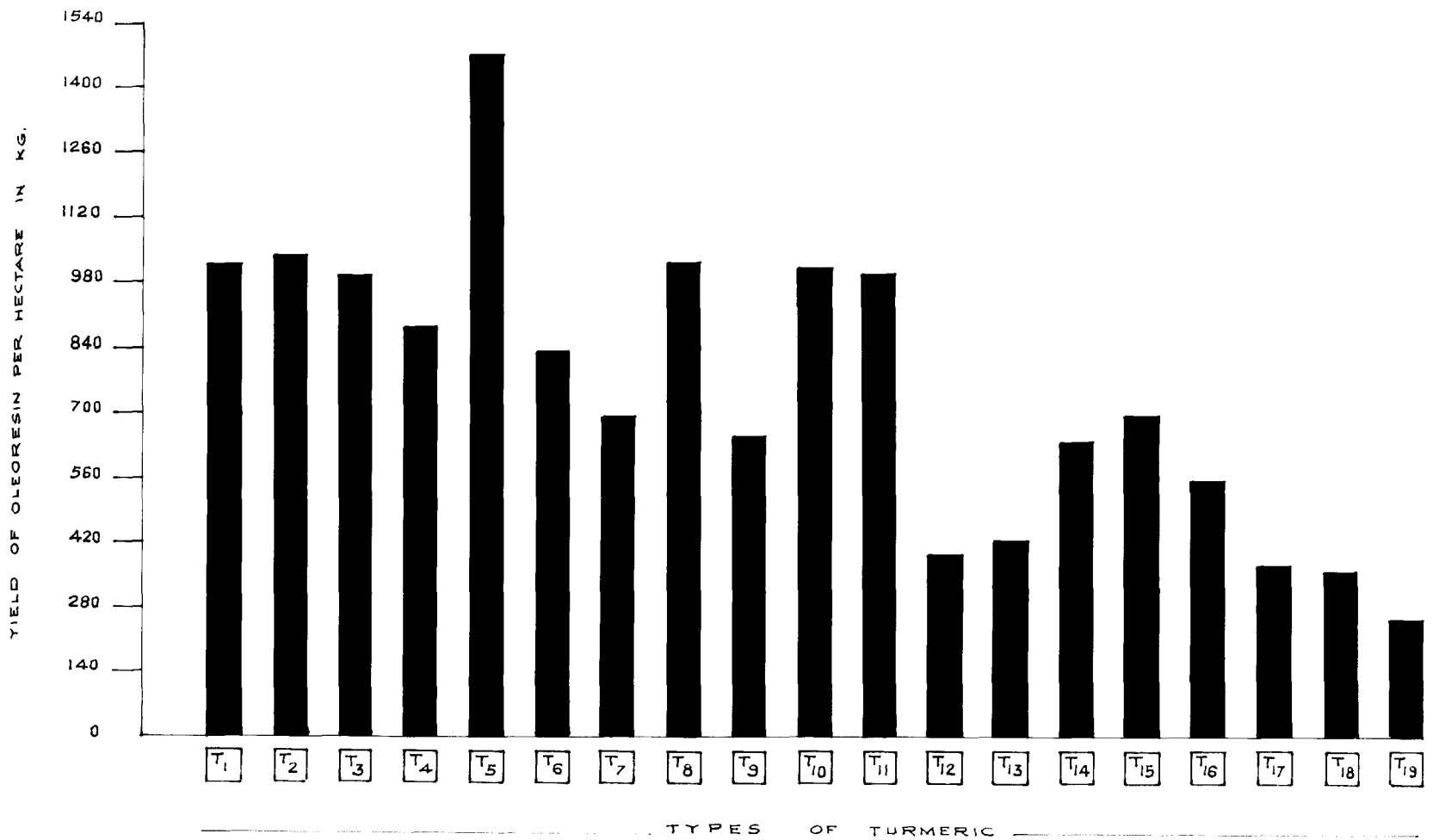
The data indicated that the uncured samples had significantly higher content of oleoresin than that of the cured samples. Maximum difference in oleoresin content between uncured and cured samples was noticed in the type VK4 (3.4 %) and the minimum in VK3 (0.22%).

Table 10. Yield of oleoresin in turmeric types
(Mean values)

Types	Oleoresin content (on dry weight basis)		Projected gross yield of oleoresin per hectare (kg)
	Cured samples (%)	Uncured samples (%)	
VK1 (Chayapasupa)	12.87	14.60	1021.1
VK2 (Kuchupudi)	14.53	16.35	1033.7
VK3 (Kodur)	14.95	15.17	990.6
VK4 (G.L.Puram-II)	15.41	18.85	883.6
VK5 (Mannuthy Local)	17.18	19.30	1470.3
VK6 (Nandyal)	16.44	17.07	831.9
VK7 (Amruthapani-Kothapeta)	13.81	14.72	688.6
VK8 (Armoor)	14.89	15.11	1016.7
VK9 (Duggirala)	14.92	15.26	650.5
VK10 (Amalapuram)	14.22	16.63	1003.2
VK11 (Vontimitta)	18.03	18.95	992.2
VK12 (Kasturi Tamuka)	12.10	14.37	473.6
VK13 (Amruthapani-Kothapeta C11-317)	14.48	14.71	424.9
VK14 (Dindrigam Ca-69)	13.69	15.07	629.4
VK15 (Duggirala C11-325)	21.10	22.77	684.1
VK16 (Rajpuri)	17.35	19.10	551. 2
VK17 (Armoor C11-324)	16.55	18.90	364.2
VK18 (G.L.Puram-I)	17.36	18.09	344.3
VK19 (Tekurpeta)	16.60	19.24	249.7
	t = 6.50**		
'F' value	189.3**	19.31**	--
C.D. (P = 0.05)	0.43	1.74	--

** Significant at 1% level

FIG. . . COMPARISON OF THE YIELD OF OLEORESIN PER HECTARE IN DIFFERENT TURMERIC TYPES.



In the case of both cured and uncured samples the oleoresin content was maximum in the type VK15 and it was significantly superior to all the other types and the least in the types VK12 and VK1. Among the cured turmeric samples the oleoresin content varied from 12.1 to 21.1 per cent while it varied from 14.37 to 22.77 per cent in the case of uncured samples. Among the cured samples the type VK15 was closely followed by VK11 (18.03%), VK18 (17.36%), VK16 (17.35%) and VK5 (17.18%). Of the above types VK11 was significantly superior to all the other types and while VK18, VK16, and VK5 were on par with each other.

The type VK5 with 1470.3 kg per ha ranked first in oleoresin yield and it was closely followed by VK2, VK1 and VK8 with a mean yield of 1033.7, 1021.1 and 1016.7 kg per hectare respectively. The yield of oleoresin per hectare was least in the type VK19, (249.7 kg), followed by VK18 (344.3 kg) and VK17 (364.2 kg).

4.2 Curcumin

The data showed that the uncured samples had significantly higher content of curcumin than that of cured sample. The difference between the cured and uncured samples varied from 0.02 (VK14) to 1.32 (VK9) per cent.

Table 11. Yield of curcumin in turmeric types
(Mean values)

Types	Curcumin content (on dry weight basis)		Projected gross yield of curcumin per hectare (kg)
	Cured samples (%)	Uncured samples (%)	
VK1 (Chayapasupa)	3.75	3.96	297.5
VK2 (Kuchupudi)	4.83	4.87	344.3
VK3 (Kodur)	3.62	4.27	239.8
VK4 (G.L.Puram-II)	3.45	4.50	197.7
VK5 (Mannuthy Local)	6.55	7.32	560.6
VK6 (Nandyal)	2.98	3.68	150.8
VK7 (Amruthapani-Kothapeta)	3.60	4.26	179.5
VK8 (Armoor)	3.01	3.08	205.5
VK9 (Duggirala)	2.33	3.65	101.6
VK10 (Amalapuram)	2.61	2.68	184.1
VK11 (Vontimitta)	3.55	4.46	195.4
VK12 (Kasturi Tanuka)	3.38	4.37	132.3
VK13 (Amruthapani-Kothapeta C11-317)	4.03	4.69	118.2
VK14 (Lindrigam Ca-69)	3.61	3.63	166.0
VK15 (Duggirala C11-325)	6.00	6.46	194.5
VK16 (Rajpuri)	3.80	4.69	120.7
VK17 (Armoor C11-324)	4.01	4.98	88.3
VK18 (G.L.Puram-I)	4.14	4.29	82.1
VK19 (Tekurpeta)	4.35	4.46	65.4
	t = 5.06**		
'F' value	226.2**	210.1**	--
C.D.(P = 0.05)	0.19	0.21	--

** Significant at 1% level

In the case of both the cured and uncured samples maximum curcumin content was noticed in VK5 among the types and it was significantly superior to rest of the types. VK5 was closely followed by VK15 and had significantly higher content of curcumin than all the other types.

Among the cured samples the curcumin content varied between 2.33 (VK9) and 6.55 (VK5) per cent, while it varied between 2.68 (VK10) and 7.32 (VK5) per cent in the case of uncured samples. The types VK2 with a curcumin content of 4.83 per cent ranked third and it was closely followed by VK19 (4.35%), VK18 (4.14%), VK13 (4.03%), VK17 (4.01%) in the case of cured samples.

The type VK5 with 560.6 kg per hectare ranked first in yield of curcumin and it was closely followed by VK2 (344.3 kg), VK1 (297.5 kg), VK3 (239.8 kg) and VK8 (205.5 kg). The yield ofcurcumin per hectare was found to be least in VK19 (65.40 kg), followed by VK18 (82.1 kg) and VK17 (88.25 kg).

5. Correlation studies

The simple linear correlation coefficients between the yield per plot and different growth characters and incidence of pest and diseases are presented in Table 12.

Table 12. Correlation coefficient for different variables

Variables correlated		Correlation coefficient ('r')
X	Y	
Yield per plot	Height of plant	+ 0.634**
	Number of tillers per plant	+ 0.221NS
	Number of leaves per plant	+ 0.440NS
	Number of leaves per tiller	+ 0.592**
	Leaf area index	+ 0.741**
	Petiole length	+ 0.688**
	Length of leaf	+ 0.831**
	Breadth of leaf	+ 0.556*
	Root characters:-	
	Number of roots per plant	+ 0.813**
	Length of root	+ 0.644**
	Mother rhizome characters:	
	Length	+ 0.240NS
	Internodal distance	+ 0.320NS
	Girth at centre	+ 0.565*
	Number of nodes	+ 0.145NS
	Primary finger characters:	
	Girth at centre	+ 0.432NS
	Length of finger	+ 0.681**
	Internodal distance	+ 0.330NS
	Intensity of shoot borer attack	- 0.767**
	Intensity of 'leaf diseases'	
	Leaf spot	- 0.443NS
	Leaf blotch	- 0.417NS

NS Not significant
* Significant at 5% level
** Significant at 1% level

It may be seen from the table that the height of plant, length of leaf, breadth of leaf, leaf area index, petiole length, number of leaves per tiller, number of roots per plant, length of root, length of primary fingers and girth of mother rhizomes were positively correlated with the yield per plant whereas the intensity of shoot borer attack was negatively correlated with the yield.

The correlation of the yield per plot with that of 'leaf spot' and 'leaf blotch' infection was negative, but not significant, whereas the number of tillers per plant, number of leaves per plant, internodal distance, length and number of nodes of mother rhizome, girth at centre and internodal distance of primary finger showed no significant correlation with the yield per plot.

6. Quantity and quality variations at different periods of maturity

The data on yield of turmeric, percentage recovery of dry produce, oleoresin and curcumin contents of turmeric at fortnightly intervals from 165th to 270th day of planting (till the final harvest of the crop) in four turmeric types viz., VK4 (G.L.Puram-II, VK5 (Mamuthy Local), VK11 (Vontimitta) and VK17 (Armoor Cll-324) are

Table 13. Yield of green turmeric per plot at different maturity periods

Maturity periods in days after planting	Types of turmeric				Mean
	Mean yield/plot ($3m^2$) in kg.				
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vontimi-tta (VK11)	Armoor C11-324 (VK17)	
165	19.46	16.74	14.57	8.40	14.79
180	23.29	23.07	18.74	9.20	18.57
195	27.75	25.50	20.75	9.34	20.83
210	30.04	29.35	22.78	10.04	23.05
225	30.30	29.68	22.20	9.52	22.92
240	31.50	32.52	24.85	9.86	24.68
255	31.96	33.57	25.70	10.12	25.33
270	32.94	34.50	26.78	10.59	26.20
				'F' value	10.50**
				C.D. (P= 0.05)	3.34

** Significant at 1% level

Table 14. Yield of green turmeric at different maturity periods
(Mean values)

Maturity periods in days after planting	Types of turmeric			
	Gross yield per ha. in kg.			
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vonti-mitta (Vk11)	Armoor C11-324 (VK17)
165	33784	29062	25295	14583
180	40434	40052	32534	15972
195	46177	44270	36024	16215
210	52152	50954	39548	17430
225	52604	51527	38541	16527
240	54687	56458	43142	17118
255	55486	58281	44618	17569
270	57187	59895	46493	18385

furnished in Tables from 13 to 20. The trend in percentage recovery of dry produce, oleoresin and curcumin at various periods of maturity is presented in Fig.3, Fig.4 and Fig.5 respectively.

6.1 Yield

6.1.1. Green turmeric

The data presented in Table 13 showed that the yield of green turmeric per plot increased with increase in maturity and that the periods of maturity had significant influence on the yield of turmeric.

Harvesting on 270th day after planting gave the highest yield of green turmeric per plot (26.20 kg) followed by harvesting on 255th day (25.33 kg), 240th (24.68 kg), 210th (23.05) and 225th (22.92 kg) day of planting. The above periods of maturity were on par with each other and harvesting on 270th, 255th and 240th day after planting gave significantly higher yield than that of 165th, 180th and 195th day after planting. Harvesting on 165th day gave the least yield. Yield per plot on 180th and 195th day gave the least yield. Yield per plot on 180th and 195th day of maturity were on par with each other.

The gross yield per hectare of green turmeric

showed the same trend as that of the yield per plot since these yields had been calculated from the yield per plot (Table 14).

6.1.2 Dry produce

The data presented in Table 15 showed significant differences in percentage recovery of dry turmeric among the different periods of maturity.

It may be seen from the Fig. 3 that the drying percentage increased with increase in maturity. The drying percentage increased from 10.84 to 17.45 per cent, 15.34 to 24.26 per cent, 13.47 to 20.63 per cent and 12.56 to 21.45 per cent in the types VK4 (G.L.Puram-II), VK5 (Mamuthy Local), VK11 (Vontimitta) and VK17 (Armoor C11-324) respectively during the period of 105 days from 165th to 270th day of planting. A sharp increase in drying percentage was noticed during the period from 165th to 180th day of planting followed by a dip during the period from 180th to 195th day, a sharp increase during the period from 195th to 225th day and thereafter a gradual increase towards the final harvest (270th day) in all the four types. Maximum percentage recovery of dry produce was recorded on 270th day after planting in

Table 15. Drying percentage at different maturity periods

(Mean values)

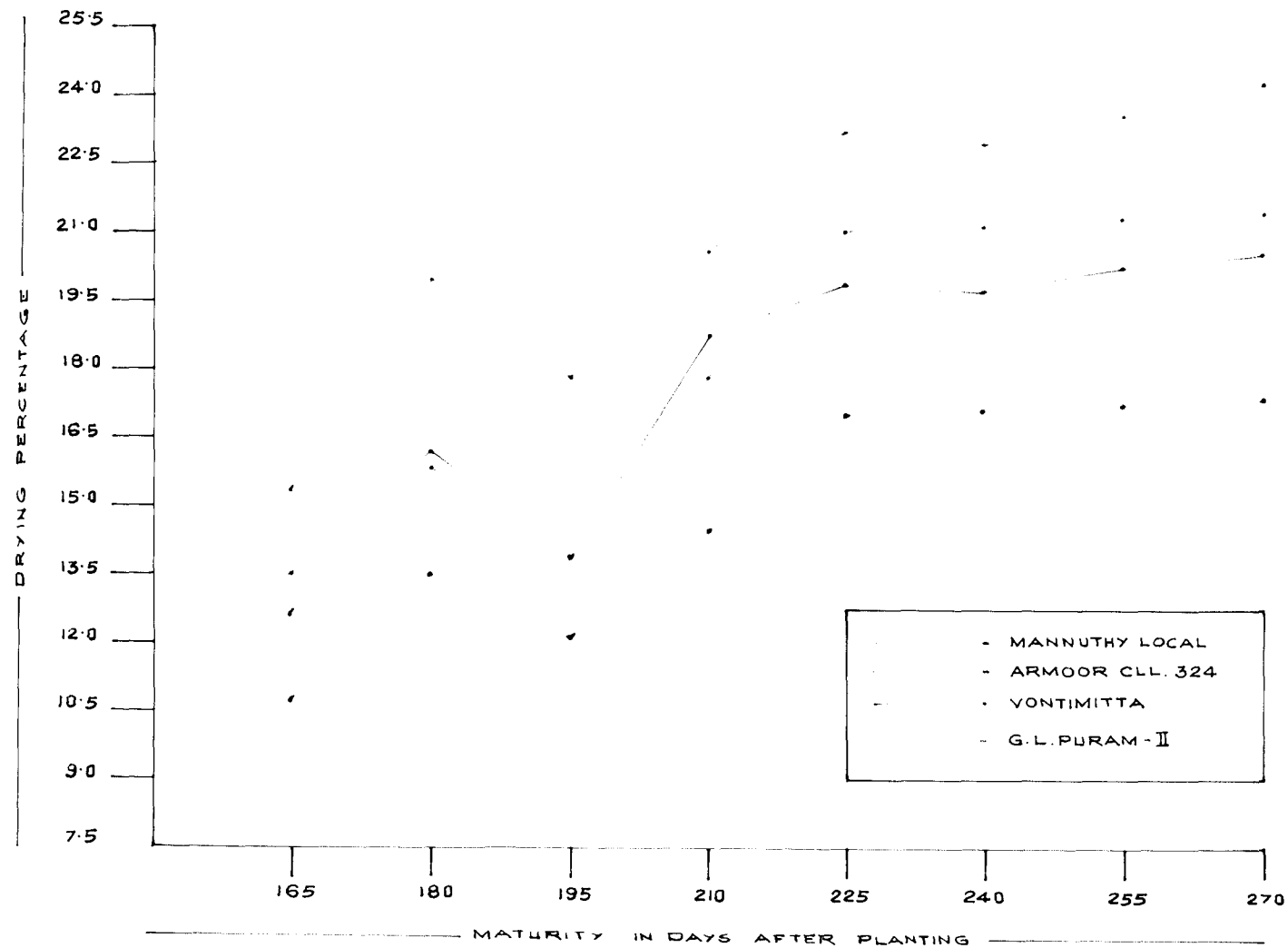
Maturity periods in days after planting	Types of turmeric				Mean
	Percentage recovery of dry produce				
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vontimi-tta (VK11)	Armoor C11-324 (VK17)	
165	10.84	15.34	13.47	12.56	13.05
180	13.47	19.92	16.14	15.97	16.37
195	12.22	17.87	14.79	13.84	14.68
210	14.56	20.49	18.68	17.85	17.89
225	16.92	23.06	19.94	20.97	20.22
240	17.08	22.93	19.76	21.08	20.21
255	17.28	23.62	20.32	21.34	20.64
270	17.45	24.26	20.63	21.45	20.94
				'F' value	106.9**
				C.D. (P = 0.05)	0.85

** Significant at 1% level

Table 16. Yield of dry produce at different maturity periods
(Mean values)

Maturity periods in days after planting	Types of turmeric			
	Gross yield per ha. in kg.			
	C.L. Puram-II (VK4)	Mannuthy Local (VK5)	Venti-mitta (VK11)	Armoor C11-324 (VK17)
165	3662.2	4458.1	3407.2	1831.6
180	5446.5	7978.4	5250.9	2550.7
195	5887.2	7911.0	5327.9	2244.1
210	7593.3	10440.4	7387.6	3111.2
225	8900.6	11882.1	7685.0	3465.7
240	9340.5	12945.8	8524.8	3608.5
255	9567.9	13765.9	9066.4	3749.2
270	9979.1	14530.5	9591.5	3343.2

FIG. . DRYING PERCENTAGE OF TURMERIC AT VARIOUS STAGES OF MATURITY.



all the types studied. Out of the four types, maximum drying percentage was noticed in VK5 (Mamuthy Local) and the least in VK4 (G.L.Puram-II) throughout their growth from 165th to 270th day after planting.

Harvesting on 270th day after planting gave the highest percentage recovery of dry produce (20.94%) among the periods of maturity and it was significantly superior to all the other periods of maturity except that on 225th, 240th and 255th day after planting. Drying percentage recorded on 255th, 240th and 225th day after planting were significantly higher than that on 165th, 180th, 195th and 210 days after planting. Drying percentage recorded on 210th day was significantly higher than that on 180th, 195th and 165th day of maturity and that on 180th day was significantly higher than that on 165th day and 195th day of maturity. The drying percentage was least on 165th day (13.05%) of planting.

The data furnished in Table 16 showed that the yield of dry produce increased with increase in maturity with the maximum on 270th day and the least on 165th day of planting in all the four types studied. However, slight decrease in gross yield per hectare of dry produce was noticed during the period from 195th 210th day of

planting in the types Mannuthy Local and Armoor C11-324. The yield of dry produce per hectare increased from 3.66 to 9.98 tonnes, 4.46 to 14.53 tonnes, 3.41 to 9.59 tonnes and 1.83 to 3.948 tonnes in G.L.Puram-II, Mannuthy Local, Vontimitta and Armoor C11-324 respectively during the period of growth from 165th to 270th day after planting.

6.2 Chemical constituents

6.2.1 Oleoresin

Data from Table 17 showed significant variation in oleoresin content among the different periods of maturity.

The oleoresin content varied from 11.21 to 19.42 per cent in VK4 (G.L.Puram-II)13.45 to 20.09 per cent in VK5 (Mannuthy Local), 12.56 to 19.24 per cent in VK11 (Vontimitta) and 14.13 to 20.37 per cent in VK17 (Armoor C11-324). It was higher during the early stages of growth upto 180th day of planting in all the types studied. Maximum oleoresin content was observed on 180th day of planting in all types except in VK11(Vontimitta) where it was on 165th day. The oleoresin content was found to be least on 210th day after planting in the types VK11 (Vontimitta) and VK4 (G.L.Puram-II) whereas in the other two types it was on 240th day after planting.

Table 17. Oleoresin content at different periods of maturity
(Mean values)

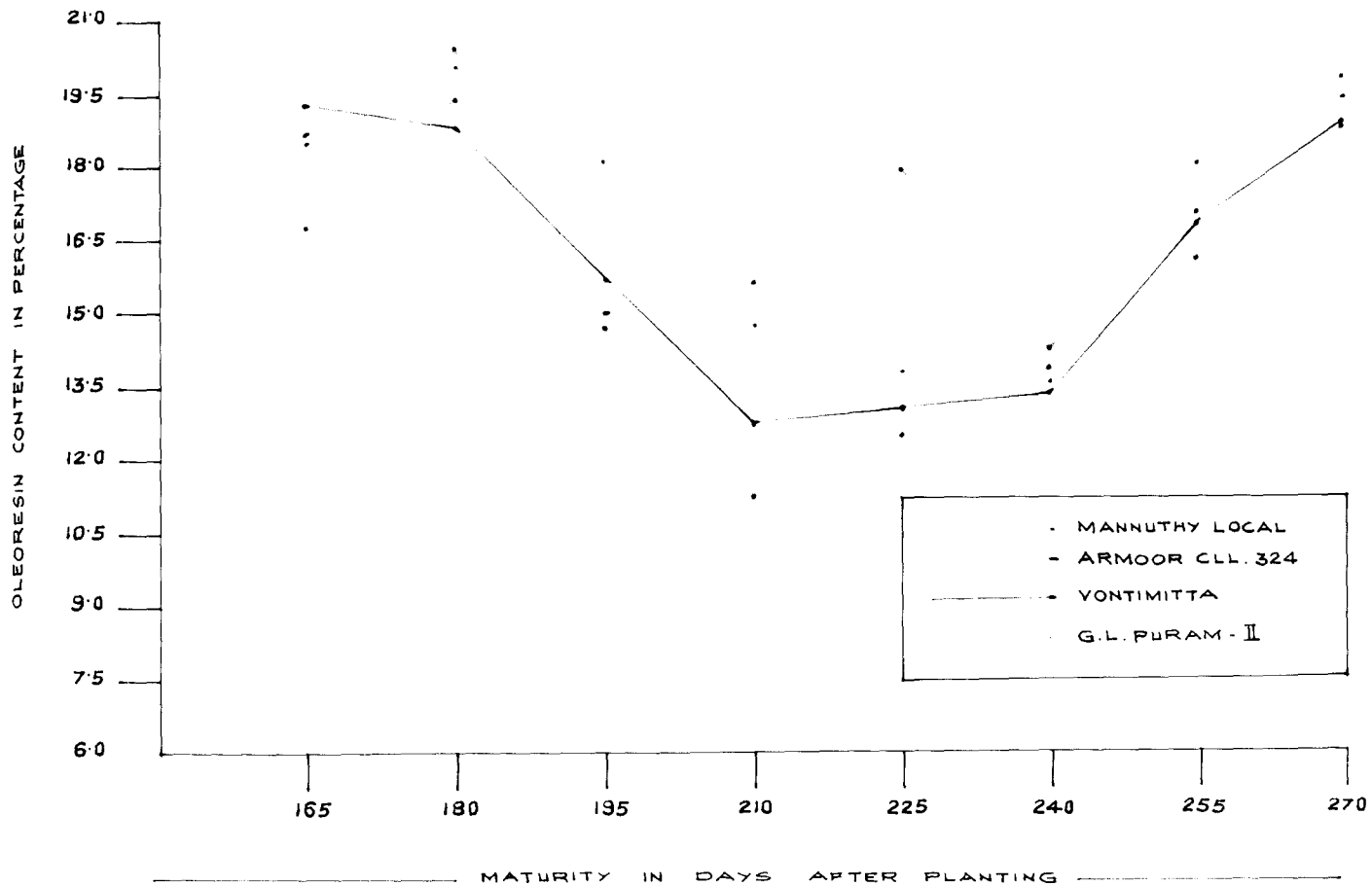
Maturity periods in days after planting	Types of turmeric				Mean
	Oleoresin content (%)				
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vonti-mitta (Vk11)	Armoor C11-324 (VK17)	
165	16.73	18.44	19.24	18.67	18.27
180	19.42	20.09	18.75	20.37	19.66
195	14.67	18.17	15.63	14.91	15.85
210	11.21	14.65	12.56	15.56	13.50
225	12.43	13.79	12.90	17.89	14.26
240	13.81	13.45	13.31	14.13	13.67
255	16.08	18.07	16.85	16.92	17.00
270	16.85	19.30	18.95	19.80	19.23
			'F' value		16.76**
			C.D. (P = 0.05)		1.81

** Significant at 1% level

Table 18. Yield of oleoresin at different periods of maturity
(Mean values)

Maturity periods in days after planting	Types of turmeric			
	Gross yield per ha. in kg.			
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vonti-mitta (VK11)	Armoor C11-324 (VK17)
165	612.7	822.0	655.5	341.9
180	1057.7	1602.8	984.4	519.6
195	863.6	1437.4	832.7	334.6
210	951.2	1529.5	927.8	484.0
225	1136.3	1638.5	991.4	620.0
240	1269.9	1741.2	1134.6	509.8
255	1541.7	2487.5	1527.7	634.4
270	1681.0	2804.4	1817.6	780.7

FIG. . OLEORESIN CONTENT OF TURMERIC AT VARIOUS STAGES OF MATURITY.

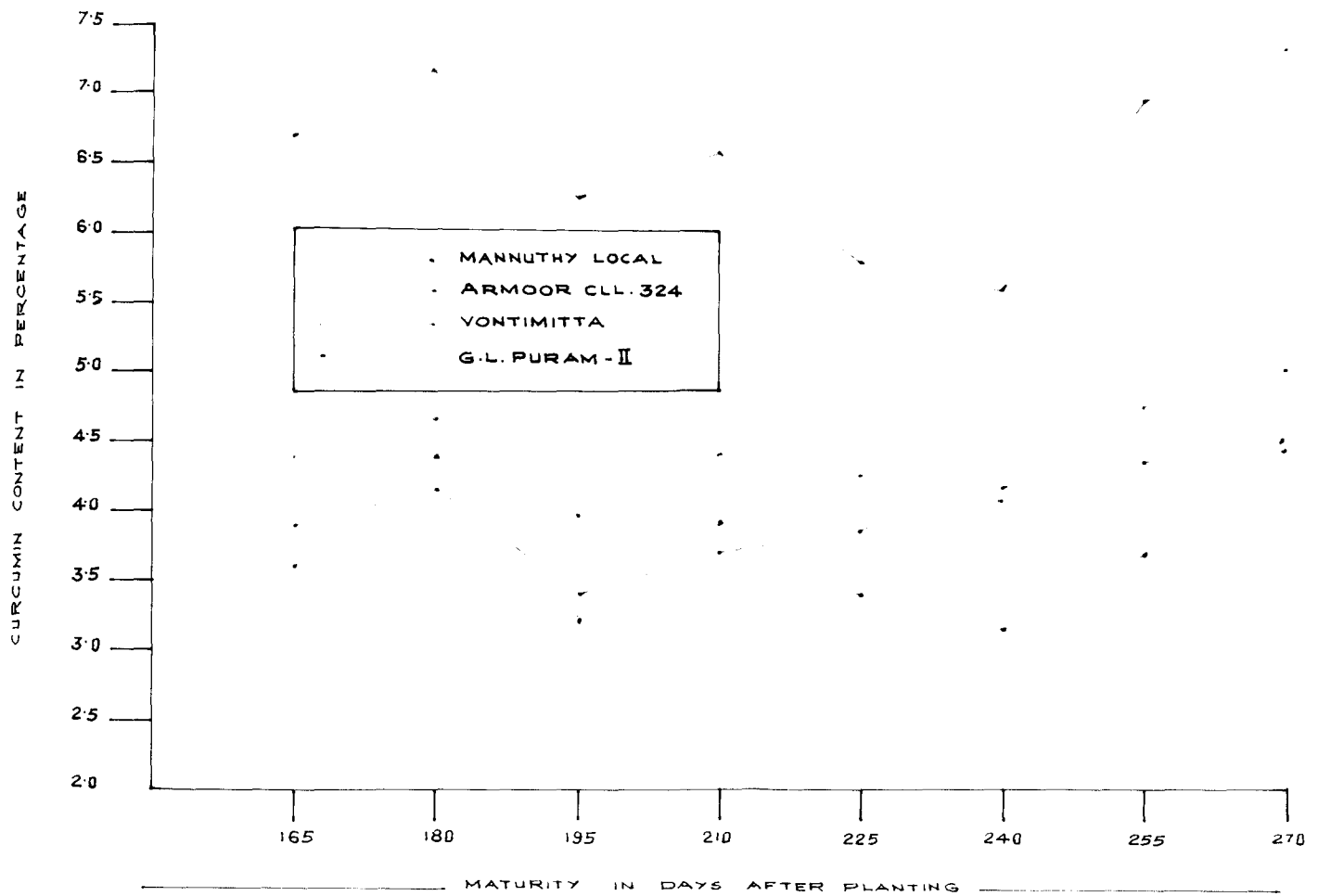


The percentage recovery of oleoresin was found to decrease during the period from 180th to 210th day after planting and thereafter an increase was noticed till 270th day in all the types except VK17 (Armoor Cll-324) where an erratic fluctuation was observed during the period between 195 and 240 days after planting (Fig.4).

Harvesting on 180th day after planting recorded the maximum percentage recovery of oleoresin among the maturity period. It was followed by harvesting on 270th day after planting and these stages of maturity were on par with each other and recorded significantly higher content of oleoresin than the rest of the stages of maturity except on 165 days after planting recorded significantly higher content of oleoresin than that on 195th, 210th, 225th and 240th day after planting. Harvesting on 195th day was significantly superior to harvesting on 210th and 240th day after planting.

The data on yield of oleoresin per hectare at various stages of maturity presented in Table 18 showed maximum yield on 270th day after planting in all the types and the least on 165th day after planting in all the types except VK17 (Armoor Cll-324) where it was on 195th day.

FIG. . CURCUMIN CONTENT OF TURMERIC AT VARIOUS STAGES OF MATURITY.



6.2.2 Curcumin

The data presented in Table 19 showed significant variation in curcumin content among the different periods of maturity.

The curcumin content varied between 3.23 and 4.50 per cent, 5.66 and 7.32 per cent, 3.44 and 4.46 per cent and 3.97 and 4.98 per cent in the types VK4 (G.L.Puram-II), VK5 (Mannuthy Local), VK11 (Vontimitta) and VK17 (Armoor C11-324) respectively during a period of 105 days from 165th to 270th day of planting. The curcumin content was found to be maximum on final harvest of the crop (270 days) in all the four types, but showed an erratic trend at different periods of maturity (Fig.5). Among the four types, Mannuthy Local recorded the maximum curcumin content throughout the growth period from 165th to 270th day after planting.

Out of the eight maturity periods harvesting on 270th day after planting gave the maximum curcumin content (5.32 per cent) among the maturity periods and it was significantly superior to the rest of the maturity periods except that on 180th and 255th day after planting.

Table 19. Curcumin content at different periods of maturity

(Mean values)

Maturity periods in days after planting	Types of turmeric				Mean
	Curcumin content (%)				
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vonti-mitta (VK11)	Armoor C11-324 (VK17)	
165	3.61	6.72	3.88	4.42	4.66
180	4.24	7.14	4.13	4.64	5.04
195	3.27	6.26	3.44	3.97	4.24
210	3.78	6.57	3.77	4.38	4.63
225	3.39	5.78	3.85	4.27	4.32
240	3.23	5.66	4.18	4.12	4.30
255	3.79	6.93	4.37	4.83	4.98
270	4.50	7.32	4.46	4.98	5.32
			'F' value		9.57**
			C.D. ($P = 0.05$)		0.42

** Significant at 1% level

Table 20. Yield of curcumin at different periods of maturity
(Mean values)

Maturity periods in days after planting	Types of turmeric			
	Gross yield per ha. in kg.			
	G.L. Puram-II (VK4)	Mannuthy Local (VK5)	Vonti-mitta (VK11)	Armoor C11-324 (VK17)
165	132.2	299.6	132.2	80.9
180	230.9	569.7	216.9	118.4
195	192.5	495.2	183.3	89.1
210	287.0	685.9	278.5	136.3
225	301.7	686.7	295.8	148.0
240	301.7	732.7	356.3	148.7
255	363.4	953.9	396.2	181.0
270	449.0	1063.6	427.8	196.4

Harvesting on 165th, 195th, 210th, 225th and 240th day were on par with each other and it was least on 195th day after planting.

The data on yield of curcumin per hectare at various stages of maturity presented in Table 20 showed maximum yield of curcumin on 270th day after planting and the least on 165th day after planting in all the four types studied.

DISCUSSION

DISCUSSION

Due to the increase in demand of turmeric both for internal consumption and for export the increase in production and productivity of this crop is essential. Therefore screening of the types suitable for high yield and quality with due emphasis on disease resistance or tolerance has been carried out. The possibility of quality change at different periods of maturity is also important for timely harvest with maximum benefit for quality and quantity. The present investigation conducted on the above aspects is discussed below.

1. Growth characters

1.1 Germination

The present study revealed significant variations in germination percentage among the types. Maximum germination is noticed in the type VK4 (G.L.Puram-II, 91.12%), closely followed by VK3 (Kodur, 90.11%), VK18 (G.L.Puram-I, 89.25%), VK14 (Dindrigam Ca-69, 89.23%) and VK1 (Chayapasupa, 89.06%), whereas the types VK9 (Duggirala, 77.82%) and VK19 (Tekurpeta, 78.17%) recorded comparatively poor germination. A variation of 74 to 95 per cent in germination had been recorded by Subbarayudu *et al.* (1976) in turmeric.

The variation in germination percentage among the types under uniform soil and cultural conditions may be due to physiological and storage conditions of the seed rhizomes.

1.2 Morphological characters

1.2.1 Height of plant

Highly significant variations has been noticed among the types with regard to the height of the plant. Pillai (1973) noticed similar variation in ginger. The height of plant is found to be maximum in the type VK1 (Chayapasupa, 41.09 cm) followed by VK6 (Nandyal, 40.21 cm), VK2 (Kuchupudi, 39.75 cm) and VK8 (Armoor, 39.67 cm), whereas the types VK14 (Dindrigam Ca-69, 22.05 cm), VK10 (Amalapuram, 23.48 cm) and VK17 (Armoor C11-324, 25.24 cm) recorded comparatively lower height. Under the uniform soil and environmental conditions the variation in height among the types may be due to genetic factors.

Highly significant positive correlation has also been noticed between the yield and height of plant and it is in agreement with the findings of Purewal (1957) who observed highly significant positive correlation in colocasia. Pillai (1973) also reported similar result

in ginger. But no such work has been reported in case of turmeric.

The increased height of the aerial shoot may be helpful for the better exposure of the leaves to the sun and thereby increase the photosynthetic efficiency of the plant which account for higher yield. This may be the possible reason for the positive correlation between the yield and height of the plant.

1.2.2 Number of tillers per plant

No significant variation is noticed with regard to the tiller production among the types and this is in conformity with the findings of Subbarayudu et al. (1976) who noticed similar result in turmeric types. The tiller production is found to be maximum in the type VK5 (Mannuthy Local, 3.7) followed by VK2 (Kuchupudi, 3.08) and VK1 (Chayapasupa, 2.85) which are found to be high yielding types whereas it is found to be poor in low yielding types such as VK14 (Dindrigam Ca-69, 2.0) and VK17 (Armoor C11-324, 2.1). However, the tiller production is not found to be correlated with the yield. The variation in tiller production among the types may be due to genetic factors as all the ether types are being grown under uniform environmental conditions.

1.2.3 Number of leaves per plant and per tiller

The data on 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 is noticed in the high yielding types like VK5 (Mannuthy Local) and VK1 (Chayapasupa) whereas the leaf production is found to be comparatively poor in low yielding types like VK17 (Annoor C11-324) and VK19 (Tekurpeta). The variation in leaf production among the types may be due to genetic factors under uniform environmental conditions. It is quite natural that when the number of tillers and height increase, the total number of leaves per plant also increases.

Highly significant and positive correlation is also 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 not significant. This may be due to the fact that in plants with more number of leaves and less number of tillers mutual shading of the leaves will be more. Under such situation due to low photosynthetic area, the yield is likely to be low. The number of leaves per tiller is found more important with regard to the yield rather than the total number of leaves per plant. Pillai (1973) noticed

significant and positive correlation between the yield and number of leaves in ginger and similar result was also reported by Shanmugam and Thamburaj (1974) in elephant foot yam.

1.2.4 Leaf characters

Highly significant variations among the types are noticed with regards to the leaf characters such as length of petiole, length, breadth and area of leaves. The leaves having significantly longer petioles are noticed in higher yielding types such as VK5 (Manmuthy Local), VK1 (Chayapasupa), VK2 (Kuchupudi) and VK4 (G.L.Puram-II).

The correlation studies revealed significant and positive correlation between the yield and leaf characters such as petiole length, leaf length, leaf breadth and leaf area index. This may be due to the fact that the leaf characters have direct bearing on the photosynthetic efficiency of the plant. The higher petiole length will definitely be helpful for better exposure of the leaf to the sun. The other factors directly increase the photosynthetic area and thereby increase the rate of photosynthesis which accounts for higher yield.

1.2.5 Root characters

The root characters such as the number and length of roots showed significant variations among the types. Highly significant and positive correlation has also been observed between the yield and root characters such as root length and number of roots per plant. Both the number and length of roots are found to be higher in high yielding types such as VK5 (Mannuthy Local) and VK1 (Chayapasupa) whereas the number and length of roots are found to be minimum in the lower yielding types such as VK18 (G.L.Puram-I), VK19 (Tekurpeta), VK16 (Rajpuri) and VK17 (Armoor C11-324). In the types with longer and more number of roots there will be better absorption of nutrients from a larger area which may perhaps account for the positive correlation between the yield and root characters.

1.2.6 Rhizome characters

1.2.6.1 Mother rhizome

The data on mother rhizome characters such as length, girth, number of nodes and internodal length showed significant variations among the types. The characters such as the length, number of nodes and internodal distance are found to be not correlated with the yield

whereas the girth at centre is found to be positively correlated with the yield. The positive correlation of the girth of mother rhizome with yield is quite natural because of higher weight due to higher girth. Girth of mother rhizome at centre is found to be higher in the case of high yielding types such as VK3 (Kodur), VK2 (Kuchupudi) and VK1 (Chayapasupa) whereas it is minimum in the low yielding type VK17(Armoor C11-324). The variation in mother rhizome characters among the types may be due to genetic factors.

1.2.6.2 Finger rhizome characters

Highly significant variation among the types is noticed with regard to the finger characters such as the number of fingers, number of nodes, length, internodal distance and girth of fingers. The primary finger characters such as the girth at centre and the internodal distance are found to be not correlated with the yield whereas the length of the primary fingers is found to be positively correlated with the yield. Comparatively longer primary fingers are found to be produced in higher yielding types such as VK1 (Chayapasupa) and VK2(Kuchupudi) whereas shorter primary fingers are found to be produced in lower yielding types such as VK16 (G.L.Puram-I), VK15 (Duggirala C11-325) and VK17 (Armoor C11-324). In plants

with the longer primary fingers, naturally more will be the production of secondary fingers and roots, and hence more will be the yield. The increase in number of fingers will also naturally increase the weight. The variation in finger characters among the types may be due to genetic factors.

1.2.7 Flowering characteristics

Out of the 19 types 15 types had flowered and types VK2 (Kuchupudi), VK8 (Armoor), VK17 (Armoor C11-324) and VK4 (G.L.Puram-II) had not flowered under Vellanikkara conditions. Flowering is noticed in all the three 'aromatica' types viz., VK14 (Dindrigam Ca-69), VK10 (Amalapuram) and VK12 (Kasturi Tamuka). Maximum flowering is noticed in the types viz., VK14 (Dindrigam Ca-69, 95.3%) and VK10 (Amalapuram, 92.7%). The flowering percentage ranged from 0 to 17.4 in 'longa' types. Flowering in tillers was noticed in the case of the two 'aromatica' types mentioned earlier. Wide variation is noticed with regard to the length of inflorescence stalk (8 to 38 cm) length of inflorescence (9.8 to 17 cm) and number of flowers per inflorescence (18 to 42) among the types.

Flowering and seed setting in turmeric had been reported by Aiyadurai (1966) and Pillai *et al.* (1975).

The variation in flowering characters may be due to genetical variation among the types. Aiyadurai (1966) opined that the climatic conditions influenced flowering to a great extent.

Not much work seems to have been done previously to study the morphological characters of turmeric types. From the morphological characters studied it was found that the Curcuma aromatica types, viz., VK10 (Amalapuram), VK14 (Dindrigam Ca-69) and VK12 (Kasturi Tamuka) were having comparatively shorter petioles, lower length, width and area of leaves. These 'aromatica' types also produced few roots, tillers and less number of slender rhizomes. They have distinct camphoraceous odour and by these characters the 'aromatica' types can be distinguished from the 'longa' types. But some of the types now recognised under C. longa are also having leaf and rhizome characters more closely related to 'aromatica' types. Perhaps they would have been evolved either by natural mutation or by natural crossing with other species of Curcuma including C.aromatica. However, it is found difficult to classify the 'longa' types based on their morphological characters although it is possible to distinguish some of them from their rhizome characters such as their length, girth and colour of the core of the

rhizomes. The height of the aerial shoots and leaf orientation also will be distinct in case of few types such as VK11 (Vontimitta), VK17 (Armoor C11-324) and VK19 (Tekurpeta).

2. Incidence of Pests and Diseases

The most important serious pest of turmeric is found to be the shoot borer Dichocrocis punctiferalis Guen. and all the turmeric types are found to be susceptible to the shoot borer attack. It is in agreement with the findings of Abraham and Pillai (1974) and Dubey et al. (1976). Highly significant variation among the turmeric types is noticed with regard to shoot borer attack. The incidence of shoot borer attack is found to be higher among the low yielding types such as VK18 (G.L.Puram-I, 84.5%), VK17 (Armoor C11-324, 75.6%), VK16 (Rajpuri, 72.6%) and VK19 (Tekurpeta, 59.9%) whereas the incidence is found to be comparatively lower among the high yielding types such as VK5 (Mannuthy Local, 18.1%), VK1 (Chayapasupa, 32.7%), VK2 (Kuchupudi, 34.9%) and VK3 (Kodur, 36.5%).

Highly significant negative correlation is noticed between the incidence of shoot borer and yield.The incidence

reduces the vegatative growth and rhizome development. Hence the yield is also reduced.

All the turmeric types are found to be susceptible to leaf diseases, viz,, 'leaf spot' (Collectotrichum capsici Butl.) and 'leaf blotch' (Taphrina maculans Butl.) and the same type is found to be infected by both. This finding does not agree with that of Reddy et al. (1963) and Rao et al. (1975) who observed that no turmeric type was susceptible to both the diseases. The present study revealed significant variation in the incidence of leaf diseases among the types. The susceptibility of both 'longa' and 'aromatica' types to 'leaf blotch' infection has been reported by Nambiar et al. (1975). Significant variation among the types with regards to the 'leaf disease' infection has been reported by Sarma and Murthy (1962), Aiyadurai (1966), Rao et al. (1975) and Subbarayudu et al. (1976).

The incidence of 'leaf spot' disease is found to be maximum in the type VK16 (Rajpuri) followed by VK12 (Kasturi Tanuka) and VK11 (Vontimitta) whereas the incidence is found to be minimum in the type VK5 (Mannuthy Local) followed by VK19 (Tekurpeta) and VK17 (Armoor Cll-324). The incidence of 'leaf blotch' disease is

found to be more severe in the types VK17 (Armoor C11-324) and VK19 (Tekurpeta) whereas in the types VK5 (Mannuthy Local), VK4 (G.L.Puram-II) and VK14 (Dindrigam Ca-69) the incidence is found to be comparatively low. The types with relatively higher incidence of 'leaf spot' disease are found to be relatively lower in the incidence of 'leaf blotch' infection except the type VK5 (Mannuthy Local) which showed minimum incidence to both.

The correlation of the yield and incidence of leaf diseases is found to be negative but not significant. The data on leaf diseases infection have revealed that the incidence of 'leaf spot' and 'leaf blotch' infection is moderate in the type VK1 (Chayapasupa) which has given the highest yield of green turmeric per hectare whereas the type VK5 (Mannuthy Local) is found to be least affected by both diseases and has given the maximum yield of dry turmeric. Leaf infection reduces the effective photosynthetic area and thereby reduces the yield. The variation in the degree of the incidence of pest and diseases among the types may be due to genetical factors.

3. Yield characters

3.1 Green turmeric

Turmeric types differed significantly with regards to the yield per plot and percentage recovery

of cured produce. Distinct differences in yield of turmeric (green and cured) among the types had been noticed by several workers (Aiyadurai, 1966; Pillai et al. 1974 & 1975; Shankaracharya, 1974; Rao et al. 1975; and Subbarayudu et al., 1976). The yield of green turmeric per hectare is found to be maximum in the type VK1 (Chayapasupa, 50086.8 kg) followed by VK3 (Kodur, 41753.5 kg), VK2 (Kuchupudi, 41371.5 kg), VK4 (G.L.Puram-II, 39166.7 kg) and VK5 (Mannuthy Local, 38173.2 kg). The yield is found to be minimum in the type VK19 (Tekurpeta, 6632 kg) followed by VK18 (G.L.Puram-I, 9687.5 kg) and VK17 (Armoor C11-324, 11510.4 kg). The higher yield in VK1 (Chayapasupa) had been reported by Pillai et al. (1974).

The variation in yield among the types may be due to genetical and morphological characters and varying degrees of incidence of pests and diseases.

3.2 Cured turmeric

Highly significant variations with regards to the percentage recovery of cured produce is noticed among the types. Desai (1939), Aiyer (1954), Sarma and Murthy (1965), Rao (1965), Aiyadurai (1966), Pillai et al. (1975), Rao et al. (1975) and Subbarayudu et al. (1976) had reported wide variation in curing

percentage among the turmeric types. The percentage recovery of cured produce is found to be significantly higher in the types VK14 (Dindrigam Ca-69, 28.17%), VK10 (Amalapuram, 27.87%) and VK5 (Manmuthy Local, 22.42%) whereas a lower recovery of cured produce is noticed in the types VK6 (Nandyal, 14.06%) and VK4 (G.L.Puram-II, 14.63%). VK1 (Chayapasupa) which produced maximum green yield, recorded only 15.84 per cent recovery. Sarma and Murthy (1960), Rao (1965), Rao *et al.* (1975), Subbarayudu *et al.* (1976) reported higher curing percentage in the type VK14 (Dindrigam Ca-69) and VK10 (Amalapuram). But the same is not in agreement with Pillai *et al.* (1975) who recorded a lower curing percentage in these types.

The gross yield of cured produce per hectare is found to be maximum in the type VK5 (Manmuthy Local, 8558.4 kg) followed by VK1 (Chayapasupa, 7933.8 kg), VK2 (Kuchupudi, 7128.3 kg), VK10 (Amalapuram, 7054.6 kg) and VK8 (Armoor, 6828.4 kg). The yield of cured produce per hectare is found to be comparatively low in the types such as VK19 (Tekurpeta, 1504.1 kg), VK18 (G.L. Puram-I, 1983 kg) and VK17 (Armoor Cll-324, 2200.8 kg).

Though VK1 (Chayapasupa), VK3 (Kodur) and VK2 (Kochupudi) ranked 1 to 3 in green yield, these types ranked second, sixth and third respectively with regards to the yield of cured produce and at the same time VK9 (Nannuthy Local) which ranked fifth in green yield produced the maximum dry produce per hectare. In the dry yield VK10 (Amalapuram) and VK8 (Armoor) ranked fourth and fifth respectively. The types with slender finger rhizome are found to produce more dry produce compared to plumpy finger rhizome which may be due to higher percentage of moisture in the plumpy rhizomes compared to the former. Since the commercial product is the cured turmeric, the out turn of cured produce is of vital importance. Hence types producing higher production of cured produce will be preferred for cultivation. The variation in percentage of cured produce among the types may be mainly due to varietal character (Sarma and Murthy, 1960; Rao, 1965; Aiyadurai, 1966 and Subbarayudu et al. (1976).

4. Qualitative Characters

4.1 Oleoresin

Turmeric types are found to differ significantly with regards to the oleoresin content. Distinct

differences in oleoresin content among the turmeric types had been reported by Lewis (1973), Krishnamurthy et al. (1972 & 1976) and Mathai (1975). The percentage recovery of oleoresin recorded in the type VK15 (Duggirala Cll-325, 21.1%) is found to be significantly superior to all the other types. This is followed by VK11 (Contimitta, 18.03%), VK4 (G.L.Puram-I, 17.36%), VK16 (Rajpuri, 17.35%) and VK5 (Mannuthy Local, 17.18%). The oleoresin content is found to be least in the type VK12 (Kasturi Tamuka, 12.1%), followed by VK1 (Chayapasupa, 12.87%) and VK14 (Dindrigam Ca-69, 13.69%). The variation in percentage recovery of oleoresin among the types is due to the genetic variation as all the turmeric types studied are being grown under the same agro-climatic conditions and subjected to the same method of processing.

The yield of oleoresin per hectare is found to be maximum in the type VK5 (Mannuthy Local, 1470.3 kg), followed by VK2 (Kuchupudi, 1033.7 kg), VK1 (Chayapasupa, 1021.1 kg) and VK8 (Armoor, 1016.7 kg), whereas the types VK19 (Tekurpeta), VK18 (G.L.Puram-I) and VK17 (Armoor Cll-324) though recorded a higher recovery of oleoresin, gave only lower yield of oleoresin per hectare as these types recorded lower yield of cured produce.

Therefore, for higher yield of oleoresin per hectare the type VK5 (Mannuthy Local), VK1 (Chayapasupa), VK2 (Kochupudi), VK8 (Armoor) and VK10 (Amalapuram) are preferred.

4.2 Curcumin

Studies on curcumin content showed significant variations among the types. Distinct differences in curcumin content in turmeric have been reported by several workers (Lewis, 1973; Mathai, 1974; Chaurasia et al., 1974; Rao et al., 1975; Krishnamurthy et al., 1976; Pillai et al., 1976; and Subbarayudu et al.,1976). The overall value of turmeric depends on the curcumin content and is more important than the volatile oil and oleoresin content. The type VK5 (Mannuthy Local) with a curcumin content of 6.55 per cent is found to be significantly superior to rest of the types and this is followed by VK15 (Duggirala C11-325, 6%), VK2 (Kuchupudi, 4.83%) and VK19 (Tekurpeta, 4.35%). The curcumin content is found to be least in the type VK9 (Duggirala, 2.33%), followed by VK10 (Amalapuram, 2.6%) and VK6 (Nandyal, 2.98%). The higher content of curcumin in VK15 (Duggirala C11-325) had been reported by Rao et al.(1975) and Subbarayudu et al.(1976).

Mathai (1974) had reported a lower content of curcumin in VK6 (Nandyal) whereas Rao *et al.* (1975) and Subbarayudu *et al.* (1976) recorded a lower content of curcumin in VK10 (Amalapuram).

The variation in curcumin content among the types may be due to genetic factors as all the types are grown under the same agro-climatic conditions.

In terms of curcumin yield per hectare VK5 (Mannuthy Local, 560.6 kg), VK2 (Kuchupudi, 344.3 kg), VK1 (Chayapasupu, 297.5 kg), VK3 (Kodur, 239.8 kg) and VK8 (Armoor, 205.5 kg) ranked maximum in the descending order.

It has been noticed that the uncured turmeric samples had significantly higher content of oleoresin and curcumin than that of the cured samples in the same type. The decrease in curcumin content in cured samples can be attributed to the leaching loss of curcumin to some extent, during the process of boiling. Turmeric can be dried properly only after it is boiled and the cells killed (Ayier, 1954) and that the boiling of turmeric rhizome is essential to reduce the drying time and to gelatinise the starch (Natarajan

and Shankaracharya, 1974). Though the uncured samples have a higher content of oleoresin and curcumin than that of cured samples, the difference is too small to compensate the higher cost involved in drying of the uncured samples. However, it is worthwhile to study the economics and the market preference of the cured and uncured produce in detail before arriving at a definite conclusion.

5. Quantity and quality variations at different periods of maturity

The studies on yield and quality variations at different periods of maturity in four turmeric types viz., VK4 (G.L.Puram-II), VK5 (Mannuthy Local), VK11 (Wontimitta) and VK17 (Armoor Cll-324) revealed significant variations in yield, percentage recovery of dry produce, oleoresin and curcumin content among the different periods of maturity. The yield of both green and dry turmeric per hectare and percentage recovery of dry produce are found to be maximum on the 270th day, followed by 255th and 240th day after planting and the least on 165th day in all the four types studied. The percentage recovery of dry produce and yield are found to increase with increase in maturity. The increase in the above factors is found

to be sharp during the period between 165 and 180 days after planting. This may be due to the rapid development of the rhizome during the period. The yield thereafter increased gradually. But the drying percentage decreased during the period from 180 to 195 days and thereafter it further increased. The increase was more pronounced during 195 to 225 days when compared to the remaining periods of maturity. The rapid development of the rhizome and higher rainfall and consequent increase in the moisture content of rhizome during the period between 180 and 195 days after planting are likely to be responsible for the decrease in the drying percentage during the period. The increase in dry matter accumulation and decrease in moisture content with the increase in maturity have contributed for further increase in percentage recovery of dry produce. Sarma and Krishnamurthy (1960) and Rao (1965) reported that the drying percentage of turmeric increased with increase in maturity but decreased with increase in moisture content of rhizomes.

Highly significant variation in oleoresin content is noticed among the different periods of maturity.

The study also revealed that the optimum maturity period varied among the types with regards to the percentage recovery of oleoresin. The recovery of oleoresin is found to be maximum on 180th day after planting in all the types except in VK11 (Vontimitta) where it is on 165th day after planting. The percentage recovery of oleoresin was found to decrease during the period between 180 and 240 days and thereafter it steadily increased and reached the maximum on 270th day at which it was on par with that on 180th day although a slight increase was noticed on 180th day of planting.

A decrease in fat and crude protein content with increase in maturity had been reported by Jogi et al. (1972) in ginger. The decrease in oleoresin content between 180 and 240 days may be due to the rapid development of rhizomes and consequent time lag in the conversion of the photosynthate into different chemical constituents of oleoresin.

The yield of oleoresin per hectare is found to be maximum on 270th day after planting and the minimum is noticed on 165th day in all the types as the yield increased when the maturity period is advanced.

The curcumin content is also found to vary significantly among the maturity periods and a similar trend as that of oleoresin is noticed. Harvesting on 270th day after planting is found to be the optimum period for getting the maximum percentage recovery and yield per hectare of curcumin in all the types studied. An increase in curcumin content is noticed during the period from 165th to 180th day after planting and thereafter a decrease was noticed upto 240th day and again an increase is noticed with the maximum on 270th day at which the curcumin content is found to be on par with that on 180th day. This is quite natural as curcumin is one of the major constituents of oleoresin. Mathai (1976) also noticed a similar trend in curcumin content at different periods of maturity.

From the yield and quality studies at different periods of maturity it is seen that harvesting of turmeric on 270th day after planting is the optimum time for getting the maximum yield of turmeric, oleoresin and curcumin in case of all the four types studied.

SUMMARY

SUMMARY

A detailed study using 19 turmeric types was conducted during the period from April 1977 to June 1978 at the College of Horticulture, Vellanikkara. The objectives were (i) to find out the possibility of distinguishing different types based on morphological parameters (ii) to screen out the types with high yield and quality (iii) to evaluate their relative susceptibility or tolerance to important pests and diseases and (iv) to evaluate the yield and quality at different periods of maturity.

1. Morphological and growth characters such as height of the plant, number of leaves per tiller and per plant, leaf characters, number and length of roots and rhizome characters of mother, primary and secondary fingers were found to differ significantly among the types. No significant variation was noticed in tiller production among the types.

2. Morphological characters such as height of plant, length and breadth of leaf, petiole length and leaf area index, number of leaves per tiller, number of roots per plant, length of roots, length of

primary fingers and girth of mother rhizomes were found to be positively correlated with the yield.

3. Fifteen types were found to flower under the Vellanikkara conditions and among the flowered types maximum flowering was noticed in the type VK14 (Dindrigam Ca.69) and the minimum in VK16(Rajpuri). Flowering was not noticed in VK2 (Kuchupudi), VK4 (G.L.Puram-II), VK8 (Armoor) and VK17 (Armoor C11-324).

4. The study revealed that morphological characters were not reliable to classify the types, although some of them could be distinguished by rhizome characters.

5. None of the types were found to be resistant to 'leaf spot' (Colletotrichum capsici) and 'leaf blotch' (Taphrina maculans) diseases, though there was significant variation in the incidence of diseases among the types. The same type was found to be affected by both diseases.

6. All the types were found to be susceptible to shoot borer (Dicherocis punctiferalis) infection. Highly significant variation was noticed in the incidence of shoot borer infection among the types and the incidence was found to be negatively correlated with yield.

7. Highly significant variation was noticed among the types with regard to the yield of green and cured turmeric. Maximum yield of green turmeric per hectare was noticed in the type VK1 (Chayapasupa, 50086.8 kg) followed by VK3 (Kodur, 41753.5 kg), VK2 (Kuchupadi, 41371.5 kg), VK4 (G.L.Puram-II, 39166.7 kg) and VK5 (Mannuthy Local, 38173.2 kg). The yield of cured produce was found to be maximum in the type VK5 (Mannuthy Local, 8558.4 kg) followed by VK1 (Chayapasupa, 7933.8 kg), VK2 (Kuchupudi, 7128.3 kg) and VK10 (Amalapuram, 7054.6 kg).

8. The percentage recovery of cured produce showed significant variation among the types. The curing percentage ranged from 14.06 to 28.17 per cent.

9. Highly significant variation was noticed among the types with regards to the percentage recovery of oleoresin and curcumin. The oleoresin content varied between 12.1 and 21.1 per cent and the variation in curcumin content was from 2.33 to 6.55 per cent. The per hectare yield of oleoresin and curcumin was maximum in the type VK5 (Mannuthy Local).

10. The uncured turmeric samples had a higher content of curcumin and oleoresin than that of cured samples.

11. The studies on yield and quality variations at different periods of maturity showed that the variation in yield, percentage recovery of dry produce, oleoresin and curcumin content were significant among the different periods of maturity. Yield of turmeric, percentage recovery of dry produce and curcumin and per hectare yield of oleoresin and curcumin were found to be maximum on 270th day after planting. The percentage recovery of oleoresin was found to be maximum on 180th day after planting and a decrease was noticed during the period between 180th and 240th day and thereafter it steadily increased and reached the maximum on 270th day at which the oleoresin content was on par with that of 180th day although a slight increase was noticed on 180th day of planting.

12. Based on the findings of the present investigation the type VK5 (Manmuthy Local), VK1

(Chayapasupa), VK2 (Kuchupudi) and VK3 (Kodur) are recommended for large scale cultivation in the plains of Kerala as these types are found to give higher dry yield of turmeric, oleoresin and curcumin per hectare. Of these VK5 (Mannuthy Local) and VK1 (Chayapasupa) are preferred because of the low incidence of pest and disease.

13. The optimum time of harvesting turmeric is found to be on 270th day after planting under Vellanikkara conditions in case of the types VK4 (S.S.Puram-II), VK5 (Mannuthy Local), VK17 (Armoor C11-324) and VK11 (Vontimitta).

REFERENCES

REFERENCES

Abraham, V.A. and Pillai, G.B. (1974). Biology and bionomics of insect pests on ginger and turmeric. Annual Report, Central Plantation Crops Research Institute, Kasaragod, pp.145.

Aiyadurai, S.G. (1966). A Review of Research on Spices and Cashew in India. Indian Council of Agricultural Research, pp.104-119.

Aiyer, T.A.K. (1954). Field Crops of India. The Bangalore Printing and publishing Co. Ltd. Bangalore, 4th Edn. pp.319-326.

Anonymous (1950). Wealth of India-Raw Materials. Council of Scientific and Industrial Research, New Delhi, Vol.II (c) pp.401-406.

Anonymous (1968). Official Analytical Methods of the American Spice Trade Association. American Spice Trade Association, INC, N.Y.07632, 2nd Ed. pp.53.

Anonymous (1974). Methods of Sampling and test for spices and condiments. Indian Standards Institution, New Delhi, IS, 1797.

Anonymous (1976). Summary of the All India Final Estimates of Principal Crops, 1975-1976. Agric. Situ. India 31 (8): 475.

Anonymous (1976). Summary of the latest All India crop estimates of turmeric, 1975-1976. Agric. Situ. India. 31 (6) : 371.

Anonymous (1977). Government of Kerala Economic Review. State Planning Board, Trivandrum, pp.77-79.

Bavappa, K.V.A. (1974). Prospects of Spice production in India. Proceedings of the Symposium on development and prospects of spice Industry in India. pp.12-15.

Chattopadhyay, S.B. (1967). Diseases of Plant Yielding Drugs Dyes and Spices. Indian Council of Agricultural Research, New Delhi.pp.100.

Chaurasia, L.O., Kulkarni, B.M., Nair, K.N.G. and Mathew, T.V. (1974). Curcumin content of Indian turmeric. Proceedings of the Symposium on development and prospects of spice Industry in India. pp.55-56.

*Desai, H.M. (1939). Scope of improvement in the technique of cultivation of some of the important garden crops under the poona conditions. Depart. Agric. Bombay Bull.182.

*Dhanlal (1944). Cultivation and curing of turmeric. The Nagpur Agricultural College magazine. 3 (4) : 45-50.

Dubey, O.P., Pillai, G.B. and Singh, V. (1975).Biology and bionomics of insect pests on ginger and turmeric. Annual Report. Central Plantation Crops Research Institute, Kasaragod, pp.154.

Dubey, O.P., Pillai, G.B. and Singh, V. (1976). Biology and bionomics of insect pests of spices. Annual Report.Central Plantation Crops Research Institute, Kasaragod. pp.173-174.

Guenther, E. (1975). The Essential Oils. Robert. E. Krieger Publishing Co., New York, Vol.V. pp.120-123.

*Jogi, B.S., Singh, I.P., Dua, H.S. and Sukhija, P.S. (1972). Change in crude fibre, fat and protein content in ginger (Zingiber officinale Rosco.) at different stages of ripening. Indian J.Agric.Sci.42 (11): 1011-1015.

Kelkar, N.C. and Rao, B.S. (1934). Essential oil from the rhizomes of Curcuma longa.L. J. Indian Inst. Sci. 17 (A) : 7-24.

Krishnamurthy, N., Mathew, A.G., Nambudiri, E.S. and Lewis, Y.S. (1972). Essential oils and oleoresins from major spices of India. Proceedings of the First National Symposium on Plantation crops.pp.181-183.

Krishnamurthy, N., Mathew, A.G., Nambudiri, E.S., Shivasankar, S., Lewis, Y.W. and Natarajan, C.P. (1976). Oil and oleoresin of turmeric. Trop. Sci. 18 (1) :37-45.

Lewis, Y.S., Krishnamurthy, N. and Nambudiri, E.S.(1974). Spice oils and oleoresins. Proceedings of the Symposium on development and prospects of spice industry in India. pp.60-62.

*Lewis, Y.S. (1973). The importance of selecting the proper variety of a spice for oil and oleoresin extraction. Proceedings of the Conference on Spices. T.P.I. London, pp. 183-185.

Mathai, C.K. (1974). Quality studies in cashew and spices. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp. 166-167.

Mathai, C.K. (1975). Quality studies in spices and cashew. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp.147.

Mathai, C.K. (1976). Quality studies in cashew and spices. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp. 166-167.

Menon, K.P.G. (1975). Indian turmeric wins world market. Indian Spices. 12 (2): 6-13.

Nambiar, K.K.N., Sarma, Y.R., and Brahma, R.N. (1977). Field reaction of turmeric types to 'leaf blotch' disease. J.Plt.Crops. 5: (2) : 120.

Natarajan, C.P. and Shankaracharya, N.B. (1974). Processing of Spices. Proceedings of the Symposium on development and prospects of spice industry in India. pp.27-28.

Parry, J.W. (1962). Spices. Chemical Publishing Co.INC, New York, Vol.2, pp.79-80.

Parry, J.W. (1969). Spices. Chemical Publishing Co.INC, New York, Vol.1, pp.220-221.

Pillai, T.P.K. (1973). Germplasm collection and screening in ginger. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp.142.

Pillai, T.P.K. and Nambiar, M.C. (1974). Germplasm collection and cataloguing of turmeric. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp.136.

Pillai, T.P.K. and Nambiar, M.C. (1975). Germplasm collection and cataloguing of turmeric. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp.138-140.

Pillai, T.P.K., Nambiar, M.C. and Ratnambal, M.J. (1976). Germplasm collection and evaluation of ginger and turmeric. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp.156-158.

Purewal Singh, S. (1957). Effect of various fertilizers in relation to spacing on development of colocasia. Indian J. Agron. 1: 245-255.

Pruthy, J.S. (1976). Spices and Condiments. National Book Trust, New Delhi, pp.223-227.

Rao, R.M., Reddy, R.K. and Subbarayudu, M. (1975). Promising turmeric types of Andhra Pradesh. Indian Spices 12 (2) : 2-5.

Rao, V.T. (1965). Curing and processing of turmeric in Andhra Pradesh with special reference to Duggirala. Spices Bull. 4 (1) : 91-95.

Reddy, S.G., Dakshinamurthy, V. and Sarma, S.S. (1963). Note on varietal resistance against leaf spot diseases in turmeric. Andhra Agric.J. 10 (9) : 146-148.

Rendle, A.B. (1971). The Classification of Flowering Plants. Cambridge University Press, London. 2nd Ed. pp, 332-337.

Rosengarten, F. (1969). The Book of Spices. Livingston Publishing Co., Pennsylvania. pp.444-452.

Sambasivarao, I. (1949). Turmeric cultivation. Madras Agric. J. XXXVI.

Sarma, S.S. and Krishnamurthy, D. (1960). Preliminary studies in the curing quality of turmeric and factors influencing the same. Andhra Agric. J. 7 (4) : 100-109.

Sarma, S.S. and Krishnamurthy, D. (1962). Varietal resistance against leaf spot disease of turmeric. Andhra Agric.J. 9 : 61.

Sarma, S.S. and Krishnamurthy, D. (1965). Type of seed rhizomes in relation to time of planting turmeric. Andhra Agric.J. 12 (3) : 84-91.

Sarma, Y.R. and Nambiar, K.K.N. (1974). Rhizome-rot of ginger and turmeric. Annual Report. Central Plantation Crops Research Institute, Kasaragod. pp. 142.

Shankaracharya, N.B. and Natarajan, C.P. (1973). Turmeric chemistry, technology and uses. Indian Spices. 10 (4) : 8-11.

Shankaracharya, N.B. and Natarajan, C.P. (1975). Technology of spices. Arecanut and spices. Bull. 2 (2) : 27-43.

Shankaracharya, N.B. (1974). Spices in India. Souvenir Publication of Symposium on spice industry in India. pp. 24-37.

Shanmugam, A. and Thamburaj, S. (1974). Association of certain quantitative characters in elephant yam (Amorphophalus campanulatus L.) South Indian Hort. 22 : 134-135.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical Methods. Oxford and IBH Publishing Co. Calcutta. India 6th Ed.

*Stockdale, F.A. (1925). Cultivation of turmeric in Ceylon. Leaf let No.34, Dept. of Agriculture, Ceylon.

Subbarayuddu, M., Reddy, R.K. and Rao, M.R. (1976). Studies on varietal performance of turmeric. Andhra Agric. J. 23 (5 & 8): 195-198

Swami, N.R.V. and Rao, K.N.(1976). Outlines of Botany. S.Viswanathan (Printers and Publishers), Pvt. Ltd., Madras-600031, 2nd Ed.pp.299-301.

* Originals not seen

APPENDIX - I

Analysis of variance

Characters	Mean square values		
	Blocks df = 3	Treatments df = 18	Error df = 54
Germination percentage	45.74	120.88	43.19
Height of plant	11.88	153.97	14.83
Number of tillers per plant	1.58	0.73	0.72
Number of leaves per tiller	2.35	1.71	0.30
Length of petiole	41.23	78.40	17.86
Length of leaf	55.36	118.07	19.55
Breadth of leaf	1.63	3.80	1.18
Leaf area index	19921.50	72172.75	13761.95
Length of mother rhizome	8.65	5.92	1.05
Length of primary finger	3.61	7.17	1.15
Length of secondary finger	0.82	4.47	0.93
Number of primary fingers per plant	0.48	2.52	0.99
Number of secondary fingers	24.56	76.56	30.71
Number of nodes of mother rhizome	4.30	4.26	1.63
Number of nodes per primary finger	1.17	2.73	0.59
Number of nodes per secondary finger	0.93	4.12	0.61

APPENDIX - II

Analysis of variance

Characters	Mean square values		
	Blocks df=3	Treatments df = 18	Error df = 54
Internodal distance of mother rhizome	0.007	0.016	0.007
Internodal distance of primary finger	0.011	0.035	0.005
Internodal distance of secondary finger	0.011	0.033	0.017
Girth of mother rhizome	5.670	13.330	1.190
Girth of primary finger	0.710	3.510	0.884
Girth of secondary finger	0.108	1.319	0.288
Number of roots per plant	609.350	1250.880	380.920
Length of root	2.254	11.357	2.174
Yield per plot	63.050	210.160	38.830
Intensity of shoot borer attack	181.760	303.050	158.470
Intensity of 'leaf blotch' disease	0.363	6.744	0.318
Intensity of 'leaf spot' disease	2.090	2.210	0.740
Curing percentage	0.224	71.070	0.210
Oleoresin content of cured samples	2.287	17.410	0.092
Oleoresin content of uncured samples	6.456	29.154	1.510
Curcumin content of cured samples	0.120	4.230	0.019
Curcumin content of uncured samples	0.113	4.475	0.021

APPENDIX - III

Analysis of variance

Quantitative and qualitative analysis of turmeric at various stages of maturity

Characters	Mean square values		
	Periods df = 7	Treatments df = 3	Error df = 21
Yield of green turmeric per plant	411.80	1846.00	118.70
Percentage recovery of dry produce	254.40	142.10	7.04
Curcumin content	4.68	39.58	1.50
Oleoresin content	179.46	18.16	32.20

MORPHOLOGICAL STUDIES
AND
QUALITY EVALUATION
OF TURMERIC (*Curcuma longa* L.) TYPES

By

JOSEPH PHILIP

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Horticulture (Plantation Crops)

COLLEGE OF HORTICULTURE

VELLANIKKARA, TRICHUR

1978

ABSTRACT

A study using 19 turmeric types was conducted during the period from April 1977 to June 1978 at the College of Horticulture, Vellanikkara with a view to find out the possibility of distinguishing different types based on morphological parameters, to screen out the types with high yield and quality, to evaluate their relative susceptibility or tolerance to important pests and diseases and to study the yield and quality variations at different periods of maturity.

The study revealed that morphological characters are not reliable to classify the turmeric types, although some of them can be distinguished by rhizome characters. The morphological characters such as the height of plant, length and breadth of leaf, leaf area index, petiole length, number of leaves per tiller, number of roots per plant, length of root, length of primary fingers and girth of mother rhizome were positively correlated with yield, whereas the intensity of shoot borer attack was negatively correlated with yield.

All the types were susceptible to the incidence of 'leaf spot', 'leaf blotch' and shoot borer infection. The type VK5 (Mannuthy Local) showed the minimum incidence of pest and diseases.

The yield of turmeric showed significant variation among the types. Maximum yield of green turmeric was noticed in the type VK1 (Chayapasupa) whereas the type VK5 (Mannuthy Local) recorded the maximum yield of cured produce.

Significant variation was noticed among the types with regards to the oleoresin and curcumin content. The oleoresin content varied between 12.1 and 21.1 per cent and the variation in curcumin content was from 2.33 to 6.55 per cent.

The uncured turmeric samples had a higher content of oleoresin and curcumin than that of cured samples.

The yield, percentage recovery of dry produce, oleoresin and curcumin varied significantly among the different periods of maturity in case of the types VK4 (G.L.Puram-II), VK5 (Mannuthy Local), VK17 (Armoor C11-324) and VK11 (Vontimitta). The dry yield, curcumin and oleoresin per hectare were maximum on 270th day whereas the maximum percentage recovery of oleoresin was on 180th and 270th day after planting.

The types VK5 (Mannuthy Local), VK1 (Chayapasupa), VK2 (Kuchupudi) and VK3 (Kodur) can be recommended for large scale cultivation in the plains of Kerala as these types are found to be superior in yield of dry produce, oleoresin and curcumin per hectare. Of these VK5 (Mannuthy Local) and VK1 (Chayapasupa) are preferred because of the low incidence of pest and diseases.

The optimum time of harvesting turmeric is found to be on 270th day after planting under Vellanikkara conditions.