COLLECTION AND EVALUATION OF WAYANAD TURMERIC (*Curcuma longa* L.) FOR YIELD AND QUALITY

by

ANU T S

(2017-12-022)

DEPARTMENT OF PLANTATION CROPS AND SPICES

COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680656
KERALA, INDIA

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THESIS

Submitted in partial fulfillment of the
requirements for the degree of

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Kerala Agricultural University

DEPARTMENT OF PLANTATION CROPS AND SPICES

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KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"COLLECTION AND EVALUATION OF WAYANAD TURMERIC (*Curcuma longa* L.) FOR YIELD AND QUALITY"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara, **ANU T S**

Date: 22.11.2019 (2017-12-022)

CERTIFICATE

Certified that this thesis entitled **"COLLECTION AND EVALUATION OF WAYANAD TURMERIC (*Curcuma longa* L.) FOR YIELD AND QUALITY"** is a record of research work done independently by **Ms. ANU T S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellanikkara,
Date: 22.11.2019

Dr. Jalaja S. Menon
(Major Advisor, Advisory Committee)
Assistant Professor and Head i/c,
Cashew Research Station,
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<u>CERTIFICATE</u>

We, the undersigned members of the advisory committee of **Ms. ANU T S** (2017-12-022), a candidate for the degree of Master of Science in Horticulture, with major field in Plantation Crops and Spices, agree that this thesis entitled **"COLLECTION AND EVALUATION OF WAYANAD TURMERIC (*Curcuma longa* L.) FOR YIELD AND QUALITY"** may be submitted by Ms. ANU T S,in partial fulfillment of the requirement for the degree.

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ANU T S

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LIST OF ABBREVATIONS AND SYMBOLS USED

Symbols	**Abbreviations**
%	Per cent
>	Greater than
^{0}C	Degree Celsius
^{0}	Degree
A_{425}	Absorbance at 425 nm
cm	Centimeter
DAP	Days after planting
et al.	And other co workers
g	Gram
ha	Hectare
kg	Kilo gram
m^2	Meter square
mg	Milli gram
ml	Milli litre
PDI	Percent Disease index
P.O.	Post Office
Sf	*Spodoptera frugiperda*
t ha^{-1}	Tonnes per hectare

Introduction

1. INTRODUCTION

Turmeric is an important sacred rhizomatous spice of India. People in Vedic period regarded turmeric as ‘Herb of Sun’ due to the orange yellow colour of the rhizome. Scientifically turmeric is known as *Curcuma longa* belonging to the ginger family- Zingiberaceae.

India is the leading producer, consumer and exporter of turmeric in the world (Chaudhary *et al*., 2006). Turmeric is native to South East Asia and cultivated in India, China, Sri Lanka, Pakistan, Indonesia *etc*. In India, the crop is cultivated in Andhra Pradesh, Tamil Nadu, Assam, Karnataka, Kerala and North Eastern region.

Economically important *Curcuma* species include *C. longa*, *C. angustifolia*, *C.montana*, *C. decipiens*, *C. alismatifolia*, *C. thorelii*, *C. comosa*. Among these, *C. longa* is studied widely for its therapeutic activity (Sasikumar, 2005). Wide range of therapeutic activity of turmeric is due to the presence of a bioactive ingredient called curcumin. Current research concentrates on the effect of curcuminoides on neuroprotective, antitumor, antioxidant, anticancer, antiinflammatory, anti-acidogenic, radioprotective, anti-nephrotoxicity, antimicrobial, antiviral, anti-proliferative, antiimmunomodulatory, hepatoprotectivity, antimalarial, anticytotoxicity, and anti-diabetic properties.

India is the home to various cultivar and species diversity of about 40 *Curcuma* species. But *Curcuma longa* is the commercially exploited species for curcumin extraction. There exist a wide variability in rhizome characters yield and biochemical componens of turmeric. Most of the indigenous cultivars in India are known by their locality name like Duggirala, Tekkurpet, Amalapuram, Erode local, Salem, Alleppey, Moovattupuzha, Thodupuzha, Wynad local and Lakdong. Some of them are reported to have high curcumin content of more than seven per cent. Indian Institute of Spice Research Calicut has released improved turmeric varieties viz. IISR Pragati, IISR Kedaram, IISR Prathibha, IISR Prabha, IISR Suguna, IISR Sudharsana and IISR Allepey Supreme. Kerala Agricultural University has released 4 varieties namely Sona, Sobha, Kanthi and Varna.

Wayanad district contributes substantial foreign exchange through crops like coffee, pepper, cardamom, tea, ginger and turmeric (Sharma and Pankaj, 2008). Wayanad is home to various tribal groups and turmeric is cultivated from time immemorable. Wayanad turmeric is reported to have 9.4 per cent curcumin content.

Due to the advent of improved varieties, the age old traditional cultivar of Wayanad is now eroding. It is important to conserve the traditional cultivars of Wayanad district. Hence it is essential to characterize and evaluate Wayanad local turmeric accessions for its yield and quality.

Keeping in view of above information, the study entitled "Collection and evaluation of Wayanad turmeric (*Curcuma longa*. L) for yield and quality" was conducted.

Review of Literature

2. REVIEW OF LITERATURE

Introduction

Turmeric belongs to the family Zingiberaceae mainly for production of curcumin, oleoresin and essential oil, used in pharmaceuticals and cosmetics (Ayer, 2017). It is a perennial or annual (Kaliyadasa *et al*., 2019), cultivated in India, Pakistan, China, Haiti (Bejar, 2018). Turmeric (*Curcuma longa*) is a crop which produces many secondary metabolites with wide range of biological functions, helpful to humans (Duraisankar and Ravindran, 2015). Taxonomy of turmeric is as follows:

Kingdom : Plantae

Subkingdom : Tracheobionta

Super division : Spermatophyta

Division : Magnoliophyta

Class : Liliopsida

Subclass : Zingiberide

Order : Zingiberals

Family : Zingiberaceae

Genus : *Curcuma*

Species : *longa*

Importance of Wayanad turmeric

Wayanad district is nestled in Western Ghats which lies at a height of 700-2100 metres above sea level. Although a backward district, substantial foreign exchange is earned for the country through cash crops like pepper, cardamom, coffee, ginger and turmeric. Principle occupation of people is agriculture. Wayanad is the homeland of different tribal communities and 17.7 per cent of the total population is comprises of tribal group (Sharma and Pankaj, 2008). Mullukurumas, Uralikurumans, Kurichians, Adiyans, Kattunaickans, Paniyans and Kurumans are some of the dominant tribal communities in Wayanad. Mananthavady, SulthanBathery, and Vythiri are the three taluks of Wayanad consisting of a population of 8,16,558, constituting 2.45 per cent of the state's population (Dileep and Nair, 2015).

Prasad and Shyama (2013) documented the medicinal plants used by tribes in Vythiri taluk of Wayanad district for the treatment of human and domestic animal ailments. Tribal peoples of Kurichia, Kattunaika and Paniya apply leaf paste of neem mixed turmeric on the udder to prevent mastitis. Kurichia and Kattunaika uses leaves of *Coccinia grandis* grounded with turmeric which is applied on cheek to relieve tooth ache. Another practice of Kurichia tribe is the application of leaf paste of *Plectranthus wightii* with turmeric for wound healing. Kurichia, Paniya and Kuruma practices the application of grounded leaf of guava and turmeric to cure abdominal pain.

Shyma and Prasad (2012) documented the traditional use of medicinal plants used by the tribes in Manathavady tribe of Wayanad district. Kurichya tribe residing in Manathavady taluk grinds the leaves of ulukkuvetty and pachamanjal together and applies on the affected part to reduce swelling.

Marjana *et al.*, 2018 studied the ethnomedicinal flowering plants used by Kurumas, Kurichiyas and Paniyas of Wayanad district. Paniya tribe applies leaves of *Chromolaena odorata* and turmeric for skin diseases. Three tribes use turmeric rhizome paste and *Phyllanthus amarus* plant extract mixture is used for skin disease and jaundice.

Traditional healers of Kani tribe uses coconut oil and turmeric for preparation of paste or medicated oil (Xavier *et al.*, 2014). Pramod *et al*. (2003) surveyed the ethnobotany religious and supernatural beliefs of Kurichiya tribe in Wayanad district. Gurusi, an analogue of blood to drive away evil spirit is prepared from fresh turmeric paste and quick lime. Dried and ground rhizome is taken for magical divining technique called 'Ariyittunokkal' or counting of rice.

Peter (2001) reported that local cultivars like Allepy, Wynad local, Lakadong, Edapalayam, Thodupuzha has curcumin content more than 7 per cent. Ratnambal *et al*., 1986 evaluated hundred turmeric accessions for quality. Cultivar diversity of Wayanad turmeric for quality parameter varied for dry recovery (20 %), oleoresin (15.3 %), oil (7.0 %), curcumin (9.4 %).

Performance in various agro ecological situations

Geetanjali *et al*. (2016) reported that the curcumin content varies from sample to sample, geographical variations, soil, climate, method of cultivation, rainfall.

Genetic variation occurs in *Curcuma longa* due to the environmental conditions within the distribution area and this variations can be utilized for better management strategies and crop improvement (Ashraf *et al*., 2017). Sandeep *et al*. (2016) revealed that most sensitive factor for curcumin were altitude, pH, nitrogen and potassium.

Singh *et al*. (2014) studied the association of growth and yield parameters with phytoconstituents of turmeric genotypes. Accession collected from North Eastern Ghat Zone yielded highest oil of 2.5 per cent and accession from Eastern Ghat Zone yielded highest curcumin (8.8 %) and oleoresin (15 %).

Sigrist *et al*. (2011) studied the genetic diversity of turmeric germplasm using microsatellite in Brazil. Thirty nine accessions were collected from states of Goiás, Mato Grosso do Sul, Minas Gerais, São Paulo and Pará. Maximum genetic diversity was obtained within the state of Brazil (São Paulo) which can be utilised for further crop improvement.

According to Sharma *et al*. (2015) wide range of variation was obtained in weight of rhizome (152.33 – 250.66 g plant $^{-1}$), number of leaves (8.26 – 13.31) and curcumin content (3.43 – 7.16 %) and suggested that these characters could provide chance of selection for further improvement. Singh *et al*., 2015 opined that the essential oil composition varies due to geographic orgin, genetic material, and method of extraction.

Salimath *et al*. (2014) evaluated turmeric cultivars for growth and yield in Southern dry zone of Karnataka. Highest rhizome yield was attributed to the maximum plant height, number of tillers and leaves, weight of secondary rhizome, mother rhizome, number of leaves per plant, plant height and leaf width.

Singh *et al*. (2013) studied the desired drug yielding trait of turmeric genotypes. Sixty turmeric genotypes were collected from 10 different agroclimatic zones and the rhizomes were analysed for curcumin, oleoresin and essential oil. They also opined that the desired drug yielding qualitative traits of turmeric include curcumin > 5%, Oleoresin > 9 %, rhizome oil > 0.8 % and leaf oil > 0.8 % on fresh basis.

Released varieties in Kerala

Indian Institute of Spice Research and Kerala Agricultural University released 8 and 4 varieties respectively. IISR Pragati, IISR, Allepey Supreme, Prabha, Pratibha, Suvarna, IISR Kedaram, Suguna and Sudarshana are the varieties released by IISR. Kerala Agricultural University has released Sona, Sobha, Kanthi and Varna.

Short duration varieties are Suguna (190 days), Sudharsana (190 days), Prathibha (188 days) and Pragati (180 days). Among the 12 varietues released, IISR Alleppey Supreme, Kedaram are tolerant to leaf blotch disease while Sona and Varna are field tolerant to leaf blotch. Suguna and Sudarshana are field tolerant to rhizome rot.

Fresh rhizome per hectare was highest in Prathibha (39.1 t ha^{-1}) followed by Pragati (38.0 t ha-^{1}), Kanthi (37.7 t ha-^{1}) and Prabha (37.5 t ha^{-1}). Suvarna and Kanthi have dry recovery of 20 and 20.2 per cent.

Highest curcumin content was obtained in Varna (7.9 %) followed by Sobha (7.4%), Suguna (7.3 %), Kanthi (7.2 %) and Sona (7.1 %). Suvarna and Sudharsana have an oil content 7 per cent. Highest oleoresin content was recorded in Pratibha (16.2 %).

Evaluation of turmeric accessions

Morphological observations

Sasikumar, 2005 described the important discriminative characters of *Curcuma spp* like plant type (erect or semi erect), leaf sheath colour (green), leaf vein (close or distant), leaf pubescence on dorsal and ventral side (glaborous or hairy) and leaf mid rib colour (green, light purple green). Nambiar (1979) suggested that to get higher yield, plant height can be used as a single morphological character for selection.

Vimal *et al*. (2018) observed maximum phenotypic and genotypic variability in plant height, number of tillers and plant girth. Plant height, number of tillers and number of leaves showed positive association with yield (Rajyalakshmi *et al*., 2013).

Vinodhini *et al*. (2018) also observed high genotypic and phenotypic variation was observed in traits like pseudostem girth, number of tillers, petiole length, number of mother, primary and secondary rhizome, length and girth of primary and oleoresin.

Both leaf length and width are significantly correlated with tuber length and plant length (Mishra *et al*., 2015). Plant height, number of leaves per plant and leaf length has positive direct effect on the wet rhizome (Prajapati *et al*., 2014).

Vijayan (2015) studied the genotypic and phenotypic correlation of plant height showed positive correlation with fresh rhizome yield per plant, plant height, number of tillers and number of leaves.

Rhizome characters

Seed rhizomes containing larger amount of reserves, resulted in larger seedling growth and taller plant (Padmadevi *et al.*, 2012). Angami *et al.*, 2017 revealed that 50 -60 g mother rhizome gave maximum plant height (122.33 cm), number of leaves (7.33), leaf length (62.79 cm), fresh rhizome yield (24.58 t ha^{-1}) and dry rhizome yield (4.79 t ha^{-1}).

Venugopal and Pariari (2017) also obtained high genetic variance in plant height (65.88 cm), yield per plot (4.09 kg $plot^{-1}$), number of leaves per plant (3.48) and curcumin content (2.54 %).

Chandra *et al*. (1997) obtained maximum range of the variability in plant height (62.9-127.3), rhizome yield per clump (121.6-329.8 g), weight of the primary rhizome (10.3-35.5 g) and weight of the mother rhizome (31.3-55.1g). Bahadur *et al.*, 2016 also added that weight of secondary rhizomes per plant, length of primary rhizome, days of maturity and number of leaves has positive effect on rhizome yield which also contribute to the improvementof rhizome yield.

Roy *et al*. (2011) observed positive significant linkage between number of rhizomes with leaf width. He also found between positive relation with plant height, leaf length, primary rhizome diameter.

Chakraborty *et al*. (2017) evaluated turmeric genotypes in terai region of West Bengal. Turmeric genotypes obtained high mean value for number of tillers per plant (3.27), leaf length (60.41cm), leaf breadth (15.06cm), rhizome yield per plot (18.09

kg per plot) and projected yield per plot (36.53 t ha^{-1}), curcumin content (5.3 %), Oleoresin (12.33 %).

Highly significant positive correlation was exihibited for rhizome yield with fresh rhizome weight per plant, mother rhizome weight, number of primary rhizomes per plant, primary rhizome and dry matter content (Verma *et al*., 2015).

Sinkar *et al.* (2005) reported that leaf length (20.38), leaf breadth (14.17) and plant height (13.75) showed maximum genotypic and phenotypic variation. Aarthi *et al*. (2018) studied the variability of curcumin content with yield components in turmeric. From the experiment it is understood that the increase in weight of mother and primary rhizome, number of secondary and curcumin content contributed to the increase in fresh rhizome yield. Rhizome mass showed significant correlation with curcumin content and essential oil (Rai *et al*., 2016).

Jan *et al*. (2012) studied the variability in turmeric germplasm using agro – morphological traits and identified variability in rhizome and leaf colour in samples collected from three districts Bannu, Haripur and Kasur district. Samples collected from Bannu and Haripur were yellow and Kasur area was dark orange. Interestingly leaf colour also varied from light green in Bannu and Haripur district to dark green in Kasur area. Syahid and Heryanto (2017) characterized 12 accessions of white turmeric and found variations in rhizome colour. They observed yellow coloured rhizomes.

Singh *et al*. (2003) observed maximum variability in yield (122.5 – 323.18 q/ha) followed by weight of mother rhizome per plant (40.50 – 181.39 g), plant height (74.10 – 141.37 cm), weight of primary rhizome per plant (10.31 – 55.57 g) and leaf number (9.93 – 30.23).

Vijayalatha and Chezhiyan (2008) assessed the turmeric accession at molecular level and morphological traits for degree of divergence. From the clusters, thirty accession were selected and the highest contributors to total divergence were yield (65.65 %), weight of primary rhizomes (10.46 %) and weight of secondary rhizome (7.77 %).

Luiram *et al*. (2018) studied the genetic variability in turmeric genotypes of North Eastern region and observed variability in traits like weight of mother, primary and secondary rhizome per plant, fresh yield per plant, number of leaves per hill, number of primary rhizome and curcumin content.

Nandkangre *et al*. (2016) characterized ginger land races by morphometric and agronomic characterization. Characters showed significant difference in number of leaves, leaf length, plant height, rhizome length, rhizome width and rhizome yield and rhizome weight per plant showed high coefficient of variation.

Vamshi *et al*. (2019) studied the yield and quality of turmeric genotypes under high altitude and tribal zone of Andhra Pradesh. Crop yield mainly depends on the vigour of the plant which is indicated by plant height, number of leaves and rhizome characters and yield can be influenced by genetic and environmental factors. Singh *et al*. (2018) reported dry matter recovery has positive correlation with weight of mother rhizome, number of primary and secondary rhizome.

Kotikal and Kulkarni (2000) reported the incidence of shoot borer (*Conogethes punctiferalis*), Leaf beetles (*Lema* spp), Leaf roller (*Udaspes folus*) in turmeric during the survey conducted in Northern Karnataka.attack. Series of rows of holes on the leaf and dead heart are the typical symptoms of shoot borer and leaf roller rolls the leaf. Kalaichelvan *et al*., 2002 reported Lema beetle has bluish black elytra with fulvous legs.

Rao *et al*. (2005) studied the genetic divergence of turmeric germplasm collections. On the basis of cluster analysis, genotypes were group into different clusters and each clusters were grouped on the basis of curcumin content and cured yield.

Biochemical observations

Based on the locations, two types of turmeric are present in India, Allepey and Madras turmeric. Allepy turmeric consist of 3.5 – 5.5 per cent oil and 4.0-7.0 per cent curcumin while Madras turmeric has 2 per cent oil and curcumin (Pawar *et al*., 2014).

Hailemichael *et al*. (2016) studied the effect of stages of maturity on the quality of different turmeric accessions. Turmeric harvested from 7 – 8 months showed higher essential oil and oleoresin and obtained 5.13 and 11.45 per cent respectively. Number of days from planting to harvest was varied from 212 to 240 (Dodamani, 2017).

Madhusankha *et al*. (2018) analysed the curcumin content and colour of Sri Lankan and Indian turmeric rhizomes. A remarkable variation of curcumin content was observed in both types of turmeric ranging from 3.76 – 5.05 per cent. Samples also showed visual colour difference from bright to orange yellowish colour.

Deb and Chakraborty (2017) evaluated the genetic variability and characterized the turmeric genotypes in Terai region in India. Turmeric genotypes were characterized based on rhizome length (11.4-6.4 cm), number of mother rhizomes (1.0-2.3), internode pattern (0.8-2.0 cm), per plot yield (7.2-13.8 kg/3m^2) and projected yield (19.2-36.9 t ha^{-1}).

Principal component analysis Bahadur and Meena (2016) revealed five major principal components which accounted for 89.33 per cent for total variation. Out of total variation, 39.75 per cent was accounted for first principle component (PC1) which includes days of sprouting, plant height, number of leaves, number of tillers, length of primary rhizome, dry matter recovery and rhizome yield.

Bahl *et al*. (2014) opined that number of leaves are the indication of vigour of turmeric plant. Patil *et al*. (2016) reported the essential oil per cent in turmeric ranges from 1.00 to 7.23 per cent. They also stated that genetic make up may attribute to the variability of essential oil. Pothitirat and Gritsanapan (2006) studied the variation of biocactive components of turmeric in Thailand. Total curcuminoid content obtained in the samples ranged from 3.07 ± 0.09to 9.58 ± 0.020 per cent. Leela *et al*. (2002); Devkota and Rajbhandari (2015) reported that the essential oil content in the rhizome was 3.8 per cent.

Seghal *et al*. (2016) obtained rhizome oil ranging between 2.09 – 2.50 per cent. Raina *et al.* (2005) isolated 0.8 per cent oil from rhizome from fresh basis. Chowdhary *et al*. (2006) studied the basic constituents in yellow and red type turmeric in Bangladesh. Oil content in yellow type and red type are 1.1 and 0.8 per cent respectively and also affirmed that the variation in cultivars may be due to the different chemotypes.

Pharmacological applications of turmeric

Turmeric is widely used in textiles, pharmaceuticals and in Hindu ceremonies and its application in current traditional Indian medicines include biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism, and sinusitis (Yadav and Tarun, 2017). Extended research on turmeric is due to the presence of curcumin in the rhizomes. Other applications of turmeric include cancer, diabetes mellitus, hepatoprotective, nephroprotective, anticoagulant and anti-HIV (Nasri *et al*., 2014).

Gupta (2013) reported that turmeric paste can be applied on the skin to improve the skin appearance and fades the blemishes. Nookola *et al*. (2015) studied the effect of dietary curcumin on hepatic steatosis and histopathology in obese mouse. The study revealed that curcumin improved the liver health by reducing percentage hepatic fat and improved the cytokine and inflammatory value.

Sethuraman *et al*. (2017) studied the autophagic cell death in *Spodoptera frugiperda* cells. The study proved that curcumin inhibited the growth of *Sf*9 cells by inducing autophagic cell death in time and dose dependent manner. The study shows the cytotoxic effects of curcumin in insect cells and the future utilization of curcumin as natural pesticide.

Methanolic extract of the significant inhibitory actions against *Escherichia coli*, *Streptococcus*, *Staphylococcus*, *Bacillus cereus*, *Micrococcus*, *Pseudomonas*, *Aspergillus* and *Penicillium* at a 20 mg ml^{-1} (Ikpeama, 2014).

Singh *et al*. (2010) compared the chemical composition and antioxidant activity in fresh and dry rhizomes. Fresh rhizomes showed more antioxidant activity and might be due to the presence of alpha and beta turmerone. Other medicinal values of turmeric include anti-venom, anti coagulant, smooth muscle relaxant, anti tubercular, anti ulcerogenic (Kanase and Khan, 2018).

Due to low toxicity, curcumin can be given in large quantity without fear of toxicity (Bhat *et al*., 2015). Safety evaluation in turmeric shows that it can be tolerated in high dose and curcumin has a potential to be developed as drug (Chattopadhya *et al*., 2004).

Materials and Methods

3. MATERIALS AND METHODS

Plant material

Seed rhizomes were collected from three taluks of Wayanad district namely Mananthavady, Vythiri and Sulthan bathery through mass media publicity. Twenty six accessions were collected from different turmeric cultivating farmers. Seventeen genotypes were selected on the basis of availability of planting material. The details of turmeric accessions are as follows:

Table No. 3.1 Details of selected Wayanad turmeric accessions.

Sl.No.	Accession No.	Place of collection
1.	WCL 3	P.P.Jose, Paraikkal (H) Pothuketty, Kumbalerry Ambalavayal
2.	WCL 5	T.G. Vasudevan Thonikkadavu, Cheengeri, Kalathuvayal
3.	WCL 8	Gangadharan, Puthiyoni, Kidangodu Sulthanbathery
4.	WCL 9	Viswanathan Sulthanbathery
5.	WCL 13	N.K. Babu, Nellara (H), Nellarachal P.O. Ambalavayal
6.	WCL 14	C.C. Kannaran Vengoor colony Krishnagiri P.O. Meenangadi

7.	WCL 15	Anilkumar P.U. Pokkadu (H), Madakkimala, Kumbalangadu
8.	WCL 16	Mathew Panaddan, Panadan, Edappatty Edappatty,Meenangadi
9.	WCL 17	K.V. Kelu, Vasdakkeveedu, Madakkunnu P.O. Vythiri,Kalpetta
10.	WCL 19	A.Balakrishnan, Ambilinilayam, Kammommum P.O. Mananthavady
11.	WCL 20	Manoj Kumar, Maranattil (H), Kaniyambetta P.O. Kappumkunnu
12.	WCL 21	Chandran, Nittammani Colony Muthiramala, Mananthavady
13.	WCL 22	K.M.Thomas Kalangara (H) Kalathuvayal P . O. Ambalavayal

P.P. Jose (Pothuketty)

T.G. Vasudevan (Chengeri)

Balakrishnan. A (Mananthavady)

Chandran (Muthiramala)

Plate 1: Collection of seed material

14.	WCL 23	M.Sujata Kottanadu P O Meppady
15.	WCL 24	RARS, Ambalavayal
16.	WCL 25	Pramod C.S. Chemmukkil (H) Nellarachal P.O. Ambalavayal
17.	WCL 26	Prakashan, Ambalavayal

METHODS

Designs and Layout

Treatments : Wayanad turmeric collections – 17

Check - Sona (KAU), Prathibha (IISR), Kanthi (KAU)

Replications : Three

Design : Randomized Block Design

Size of Plot : 3 sq.m

Planting season : April – May

Planting

Accessions were planted in the farm of Department of Plantation crops and Spices during May 2018 to January 2019. Healthy, disease free rhizome bits are taken as planting material. Beds of 3 sq.m were taken in the inter space of coconut in randomized block design with 3 replications. The layout of the experiment is given in fig 1.

Light Intensity

Light intensity in the experimental plot was observed at monthly interval and the percentage shade level was calculated as follows

$$\text{Shade percentage} = \frac{\text{Light intensity (open field)} - \text{Light intensity (inside the field)}}{\text{Light intensity (open field)}} \times 100$$

Table No. 3.2 Percentage shade level of the field

Month	Average light intensity in the plot (lx)	Light intensity in the open field (lx)	Percentage shade level (%)
May	1980	4565.2	56.62
June	1954.2	4203.9	53.51
July	1932.6	4167.8	53.63
August	1954	4109.2	52.44
September	1970.5	4298.3	54.15
October	1970	4295.8	54.14
November	1959	4325.8	54.71
December	1939.2	4322.5	55.13
Average shade percentage			54.29

Plate 2: Field preparation and sowing

Plate 3: Field View

Replication I			Replication II – III			Replication III	
T 1	T 7	T 15	T 6	T 10	T 17	T 6	T 13
T 2	T 8	T 16	T 7	T 11	T 18	T 7	T 14
T 3	T 9	T 17	T 8	T 12	T 19	T 8	T 15
X	T 10	X	T 9	X	T 20	X	T 16
T 4	T 11	T 18	T 5	T 13	T 1	T 9	T 17
T 5	T 12	T 19	T 4	T 14	T 2	T 10	T 18
T 6	T 13	T 20	T 3	T 15	T 3	T 11	T 19
X	T 14	X	T 2	X	T 4	X	T 20
			T 1	T 16	T 5	T 12	

X : Coconut Palms

T1 : Sona	**T2: Prathibha**	**T3: Kanthi**	**T4: WCL 3**	**T5: WCL 5**
T6: WCL 8	**T7: WCL 9**	**T8 : WCL 13**	**T9: WCL 14**	**T10: WCL 15**
T11: WCL 16	**T12: WCL 17**	**T13: WCL 19**	**T14: WCL 20**	**T15 : WCL 21**
T16: WCL 22	**T17: WCL 23**	**T18: WCL 24**	**T19: WCL 25**	**T20: WCL 26**

Fig 1 : Layout of the experiment

OBSERVATIONS

Obsevations were taken as per the NBPGR minimal descriptor for turmeric. Morphological observations on plant were taken at the full expression time and the rhizomes characters were taken after harvest and curing.

Morphological observation at 150 DAP

Morphological observations on plant, leaf and stem were taken during full expression time ie, at 150 DAP. All the observations are made on the main shoot or the pseudostem.

Qualitative characters

Pseudostem colour

Pseudostem colour was recorded at full foliage stage and was visually assessed in the pseudostem as

a. Green
b. Light pink
c. Others

Leaf orientation

Leaf orientation was determined by taking the angle of the leaf plain with the shoot axis. The leaf orientation was assessed as

a. Erect (less than 45^0)
b. Semi erect ($45^0 – 85^0$)
c. Horizontal (more than 85^0).

Leaf shape

Shape of the leaf was recorded at the full foliage stage and was determined as

a. Elliptic – oblong
b. Oblong
c. Others

Leaf base shape

Leaf base shape was recorded at full foliage as

a. Obtuse-cuneate
b. Others

Leaf tip

Leaf tip was recorded at the full foliage and recorded as

a. Accuminate - cuadate
b. Others

Leaf midrib colour

Colour of the leaf midrib was observed at full foliage stage .

Pubescence on leaves

Pubesence of the leaf was observed at full foliage.

a. Glabrous
b. Others

Colour of leaf on dorsal side

Leaf Colour on dorsal side was observed at full foliage and determined as green, light green and dark green.

a. Light green
b. Green
c. Dark green

Colour of leaf on ventral side

Leaf Colour on ventral side was observed at full foliage stage and taken as

a. Green
b. Dark green

Venation pattern

Venation pattern was determined by visually assessing the width of two adjacent parallel veins and categorized into

a. Close
b. Distant

Leaf margin

Leaf margin was assessed visually and was categorized into

a. Even
b. Wavy

Quantitative characters

Height of main tiller (cm)

Height of the main tiller is recorded from soil level to the tip of the leaf of the main shoot and the mean height of the main tiller was expressed in cm.

Girth of main tiller (cm)

Girth of the main tiller is recorded and expressed in cm.

Number of leaves on main tiller

Number of leaves on the main shoot was counted from each replication.

Number of tillers per clump

Number of tillers in each clump was counted from each replication.

Petiole length

Length of petiole was determined by measuring from the base of the leaf and was expressed in cm.

Length of leaf

Length of the leaf was taken from the tip of the petiole to the leaf blade tip from leaves of the main shoot and was expressed in cm.

Width of leaf

Maximum width of the leaf was taken from the leaf of main shoot and was expressed in cm.

Rhizome characters

Rhizome characters were taken after harvest and curing.

Qualitative characters

Branching of rhizome

Branching of rhizome was visually assessed on the fresh rhizome and categorized into

a. Horizontal
b. Curved
c. Intermediate

Rhizome nature

Rhizome nature was visually assessed on the fresh rhizome and was categorized into

a. Slender
b. Plumpy
c. Others

Rhizome habit

Rhizome habit was visually assessed on the fresh rhizome and was categorized into

a. Compact
b. Intermediate
c. Loose.

Rhizome inner core colour

Rhizome inner core colour was visually assessed by using colour chart on the fresh rhizome and was categorized

a. Orange
b. Yellow
c. Light Yellow
d. Reddish Yellow

e. Lemon Yellow
f. Greenish yellow
g. Bluish yellow
h. Whitish yellow
i. Others

Status of tertiary rhizome

Status of teritiary rhizome was visually assessed by the presence or absence of tertiary rhizome.

a. Absent
b. Present

Type of roots

Type of roots are visually assessed and categorized into

a. Tuberous
b. Non tuberous roots.

Incidence of pests and diseases

Incidence of pest and disease is determined by the presence or absence of disease on the plant through visual assessement.

Quantitative characters

Rhizome internode pattern

Rhizome internode pattern was determined by measuring the distance between two adjacent internodes and expressed in cm.

Length of primary rhizome

Maximum length of primary rhizome was determined by measuring the attachment of mother rhizome to the tip and expressed in cm.

Width of primary rhizome

Maximum width of the primary rhizome was determined using screw guage and expressed as cm.

Number of mother rhizome

Number of mother rhizome was determined by counting the mother rhizome in the fresh clump.

Number of primary rhizome

Number of primary rhizome was determined by counting the primary rhizome in the fresh clump.

Number of secondary rhizome

Number of secondary rhizome was determined by counting the secondary rhizomes in the fresh clump.

Weight of mother rhizome

Weight of the mother rhizome was determined by weighing the mother rhizome and was expressed in gram (g).

Weight of primary rhizome(g)

Weight of primary rhizome was determined by weighing a primary rhizome and was expressed in gram (g).

Weight of secondary rhizome

Weight of secondary rhizome was determined by weighing a secondary rhizome and was expressed in gram (g).

Fresh yield per plant (g plant^{-1})

Fresh yield per plant was determined by weighing a clump and was expressed in gram per plant (g plant $^{-1}$).

Dry yield per plant (g plant^{-1})

Rhizomes after harvest was washed and cleaned and then dried under sun. Then the rhizomes are kept in hot air oven at 70^0C. The dry weight was taken and was expressed in gram per plant (g plant $^{-1}$).

Fresh yield per plot (kg plot^{-1})

Fresh yield from each plot was recorded and was expressed in kilogram per plot (kg plot^{-1})

Dry yield per plot (kg plot^{-1})

Rhizomes were harvested and washed, then dried under sun. Then then rhizomes were kept under the hot air oven at 70^{0}C. The dry weight was expressed in kilogram per plot (kg plot^{-1}).

Curing per cent

Fresh rhizomes were taken and boiled in water for 40 minutes till it started to frothing with white fumes and gives a typical odor. Cured rhizomes were dried in hot air oven at 58 – 60^{0}C for 4 – 5 days.

Biochemical studies

Curcumin content (%)

0.5 g moisture free turmeric sample is taken in a volumetric flask and dissolve it in 250 ml absolute ethanol. The flask was fitted with air condenser and refluxed over a heating mantle for 3 – 5 hours. The cooled extract was then decanted into a volumetric flask and volume was again made up. One to two ml of the aliquot was diluted to 10 ml with absolute alcohol. The intensity of yellow colour was measured in spectrophotometer at 425 nm (Sadasivam and Manickam, 2002). Curcumin content was calculated as

$$\text{Curcumin content} = \frac{A_{425} \text{ x } 0.0025 \text{ x volume made up x dilution factor x } 100}{0.42 \text{ x weight of the sample (g) x } 1000}$$

Oleoresin content (%)

Oleoresin was extracted by Soxhlet extraction method. Oven dried turmeric powder was taken in a thimble and kept in soxhlet extractor. Two fifty milli litre acetone was added in the flask and extraction apparatus was assembled. Extraction was carried out in water bath until the solvent becomes colourless and the extract was transferred to a beaker carefully. The extract was desolvated and weight was recorded (Singh *et al*., 2013). The percentage oleoresin was calculated as

$$\text{Oleoresin (\%)} = \frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \text{ x } 100$$

Essential oil (%)

Turmeric powder (30 g) is taken in a round bottom flask and flask is fitted with Clevenger apparatus for essential oil extraction. The apparatus was kept on a thermostatically controlled heating mantle and the temperature was maintained at 90^0C till boiling and then kept at 70^0C for 3 hours for distillation. Distillation was cooled to room temperature and oil is allowed to settle till a clean layer is formed (ASTA, 1968b). Oil content was measured as

$$\text{Essential oil (\%)} = \frac{\text{Volume of oil (ml)}}{\text{Weight of sample (g)}} \times 100$$

Selection Index

Percent disease index

Disease incidence was calculated as percent disease index. Ten leaves were selected randomly and scores were given on scale 0 – 9. Percent disease index was calculated using the formula (Rao *et al*., 2015)

$$\text{Percent Disease Index} = \frac{\text{Sum of all numerical disease ratings x 100}}{\text{No. observations assessed x maximum disease rating}}$$

Dry rhizome recovery

Dry rhizome recovery (drying percent) of rhizomes was calculated as follows (Kandiannan *et al*., 2015).

$$\text{Dry recovery (Drying percent)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Selection index score was calculated from the fresh rhizome yield per clump (g), curcumin content (%), dry rhizome recovery and disease reaction (PDI). The scores were given as per the score chart (Chandra *et al*., 1998) given in Table 2.

Table No. 3.3. Scoring of accessions

Sl.No.	Character	Score 1	Score 2	Score 3
1.	Fresh rhizome yield /clump (g)	< 350	350 – 500	> 500
2.	Curcumin (%)	< 5	5 – 6.5	> 6.5
3.	Dry recovery (%)	< 15	15 – 16.5	> 16.5
4.	Disease reaction (PDI)	> 20	1 – 20	0.0

Result and Discussion

4. RESULT AND DISCUSSION

This study was conducted to evaluate the yield and quality of Wayanad local turmeric accessions. Seventeen Wayanad local turmeric accessions and three checks consisting of released varieties Sona, Kanthi and Prathibha were evaluated for the growth, yield and biochemical parameters during 2018 to 2019 in the Department of Plantation crops and Spices farm at Vellanikkara. The parameters were statistically analysed to evaluate yield and quality of Wayanad turmeric types and the results are presented below.

Morphological observations

Morphological observations on leaf and stem characters were made at 150 DAP are tabulated in Table 4.1 and 4.2.

Qualitative Observations

Pseudostem colour

Turmeric accessions were visually assessed for pseudostem Colour at 150 DAP depicted in Table 4.1. Green Colour was observed for pseudostem in all turmeric accessions. Similar results were obtained by Syahid and Heryanto (2017) in *C. zedoaria* and Sarma *et al*., 2016 in *Curcuma rubrobracteata*. Khumaida *et al*. (2019) reported green colour pseudostem in *Curcuma aeruginosa*.

Leaf orientation

Leaf orientation in turmeric accessions was observed at 150 DAP depicted in Table 4.1. The angle between leaf plain and shoot axis in turmeric accessions was less than 45^0 and were erect.

Sasikumar (2005) described the erect plant type as an important discriminating qualitative feature of Curcuma species. Deb and Chakraborthy (2017) also reported the erect disposition of leaf in *Curcuma longa*.

Leaf shape

Leaf shape of turmeric accessions was visually assessed at 150 DAP and illustrated in Table 4.1. Shape of the leaf in turmeric accessions was elliptic – oblong. Syazana *et al*. (2018) reported elliptic – oblong leaves in *Amomum bungoensis*. Sirirugsa *et al*. (2007) reported the elliptic shape of turmeric leaf in a study conducted at Thailand . Samant (2012) reported leaf shape as oblong- lanceolate that tapers at both ends as in *Curcuma amada*.

Leaf base shape

Leaf base shape in turmeric accessions was observed at 150 DAP and given in Table 4.1. Leaf base shape observed in turmeric accessions were observed as cuneate.

Leaf tip

Leaf tip of turmeric accessions was observed at 150 DAP and given in Table 4.1. Leaf tip observed in turmeric accessions was accuminate – caudate. Similar result was reported by Syahid and Heryanto (2017) were the leaf tip was acuminate in *Curcuma zeodoria*. Chen *et al*. (2011) reported accuminate – caudate leaf tip in *Zingiber nanlingensis*.

Leaf mid rib colour

Leaf mid rib Colour of turmeric was observed at 150 DAP given in Table 4.1. Colour of leaf mid rib in turmeric accessions was observed to be pale green. Srivastava *et al*. (2007) reported purple mid rib colour in *Curcuma zeodoaria*. Das *et* *al*. (2013) reported purple streaks on the middle region of leaf lamina in *Curcuma ceasia*.

Pubescence on leaves

At 150 DAP, leaves were examined for the presence or absence of hair at both sides. Leaves of turmeric accessions were devoid of hairs and the leaves were glaborous. Katsuko *et al.* (2008) observed the absence of hair on the upper as well as lower side in leaf of *Curcuma kwangsiensis*. Glaborous leaf surface is reported in *Curcuma gulinqingensis* (Chen and Xia, 2013).

Colour of leaf on ventral side

Colour of the leaf on the ventral side of turmeric accessions was observed at 150 DAP and given in Table 4.1. The colour of leaf on the ventral side of turmeric accessions was dark green. Green colour was observed on the leaf sheath of *Curcuma kwangsiensis* (Katsuko *et al.*, 2008). Jan *et al*. (2012) observed leaf colour as dark green colour in Kasur area and light green from Bannu area.

Colour leaf on dorsal side

The colour of leaf on dorsal side was examined in the turmeric accessions at 150 DAP and were found to be light green in all accessions (Table 4.1). Skornickova and Sabu (2005) reported the light green colour of leaf on the dorsal side of *Curcuma aromatica*. Bai *et al*. (2018) observed pale green colour on the abaxial side of *Zingiber pauciflorum*. Dull green colour was observed in abaxial side of *Larsenianthus assamensis* of Zingiberaceae (Kress *et al.*, 2005).

Venation pattern

Venation pattern in the turmeric accessions was visually assessed and recorded at 150 DAP (Table 4.1). Venation pattern observed in turmeric accessions were distant. Sasikumar (2005) reported the distant venation pattern as a discriminating qualitative feature of *Curcuma* species. Khumaida *et al*. (2019) characterized *Curcuma aeruginosa* into distant venation pattern.

Leaf margin

Margin of the leaf was observed at 150 DAP on the main tiller. Margin of turmeric accessions were observed as even. Elias *et al*. (2015) reported that margin of *Curcuma anguistifolia* as entire.

Table : 4.1 Morphological observations of turmeric accessions at 150 DAP

Treatments	Pseudostem Colour	Leaf orientation	Leaf shape	Leaf base shape	Leaf tip	Leaf midrib colour	Colour of leaf on dorsal side	Colour of leaf on ventral side	Venation pattern	Leaf margin
Sona	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
Pratibha	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
Kanthi	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 3	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 5	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 8	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 9	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 13	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 14	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 15	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 16	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 17	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 19	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 20	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 21	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 22	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 23	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 24	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 25	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even
WCL 26	Green	Erect	EO	Cuneate	AC	PG	LG	DG	Distant	Even

EO : Elliptic-oblong; AC : Accuminate caudate; PG : Pale green; LG : Light green; DG : Dark green

Pseudostem colour : Green
Leaf orientation: Erect

Accuminate caudate

Cuneate

Leaf margin: Even
Venation pattern: Distant

Dark green colour on the ventral side

Light green colour on the dorsal side

Pale green coloured mid rib

Plate 4: Qualitative morphological characters

Quantitative Observations

The observations on germination percentage was observed at 28 DAP and quantitative observations on height of the main tiller, girth of the main tiller, number of leaves on the main tiller, number of tillers per clump, petiole length, length of leaf and width of leaf were taken at 150 DAP and tabulated in Table 4.2.

Germination percentage (%)

There was no– significant variation in germination percent. However, highest germination percentage was observed in Sona (96.53 %) and WCL 14 (96.53 %). Germination per cent was in the range of 88.89 – 96.52 % (Table 4.2).

Since there was no significant variation in germination percentage, the seed material can be considered as uniform. Emergence of sprout depends on the rhizome size, time, depth of planting. It was also reported by Kumar and Gill (2010) that the germination percent will not be affected by planting material.

Height of the main tiller (cm)

Among 20 accessions, WCL 23 (165.80 cm) recorded highest height of the main tiller. The highest was recorded in Sona (159.90 cm), Prathibha (159.5 cm), Kanthi (159.10 cm), WCL 5 (152.03 cm), WCL 20 (156.75 cm), WCL 24 (157.01 cm) and WCL 25 (156.21 cm) were on par. Lowest plant height was recorded in WCL 15 (126.54 cm), WCL 16 (133.60 cm) and WCL 14 (137.12 cm) (Table 4.2).

Highest plant height was observed for WCL 23 (165.80 cm) which performed better than the check Sona (159.90 cm), Kanthi (159.10 cm) and Prathibha (159.5 cm). According to Nambiar (1979), plant height can be used as single morphological character for higher yield. Plant height is an indication of vigour of the plant (Vamshi *et al*., 2019). Kumari *et al*. (2014) recorded significant variation in plant height ranging from 75.96 to 111.21 cm.

Girth of the plant (cm)

Highest girth of the main tiller was obtained in accession WCL 3 (15.04 cm). The girth of WCL 13 (13.13 cm), WCL 16 (14.37 cm), WCL 21 (13.35 cm) and WCL 24 (13.96 cm) were on par with WCL 3 (Table 4.2). Sona (10.75 cm) recorded lowest girth of the main tiller which was on par with remaining accessions.

Girth of the main tiller varied from 10.75 – 15.04 cm. Significant variation in plant diameter was observed by Deb *et al*. (2013) and Bandyopadhyay *et al*. (2016). Padmadevi *et al*. (2012) found that stem girth differed when different grades of rhizomes were used. Pirjade *et al*. (2007) opined that the difference in pseudostem girth might be due to the inherent characteristics of plant and response to the environment.

Number of leaves on the main tiller

Number of leaves present on the main tiller was tabulated in Table 4.2. Number of leaves on the main tiller was more in WCL 15 (8.20) and WCL 16 (8.20). Number of leaves on main stem observed in Prathibha (8.43), WCL 5 8(8.37), 24(8.50). Accessions WCL 26 (7.00) has the lowest number of leaves on the leaves which was on par with WCL 23 (7.23). Sona (7.97), Kanthi (7.77), WCL 3 (7.93), WCL 8 (7.97), WCL 9 (7.73), WCL 13 (7.93), WCL 14 (8.27), WCL 17(8.13), WCL 19(7.40), WCL 20 (7.80), WCL 21 (7.97), WCL 25 (7.87) has less number of leaves in main tiller.

Number of leaves on the plant is an indication of vigour (Bahl *et al*., 2014). Basak and Jana (2016) obtained higher number of leaves in Suranjana (8.55) in a trail conducted to study the comparative effect between conventional nutrient management practices (P1- inorganic N:P:K @120:60:60 kg ha^{-1} (RDF) + FYM @15 t ha^{-1}) and organic nutrient management practices (P2- FYM @ 15tonnes/ha and vermicompost @ 7.5 t ha^{-1} + Azophos @5 kg ha^{-1}) at West Bengal.

Number of tillers on the main tiller

Highest number of tillers on the main tillers was recorded in WCL 22 (2.63) Accesssions WCL 26 (2.13). WCL 13 (1.63), WCL 16 (1.53), WCL 20 (1.60), WCL 21 (1.97), WCL 23 (1.87), and WCL 25 (1.53) were on par with WCL 22. Lowest number of tillers on the main tillers Kanthi (1.07), WCL 8 (1.07), WCL 15 (1.07), WCL 24 (1.07) and remaining accessions were on par. Variability in number of tillers could be due to the genetic factors (Philip, 1978). Variability in tiller number is contributed to additive gene effect (Rajyalakshmi *et al*., 2013).

Petiole length (cm)

Petiole length was taken by 150 DAP and is furnished in Table 4.2. Petiole length was highest in WCL 25 (35.95 cm) and WCL 24 (35.46 cm). Accessions Sona (30.24 cm), Kanthi (30.15 cm), WCL 3 (31.27), WCL 5 (34.96 cm), WCL 8 (29.61 cm), WCL 13 (30.61), WCL 14 (28.33 cm), WCL 16 (31.95 cm), WCL 17 (34.01cm) WCL 19 (31.37 cm), WCL 20 (34.54 cm),WCL 21 (29.19 cm), WCL 22 (31.15 cm), WCL 23 (30.58 cm) and WCL 26 (29.13 cm) were on par with WCL 24 and WCL 25. Lowest petiole length was found in WCL 15 (24.25 cm) and remaining were on par with WCL 15. Deb and Chakraborthy (2017) evaluated variability in petiole length of 27 genotypes in West Bengal. Highest petiole length was obtained in TCP 14 (48.9) and lowest was obtained in CL 54 (13.3 cm).

Length of the leaf (cm)

Highest leaf length was observed in Kanthi (75.23 cm). Sona (70.43 cm), WCL 3 (64.79 cm), WCL 19 (67.55 cm), WCL 21 (63.77 cm), WCL 23 (68.42 cm), WCL 24 (68.86 cm) and WCL 25 (67.50 cm) .Lowest length of leaf was observed in WCL 13 (50.83 cm) and remaining was on par with remaining accessions. Deb and Chakraborty (2017) also observed significant variability length of the leaf. Leaf length varied in 27 genotypes ranges from 38.6 cm (RH 410) – 73.7 cm (TCP-161).

Width of leaf

Width of the leaf was taken after 150 DAP and depicted in Table 4.2. Highest leaf width was found in WCL 16 (18.60 cm). Accessions WCL 25 (17.78 cm), WCL 26 (16.47 cm), WCL 21 (16.95 cm), WCL 19 (16.29 cm), WCL 15 (16.29), WCL 14 (16.55 cm) and WCL 8 (16.53 cm) which was on par with WCL 16. Lowest width of leaf was observed in WCL13 (15.11 cm) and WCL 23 (15.12 cm) and the remaining accessions were on par. Deb and Chakraborthy (2017) observed variability in leaf width of 27 genotypes of turmeric ranging from 10.7 – 18.4 cm.

Morphological quantitative characters of Wayanad turmeric accessions at 150 DAP

Treatments	Germination percentage (%)	Height of the main tiller (cm)	Girth of the main tiller (cm)	Number of leaves on the main tiller	Number of tillers on the main tiller	Petiole length (cm)	Length of the leaf (cm)	Width of the leaf (cm)
Sona	96.53	159.90^{ab}	10.75^{e}	7.97^{abc}	1.13^{bcd}	30.24^{abcd}	70.47^{ab}	15.89^{bc}
Pratibha	93.75	159.5^{abc}	12.12^{bcde}	8.43^{ab}	1.33^{bcd}	25.77^{cd}	59.18^{bcd}	15.72^{bc}
Kanthi	95.83	159.10^{abc}	11.03^{de}	7.77^{abc}	1.07^{d}	30.15^{abcd}	**75.23^{a}**	16.17^{bc}
WCL 3	93.05	142.97^{def}	**15.04^{a}**	7.93^{abc}	1.37^{bcd}	31.27^{abcd}	64.79^{abc}	16.16^{bc}
WCL 5	95.14	152.03^{abcde}	12.30^{bcde}	8.37^{ab}	1.73^{abcd}	34.96^{ab}	63.36^{abcd}	15.98^{bc}
WCL 8	96.52	143.08^{def}	12.35^{bcde}	7.97^{abc}	1.07^{d}	29.61^{abcd}	61.43^{bcd}	16.53^{abc}
WCL 9	95.14	143.00^{def}	11.66^{cde}	7.73^{abc}	1.33^{bcd}	27.40^{bcd}	62.35^{abcd}	15.89^{bc}
WCL 13	93.05	144.53^{cdef}	13.13^{abcd}	7.93^{abc}	1.63^{abcd}	30.61^{abcd}	50.80^{d}	15.11^{c}
WCL 14	**96.53**	137.12^{efg}	12.49^{bcde}	8.27^{abc}	1.13^{bcd}	28.33^{abcd}	57.43^{bcd}	16.55^{abc}
WCL 15	92.36	126.54^{g}	11.76^{cde}	**8.60^{a}**	1.07^{d}	24.25^{d}	54.62^{cd}	16.29^{abc}
WCL 16	96.52	133.60^{fg}	14.37^{ab}	**8.60^{a}**	1.53^{abcd}	31.95^{abc}	61.99^{bcd}	**18.60^{a}**
WCL 17	95.83	150.61^{bcde}	12.23^{bcde}	8.13^{abc}	1.40^{bcd}	34.01^{ab}	60.26^{bcd}	15.81^{bc}
WCL 19	91.66	143.59^{def}	11.72^{cde}	7.40^{abc}	1.20^{bcd}	31.37^{abcd}	67.55^{abc}	16.29^{abc}
WCL 20	89.58	156.75^{abcd}	12.37^{bcde}	7.80^{abc}	1.60^{abcd}	34.54^{ab}	58.22^{bcd}	16.08 ^{bc}
WCL 21	91.66	143.56^{def}	13.35^{abcd}	7.97^{abc}	1.97^{abc}	29.19^{abcd}	63.77^{abc}	16.95^{abc}
WCL 22	91.66	144.02^{cdef}	12.46^{bcde}	8.20^{abc}	**2.63^{a}**	31.15^{abcd}	62.53^{abcd}	15.65^{bc}
WCL 23	88.89	**165.80^{a}**	11.27^{de}	7.23^{bc}	1.87^{abc}	30.58^{abcd}	68.42^{ab}	15.13^{c}
WCL 24	94.44	157.01^{abcd}	13.96^{abc}	8.50^{ab}	1.07^{d}	**35.46^{a}**	68.86^{ab}	16.22^{bc}
WCL 25	93.75	156.21^{abcd}	12.44^{bcde}	7.87^{abc}	1.53^{abcd}	**35.95^{a}**	67.50^{abc}	17.79^{ab}
WCL 26	95.13	142.83^{def}	11.47^{de}	7.00^{c}	2.13^{ab}	29.13^{abcd}	63.34^{abcd}	16.47^{abc}
Range	88.89-96.52	165.80- 126.54	10.75 – 15.04	7.00-8.6	1.07-2.63	24.25 -35.95	50.80-75.23	15.11-16.08

Plate 5: Harvest and storage of turmeric

Rhizome Characters

The plants were harvested at maturity and observations on rhizome characters were taken in fresh and cured rhizomes.

Qualitative Characters

Qualitative characters of rhizomes include branching of rhizome, rhizome nature, rhizome habit, rhizome inner core Colour, status of tertiary rhizome, type of roots and were tabulated in Table 4.3. The incidence of pest and disease, percent disease incidence and percent leaf infested are depicted in Table 4.4 and Table 4.5 respectively.

Branching of rhizome

Branching of rhizomes were observed after harvest and depicted in Table 4.3. Horizontal and curved types of branching were observed in turmeric rhizomes. Horizontal branching was observed in Prathibha, WCL 3, WCL 13, WCL 16, WCL 17, WCL 24, WCL 25. All other accessions have curved branching. Chaveerach *et al*. (2008) reported horizontal branching in *Curcuma sattayasaii* and protruding secondaries of *C. zedoarides* were found to be curved.

Rhizome nature

Plumpy and slender rhizome characters were observed in rhizomes (Table 4.3). Plumpy rhizome nature was observed in Prathibha, WCL 16, WCL 17, WCL 20, WCL 21, WCL 24 and WCL 25. All other accessions were observed as slender rhizome.

Rhizome habit

Two types of rhizome habits were observed in turmeric accessions. Loose type of rhizome habit was observed in released varieties like Sona, Prathibha and

Kanthi. Accessions WCL 3, WCL 5, WCL 17, WCL 21, WCL 22, WCL 23, WCL 24, WCL 26 were also loose. Compact rhizome habit was observed in WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 16, WCL 19, WCL 20, WCL 25. Gujarat Navsari turmeric 1 has compact rhizome type of rhizome habit with a fresh yield of 33.60 t ha^{-1} (Saravaiya *et al*., 2011).

Rhizome inner core Colour

Rhizome inner core Colour was observed after the harvest. Prathibha, Kanthi and WCL 3 showed reddish orange inner core Colour. WCL 24 showed light yellow inner core Colour and all others were orange colour.

Kumari *et al*. (2017) observed light orange yellow rhizome Colour among 10 germplasm. Jan *et al*. (2012) also observed variation in different rhizome inner core colour as light. Saravaiya (2011) reported the red orange core colour in GN turmeric 1. Mishra *et al*. (2015) also observed three colour variation in rhizome as yellow, orange and red in 65 germplasm collected from Uttarakand, Tamil Nadu, Lucknow, Faziabad and Assam.

Status of teritiary

After harvest, the status of teritiary was observed in the fresh rhizome of turmeric accessions. Presence or absence of teritiary rhizomes were examined in turmeric accessions. Teritiary rhizomes were present in turmeric accessions. Khumaida *et al*. (2019) also observed presence of teritiary rhizomes in *Curcuma aeruginosa*.

Type of roots

Type of roots was examined in turmeric accessions. But all the twenty turmeric accessions observed were devoid of tubers and were non tuberous. *Alpinia calcarata* has non tuberous root stock stolon (Bhunia and Mondal, 2012; Uma and

Rhizome characters of Wayanad turmeric accessions

Treatments	Branching of rhizome	Rhizome nature	Rhizome habit	Rhizome inner core Colour	Status of teritiary	Type of roots
Sona	Curved	Slender	Loose	Orange	Present	Non tuberous
Pratibha	Horizontal	Plumpy	Loose	Reddish Yellow	Present	Non tuberous
Kanthi	Curved	Slender	Loose	Reddish yellow	Present	Non tuberous
WCL 3	Horizontal	Slender	Loose	Reddish Yellow	Present	Non tuberous
WCL 5	Curved	Slender	Loose	Orange	Present	Non tuberous
WCL 8	Curved	Slender	Compact	Orange	Present	Non tuberous
WCL 9	Curved	Slender	Compact	Orange	Present	Non tuberous
WCL 13	Horizontal	Slender	Compact	Orange	Present	Non tuberous
WCL 14	Curved	Slender	Compact	Orange	Present	Non tuberous
WCL 15	Curved	Slender	Compact	Orange	Present	Non tuberous
WCL 16	Horizontal	Plumpy	Compact	Orange	Present	Non tuberous
WCL 17	Horizontal	Plumpy	Loose	Orange	Present	Non tuberous
WCL 19	Curved	Slender	Compact	Orange	Present	Non tuberous
WCL 20	Curved	Plumpy	Compact	Orange	Present	Non tuberous
WCL 21	Curved	Plumpy	Loose	Orange	Present	Non tuberous
WCL 22	Curved	Slender	Loose	Orange	Present	Non tuberous
WCL 23	Curved	Slender	Loose	Orange	Present	Non tuberous
WCL 24	Horizontal	Plumpy	Loose	Light yellow	Present	Non tuberous
WCL 25	Horizontal	Plumpy	Compact	Orange	Present	Non tuberous
WCL 26	Curved	Slender	Loose	Orange	Present	Non tuberous

Horizontal

Curved

Plumpy

Slender

Loose

Compact

Plate 6: Qualitative rhizome characters

Light Yellow

Orange

Reddish Yellow

Status of teritiary

Non tuberous roots

Plate 6 (contd..): Qualitative rhizome characters

Muthukumar, 2014). Srivastava *et al*. (2007) also compared the macroscopic characters of three *Curcuma* species and reported that root tubers were present in *C. aromatica* and *C. zeodoaria* while absent in *C. amada*.

Incidence of pest and disease

Incidence of pest and disease

Incidence of disease was examined in turmeric accessions and presented in Table 4.4. Three diseases observed in turmeric accessions were leaf blotch, leaf spot and rhizome rot.

Leaf blotch was absent in Prathibha, WCL 3, WCL 13, WCL 14, WCL 15, WCL 16, WCL 24 and WCL 25. All the accessions were infested with leaf spot.. The rhizome rot infestation was absent in ten accessions studied but present in accessions Sona, Prathibha, Kanthi, WCL 8, WCL 13, WCL 14, WCL 15 and WCL 20.

Incidence of pest was also observed in turmeric accessions and presented in Table 4.4. Lema beetle (*Lema pruesta*), Shoot borer (*Conogethes punctiferalis*) and leaf folder (*Udaspes folus*) were the three pests infested the turmeric accessions.

The infestation of lema beetle and shoot borer was noticed in all accessions studied. But leaf roller infestation was observed only in few accessions viz. Prathibha, WCL 5, WCL 17, WCL 24. The accessions Sona, Kanthi, WCL 3, WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 16, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23, WCL 25, WCL26 were found tolerant to leaf roller.

Percent disease incidence and percent leaf infestation

Percent disease incidence of leaf blotch was depicted in Table 4.5. Percent disease Incidence was totally absent in Prathibha, WCL 3, WCL 13, WCL 14, WCL 15, WCL 16 and WCL 25 (0.0) and can be considered as highly tolerant. Accessions

Sona (2.96), Kanthi (2.96), WCL 20 (1.11), WCL 21 (0.56),WCL 24 (0.025.) were tolerant accessions. Accession WCL 5 (67.59) recorded highest per cent disease index of leaf blotch and can be considered as highly susceptible.

No significant variation was observed in the per cent disease index of leaf spot. Though not significant, highest leaf spot disease index was noticed in WCL 19 (15.19). Since it is less than 20% it can be considered as moderately resistant in reaction.

Prathibha, WCL 3, WCL 13, WCL 14, WCL 15, WCL 16 and WCL 25 which were found to be highly resistant to leaf blotch disease. Accession WCL 5 recorded highest disease reaction and was recorded as highly susceptible. Moderate resistance was observed in WCL 26. Rao *et al*. (2015) screened 295 turmeric germplasm at Horticulture Research Station, Kammarpally, Andra Pradesh and the percent disease index of leaf spot ranged from 0.00 to 75.28.

Chakraborthy *et al*. (2017) has reported a lowest PDI of 12.78 for leaf blotch and PDI of 7.62 in accession TCP 129. But in the present study lowest PDI of 0.00 percentage was reported in accessions Prathibha, WCL 5, WCL 13, WCL 14, WCL 15, WCL 16 and WCL 25. It was also reported that PDI of leaf spot 38.38 in RH 410 where as in present study highest PDI of 15.78 in accession WCL 19.

Among the pests observed, Lema beetle infestation was found highest and percent leaf infestation was calculated and recorded in table 4.5. Lema beetle infestation was lower than 10 percent in all accession studied. Though not significant ,the highest infestation was recorded in WCL 21 (7.48 %) and lowest in Sona (3.43 %). Kotikal and Kulkarni (2000) recorded percent plant infested by shoot borer, leaf beetle (Lema sp) and caterpillars in turmeric North Karnataka. Percent disease incidence of shoot borer (10.00 ± 3.33 m2), leaf beetle (0.27 ± 13 m2) and caterpillars (0.82 ± 0.23 m2) and was high in grand growth stage (100 – 120 DAP).

Incidence of pest and disease in Wayanad turmeric accessions

Treatments	Leaf blotch	Leaf spot	Rhizome rot	Shoot borer	Leaf roller	Lema beetle
Sona	Present	Present	Present	Present	**Absent**	Present
Pratibha	**Absent**	Present	Present	Present	Present	Present
Kanthi	Present	Present	Present	Present	**Absent**	Present
WCL 3	**Absent**	Present	**Absent**	Present	**Absent**	Present
WCL 5	Present	Present	**Absent**	Present	Present	Present
WCL 8	Present	Present	Present	Present	**Absent**	Present
WCL 9	Present	Present	**Absent**	Present	**Absent**	Present
WCL 13	**Absent**	Present	Present	Present	**Absent**	Present
WCL 14	**Absent**	Present	Present	Present	**Absent**	Present
WCL 15	**Absent**	Present	Present	Present	**Absent**	Present
WCL 16	**Absent**	Present	**Absent**	Present	**Absent**	Present
WCL 17	Present	Present	**Absent**	Present	Present	Present
WCL 19	Present	Present	**Absent**	Present	**Absent**	Present
WCL 20	Present	Present	Present	Present	**Absent**	Present
WCL 21	Present	Present	**Absent**	Present	**Absent**	Present
WCL 22	Present	Present	**Absent**	Present	**Absent**	Present
WCL 23	Present	Present	**Absent**	Present	**Absent**	Present
WCL 24	**Absent**	Present	**Absent**	Present	Present	Present
WCL 25	**Absent**	Present	**Absent**	Present	**Absent**	Present
WCL 26	Present	Present	**Absent**	Present	**Absent**	Present

Percent disease incidence and percent leaf infestation of Lema beetle in turmeric accessions

Treatments	PDI Leaf Blotch	PDI Leaf Spot	Percent leaf infestation of lema beetle (%)
Sona	2.96 (0.91)[d]	3.52 (0.09)	**3.73**
Pratibha	**0.00** (0.02)[d]	5.37 (0.13)	4.40
Kanthi	2.96 (0.09)[d]	3.15 (0.08)	8.27
WCL 3	**0.00** (0.02)[d]	7.96 (0.20)	7.20
WCL 5	67.59 (1.69)[a]	1.85 (0.04)	4.94
WCL 8	36.85 (0.92)[b]	9.44 (0.23)	5.69
WCL 9	38.33 (0.95)[b]	3.52 (0.08)	5.95
WCL 13	**0.00** (0.02)[d]	3.89 (0.10)	4.79
WCL 14	**0.00** (0.02)[d]	3.89 (0.09)	5.77
WCL 15	**0.00** (0.02)[d]	7.59 (0.20)	3.95
WCL 16	**0.00** (0.02)[d]	5.93 (0.15)	4.77
WCL 17	20.74 (0.51)[bcd]	8.15 (0.21)	6.64
WCL 19	29.07 (0.09)[bc]	**15.19** (0.38)	5.95
WCL 20	1.11 (0.04)[d]	1.48 (0.05)	4.99
WCL 21	0.56 (0.03)[d]	5.19 (0.14)	**7.48**
WCL 22	20.37 (0.50) [bcd]	9.63 (0.24)	3.89
WCL 23	9.63 (0.24)[cd]	7.41 (0.18)	6.03
WCL 24	0.025 (0.02)[d]	3.33 (0.08)	6.56
WCL 25	**0.00** (0.02)[d]	3.52 (0.09)	6.36
WCL 26	17.96 (0.44)[bcd]	1.85 (0.05)	5.38

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Leaf blotch (*Taphrina maculens*)

Leaf spot (*Collectotrichum capsici*)

Rhizome rot (*Pythium aphanidermatum*)

Plate 7: Incidence of disease

Lema Beetle (*Lema preusta*)

Shoot borer (*Conogethes punctiferalis*)

Leaf roller (*Udaspes folus*)

Plate 8: Incidence of pest

Quantitative characters

Quantitative characters include rhizome internode length, length of primary rhizome, width of primary rhizome, number of mother rhizome, number of secondary rhizome, weight of secondary rhizome, fresh yield per plant, fresh yield per plot, dry yield per plant and plot, curing percentage and dry recovery. Observations on quantitative parameters are furnished in the Table 4.6, 4.7 and 4.8.

Length of primary rhizome (cm)

Length of primary rhizome was highest in Sona (12.69 cm), which was on par with Kanthi (11.28 cm) (Table 4.6). Lowest length of primary rhizome was recorded in WCL 8 (6.49 cm). Accessions WCL 5(8.01 cm), WCL 3 (7.99 cm), WCL 14 (6.72 cm), WCL 15 (7.97 cm), WCL 16 (7.15 cm), WCL 17 (7.79 cm), WCL 19 (7.76 cm), WCL 22 (7.96) and WCL 25 (7.73 cm) were on par with WCL 8. Kumari *et al*. (2017) also observed highest rhizome length in Prabha (12.23 cm). Kumari *et al*. (2014) evaluated 10 germplasm in Faziabad and observed significant variation in rhizome length ranging from 5.26 – 11.83 cm. In this study also length of primary rhizome vary from 6.49 – 12.69 cm

Width of primary rhizome (cm)

Highest width of primary rhizome was recorded in Prathibha (3.08 cm). Accessions WCL 13 (2.61 cm), WCL 17 (2.67 cm), WCL 20 (2.69 cm), WCL 21 (2.73 cm), WCL 24 (2.75 cm), WCL 25 (2.86 cm) and WCL 26 (2.81 cm) were on par with Prathibha (Table 4.6). The accession Prathibha, WCL 16, WCL 17, WCL 20, WCL 21, WCL 21, WCL 24 and WCL 25 were also tabulated as plumpy (Table 4.3) Lowest width of primary rhizome was observed in WCL 15 (1.44 cm). Tomar *et al*. (2005) reported positive direct effect of primary rhizome thickness with rhizome yield.

Number of mother rhizome

Highest number of mother rhizome was observed in WCL 23 (1.67) which is on par with WCL 9 (1.53). Lowest number of mother rhizome was observed in Sona (1.00), Prathibha (1.00), Kanthi (1.00), WCL 8 (1.00), WCL 15 (1.00), WCL 16 (1.00), WCL 17 (1.00), WCL 19 (1.00), WCL 22 (1.00), WCL 25 (1.00) (Table 4.6). Salimath *et al*. (2014) obtained mother rhizome ranging from 1.49 – 2.43 where as it was only 1.00-1.67 in this study.

Number of primary rhizome

Highest number of primary rhizome was recorded in WCL 23 (7.33) and Kanthi (7.27) as seen in Table 4.6. Accessions Sona (6.73), WCL 5 (6.40), WCL 9 (5.80), WCL 13 (6.27), WCL 14 (5.93), WCL 19 (6.40), WCL 20 (6.73), WCL 21 (5.87) and WCL 25 (5.67) were on par with WCL 23 and Kanthi. Lowest number of primary rhizome was found in WCL 3 (3.87) and WCL 15 (3.87).and number of primary rhizomes in Prathibha (4.60), WCL 8 (4.93), WCL 16 (4.73), WCL 17 (4.93), WCL22 (5.33), WCL 24 (5.40) and WCL 26 (4.87) were on par with WCL 3 (3.87) and WCL 15 (3.87). Venugopal and Pariari (2017) recorded highest number of primary rhizome in Rajendra Sonia (6.81) followed by Suguna (6.69). Bandopadhya *et al*. (2016) recorded highest number of primary rhizomes for accession TCP 70 (6.33).

Number of secondary rhizome

Number of secondary rhizomes was recorded and depicted in Table 4.6. Highest number of secondary rhizome was recorded in Kanthi (23.07). Accessions Sona (20.47) and WCL 23 (20.33) were on par with Kanthi. Lowest number of secondary rhizome was recorded in WCL 3 (3.73). Accessions WCL 8 (4.27), WCL 14 (8.73), WCL 15 (5.07), WCL 16 (5.93) and WCL 25 (4.80) were on par with WCL 3.

Rhizome quantitative characters of Wayanad turmeric accessions

Treatments	Length of primary rhizome (cm)	Width of primary (cm)	Number of mother rhizome	Number of primary rhizome	Number of secondary rhizome	Rhizome internode length (cm)
Sona	**12.69^{a}**	1.70^{de}	1.00^{c}	6.73^{ab}	20.47^{ab}	1.24^{abc}
Prathibha	8.76^{de}	**3.08^{a}**	1.00^{c}	4.60^{de}	9.47^{de}	0.99^{bcd}
Kanthi	11.28^{ab}	2.21^{abcde}	1.00^{c}	**7.27^{a}**	**23.07^{a}**	1.08^{abcd}
WCL 3	7.99^{defg}	1.70^{de}	1.07^{c}	3.87^{e}	3.73^{g}	0.86^{bcd}
WCL 5	8.01^{defg}	1.69^{de}	1.13^{bc}	6.40^{abc}	13.93^{cd}	0.77^{d}
WCL 8	6.49^{g}	1.73^{de}	1.00^{c}	4.93^{cde}	4.27^{fg}	0.97^{bcd}
WCL 9	10.25^{bc}	2.13^{abcde}	1.53^{ab}	5.80^{abcd}	16.27^{bc}	1.27^{ab}
WCL 13	8.57^{de}	2.61^{abcd}	1.27^{bc}	6.27^{abcd}	9.80^{de}	0.99^{bcd}
WCL 14	6.72^{fg}	1.96^{bcde}	1.20^{bc}	5.93^{abcd}	8.73^{defg}	0.84^{cd}
WCL 15	7.97^{defg}	1.44^{e}	1.00^{c}	3.87^{e}	5.07^{efg}	0.98^{bcd}
WCL 16	7.15^{efg}	2.12^{abcde}	1.00^{c}	4.73^{cde}	5.93^{efg}	0.79^{d}
WCL 17	7.79^{defg}	2.67^{abcd}	1.00^{c}	4.93^{cde}	12.00^{cd}	0.85^{bcd}
WCL 19	7.76^{defg}	1.46^{e}	1.00^{c}	6.40^{abc}	12.90^{cd}	0.80^{d}
WCL 20	8.24^{def}	2.69^{abcd}	1.07^{c}	6.73^{ab}	13.20^{cd}	0.85^{bcd}
WCL 21	8.28^{def}	2.73^{abcd}	1.20^{bc}	5.87^{abcd}	9.87^{de}	0.89^{bcd}
WCL 22	7.96^{defg}	1.75^{cde}	1.00^{c}	5.33^{bcde}	12.13^{cd}	0.97^{bcd}
WCL 23	10.85^{b}	1.73^{de}	**1.67^{a}**	**7.33^{a}**	20.33^{ab}	1.17^{abcd}
WCL 24	10.71^{b}	2.75^{abcd}	1.07^{c}	5.40^{bcde}	9.07^{def}	1.14^{abcd}
WCL 25	7.73^{defg}	2.86^{ab}	1.00^{c}	5.67^{abcd}	4.80^{efg}	**1.45^{a}**
WCL 26	8.98^{cd}	2.81^{abc}	1.13^{bc}	4.87^{cde}	10.07^{de}	0.90^{bcd}
Range	6.49 – 12.69	1.44 - 3.08	1.00 – 1.67	3.87 - 7.33	3.73 - 23.07	0.77 – 1.55

Length of rhizome

Single mother rhizome

More than one mother rhizome

Number of mother rhizome

Plate 9: Quantitative rhizome characters

An experiment was conducted in Uttar Pradesh to study the magnitude of association among the growth, yield its attributing characters and quality parameters and reported that number of secondary was significantly correlated with weight of secondary rhizomes per plant rhizome. The number of secondary rhizome in twenty accessions studied were varied from 3.73 – 23.07 (Vimal *et al*., 2018).

4.2.2.1 Rhizome internode length (cm)

Highest rhizome inter node length was recorded in WCL 25 (1.45 cm) which is on par with WCL 9 (1.27 cm) (Table 4.6). Lowest rhizome intermodal length was observed in accessions WCL 5 (0.77 cm) and remaining accessions were on par. The rhizome interned length ranged between 0.77 – 1.55. Deb and Chakraborthy (2017) also observed variation in rhizome internode pattern ranging from 0.8 – 2.0 cm.

Weight of mother rhizome (g)

Weight of mother rhizome was highest in WCL 24 (68.70 g). The weight of mother rhizomes of accessions WCL 21 (57.43 g), WCL 23 (57.33 g), WCL 14 (55.43 g), WCL 26 (49.73 g) and WCL 16 (49.72g) were on par with WCL 24 (Table 4.7). Lowest weight of mother rhizome was recorded in WCL 5 (29.67 g) followed by WCL 22 (32.40 g), WCL 15 (33.76 g). Pirjde *et al*. (2007) observed variability in mother rhizome weight in turmeric. He also opined that variability might be due to the varietal difference and their response to the agro-climatic conditions.

Weight of primary rhizome (g)

Weight of primary rhizome was taken and illustrated in Table 4.7. Weight of primary rhizome was significantly highest in WCL 24 (26.67 g). Lowest weight of primary rhizome was recorded in WCL 5 (10.67 g) and WCL 8 (10.67 g). The weight of primary rhizomes in accessions WCL 3 (11.74 g), WCL 13 (15.67 g) WCL 14 (12.00 g), WCL 15 (16.00 g),WCL 16 (14.55 g), WCL 19 (13.67 g), WCL 20 (15.67

g), WCL 17 (16.00 g), WCL 22 (16.08 g), WCL 25 (17.67 g) and WCL 26 (17.10 g) were on par with WCL 5 and WCL 8.

Bahadur *et al*. (2016) recorded wide range of variation in weight of primary rhizome per plant (20.08 – 84.78 g plant^{-1}). Singh *et al*. (2003) also reported variability in the weight of primary finger per clump and suggests that this can be used for selecting superior genotype.

Weight of secondary rhizome (g)

Weight of secondary rhizome was highest in WCL 14 (6.38 g). The weight of secondary rhizomes in accessions WCL 9 (5.02 g), Prathibha (5.00 g), Sona (4.62 g) and WCL 24 (4.45 g) were on par with WCL 14 (Table 4.7). Lowest weight of secondary rhizome was recorded in WCL 8 (1.42 g). Accessions Kanthi (2.92 g), WCL 3 (2.38 g), WCL 5 (2.80 g), WCL 13 (3.53 g), WCL 15 (1.73 g), WCL 16 (2.05 g), WCL 17 (2.56 g), WCL 19 (2.16 g), WCL 20 (3.00 g), WCL 21 (2.38 g), WCL 25 (3.56 g) and WCL 26 (2.85 g) were on par with WCL 8. Singh *et al*. (2003) also observed significant variation in weight of secondary rhizomes. Kumar and Gill (2010) recorded significant variation in weight of secondary rhizomes with different harvest dates.

Fresh yield per plant (g plant^{-1})

Fresh rhizome yield per plant was highest for WCL 24 (350.33 g) and WCL 23 (350.08g plant-1). The recorded rhizome yield per plant from accessions Kanthi (335.60g plant-1) and WCL 25 (274.67g plant-1) were on par (Table 4.7). The fresh yield per plant was lowest in WCL 16 (116.05 g plant^{-1}). The study also revealed a variation in rhizome yield per plant in a range of 116.25 – 350.33. Chandra *et al*. (1997) observed significant variation in fresh rhizome yield per clump and the total rhizome weight per clump recorded 121.62 – 329.78 g. Aarthi *et al*. (2018) reported that fresh rhizome yield per plant can determine the economic value of turmeric. The plant height was highest in accession WCL 23. The same accession has also recorded a good number of leaves in this study. The height of tiller and number of leaves from accession WCL 24 was also comparable. The number of mother rhizome and primary rhizome was also highest in accession WCL 23 (1.67 and 7.33 respectively). The weight of mother rhizome and primary rhizome were highest in accession WCL 24 Naidu and Murthy (2013) reported that plant height and number of leaves can attributed to the highest yield. Luiram *et al*. (2018) evaluated 32 genotypes in North Eastern region of India and the fresh rhizome yield per plant ranged from 150.7 – 374.47 g.

Fresh yield per plot (kg 3m^{-2})

Highest fresh yield per plot was recorded in WCL 25 (9.69 kg 3m^{-2}). The fresh yield per plot from accessions WCL 24 (9.36 kg 3m^{-2}), WCL 23 (9.13 kg 3m^{-2}), Kanthi (8.78 kg 3m^{-2}), WCL 20 (8.50 kg 3m^{-2}), WCL 9 (8.11 kg 3m^{-2}), WCL 22 (7.42 kg 3m^{-2}), Sona (7.21 kg 3m^{-2}), WCL 13 (7.16 kg 3m^{-2}), and WCL 26 (7.07 kg 3m^{-2}) were on par with WCL 25. Lowest fresh yield per plot WCL 8 (2.17 kg 3m^{-2}), WCL 16 (2.24 kg 3m^{-2}) and WCL 15 (2.64 kg 3m^{-2}) (Table 4.7).

Chakraborthy *et al*. (2017) recorded yield of 14.34 kg plot $^{-1}$of size 3 sq.m for TCP 129 which also recorded a low PDI for leaf blotch (12.78) in an experiment conducted at West Bengal. In the present study, accession WCL 25 recorded highest yield of 9.69 kg plot^{-1} from a plot of size 3sq.m and also a lowest PDI for leaf blotch (0.00). The same accession WCL 25 has highest internode length and better width of primary rhizome, number of tillers, leaf length, leaf width, petiole length, height, and also plumpy and compact rhizomes with orange inner core.

Yield attributes of Wayanad turmeric accessions

Treatments	Weight of mother rhizome (g)	Weight of primary rhizome (g)	Weight of secondary rhizome (g)	Fresh yield per plant (g plant^{-1})	Fresh yield per plot (kg 3m^{-2})	Fresh yield per hectare (t ha^{-1})
Sona	35.68^{cd}	18.00^{bcd}	4.62^{abc}	241.06^{cde}	7.21^{abcde}	24.74^{abcde}
Pratibha	35.15^{cd}	19.07^{bc}	5.00^{ab}	212.77^{cdefg}	6.40^{bcdef}	21.33^{bcdef}
Kanthi	45.33^{bcd}	20.58^{b}	2.92^{bcdef}	335.60^{ab}	8.78^{ab}	29.29^{ab}
WCL 3	47.12^{bcd}	11.74^{de}	2.38^{cdef}	158.29^{efghi}	3.34^{fg}	11.13^{fg}
WCL 5	29.67^{d}	10.67^{e}	2.80^{bcdef}	174.08^{defghi}	4.18^{efg}	13.94^{efg}
WCL 8	37.33^{bcd}	10.67^{e}	1.42^{f}	139.58^{ghi}	2.17^{g}	7.24^{g}
WCL 9	46.58^{bcd}	19.37^{b}	5.02^{ab}	256.33^{bcd}	8.11^{abc}	27.04^{abc}
WCL 13	42.31^{bcd}	15.67^{bcde}	3.35^{bcdef}	165.33^{efghi}	7.16^{abcde}	23.97^{abcde}
WCL 14	55.34^{abc}	12.00^{cde}	**6.38^{a}**	152.44^{fghi}	5.14^{cdefg}	17.13^{cdefg}
WCL 15	33.76^{d}	16.00^{bcde}	1.73^{ef}	126.89^{hi}	2.64^{g}	8.81^{g}
WCL 16	49.72^{abcd}	14.55^{bcde}	2.05^{def}	116.25^{i}	2.23^{g}	7.45^{g}
WCL 17	36.00^{cd}	16.00^{bcde}	2.56^{bcdef}	251.16^{bcd}	5.04^{cdefg}	16.08^{cdefg}
WCL 19	35.58^{cd}	13.67^{bcde}	2.16^{cdef}	225.84^{cdef}	4.16^{efg}	13.89^{efg}
WCL 20	45.00^{bcd}	15.67^{bcde}	3.00^{bcdef}	221.90^{cdefg}	8.50^{ab}	28.36^{ab}
WCL 21	57.43 ^{ab}	18.00^{bcd}	2.38^{cdef}	173.08^{defghi}	4.79^{defg}	15.96^{defg}
WCL 22	32.40^{d}	16.08^{bcde}	3.32^{bcd}	204.89^{cdefghi}	7.42^{abcd}	24.74^{abcd}
WCL 23	57.33^{ab}	19.66^{b}	3.98^{bcde}	**350.08^{a}**	9.12^{ab}	30.42^{ab}
WCL 24	**68.70^{a}**	**26.60^{a}**	4.45^{abcd}	**350.33^{a}**	9.36^{ab}	31.19^{ab}
WCL 25	44.00^{bcd}	17.67^{bcde}	3.56^{bcdef}	274.66^{abc}	**9.69^{a}**	**32.32^{a}**
WCL 26	49.73^{abcd}	17.10^{bcde}	2.85^{bcdef}	250.3^{bcd}	7.07^{abcde}	23.57^{abcde}
Range	29.67 – 68.70	10.67 – 26.60	1.42 – 6.38	116.25–350.33	2.17 – 9.69	7.45 – 32.32

Fresh yield per hectare (t ha^{-1})

Fresh yield per plot varied significantly among the turmeric accessions. Highest fresh yield per hectare was recorded in WCL 25 (32.33kg ha^{-1}). The yield per plot from accessions WCL 24 (31.19 kg ha^{-1}), WCL 23 (30.42 t ha^{-1}), Kanthi (29.29 t ha^{-1}), WCL 20 (27.36 t ha^{-1}), WCL 9 (27.04 t ha^{-1}), Sona (24.74 t ha^{-1}), WCL 22 (24.74 t ha^{-1}), WCL 13 (23.97 t ha^{-1}) and WCL 26 (23.57 t ha^{-1}) were on par. Lowest fresh yield per plot was recorded in WCL 8 (7.24 t ha^{-1}), WCL 15 and WCL 16 (Table 4.7).

Salimath *et al*. (2014) were the fresh rhizome yield per hectare ranged from 16.75 – 33.76 t ha^{-1}. Shankar *et al*. (2014) also obtained highest mean fresh rhizome yield per hectare for genotype IGSJT-10-2 (30.32 t ha^{-1}). Higher yield is an important factor for character for selection of genotype (Pandey, 2013).

Dry yield per plant (g plant^{-1})

Highest dry yield per plant was recorded in WCL 23 (61.74 g plant^{-1}). Accessions Kanthi (55.86 g plant^{-1}), WCL 24 (50.47 g plant^{-1}), WCL 17 (48.98 g plant^{-1}), WCL 25 (47.85 g plant^{-1}) which was on par with WCL 23. Lowest dry yield per plant was recorded in WCL 16 (20.46 g plant^{-1}) and WCL 15 (21.16 g plant^{-1}).

Accessions WCL 8 (24.78 g plant^{-1}), WCL 13 (27.59 g plant^{-1}), WCL 3 (28.27 g plant^{-1}), WCL 22 (29.50 g plant^{-1}), WCL 21 (30.79 g plant^{-1}), WCL 14 (31.87 g plant^{-1}) and WCL 5 (34.00 g plant^{-1}) were on par with WCL 15 and WCL 16. (Table 4.8).

Krishna *et al*. (2019) reported variability in dry rhizome per plant ranging from 41.38-123.14 kg per plant. Vijayan (2015) recorded highest dry rhizome per plant in Kedaram harvested at 240 DAP.

Dry yield per plot (kg 3m^{-2})

Highest dry weight per plot was recorded in WCL 25 (1.67 kg 3m^{-2}) and WCL 23 (1.60 kg 3m^{-2}). Sona (1.32 kg 3m^{-2}), Prathibha (1.37 kg 3m^{-2}), Kanthi (1.46 kg 3m^{-2}), WCL 9 (1.38 kg 3m^{-2}), WCL 13 (1.17 kg 3m^{-2}), WCL 20 (1.49 kg 3m^{-2}), WCL 24 (1.32 kg 3m^{-2}) and WCL 26 (1.29 kg 3m^{-2}) were on par with WCL 25 and WCL 23. Lowest dry yield per plot was recorded in WCL 8 (0.38 kg 3m^{-2}),WCL 16 (0.39 kg 3m^{-2}) and WCL 15 (0.44 kg 3m^{-2}). Accession WCL 3 (0.59 kg 3m^{-2}), WCL 5 (0.84 kg 3m^{-2}), WCL 19 (0.97 kg 3m^{-2}) and WCL 21 (0.86 kg 3m^{-2}) were on par with WCL 8, WCL 15 and WCL 16 (Table 4.8).

Hossain (2005) obtained highest dry yield when the shoots were completely withered and harvested in January. Kanndianan *et al.*, 2015 recorded obtained varied dry rhizome yield per plot ranking from 1.29 to 2.09 kg. Kedaram (3.28 kg) gave highest dry rhizome yield per plot at 240 DAP (Vijayan, 2015).

Dry yield per hectare (t ha^{-1})

Dry yield per hectare varied significantly among the turmeric accessions. Dry yield per hectare was highest for WCL 25 (5.56 t ha^{-1}) and WCL 23 (5.34 t ha^{-1}). Released varieties Sona (4.40 t ha^{-1}), Prathibha (4.58 t ha^{-1}), Kanti (4.87 t ha^{-1}) and accessions WCL 9 (4.62 t ha^{-1}), WCL 13 (3.89 t ha^{-1}), WCL 20 (4.97 t ha^{-1}), WCL 24 (4.41 t ha^{-1}) and WCL 26 (4.31 t ha^{-1}) were on par with WCL 25 and WCL 23. Lowest dry yield per plot was observed in WCL 8 (1.28 t ha^{-1}), WCL 15 (1.47 t ha^{-1}) and WCL 16 (1.32 t ha^{-1}) (Table 4.8). Accessions WCL 3 (1.98 t ha^{-1}), WCL 5 (2.80 t ha^{-1}), WCL 19 (2.65 t ha^{-1}) and WCL 21 (2.87 t ha^{-1}) were on par with WCL 8, WCL 15 and WCL 16.

Kumar and Gill (2010) also obtained highest significant variation in dry rhizome yield per hectare when different planting material was used. Kamal and Yousaf (2012) observed similar variation of dry yield per hectare (2.38 – 5.59 t ha^{-1})

on the application of different organic manure. Yield of turmeric is represented by fresh or dry weight per hectare and is influenced by varietal difference, agro ecology, soil conditions and climatic conditions (Joy *et al*., 1998).

Dry rhizome recovery (%)

Highest dry rhizome recovery was recorded in WCL 14 (20.83 %) and was on par with WCL 5 (20.54 %), WCL 17 (19.41 %), WCL 19 (18.96 %), WCL 26 (18.27 %), Sona (18.24 %), WCL 20 (18.06 %), WCL 3 (17.93 %) and WCL 21 (17.75 %). Lowest dry rhizome recovery was observed in WCL 22 (14.41 %) (Table 4.8).

Varietal variation was noted in dry recovery of turmeric (Kandinnan *et al*., 2015). The variation in cultivar is due to the growth of initial period of turmeric where organic material production is increased and translocated to different tissue resulting in lesser space for moisture (Patil *et al*., 2016).

Curing percentage (%)

After harvest, turmeric accessions were cured, dried and curing percentage was calculated and depicted in Table 4.8. Highest curing percentage was recorded in WCL 14 (23.33 %) followed by WCL22 (20.00 %) and WCL 8 (19.85 %). Lowest curing per cent was observed in WCL 21 (14.40 %) and WCL 17 (14.51 %). Accessions WCL 23 and WCL 24, which were recorded highest fresh rhizome yield, have lower curing percent. Hanasmashetti *et al.* (2002) also obtained highest curing percentage was obtained in cultivars PCT 8 (24.37 %) and CLI- 62 (22.31 %) irrespective of planting material. Singh and Patel (2016) reported significant influence of variety on curing percentage.

Curing percent and dry yield attributes of Wayanad turmeric accessions

Treatments	Dry rhizome recovery (%)	Curing percentage (%)	Dry yield per plant (kg plant $^{-1}$)	Dry yield per plot (kg 3m^{-2})	Dry yield per hectare (t ha^{-1})
Sona	18.24^{abc}	19.38^{bc}	44.15^{bcdefg}	1.32^{abcd}	4.40^{abcd}
Pratibha	17.77^{bc}	17.12^{defg}	45.36^{bcdef}	1.37^{abc}	4.58^{abc}
Kanthi	16.64^{cd}	18.72^{bcd}	55.86^{ab}	1.46^{abc}	4.87^{abc}
WCL 3	17.92^{abc}	16.14^{efgh}	28.27^{hij}	0.59^{fg}	1.98^{fg}
WCL 5	20.53^{ab}	16.96^{defg}	34.00^{defghij}	0.84^{defg}	2.80^{defg}
WCL 8	17.73^{bc}	19.85^{b}	24.77^{ij}	0.38^{g}	1.28^{g}
WCL 9	17.25^{cd}	17.45^{def}	43.44^{bcdefg}	1.38^{abc}	4.62^{abc}
WCL 13	16.73^{cd}	16.04^{fgh}	27.58^{ij}	1.17^{abcde}	3.89^{abcde}
WCL 14	**20.83^{a}**	**23.33^{a}**	31.86^{efghij}	1.08^{bcdef}	3.60^{bcdef}
WCL 15	16.84^{cd}	17.34^{defg}	21.37^{j}	0.44^{g}	1.47^{g}
WCL 16	17.69^{bc}	17.46^{def}	20.49^{j}	0.39^{g}	1.32^{g}
WCL 17	19.41^{abc}	14.51^{h}	48.98^{abc}	0.97^{cdef}	3.25^{cdef}
WCL 19	18.96^{ab}	17.95^{cde}	42.5^{bcdefgh}	0.97^{efg}	2.65^{efg}
WCL 20	18.05^{ab}	18.21^{bcd}	39.27^{cdefghi}	1.49^{ab}	4.97^{ab}
WCL 21	17.74^{ab}	14.40^{h}	30.79^{fghij}	0.86^{defg}	2.87^{defg}
WCL 22	14.41^{e}	20.00^{b}	29.49^{ghij}	1.07^{cdef}	3.57^{bcdef}
WCL 23	17.73^{bc}	15.59^{gh}	**61.74^{a}**	**1.60^{a}**	**5.34^{a}**
WCL 24	14.57^{de}	16.04^{fgh}	50.47^{abc}	1.32^{abcd}	4.41^{abcd}
WCL 25	17.71^{bc}	15.59^{gh}	47.85^{abcd}	**1.67^{a}**	**5.56^{a}**
WCL 26	18.24^{abc}	18.63^{bcd}	45.60^{bcde}	1.29^{abcde}	4.31^{abcde}
Range	14.41 – 20.83	14.51 - 23.33	20.49 – 61.74	0.39 – 1.67	1.32 – 5.56

Biochemical characters

After curing and drying, biochemical characters of turmeric accessions were analyzed. Curcumin, oil and oleoresin were extracted from the turmeric samples. From curcumin content, curcumin yield per hectare was also estimated. Biochemical characters were furnished in the Table 4.9.

Curcumin content (%)

After curing and drying, the samples were powdered and curcumin content was estimated and tabulated in Table 4.9. Highest curcumin content was recorded in WCL 5 (10.18 %) followed by WCL 26 (9.31 %) and WCL 25 (9.27 %). Lowest curcumin content was recorded in WCL 9 (3.70 %).

The accession which recorded highest curcumin, WCL 5 (10.18 %) has recorded lower yield values in terms of weight of mother rhizome (29.67 g), weight of primary rhizome (10.67 g), fresh and dry yield per hectare (13.94 t ha^{-1} and 2.80 t ha^{-1}) and curcumin yield per hectare (286.06 kg ha^{-1}). The accessions which were next to WCL 5 in curcumin content are WCL 25 (9.27 %) and WCL 26 (9.31 %) which were recorded better yield attributes and the highest yield was from accession WCL 25 (32.32 t ha^{-1}).

Among the three checks Prathibha recorded highest curcumin (6.18 %). All the accession evaluated were recorded a curcumin content higher than the check Prathibha except WCL 9 (3.7 %), WCL 17 (4.94 %) and WCL 24 (4.55 %).

Ratnambal (1986) obtained high curcumin in accessions Edapalayam (10.9 %), Palapally (10.7 %), Erthakulam (10.3 %), Thodupuzha (9.5 %) and Wynad local (9.4 %). Sandeep *et al.* (2016) reported that phytoconstituents in turmeric vary from place to place due to the influence of environment and agroclimatic condition.

Oleoresin (%)

Fresh turmeric samples were powdered and oleoresin content was estimated by soxhlet extraction method and depicted in Table 4.9. Highest oleoresin was obtained in WCL 3 (19.90 %) and WCL 22 (19.56 %). Lowest oleoresin content was obtained in WCL 9 (6.60 %).

The accession with high curcumin WCL 5 recorded an oleoresin content of 10.42 % comparable to check Sona. Accession WCL 25 and WCL 26 which were better in rhizome yield per hectare and curcumin content with comparable oleoresin content (18.57 % & 18.21 % respectively).

WCL 3 (19.90 %) and WCL 22 (19.56 %) performed significantly higher than the check Sona (10.17 %), Prathibha (14.10 %) and Kanthi (8.11 %). Variation in oleoresin content ranged from 6.60 - 19.90 per cent.

Ratnambal (1986) evaluated 44 turmeric accessions for quality. Oleoresin content in the accessions varied from 19.00 ('Amritapani') to 10.00 % (Nowgong, Assam). Vijayan, (2015) studied the effect of different harvest dates and varieties on oleoresin and highest oleoresin was obtained in Sudarsana (17.58 %) harvested 240 DAP. Green and Mitchell (2014) also reported significant increase in oleoresin with respect to time of harvest.

Essential oil (%)

Essential oil was extracted using hydrodistillation and calculated the oil content and details are furnished in Table 4.9. Highest amount of essential oil was recorded in Sona (4.00 %) and Prathibha (4.00 %). WCL 5 (2.83 %), WCL 16 (3.00 %) and WCL 17 (3.16 %) were on par with Sona and Prathibha. WCL 8 (1.00 %) recorded the lowest essential oil content.

Accession WCL 5 which has the highest curcumin content of 10.18 per cent has an essential oil content comparable to Sona and Prathibha. Accessions WCL 9, WCL 13, WCL 20, WCL 24, WCL 23, WCL 25 and WCL 26 and check Kanthi have comparatively less essential oil content.

On dry basis, Devkota and Rajbhandari (2015) obatained 3.00 per cent oil. Variation in oil content can also be due the time of harvest, conditions of distillation (Ratnambal, 1986).Alex (2005) characterized Kasthuri turmeric collected from locations of Kerala and essential oil content ranged from 0.25 – 5.83 per cent. Sandeep *et al*. (2016) demonstrated the variation in oil and curcumin content associated with soil nutrients and environmental factors.

Curcumin Yield (kg ha^{-1})

Curcumin yield was found to be highest in WCL 25 (551.40 kg ha^{-1}). Curcumin yield from accession WCL 20 (442.42kg ha^{-1}), WCL 23 (422.55kg ha^{-1}) and WCL 26 (401.70kg ha^{-1}) were on par with WCL 25 (Table 4.9). Yield of curcumin was lowest in WCL 16 (97.19kg ha^{-1}).

Dry yield per hectare was highest in WCL 25 and WCL 23. Yield from WCL 20 and WCL 26 were also on par. The accession WCL 25 has a curcumin content of 9.27 % and significantly highest rhizome yield of 32.32 t ha^{-1}. The fresh rhizome yield from WCL 20 (28.36 t ha^{-1}) was on par with WCL 25 and has a curcumin content of 8.9 %. The fresh rhizome yield of accession WCL 23 (30.42t ha^{-1}) was on par with WCL 25 and has a curcumin content of 7.91per cent. Though the curcumin content was highest in WCL 5 (10.18 %) the dry yield per hectare was low (2.80 kg ha^{-1}). Hence the curcumin yield was low for WCL 5 (286.06 kg ha^{-1}).

Among the check varieties, Prathibha recorded highest curcumin yield of 286.52 kg ha^{-1}. The accessions WCL13, WCL 14, WCL 20, WCL 22, WCL 23, WCL 25 and WCL 26 recorded higher curcumin yield than the check varieties.

Hanamashetti *et al*., 2002 reported variation in curcumin yield from186.14 to 545.91 kg ha^{-1} based on planting material used. Ratnambal (1986) obtained high curcumin in accessions Edapalayam (10.9 %), Palapally (10.7 %), Erthakulam (10.3 %), Thodupuzha (9.5 %) and Wynad local (9.4 %). Sandeep *et al*. (2016) reported that phytoconstituents in turmeric vary from place to place due to the influence of environment and agroclimatic condition

4.9 Biochemical characters of Wayanad turmeric accessions

Treatments	Curcumin Content (%)	Oleoresin (%)	Essential Oil (%)	Curcumin Yield (kg ha^{-1})
Sona	5.43 ^{j}	10.17^{h}	**4.00^{a}**	230.36^{efgh}
Pratibha	6.18^{i}	14.01^{f}	**4.00^{a}**	286.52^{defg}
Kanthi	5.33^{j}	8.11^{ij}	2.00^{bcde}	259.69^{efg}
WCL 3	8.50^{de}	**19.90^{a}**	1.49^{de}	169.02^{fghij}
WCL 5	**10.18^{a}**	10.42^{h}	2.83^{abc}	286.06^{defg}
WCL 8	8.08^{fg}	14.20^{f}	1.00^{e}	103.89^{ij}
WCL 9	3.70^{m}	6.60^{k}	1.83^{cde}	171.04^{fghij}
WCL 13	8.06^{fg}	10.17^{h}	2.33^{bcd}	314.52^{bcde}
WCL 14	8.34^{ef}	11.66^{g}	1.99^{bcde}	310.05^{cdef}
WCL 15	8.02^{g}	8.46^{j}	2.16^{bcde}	118.34^{hij}
WCL 16	7.37^{h}	7.60^{j}	3.00^{abc}	97.19^{j}
WCL 17	4.95^{k}	16.45^{d}	3.16^{ab}	161.04^{ghij}
WCL 19	8.69^{cd}	14.22^{f}	2.16^{bcde}	230.36^{efghij}
WCL 20	8.90^{c}	14.30^{f}	2.49^{bcd}	442.42^{ab}
WCL 21	8.12^{fg}	14.41^{f}	1.99^{bcde}	233.57^{efghi}
WCL 22	8.70^{cd}	**19.57^{a}**	2.00^{bcde}	310.72^{cdef}
WCL 23	7.91^{g}	15.50^{e}	2.16^{bcde}	422.55^{abc}
WCL 24	4.55^{l}	17.52^{c}	1.83^{cde}	200.98^{efghij}
WCL 25	9.27^{b}	18.57^{b}	1.83^{cde}	**551.40^{a}**
WCL 26	9.31^{b}	18.21^{b}	1.33^{de}	401.70^{abcd}
Range	3.70 -10.18	6.60 - 19.90	1.00 – 4.00	97.19 – 551.40

4.5 Selection index

Selection index scores were calculated from fresh yield per plant (g), curcumin content (%) and disease reaction (PDI). Scores were given for each of the parameters and accessions having highest score were selected as superior accessions. The selection index scores were calculated and tabulated in Table 4.10.

Highest score of 12 was obtained by WCL 3, WCL 13 , WCL 14 , WCL 15 , WCL 16 , WCL 23 and WCL 25 .The genotypes having highest scores indicates the superiority of the genotypes over others. These genotypes can be used for further crop improvement programme. Surprisingly all the check and local accessions have recorded a fresh yield per plant less than 350 g $plant^{-1}$ and were obtained a score of 1 except WCL 23 (350.08g) and WCL 24 (350.33g) which got a score of 2. But the curcumin content of WCL 24 was as low as 4.55%. All the accessions which were scored 12 have a curcumin content above 6.5% which is obviously higher than the three checks. It is interesting to note that the PDI for leaf blotch was absolutely zero for WCL 25 and can be considered as a highly resistant accession. The PDI of accession WCL 23 was also less than 10 and hence comes under the category of resistant.

The check Prathibha, accessions WCL 20, WCL 21 and WCL 26 can be considered in second set of best accession having a score of 11 which also has a curcumin content above 6.5 per cent except Prathibha which is having a curcumin content of 6.16 per cent. Selection index score was found to be the lowest (8) for accessions WCL 9, WCL 17 and WCL 22 were found to be the lowest as 8.

Chandra *et al*. (1998) calculated selection index score for seventeen genotypes. Highest score was obtained for TC 17 (13) which was rated as superior among seventeen genotype. They also suggest that it is also important to consider disease incidence along with yield and quality.

Accessions were classified based on their performance over check with respect to curcumin content, curcumin yield and fresh rhizome yield per hectare (Table 4.11). The accessions WCL 3, WCL 5, WCL 8, WCL 13, WCL 14, WCL 15, WCL 16, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23, WCL 25 and WCL 26 have higher curcumin content than the checks. While curcumin yield of accessions WCL 13, WCL 14, WCL 20, WCL 22, WCL 23, WCL 25 and WCL 26 were over and above the checks. Accessions WCL 23, WCL 24 and WCL 25 recorded high fresh yield per hectare over and above the check.

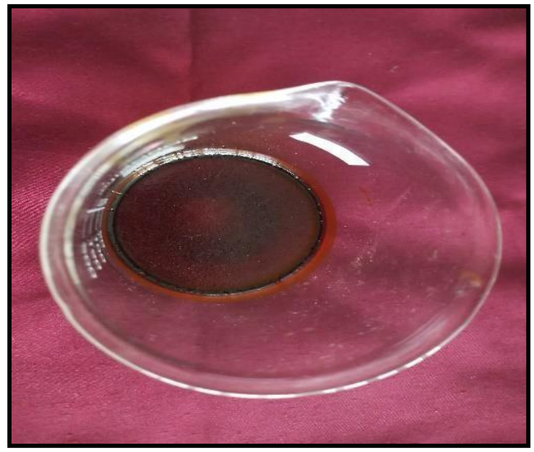
When the curcumin content, curcumin yield and fresh rhizome yield per hectare were compared with checks, two accessions, WCL 23 and WCL 25 were found to be superior over the check with respect to all these characters. These two accessions were also resistant to leaf blotch and leaf spot.

Both the accessions were similar in all the morphological parameters except in rhizome nature, habit and branching. The rhizomes of accession 25 were plumpy, horizontal in branching and compact in habit. The rhizomes of accession 23 were slender, curved in branching and loose in habit. The two accessions have orange inner core colour. The fresh yield per plant was high in WCL 23 (350.08 g), but the fresh yield per hectare was high in accession WCL 25 (32.32t ha^{-1}) and also the curcumin yield (551.4 kg ha^{-1}). The oil content was high in accession WCL 23 (2.16%).

Selection index score for Wayanad turmeric accessions

Treatments	Fresh yield per plant (g plant $^{-1}$)	Curcumin content (%)	Dry rhizome recovery (%)	Leaf blotch (*Taphrina maculans*)	Leaf spot (*Colletotricum capsici*)	Total selection index scores (15)
Sona	241.07 (1)	5.43 (2)	18.24 (3)	2.96 (2)	3.52 (2)	10
Pratibha	212.77 (1)	6.18 (2)	17.77 (2)	0.00 (3)	5.37 (2)	11
Kanthi	335.60 (1)	5.33 (2)	16.64 (3)	2.96 (2)	3.15 (2)	10
WCL 3	157.91 (1)	8.50 (3)	17.92 (3)	0.00 (3)	7.96 (2)	**12**
WCL 5	174.08(1)	10.18 (3)	20.53 (3)	67.59 (1)	1.85 (2)	10
WCL 8	139.67 (1)	8.08 (3)	17.73 (3)	36.85 (1)	9.44 (2)	10
WCL 9	256.33 (1)	3.70 (1)	17.25 (3)	38.33 (1)	3.52 (2)	8
WCL 13	165.33 (1)	8.06 (3)	16.73 (3)	0.00 (3)	3.89 (2)	**12**
WCL 14	152.44 (1)	8.34 (3)	20.83 (3)	0.00 (3)	3.89 (2)	**12**
WCL 15	125.60 (1)	8.02 (3)	16.84 (3)	0.00 (3)	7.59(2)	**12**
WCL 16	116.08 (1)	7.37(3)	17.69 (3)	0.00 (3)	5.93 (2)	**12**
WCL 17	251.17 (1)	4.95 (1)	19.41 (3)	20.74 (1)	8.15(2)	8
WCL 19	230.17 (1)	8.69 (3)	18.96 (3)	29.07 (1)	15.19 (2)	10
WCL 20	221.90 (1)	8.90 (3)	18.05 (3)	1.11 (2)	1.48 (2)	11
WCL 21	173.08 (1)	8.12 (3)	17.74 (3)	0.56 (2)	5.19 (2)	11
WCL 22	204.89 (1)	8.70 (3)	14.41 (1)	20.37 (1)	9.63 (2)	8
WCL 23	350.08 (2)	7.91 (3)	17.73 (3)	9.63 (2)	7.41 (2)	**12**
WCL 24	350.33 (2)	4.55 (1)	14.57 (1)	0.00 (3)	3.33 (2)	9
WCL 25	274.67 (1)	9.27 (3)	17.71 (3)	0.00 (3)	3.52 (2)	**12**
WCL 26	250.33 (1)	9.31 (3)	18.24 (3)	17.96 (2)	1.85 (2)	11

Essential oil



Oleoresin

Curcumin

Plate 10: Biochemical characters

Performances of Wayanad turmeric accessions over check

Characters	Accessions
Curcumin content (%)	WCL 3, WCL 5, WCL 8, WCL 13, WCL 14, WCL 15, WCL 16, WCL 19, WCL 20, WCL 21, WCL 22, **WCL 23**, **WCL 25**, WCL 26
Fresh yield per hectare (t ha^{-1})	**WCL 23**, WCL 24, **WCL 25**
Curcumin Yield (Kg ha^{-1})	WCL 13, WCL 14, WCL 20, WCL 22, **WCL 23**, **WCL 25**, WCL 26

Sona

Prathibha

Kanthi

Plate 11: Check

WCL 19

WCL 20

WCL 21

Plate 12: Accessions collected from Manathavady

WCL 15

WCL 17

WCL 23

Plate 13: Accessions collected from Vythiri

WCL 3

WCL 5

WCL 8

WCL 9

WCL 13

WCL 14

WCL 16

WCL 22

WCL 24

WCL 25

WCL 26

Plate 14: Accessions collected from Sultanbathery

4.6 Cluster Analysis

Cluster dendrogram was performed based on the Eucledian distance using R console software. Clusters were formed based on the quantitative parameters recorded in the turmeric accessions (Fig 2). Four clusters were formed based on the parameters like height of the main tiller, girth of the main tiller, number of leaf and tiller, petiole length, leaf length, leaf width, length of the primary, width of the primary, rhizome internode pattern, fresh yield per plant, fresh yield per plot, fresh yield per hectare, curcumin content, essential oil and oleoresin. Number of accessions in each cluster was as shown in Table 4.12 Cluster I constitutes WCL 15, WCL 16, WCL 8, WCL 3, WCL 14, WCL 13, WCL 5, WCL 21. Cluster II includes Kanthi, WCL 23, WCL 24 and WCL 19, WCL 22, Prathibha and WCL 20 forms Cluster III. Cluster IV comprises of WCL 25, Sona, WCL 9, WCL 17, WCL 26.

Table 4.12 Accessions constituting each cluster

Cluster	Accessions
Cluster I	WCL 15, WCL 16, WCL 8, WCL 3, WCL 14, WCL 13, WCL 5, WCL 21
Cluster II	WCL 23, WCL 24, Kanthi
Cluster III	WCL 19, WCL 22, WCL 20, Prathibha
Cluster IV	WCL 25, WCL 9, Sona, WCL 17, WCL 26

Cluster I and Cluster IV were predominantly occupied by accessions collected from Sultanbathery except WCL 15 (Vythiri) and WCL 21 (Manathavady) and WCL 17 (Vythiri).

Maximum eucledian distance was obtained between the accessions WCL 16 and WCL 23 (237.55) falling in the clusters I and II respectively (Appendix I) implying the diversity of turmeric accessions collected from different locations of Wayanad. Lowest eucledian distance was obtained between the accessions WCL 23 and WCL 24 (11.36) in cluster II and WCL 5 and WCL 21 in cluster I alluding the similarity of the accessions falling in same cluster.

The cluster dendrogram shows that variability exist between different accession collected from different locations of Wayanad district. This implies the scope of utilizing the genotypes for crop improvement programmes based on yield and biochemical characters.

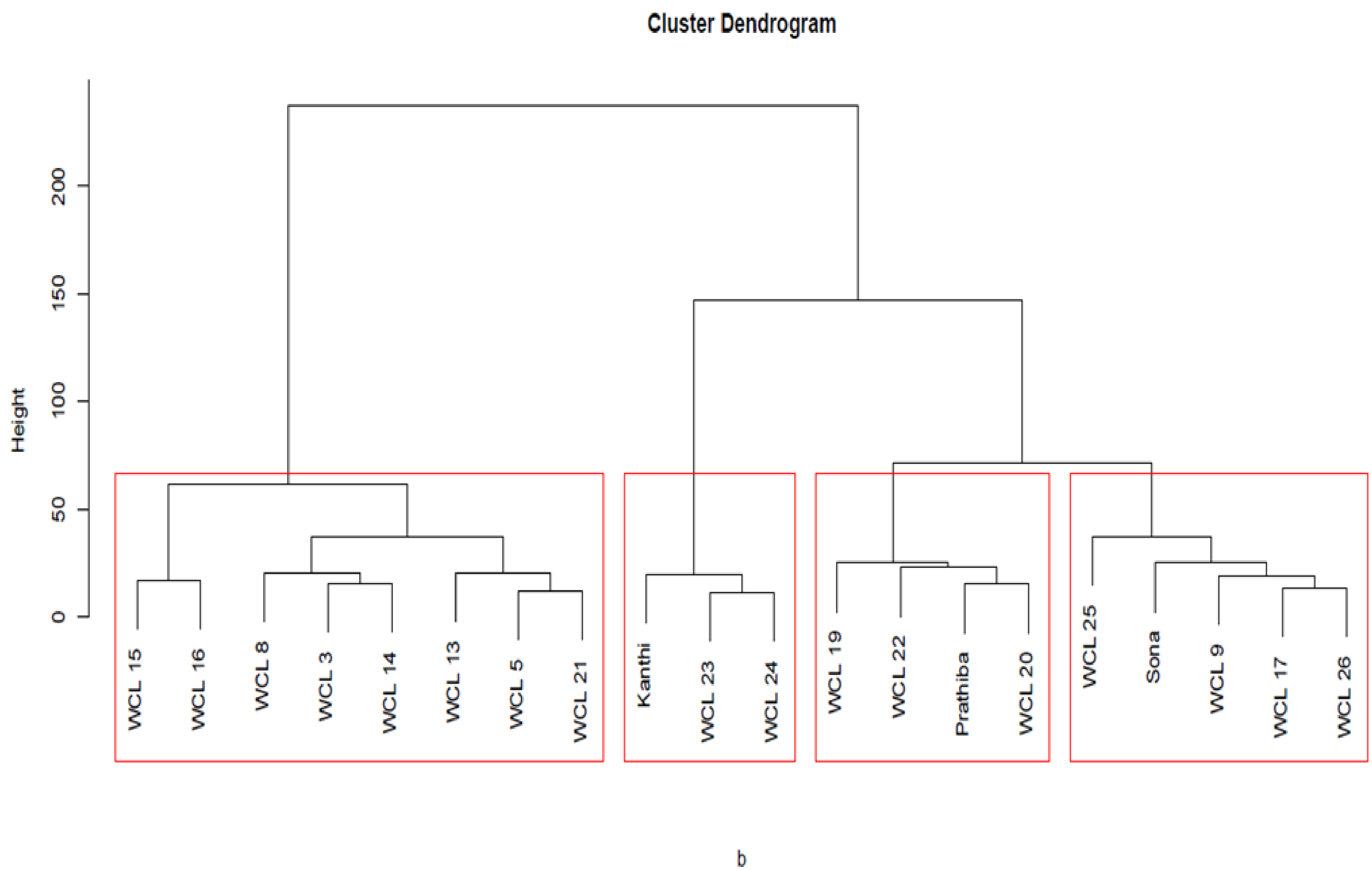


Fig 2: Cluster analysis of Wayanad turmeric accessions

Summary

5. SUMMARY

The study entitled “Collection and evaluation of Wayanad turmeric (*Curcuma longa* L.) for yield and quality” was carried out in Department of Plantation Crops and Spices from 2018 to 2019. The traditional Wayanad turmeric available in various locations of Wayanad district were collected through mass media publicity. The seed materials of 26 accessions collected from three taluks Mananthavady, Vythiri and Sultanbathery were sorted and 17 accessions having sufficient quantity of seed material for replicated trial was planted in the Department of plantation crops and spices farm and were evaluated with three released varieties, Sona, Pratibha and Kanthi as checks. The experiment was laid out in randomized block design in the partial shade of 54.29 per cent in coconut palm field.

Morphological observations of turmeric accessions were taken at 150 days after planting. No variation was observed in qualitative morphological characters. All the accessions had erect leaf orientation with green colour pseudostem. The leaf shape was elliptic – oblong with acuminate – caudate tip and cuneate base. The leaf Colour was dark green on the ventral side and light green on the dorsal side with pale green mid rib. Leaf was glaborous on both sides with even margin with distant venation.

No significant difference was observed in germination percentage which showed the uniformity of the planting material. The biometric observations were recorded at 150 days after planting. The highest plant height was observed for WCL 23 which also has highest fresh rhizome yield per plant. Girth of the main tiller was highest for WCL 3. Number of leaves were highest in WCL 15 and WCL 16. Length of the leaf was highest for Kanthi and width was highest in WCL 20.

Though there was no variation in the qualitative morphological characters, the rhizome characters varied among the 20 accessions studied. Two types of branching in rhizome was observed in turmeric accessions. Horizontal branching was observed in Prathibha, WCL 3, WCL 13, WCL 16, WCL 17, WCL 24, WCL 25. Curved rhizome was observed from Sona, Kanthi, WCL 5, WCL 8, WCL 9, WCL 14, WCL 15, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23 and WCL 26.

Slender and plumpy nature were observed in the 20 turmeric accessions. Plumpy rhizomes were observed in Prathibha, WCl 16, WCL 17, WCL 20, WCL 21, WCL 24 and WCL 25. Slender rhizomes were observed in Sona, Kanthi, WCL 3, WCL 5, WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 19, WCL 22, WCL 23, WCL 26.

Loose rhizome habit was observed in Sona, Prathibha, Kanthi, WCL 3, WCL 5, WCL 17, WCL 21, WCL 22, WCL 23, WCL 24 and WCL 26. Compact rhizome habit was observed in WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 16, WCL 19, WCL 20 and WCL 25.

Three rhizome inner colour was observed in 20 turmeric accessions. Prathibha, Kanthi and WCL 3 had reddish orange colour accessions WCL 5, WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 16, WCL17, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23, WCL 25 and WCL 26 has orange colour. Although WCL 24 has light yellow inner colour it has highest fresh rhizome yield per plant and high resistance to leaf blotch, the curcumin yield was low.

Each rhizome clump had tertiary rhizome and non tuberous roots. Lema beetle, shoot borer and leaf roller are the three pest which infested turmeric accessions. Lema beetle incidence was present in all the accessions and percent leaf infestation of lema beetle was lowest in Sona. Shoot borer incidence was also present all the turmeric accessions. Leaf roller attack was absent in all the accessions except Prathibha, WCL 5 and WCL 24.

In the present study accessions were categorized based their disease reaction into highly resistant, resistant, moderately resistant and susceptible. Pratibha, WCL 3, WCL 13, WCL 14, WCL 15, WCL 16 and WCL 25 were highly resistant accessions against leaf blotch. Resistant accessions were Sona, Kanthi, WCL 23 and WCL 24. Accessions WCL 26 was moderately resistant to leaf blotch. Susceptible accessions were WCL 8, WCL 9, WCL 17 and WCL 19 were susceptible and WCL 5 was highly susceptible. WCL 15 was moderately resistant to leaf spot disease while all others were resistant to leaf spot.

Leaf blotch, leaf spot and rhizome rot were three diseases noted in turmeric accessions. Leaf blotch was absent in Prathibha, WCL 3, WCL 13, WCL 14, WCL 15, WCL 16, WCL 24 and WCL 25. These accessions were highly resistant to leaf blotch. Leaf spot was invariably present in all the accessions and WCL 19 was moderately resistant to leaf spot and rest of the accessions were resistant. Rhizome rot was absent in accessions WCL 3, WCL 5, WCL 9, WCL 16, WCL 17, WCL 19, WCL 21, WCL 22, WCL 23, WCL 24, WCL 25, WCL 26. Four accessions WCL 3, WCL 16, WCL 24 and WCL 25 did not show any incidence of leaf blotch and rhizome rot.

Length of primary rhizome was highest in Sona and width of primary rhizome was highest for Prathibha. Number of mother rhizome and primary rhizome was highest for WCL 23 than the check. Number of secondary was highest for Kanthi and weight of secondary was highest for WCL 14. Dry recovery and curing percentage was highest for WCL 14 over and above the check.

Although the highest weight of mother rhizome, primary rhizome, fresh rhizome yield per plant and dry rhizome yield per plant was recorded by WCL 24, the curcumin yield was less for WCL 24. Accession WCL 25 had highest fresh rhizome and dry yield per plot, projected yield and dry rhizome yield per hectare with high resistance against leaf blotch.

Curcumin content was highest for WCL 5 over and above the check. But the curcumin yield per hectare was low for WCL 5. Oleoresin content was highest for WCL 3 and essential oil was highest for Sona and Prathibha.

Accessions WCL 3, WCL 13, WCL 14, WCL 15, WCL 16 and WCL 25 higher selection index score which indicates the superiority of the accessions over the others and can be selected for further improvement. These accessions has fresh rhizome yield per hectare ranging from 116.08 – 274.64 g plant^{-1}, curcumin content of 7.37 – 9.27 % and dry rhizome recovery of 16.73 – 20.83 %.

Wayanad turmeric accessions were compared with check for curcumin content, fresh rhizome yield per hectare, oil, oleoresin and curcumin yield. Accessions WCL 23, WCL 24 and WCL 25 performed over and above the check in fresh rhizome yield per hectare. Compared to the check, accessions WCL 3, WCL 5 WCL 8, WCL 9, WCL 13, WCL 14, WCL 15, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23, WCL 25, WCL 26 had higher curcumin content. Accessions WCL 13, WCL 14, WCL 20, WCL 23, WCL 25 and WCL 26 had higher curcumin yield than the check. Accessions WCL 3, WCL 8, WCL 17, WCL 19, WCL 20, WCL 21, WCL 22, WCL 23, WCL 24, WCL 25 and WCL 26 had oleoresin content over and above the check.

Accessions WCL 23 and WCL 25 performed better than check in curcumin content, fresh yield per hectare and curcumin yield. Hence WCL 23 and WCL 25 are identified as plus genotypes. These plus genotypes have curcumin content of 7.91 – 9.31 per cent, curcumin yield of 401.70 – 551.40 kg ha^{-1} and fresh rhizome yield per hectare ranging from 30.42 – 32.32 t ha^{-1}. WCL 3, WCL 13, WCL 14, WCL 15, WCL 16, WCL 23 and WCL 25 can be selected for further improvement and breeding programs.

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Annexure

ANNEXURE I

Eucledian distance between accessions in cluster dendrogram

Accessions	Sona	Prathibha	Kanthi	WCL 3	WCL 5	WCL 8	WCL 9	WCL 13	WCL 14	WCL 15	WCL 16	WCL 17	WCL 19	WCL 20	WCL 21	WCL 22	WCL 23	WCL 24	WCL 25
Prathibha	31.54																		
Kanthi	94.84	124.42																	
WCL 3	86.73	58.94	179.84																
WCL 5	69.25	41.80	163.10	21.40															
WCL 8	105.20	76.70	198.67	20.57	37.10														
WCL 9	25.02	47.82	82.02	100.62	84.59	118.98													
WCL 13	79.95	50.97	172.79	23.00	20.65	33.31	92.06												
WCL 14	93.07	64.73	185.89	15.72	28.08	18.24	104.98	18.17											
WCL 15	121.43	93.25	213.44	39.46	55.73	23.44	132.23	45.99	29.62										
WCL 16	21.31	101.50	222.49	45.17	61.39	26.41	142.09	54.55	38.53	17.14									
WCL 17	21.31	40.75	87.83	93.67	77.61	112.41	19.25	87.31	100.03	127.79	136.66								
WCL 19	26.28	24.50	112.55	67.99	52.91	86.79	35.37	63.84	74.57	101.79	110.66	27.90							
WCL 20	24.81	15.27	115.35	68.22	50.79	86.55	39.19	58.82	73.46	102.53	110.70	32.89	22.73						
WCL 21	73.58	45.08	169.84	17.44	11.99	36.04	87.38	18.55	23.59	52.94	60.85	81.32	54.77	54.52					
WCL 22	41.89	20.00	132.87	48.87	35.26	68.11	53.55	42.37	54.43	83.08	91.94	48.02	25.00	22.93	34.75				
WCL 23	109.99	138.23	19.13	194.34	177.62	213.27	97.29	187.02	200.59	228.37	237.55	101.68	127.44	129.03	185.01	147.15			
WCL 24	109.99	138.23	19.82	194.35	177.59	213.00	96.35	186.71	200.05	227.67	236.94	101.06	126.75	129.05	184.59	146.49	11.36		
WCL 25	37.01	64.70	62.99	119.37	102.92	138.59	28.74	112.04	125.56	154.04	162.65	30.89	54.39	53.95	107.58	71.66	76.45	75.94	
WCL 26	23.12	41.93	88.57	93.06	78.09	112.16	14.95	86.34	98.71	126.24	135.96	13.58	27.29	33.16	80.31	45.58	102.85	101.86	30.42

Collection and evaluation of Wayanad turmeric (*Curcuma longa* L.) for yield and quality

by

ANU T S

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Abstract

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DEPARTMENT OF PLANTATION CROPS AND SPICES

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Abstract

Turmeric (*Curcuma longa* L.) is a rhizomatous perennial herb and an important sacred spice of India. It is used as a spice, colourant and an aromatic stimulant in several medicinal preparations. Wayanad local turmeric is reported to contain an average of 9.4 per cent curcumin. Due to the advent of improved varieties, the traditional cultivars of Wayanad are eroding. Keeping in view of this fact the study was undertaken to evaluate the local Wayanad accessions for yield and quality.

Twenty six accessions of traditional ecotypes were collected from three taluks of Manathavady, Vythiri and Sultanbathery of Wayanad district through mass publicity. Seventeen accessions having sufficient planting materials for replicated trial were selected for field trial along with three improved varieties, Sona, Kanthi and Prathibha as checks. The crop was raised under the partial shade of 54.29 per cent in the coconut farm of the Department of Plantation crops and spices in randomized block design.

Morphological observations were taken at 150 days after planting. Wayanad local turmeric accessions performed better than the check in all the biometric characters except length of the leaf. The plant height was highest for WCL 23 and girth was highest for WCL 3. The number of leaves on the main tiller was significantly high in WCL 15 and 16 while number of tillers per clump was highest in WCL 22. Leaf with maximum length and width were recorded in Kanthi and WCL 16 respectively.

Horizontal rhizome branching was observed in the Prathibha , 3, 13, 16, 17, 24 and 25. The variety Prathibha and accessions 16, 17, 20, 21, 24 and 25 showed plumpy rhizomes. Compact rhizomes were observed in 8, 9, 13, 14,15, 16, 19, 20 and 25. The inner core colour of the rhizome was light yellow in accession WCL 24 and reddish yellow Colour was observed in Prathibha, Kanthi and WCL 3. All other accessions had orange inner core colour.

The accessions and varieties were categorized based on percent disease index. The variety Prathibha and accessions 3, 13, 14, 15, 16 and 25 were highly resistant to leaf blotch. Accession WCL 5 was highly susceptible to leaf blotch. All the accessions were resistant in disease reaction to leaf spot except WCL 19, which was moderately resistant. The incidence of pests like lema beetle and shoot borer were observed in all accessions while leaf roller incidence was noticed only in Prathibha, WCL 5, WCL 17 and WCL 24.

Fresh rhizome yield per plant was significantly high in accessions WCL 24 (350.33 g) and WCL 23 (350.08 g) and were on par with Kanthi (335.60 g) and WCL 25 (274.66 g). Accession WCL 25 was superior in fresh rhizome yield per plot and per hectare (32.32 t ha^{-1}). Accessions WCL 23 and WCL 25 performed over and above the checks in terms of fresh yield, curcumin content and curcumin yield.

Curcumin content was high for WCL 5 (10.18 %) followed by WCL 25 (9.27 %) and WCL 26 (9.31 %). The accession WCL 5 was highly susceptible to leaf blotch and curcumin yield (286.06 kg ha^{-1}) was low. The fresh rhizome yield was highest in WCL 25 (32.32 t ha^{-1}). Curcumin yield was highest for WCL 25 (551.40 kg ha^{-1}) and accessions WCL 20, WCL 23, and WCL 26 were on par with WCL 25. Oleoresin content was significantly high in accessions WCL 3 (19.90 %) and WCL 22 (19.57 %). Essential oil content was highest for Sona (4.00 %) and Prathibha (4.00 %).

Selection index was also calculated from fresh rhizome yield per clump curcumin content, dry rhizome recovery and disease reaction. Accessions 3, 13, 14, 15, 16, 23 and 25 had a highest score of 12 and these were identified as superior accessions which can be used for further crop improvement programme.