HARVESTING STAGES AND CHITOSAN SPRAYS ON CURCUMIN YIELD IN TURMERIC (*Curcuma longa* L.)

by

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(2018-12-023)

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2020

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THESIS

Submitted in partial fulfilment of the requirements for the degree of

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Faculty of Agriculture
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DEPARTMENT OF PLANTATION CROPS AND SPICES
COLLEGE OF HORTICULTURE
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DECLARATION

I, hereby declare that this thesis entitled **"HARVESTING STAGES AND CHITOSAN SPRAYS ON CURCUMIN YIELD IN TURMERIC (*Curcuma longa* L.)"** 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.

Ashwini. S

Vellanikkara

04-11-2020

Ashwini S

(2018-12-023)

CERTIFICATE

Certified that this thesis entitle **"HARVESTING STAGES AND CHITOSAN SPRAYS ON CURCUMIN YIELD IN TURMERIC (*Curcuma longa* L.)"** is a record of research work done independently by **Mrs. Ashwini S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to her.

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(Major Advisor, Advisory Committee)
Assistant Professor and Head (i/c)
Cashew research station, Madakkathara

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CERTIFICATE

We, the undersigned members of the advisory committee of **Mrs. Ashwini S (2018-12-023)**, a candidate for the degree of **Master of Science in Horticulture**, with major field in Plantation Crops and Spices, agree that this thesis entitled **"HARVESTING STAGES AND CHITOSAN SPRAYS ON CURCUMIN YIELD IN TURMERIC (*Curcuma longa* L.)"** may be submitted by **Mrs. Ashwini S**, in partial fulfilment of the requirement for the degree.

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Ashwini S

Affectionately dedicated

To my family

And

To my guide

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LIST OF ABBREVATIONS AND SYMBOLS USED

Symbols	Abbrevations
%	per cent
ha	Hectare
mg	Milli gram
g	Gram
kg	Kilo gram
cm	Centimeter
m^2	Meter square
ml	Milli litre
L	Litre
h	Hour
spp.	Species
DAP	Days after planting
RBD	Randomized block design
ppm	Parts per million
et al.	and other co workers
$g\ L^{-1}$	Gram per litre
$t\ ha^{-1}$	Tonnes per hectare
NS	Not significant
sp	Species
Acc	Accessions

Introduction

1. INTRODUCTION

Turmeric (*Curcuma longa* L.) is a perennial, rhizomatous, herbaceous plant under Zingiberaceae family with chromosome number 2n = 63. It is a native of South East Asia and considered as a sacred spice crop in India. India is the largest producer, consumer and exporter of turmeric in the world. Turmeric plays a significant role in the national economy and it is an important commercial spice and medicinal plant, highly valued for its active constituent curcumin.

The important species of turmeric are *Curcuma longa*, *Curcuma angustifolia*, *Curcuma montana*, *Curcuma decipiens*, *Curcuma alismatifolia*, *Curcuma thoreli*, *Curcuma comosa* and *Curcuma aromatica*. *Curcuma longa* is one of the highly valued species as it contains a wide range of phytochemicals. The turmeric rhizomes contain carbohydrates, minerals, essential oils and curcumin. Aroma of turmeric is due to the presence of volatile oils like turmerone, ar- turmerone, Zingiberene. α-phellandrene, curlone, 1, 8-cineol (Surwase et al., 2013).

The main bio active constituent of turmeric is curcumin (1,7-bis-(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-2,5-dione) (Nisar *et al.*,2015). Curcumin is having chemical formula $C_{21}H_{20}O_6$, molecular weight of 368 g mol^{-1} and a melting point of 183°C. It possesses a wide range of biological properties.

Curcuminoids are the compounds responsible for its bright colour in turmeric. Curcuminoids consists of curcumin, demethoxy curcumin and bismethoxy curcumin. Curcumin is the primary or principal curcuminoid in turmeric. Commercially curcumin is extracted from *Curcuma longa* species.

Curcumin possess antioxidant, anticancer, anti-inflammatory, anti-acidogenic, radioprotective, anti-nephrotoxicity, antimicrobial, antiviral, anti-proliferative, hepatoprotectivity, antimalarial, antidiabetic, neuroprotective and anti tumor properties.

Turmeric is widely used as condiment, spice, in religious functions, as a synthetic dye in food, as a medicine and in cosmetics preparations. Turmeric with high curcumin content fetches high demand in the international market and has a great scope for export.

Turmeric has gained attention for its medicinal properties in the ancient medical system and now it is getting popular in modern medical applications too. Indian turmeric has high curcumin content. Curcumin content may vary with the cultivars, agronomic practices and the stages of harvest.

The varietal difference affects the yield as well as quality. To obtain high yield and quality, it requires effective crop management practices and selection of suitable cultivars. Kerala Agricultural University has released popular varieties *viz.,* Sobha, Sona, Kanthi and Varna. Indian Institute of Spice Research (IISR), Calicut released varieties *viz.,* Prathibha, Pragati, Kedaram, Prabha, Suguna, Sudharsana and Allepey Supreme. Some indigenous cultivars *viz.,* Wayanad local, Erode local and Salem also got popularity due its characters such as high yield, curcumin and low starch etc.

Optimum stage of harvest is necessary to obtain high yield and curcumin. The chemical compound in turmeric varies with the rhizome maturity. Rhizome yield, curcumin content and essential oil content are affected by rhizome maturity (Cooray *et al*., 1988).

Some elicitors like salicylic acid, methyl jasmonic acid, chitosan and ethephon are recorded to increase yield and quality parameters. Chitosan is the deacetylated form of chitin, which can be used as an elicitor to improve plant yield and biochemical characters. Chitosan sprays had influenced physiochemical properties and biological properties. Chitosan plays a vital role in enhancing the yield and secondary metabolites (Manoj, 2017).

Review of literature

Curcumin content and yield in turmeric increased with foliar sprayings of chitosan (Anasuya and Sathyabhama, 2016). Stage of harvest and genotypes also plays a vital role in turmeric yield and quality (Vijayan, 2015). In this context, the present study entitled “Harvesting stages and chitosan sprays on curcumin yield in turmeric (*Curcuma long* L.)” was carried out to evaluate yield and quality of turmeric cultivars as influenced by the foliar sprays of chitosan in three popular genotypes *viz.*, Sobha, Prathibha and Wayanad local at different harvesting stages.

2. REVIEW OF LITERATURE

INTRODUCTION

From the dawn of the civilization, medicinal plants have provided a reliable source for preparing medicines as well as combating disease. Turmeric belonging to the Zingiberaceae family is extensively useful medicinal and spice crop. Turmeric is commercially traded and highly valued for its aroma and colouring properties. (Nasri *et al*., 2014). India is known as the spice bowl of the world and has great scope for the cultivation of turmeric in India and Indian turmeric possess high demand in world market due to its superior quality (Angles, 2011). Due to its various medicinal, biological, pharmacological activities turmeric has a high market potential and high cost price (Waghmare *et al*., 2015).

Taxonomical classification of turmeric (Chanda and Ramachandra, 2019)

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Order	:	Zingiberals
Family	:	Zingiberaceae
Genus	:	*Curcuma*
Species	:	*longa*

Turmeric is an underground stem or rhizome with dull orange interior and gives a bright yellow colour when powdered (Lal, 2012). History of turmeric dates back to 4000 years to the Vedic period, where it was used for culinary and religious purpose (Yadav and Tarun, 2017). Turmeric also known as *Curcuma longa*, is derived from the Persian word, “kirkum” meaning “saffron” in reference to the vibrant yellow-orange colour of the rhizome (Bhowmik *et al*.,2009). Turmeric (*Curcuma longa* L.) is one of the most important spice and medicinal plant, highly valued for its curcumin, oleoresin, essential oil (Ayer, 2017).

Turmeric is an aromatic spice crop having a special importance in the preparation of traditional medicine, ayurvedic medicine, cosmetics, dye, and food, volatile and non-volatile compounds. Turmeric is having several properties and has a great demand worldwide (Jayaprakash *et al*., 2005).

VARIABILITY OF VARIETIES

The plant character varies with cultivars. The variation in turmeric yield of different cultivars under the same agro- climatic conditions is influenced by its genetic factors (Kumar *et al*., 2015).

Chaudhary *et al.* (2006) studied varietal performance and yield variability of different varieties. Five genotypes were evaluated *viz*., Suvarna, Rajendra sonia, Krishna, Suguna and Sudarshana to select superior one. Krishna a long duration genotype performed better than the other early maturing genotypes and a significant variability in yield attributing characters between cultivars was also noticed.

Luiram *et al*. (2018) conducted an experiment by evaluating 32 genotypes for yield and quality parameters. Curing per cent and oleoresin varied significantly. Highly significant variation was noticed in curcumin content (1.72 – 6.51%).

Long, medium and short duration turmeric genotypes evaluated in Andhra Pradesh revealed variation in yield and bio chemical characters. Long duration genotype Duggirala (168 g $plant^{-1}$) had a higher yield and short duration genotype PCT-14 had higher curcumin content (4.06 %) (Rao *et al.*, 2006).

Turmeric cultivars were evaluated and variability for growth and yield parameters were observed. Among the cultivars, Salem, Rajpur, CLT-325 and Prathibha performed significantly better in growth and yield parameters (Salimath *et al*., 2014).

CHITOSAN

Chitosan is a deacetylated biopolymer of chitin, used in food, cosmetic, medical and agricultural sectors (Du Jardin, 2015). Chitosan is a linear polymer of α (1→4) linked 2 amino-2- deoxy-β-D-glucopyranose and is derived by N-deacetylation (Dutta *et al.,* 2004). Chitosan and chitin are N-acetyl-D-glucosamine and D-glucosamine where the monomer ratio in polymer chain can define its physical, chemical and biological properties. Chitosan contains higher proportion of N-acetyl-D-glucosamine and are not abundantly found in nature (Pichyankura and Chadchawan, 2015).

Chitosan is a natural alternative for plant growth regulators (Acemi *et al*., 2018). It is found in shells of crustaceans and carapaces of insects, cell membranes of fungi and some algae (Nge *et al*., 2006). Chitosan is biodegradable, biocompatible, non- toxic and non- carcinogenic, making it useful in many fields (Alves *et al.*, 2008).

Chitosan can induce defence reactions in plants by induction of chitinase, chitosanase and β-1, 3 glucanase isoforms. Chitosan can remove heavy metals and dyes, control algal contamination from lakes and acts as soil conditioner. Foliar application of chitosan increase stomatal conductance and reduce transpiration without affecting plant height, root length, leaf area or plant biomass. Besides it is used as a seed coating material in cereals, nuts, fruits and vegetables. It acts as a carrier promoting slow release of fertilizer and improves water retention of soil (Pandey *et al*., 2018).

Depending on the plant structure, concentration, molecular weight, incubation period and solvent of chitosan molecule, plant response can vary. Lactic acid dissolved chitosan show the best inhibitory effect as compared to dissolved in formic acid and acetic acid (Hassan and Chang, 2017). Poor solubility is a limiting factor in its utilization (Dutta *et al*., 2004).

CHITOSAN PREPARATION

Chitosan is a natural polysaccharide, produced after the N-deacetylation of chitin (Sharif *et al*., 2018). Collected crustacean shells size reducted in to small pieces. From crustacean shells, removal of proteins and calcium carbonate has to be done. Protein presented in crustacean shells is separated by using NaOH. Then washed with HCl and later dewatering and discoloration of chitin is carried out. Finally, chitin is deacetylated with sodium hydroxide at 120°C for 1-3 hours and washed to get chitosan. In this treatment 70 per cent of deacetylated chitosan is obtained (Dutta et al., 2004).

Crustacean shell → Decalcification → Deprotenization → Demineralization

↓

Chitosan ← Washing and drying ← Deacetylation ← Chitin ← Discoloration

EFFECT OF CHITOSAN ON PLANT CHARACTERS

Field experiment was conducted in Oonjallur village of Erode district, Tamil Nadu, to study the effect of chitosan on growth, yield and curcumin content. Turmeric plants sprayed with chitosan 0.1 per cent at regular interval of 30 days upto 210 days increased the number of leaves per plant and shoot height compared to the control and over all curcumin production per plant. Fifty six per cent increases in curcumin content were observed in rhizomes and over all production were doubled with foliar application of chitosan (Sathiyabama *et al*., 2016).

Chilli seedlings transplanted in soil containing high molecular weight chitosan (0.1%) increased the plant height, number of leaves per plant, leaf width and leaf length (Chookhongkha *et al*., 2012).

An experiment was conducted at Bangladesh Institute of Nuclear Agriculture during 2010 – 2011 for studying the effect of foliar application of chitosan on growth and yield of okra. Five concentrations of chitosan spray *viz*., 0, 50, 75, 100 and 125 ppm was sprayed on 25, 40 and 55 days after planting. Result showed that plant height and leaf number increased significantly till 100 ppm. The increase in growth parameters was not significant after 100 ppm. The study also indicates that the application of chitosan in early growth stage had tremendous effect on the growth and development in okra (Mondal *et al*., 2012).

Chitosan sprays affected the growth and developmental characters of Indian spinach. Height of the plant, number of leaves and fresh weight of stem and leaf increased with chitosan application (Mondal *et al*., 2011).

Foliar spraying of chitosan 2 ml L^{-1} and seaweed extract 2 g L^{-1} significantly improved the plant height, number of leaves, head weight, fresh and dry weight and the quality parameters such as total soluble solids in globe artichoke (Saif-Eldeen *et al.,* 2014). An experiment was conducted in Lettuce (*Lactuca sativa*) to study the influence of chitosan, when used as soil amendment. Results showed that chitosan at 0.05 per cent, 0.02 per cent and 0.15 per cent increased leaf area (856, 847 and 856 cm^2, respectively) over control (674 cm^2) (Xu and Mou, 2018).

Abdel-Mawgoud (2010) recorded increased plant height, number of leaves and yield in strawberries with foliar application of chitosan.

Chitosan acts as a biostimulant in freesia. Chitosan treated plants exhibited more number of leaves, flowers, corms and earliness in flowering. There was an increased in corm weight and chlorophyll content in plants treated with chitosan (Salachna and Zawadzinska, 2014)

Chitosan oligosaccharide at 200 and 500 ppm concentration tends to promote plant height and 50 ppm and 200 ppm concentration tends to increase polyphenol content in Greek oregano (Yin *et al*., 2012).

Chilli seeds cultured in soil containing high molecular weight chitosan at 1.0 per cent resulted in significantly highest fresh fruit weight per plant, fruit number per plant, seed number per fruit and seed weight in chilli (Chookhongkha *et al*., 2012).

Foliar application of chitosan in rice production improved the morphological characters like plant height, number of tillers, length of panicle and yield of rice when compare to control (Sultana *et al*., 2015).

Ghoname *et al*. (2010) recorded that chitosan sprays promoted plant vegetative growth as well as fresh and dry weight, individual fruit weight and number of fruits in sweet pepper.

Malekpoor *et al*. (2016) found that chitosan plays positive role in growth and development of basil in water deficient condition by reducing transpiration rate.When plants treated with Chitosan at 0.4 g L^{-1} by foliar sparys on *Ocimum basilicum* recorded better in plant growth characters when compared to untreated plants.

EFFECT OF CHITOSAN ON PEST AND DISEASE INCIDENCE

Chitosan acts as a defence booster in plant by enhancing the plant immunity and antimicrobial activity, and improve defence response (Raho *et al.*, 2011; Zhang *et al*., 2011)

Anusuya and Sathiyabama (2014) studied the effect of chitosan on rhizome rot of turmeric caused by *Pythium aphanidermatum*. Gel electrophoresis revealed that chitinase and chitosanase isoforms in leaves of turmeric treated with chitosan 0.1 per cent. Chitosan treated turmeric plants showed more resistance than control by increased activity of defense enzymes.

Rabea *et al* (2005) observed the insecticidal activity of chitosan on *Spodoptera littoralis.* Chitosan spray of 5 g L^{-1} resulted in 75 percent mortality rate observed after 4 days.

Field experiment was conducted to study the effect of chitosan on growth, yield and curcumin content at Bharathidasan University, Tiruchirapally, and Tamil Nadu. Study showed that foliar application of chitosan induced the activity of defense enzyme such as β–1, 3 glucanase, peroxidase and polyphenol oxidase in the leaves and rhizomes. In addition, result also suggests that chitosan can be used as an eco friendly compound to induce defense responses (Anusuya and Sathiyabama, 2014)

Disease severity in orchids was reduced by chitosan by increasing the activity of PAL and PPO, lignification resulting from increased biosynthesis of phenolic compounds or induced secondary metabolities and SAR. Disease resistance might be mediated *via* an increase in the concentrations of jasmonic acid and also involvement of stomatal closure by ABA (Uthairatanakij *et al*., 2007).

To compare the effectiveness in inducing resistance against *Blumeria graminis* f.sp.*hordei*, an investigation was conducted to study the underlying defense response in barley plant by the application of chitosan and BHT (Benzothiadiazole). Both compounds reduced the infection significantly on primary leaf, by 55 per cent and 68 per cent at 3 days of induction phase. This shows the induction of a good level of local resistance (LAR) (Faoro *et al.,* 2008).

Chitosan at low molecular weight has the highest inhibitory effect on *Rhizopus stolonifera*, *Botrytis cinerea*, *and Penicillium expansum* and also act as natural nematicide. High molecular weight chitosan show better efficacy on *Fusarium oxysporum* f. sp.*vasinfectum* and *Alternaria solani f. oxysporum* and *Valsa mal* (Hassan and Chang, 2017).

EFFECT OF CHITOSAN ON PHOTOSYNTHETIC RATE

Chookhongkha *et al*. (2012) investigated physiological and biochemical reactions in chilli and noticed that when chilli grown in soil mixed with 1 per cent chitosan, chlorophyll content, number of fruits per plant and number of seeds per fruit was increased. Application of chitosan in leaves also increased photosynthesis leading to an overall improvement in plant development.

Chitosan nano particles at 10 ppm had influence on growth and nutrients uptake of coffee. Improved chlorophyll content and photosynthesis in coffee seedlings were noticed with application of chitosan nano particles (Van *et al.,* 2013).

BIOSTIMULANT EFFECT OF CHITOSAN ON BIOCHEMICAL CONTENT

Anasuya and Sathyabama (2016) found that foliar sprayings of chitosan recorded four fold increas in curcumin content when compared to the plants maintained as control.

Manoj (2017) conducted a study to evaluate the effect of different elicitors such as ethephone, methyl jasmonoids, potassium phosphate, salicylic acid and chitosan. Spraying of elicitors was carried out in three stages at 120, 150 and 180 DAP. Among all elicitors, chitosan sprayed plants recorded higher yield and curcumin.

Chitosan has a positive charge on some specific biological and physiological activities. Chitosan acts as tool to improve the phenolic contents. Chitosan treated grapes possessed increased the poly phenol levels (Garcia and Plaza, 2013).

Elicitor chitosan is provided through hydroponic nutrient media to *Withenia somnifera* plants. Results showed increased Withaferin A content in chitosan treated plants by 69% than the plants maintained as control (Gorelick *et al*., 2015).

Chitosan treated *Eustoma grandiflorum* increased the bud development and anthocyanin accumulation in developing flowers (Uddin *et al*., 2004). Tomato plants showed significant increase in ascorbic acid content when treated with chitosan (El-Gawad and Bondok, 2015).

Effect of chitosan treatment on physiochemical and its biological properties of sweet basil was investigated by Kim *et al*. (2005). Results showed that chitosan treated plants recorded increased phenolic content significantly at 0.1 per cent. The main compounds in sweet basil rosemaric acid (2.0 mg g^{-1}), and eugenol (2%) were recorded higher in chitosan treated plants when compared to the control.

Folair spray at 100 mg L^{-1} is effective in improving the biosynthesis in *Artemisia annua* L. Artemisin content increases from 4 hours after chitosan application and reached maximum amount of 53 per cent at 48 hours. At 8 hours after chitosan treatment, dihydroartemisinic acid was significantly higher than control (Lei *et al*., 2011).

Menthol in *Mentha piperita* was increased by adding chitosan 200 mg L^{-1} to the cell culture in shake flasks. Higher yield of menthol 166 mg L^{-1} was obtained in plants given chitosan and this was due to increased conversion of pulegone to menthol (Chang *et al.,* 1998).

Chitosan-silver nanoparticles were used to induce biochemical variations in chickpea (*Cicer aritium* L.). This confirmed significant growth promotory effect as well as biochemical variation capabilities of Ag-CS Nps (Anusuya and Banu, 2016).

CURCUMIN

Curcumin is a phytochemical present in turmeric which gives yellow color to turmeric. Curcumin was isolated at 1815 for the first time by Vogel Jr in *Curcuma longa* L. It was structurally characterized by Milobedeska and synthesized by Lampe (Noorafshan and Ashkani- Esfahani, 2013).

Curcumin is the major coloring compound in turmeric. Curcumin, demthoxycurcumin and bismethoxycurcumin are related compounds of curcumin (Revathy *et al*., 2011). In curcumin these three curcuminoids are present in the ratio of 80 percent curcumin, 15 percent demethoxycurcumin and 5 percent bis methoxycurcumin. Curcumin is insoluble in water and it is soluble in some chemicals like ethanol and acetone (Ireson *et al*., 2001).

INFLUENCE OF HARVESTING STAGES ON YIELD AND CURCUMIN CONTENT OF TURMERIC

An experiment conducted by Asghari *et al*. (2009) to study the influence of harvesting stages on curcumin content in *Curcuma longa*. The crop was harvested from 2 months onwards to 10 months in a two months interval. The results showed that curcumin content was increased from 0.25 - 2.7 per cent with increasing harvesting stage.

A study was conducted by Kumar and Gill (2009) in Punjab to evaluate the effect of harvesting stages in turmeric. Improvement in curcumin content was noticed with delayed harvest.

Hossain (2010) in Okinawa, Japan conducted an experiment to evaluate impact of harvesting stage on the shoot biomass and yield in different cultivars of turmeric. The highest dry yield was obtained from plants harvested in the month of January when plants were withered fully.

Rao *et al*. (2006) in Andhra Pradesh evaluated the curcumin content and yield from long, medium and short duration genotypes and recorded that higher yield was obtained from the long duration genotypes compared to short and medium duration genotypes but the curcumin content was highest in the short duration genotype.

Aarthi *et al*. (2018) studied the correlation analysis between yield and curcumin content in Kerala by using 15 genotypes and observed that there was a positive correlation between yield and curcumin content.

Singh *et al*. (2014) recorded that curcumin content was positively correlated with all yield parameters including plant height, tiller number, number of leaves, and leaf area and rhizome biomass in turmeric.

A study conducted by Hailemichael *et al*. (2016) to evaluate the performance of quality parameters in different stages of rhizome development by using three accessions at five different stages of harvest. The crop harvested at monthly intervals starting from 7 month to 11 months and quality parameters were found to be influenced by stage of harvest and the high quality turmeric was observed when rhizomes were harvested at 7 to 8 months.

Policegoudra *et al*. (2007) investigated the accumulation of bioactive compounds during growth and development stages of mango ginger. The highest accumulation rate was recorded at 180 days after planting and is considered as standard for harvest to get quality rhizome compare to conventional harvest at 210 - 240 days.

Vijayan (2015) conducted an experiment with different harvesting stages and found that yield and quality parameters vary with the harvesting stages. The maximum yield and curcumin content were significantly higher when crop was harvested at 8 months.

A chemical compound in turmeric varies with the stage of maturity of the crop. In *Curcuma longa*, the essential oil content recorded maximum at 7.5 – 8 months and maximum curcumin per bush was highest when crop is at 9 months. These months were found to be the optimum stages to harvest rhizomes for getting maximum yield of oil and curcumin (Cooray, 1987).

To study the effect of blanching, harvesting and location on the curcuminoid content, an experiment was conducted in the Biotechnology Centre, Faculty of Science and Technology, University of West Indies, Jamaica. In the experiment, turmeric was collected from two locations namely Hanover and St. Andrews with four harvesting periods. The study revealed that there was a decrease in curcumin content from 5^{th} – 9^{th} month in Hanover and 6^{th} to 9^{th} month in St. Andrews. Curcumin yield was highest in 5.5 months of maturity and there was a decline in of pigment towards full maturity. Curcuminod level peaks during a certain stages of plant maturation as a consequence of dynamic changes like plant growth, rate of biosynthesis and probable decrease in gene expression for these pigments due to loss of plant vigour over time (Green and Mitchell, 2014).

CURS (Curcumin synthase) is an enzyme responsible for curcumin synthasis and *CURS* gene plays an important role in curcumin biosynthesis. Sandeep *et al*. (2017) recorded that curcumin content varied among different harvesting period and genotypes. There was a positive correlation in the *CURS* gene expression and curcumin content with different harvesting time at particular zone.

INFLUENCE OF HARVESTING STAGES ON YIELD OF VARIOUS CROPS

In sorghum, quality and yield properties were affected by the stage of harvest. Physiological maturity stage is the suitable time for harvesting sorghum for getting high yield and quality fodder (Atis *et al*., 2012).

Effect of harvesting stage on quality and yield parameters was studied by Ayub *et al.* (2009) the crop harvested at 40, 50, 60 days after sowing by giving 10 days interval for each harvest. It was found that harvesting at 60 days after sowing was superior in terms of yield and quality.

Accumulation of essential oil and herb yield in thyme was higher in early fruit set stage when 50 per cent of fruits matured in inflorescence. Essential oil was 0.75 per cent in these stages and at later stages there was a decline in the oil percentage (Omidbaigi *et al*., 2000).

Harvetsing stage plays a major role in imparting good grain quality in maize. Maize harvested after the physiological maturity stage, when crop is at 20 percentage moisture content is considered as suitable harvest time for maize (Barary, 2014).

A study was conducted to determine the β-elemene, curcumin, curcumol, curdione and germacrone and to determine the harvest stages suitable for *Curcuma weyujin.* The study showed that the crop can be harvested in December to early

January. Chemical finger printing of extract indicated that there was no phytochemical changes in different growth stages *of C.wenyujin* but the content are constantly fluctuating with season and time of collection (Zhang *et al*., 2013).

PHARMACEUTICAL APPLICATIONS OF TURMERIC

Turmeric have antioxidant, antiinflammatory, anticarcinogenic, anticoagulant, antifertility, antidiabetic, antibacterial, antimutagenic, antifungal, antiviral, antiprotozoal, antifibrotic, antiulcer, antivenom, hypotensive and hypocholesteremic activities (Rathaur, 2012).

Curcumin have antifungal, antimicrobial, anticancerous, heptoprotective (Nawaz *et al.*, 2011). Curcumin is also have propertities like antioxidant, anti-inflammatory, anti-diabetic, anti- coagulant, and anti-HIV and used in certain type of cancer treatment (Nasri*et al*., 2014). Curcumin have anti-aging property and prevents wrinkles and maintains the skin health (Gupta *et al*., 2013). It also possesses properties such as, anti-platelet aggregation, antimutagenic and used in treatment of dental problems (Nagpal *et al*., 2013).

Curcumin is considered as a medicine from ancient time and it is recommended to control allergy, asthama and helps in wound healing (Zahmatkesh *et al*., 2016).

Curcumin plays a role in maintaining health and preventing respiratory disorders like bronchitis. Haridra in milk mixed with jaggery is given internally for rhinitis and cough. Haridra with fumes wick is given for asthma and congestion. Turmerone, curcuminoids, curcumin and tetrahydrocurcumin has anti asthamatic action (Krup *et al*., 2013).

Ancient Hawaiians used turmeric for prevention and treatment of gastrointestinal ulcers, sinus infection and ear infections (Duraisankar and Ravindran, 2015). Studies on animals show that turmeric has numerous potential in prevention of diseases like proinflammatory diseases, cancer, neurodegenerative disease, depression, diabetes, obesity and atherosclerosis. Spice also showed modulation in cell signalling pathways at molecular level (Gupta *et al*., 2013).

Dried rhizomes are used on fresh wound a counter irritant on insect stings, dried rhizomes are used on fresh wounds and to facilates the scabbing process in chicken pox and smallpox. Aloevera juice mixed turmeric powder is used externally to treat wounds (Deb *et al*., 2013).

Materials andmethods

3. MATERIALS AND METHODS

The experiment entitled “Harvesting stages and chitosan sprays on curcumin yield in turmeric *(Curcuma longa* L.)” was conducted in Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, during 2019-2020. The materials and methods adopted for the study are mentioned in this chapter.

PLANTING MATERIAL

The study was conducted using seed material of Turmeric, stored in zero energy chambers of Department of Plantation Crops and Spices. The genotypes used were Sobha (released by Kerala Agricultural University), Prathibha (released by Indian Institute of Spice Research) and Wayanad local accession (Acc, WCL 23) a local accession from Wayanad district identified as superior in the previous study of Department of Plantation Crops and Spices.

DETAILS OF EXPERIMENT

Land preparation and planting

The open field was cleared, deep ploughed and beds were taken. The cultivation practices were carried out according to Kerala Agriculture University Package of Practices (POP, 2016) and the fertilizers were applied on the basis of results obtained after soil sampling.

Design and layout

Design	: Factorial RBD
Plot size	: $3m^2$
Spacing	: 0.25 X 0.25 m
Treatments	: 27
Replications	: 3
Month of Planting	: May

Details of treatments

Genotypes

V1 - Sobha

V2 -Prathibha

V3- Wayanad local (Acc WCL 23)

Stages of harvest

H1 - 210 Days afterplanting

H2 - 240 Days after planting

H3 - 270 days after planting

Foliar spray

C1- Chitosan spray 0.1%
C2- Water spray
C3- Absolute control

Foliar application of chitosan

Biostimulant chitosan at a concentration of 1 g L^{-1} as recorded by Anusuya and Satiyabama,(2016) was given as foliar spray at monthly intervals, starting from two month after planting. Five rounds of foliar sprays of chitosan were given starting from 60 Days After Planting (DAP) to 180 DAP during the crop growth period. Chitosan, being insoluble in water, was dissolved in 0.25 per cent glacial acetic acid and sprayed.

Chitosan used for the present study was collected from Matsyafed Chitin and Chitosan plant, Neendakara, Kollam, Kerela. Low density chitosan flakes were used for the study.Details of the treatment combinations are listed in Table 1.

Table 1. Details of the treatments given during the experiment

Treatments	Genotypes	Stages of harvest	Chitosan spray
V1H1C1	Sobha	Harvesting at 210 DAP	Chitosan spray at 1 g L^{-1}
V1H1C2	Sobha	Harvesting at 210 DAP	Water spray
V1H1C3	Sobha	Harvesting at 210 DAP	Absolute Control
V1H2C1	Sobha	Harvesting at 240 DAP	Chitosan spray at 1 g L^{-1}
V1H2C2	Sobha	Harvesting at 240 DAP	Water spray
V1H2C3	Sobha	Harvesting at 240 DAP	Absolute Control
V1H3C1	Sobha	Harvesting at 270 DAP	Chitosan spray at 1 g L^{-1}
V1H3C2	Sobha	Harvesting at 270 DAP	Water spray
V1H3C3	Sobha	Harvesting at 270 DAP	Absolute Control
V2H1C1	Prathibha	Harvesting at 210 DAP	Chitosan spray at 1 g L^{-1}
V2H1C2	Prathibha	Harvesting at 210 DAP	Water spray
V2H1C3	Prathibha	Harvesting at 210 DAP	Absolute Control
V2H2C1	Prathibha	Harvesting at 240 DAP	Chitosan spray at 1 g L^{-1}
V2H2C2	Prathibha	Harvesting at 240 DAP	Water spray
V2H2C3	Prathibha	Harvesting at 240 DAP	Absolute Control
V2H3C1	Prathibha	Harvesting at 270 DAP	Chitosan spray at 1 g L^{-1}
V2H3C2	Prathibha	Harvesting at 270 DAP	Water spray
V2H3C3	Prathibha	Harvesting at 270 DAP	Absolute Control
V3H1C1	Wayanad local (Acc WCL 23)	Harvesting at 210 DAP	Chitosan spray at 1 g L^{-1}
V3H1C2	Wayanad local (Acc WCL 23	Harvesting at 210 DAP	Water spray
V3H1C3	Wayanad local (Acc WCL 23	Harvesting at 210 DAP	Absolute Control
V3H2C1	Wayanad local (Acc WCL 23)	Harvesting at 240 DAP	Chitosan spray at 1 g L^{-1}
V3H2C2	Wayanad local (Acc WCL 23	Harvesting at 240 DAP	Water spray
V3H2C3	Wayanad local (Acc WCL 23	Harvesting at 240 DAP	Absolute Control
V3H3C1	Wayanad local (Acc WCL 23)	Harvesting at 270 DAP	Chitosan spray at 1 g L^{-1}
V3H3C2	Wayanad local (Acc WCL 23	Harvesting at 270 DAP	Water spray
V3H3C3	Wayanad local (Acc WCL 23	Harvesting at 270 DAP	Absolute Control

Fig .1. Layout of experiment

Replication 1			Replication 2		
V1H1C1	V2H1C1	V3H1C1	V1H3C3	V2H3C3	V3H3C3
V1H2C1	V2H2C1	V3H2C1	V1H2C3	V2H2C3	V3H2C3
V1H3C1	V2H3C1	V3H3C1	V1H1C3	V2H1C3	V3H1C3
V1H1C2	V2H1C2	V3H1C2	V1H3C2	V2H3C2	V3H3C2
V1H2C2	V2H2C2	V3H2C2	V1H2C2	V2H3C2	V3H2C2
V1H3C2	V2H3C2	V3H3C2	V1H1C2	V2H2C2	V3H1C2
V1H1C3	V2H1C3	V3H1C3	V1H3C1	V2H3C1	V3H3C1
V1H2C3	V2H2C3	V3H2C3	V1H2C1	V2H2C1	V3H2C1
V1H3C3	V2H3C3	V3H3C3	V1H1C1	V2H1C1	V3H1C1

XXXX

Replication 3	
V1H1C1	V1H2C1
V1H3C1	V2H1C1
V2H2C1	V2H3C1
V3H3C1	V3H2C1
V3H3C1	X
V1H1C2	V1H2C2
V1H3C2	V2H1C2
V2H2C2	V2H3C2
V3H1C2	V3H2C2
V3H3C2	X
V1H1C3	V1H2C3
V1H3C3	V2H1C3
V2H2C3	V2H3C3
V3H1C3	V3H2C3
V3H3C3	X

V1- Sobha	H1- Harvest at 210 DAP	C1- Chitosan Spray g L^{-1}
V2- Prathibha	H2- Harvest at 240 DAP	C2- Water spray
V3 –Wayanad local (Acc WCL 23)	H3 – Harvest at 270 DAP	C3- Control

X- Open space


Planting of turmeric rhizomes


Plate 1. Land preparation and planting

Application of manures

Morphological Observations at 100,120, 150 DAP

Field view of ezperimettal plot

Plate 2. Fertilizer application, morphological observations and general field view

Foliar sprays of chitosan

Plate 3. Spraying of chitosan

OBSERVATIONS

Morphological observations were taken by selecting ten plants randomly from each bed. Observations were recorded at 100, 120 and 150 DAP. Harvesting of the crop was done at three different stages *i.e.*, 210, 240 and 270 DAP. Rhizome characters were recorded at the time of harvest. Ten plants were selected randomly from each bed at the time of harvest and rhizome characters and quality parameters were recorded.

Morphological characters

Height of the main tiller (cm)

Height of main tiller was measured at 100,120 and150 DAP. Ten plants were randomly chosen from each treatment replication. The height was determined by measuring the length from the base of plant to the tip of longest and completely opened leaf and expressed in centimeter.

Girth of main tiller (cm)

Girth of the main tiller was measured at the collar region of main tiller of ten randomly selected plants during 100, 120 and 150 DAP. It was determined by using a thread and measured on a scale and expressed in cm.

Number of leaves on main tiller

Ten plants were randomly selected from each treatment replication at three growth stages *viz*. 100, 120 and 150 DAP. Total number of leaves on main tiller of each plant was counted and recorded.

Number of tillers per clump

Ten plants were randomly selected from each treatment replication and the total number of tillers of individual plant were counted and recorded at 100, 120 and 150 DAP.

Leaf Area (cm^2)

Leaf area was estimated non-destructively, at three growth stages *viz*., 100, 120 and 150 DAP. Ten plants were randomly selected from each treatment replication and the fourth leaf from the top of each plant was used for measuring length and breadth (Lingyun *et al*., 2017). Leaf area was calculated using a formula, suggested by Panja and Gayen (2009).

Leaf area (A) = 5.71+0.72 (LxB)

(A is the estimated leaf area and L and B represents length and breadth of leaf respectively).

Physiological Parameters

Photosynthetic rate

Photosynthetic rate was measured active tillering stage (150 DAP) using Infra Red Gas Analyser (IRGA model LI-6400, LiCor Inc. Lincoln, Nebraska, USA). Observations were recorded from the 4^{th} leaf from the top (Lingyun *et al*., 2017) of

Plant in each treatment, during morning hours (9-10 am) and expressed as µ mol CO_2 m^{-2} s^{-1}.

Observations on rhizome characters at harvest

Length of primary rhizome (cm)

Ten plants were randomly selected from each treatment replications at each stage of harvest. Length of the primary rhizomes was determined by measuring the length, starting from the point of attachment to the mother rhizome to the apex point and was expressed in cm.

Width of primary rhizome (cm)

Width of the primary rhizome was recorded using a thread and measured on scale, at three stages of harvest *viz.*, 210, 240 and 270 DAP. Primary rhizomes from the randomly selected plant from each treatment replication were used for determining the width and expressed in centimeter.

Number of mother rhizome

Ten plants were randomly chosen from each treatmen treplication and total number of mother rhizomes in each clump was counted and recorded, at three harvesting stages viz., 210, 240 and 270 DAP.

Number of primary rhizome

Number of primary rhizomes in each clump was counted after selecting ten rhizomes from randomly from each treatment replication. Observation on number of primary rhizome was recorded during three different harvesting stages.

Number of secondary rhizome

Ten clumps of rhizomes were randomly chosen from each treatment replication at each stage of harvest. Number of secondary rhizomes that are arising from the primary rhizomes was determined by counting all the secondary rhizomes from each clump.

Weight of mother rhizome (g)

Weight of mother rhizomes was determined by weighing the weight of mother rhizome from randomly collected clump. Ten randomly selected rhizome clumps from each treatment replication during each stage of harvest were collected and weight was recorded and expressed in gram (g).

Weight of primary rhizome (g)

Weight of primary rhizome was determined by weighing the primary rhizome from each clump which was randomly chosen at different harvesting stages. Weight was expressed in gram (g).

Weight of secondary rhizome (g)

Weight of secondary rhizome was determined by weighing the secondary rhizome from randomly selected clumps. Weight of secondary rhizome was measured during all three harvesting stages and was expressed in gram (g).

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

Fresh rhizome yield per plant was recorded by weighing the freshly harvested rhizome clumps from ten randomly selected plants in each treatment replication, at each stage of harvests *viz.,* 210, 240 and 270 DAP. The fresh rhizomes after harvest were cleaned off roots, air dried and weight was recorded in an electronic balance. The Fresh rhizome yield from turmeric was expressed in gram (g).

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

Three samples of fresh rhizomes from each treatment were cleaned and made into small pieces. Hundred grams of the fresh samples were dried in cabinet drier at 70^{0}C. The drying percent was calculated from the dry weight.

$$\text{Drying per cent} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

The average dry weight per plant was computed by multiplying fresh weight and drying per cent and expressed as dry weight per plant in gram.

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

The entire plants from plots of three square meters were harvested from each treatment beds. Immediately after harvest, the roots were removed and cleaned. The fresh weight of the rhizomes from each treatment plots was recorded as fresh yield per plot and was expressed in kilogram (kg).

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

Dry yield per plot was calculated by multiplying fresh yield per plot with drying percent as described in *3.3.3.10*. Dry weight per plot was expressed in kilogram.

Curing percent (%)

Fresh turmeric rhizomes were taken and washed to remove the dirt and soil adhering to it. Then it was boiled in water for 40 minutes, till the rhizomes become soft and start emitting typical turmeric odor. Then it was cut into small pieces and was dried in cabinet drier and the curing percentage was computed.

Pest and disease incidence

Crop was monitored throughout the growth period for checking the incidence of pest and diseases. However, no serious pest and disease incidence was notice except leaf spot.

Biochemical studies

Curcumin content (%)

The curcumin content was estimated by ASTA method as suggested by Sadasivam and Manickam (2002). Turmeric was cured, dried and powdered. To a conical flask, 0.2 g of moisture free turmeric powdered sample was added along with 100ml absolute ethanol. The sample was refluxed over a heating mantle for 3 – 5 hours, and the sample was cooled and decanted into 100 ml volumetric flask. Volume was made up to 100 ml and from that one ml of the aliquot was taken and diluted with 4 ml of absolute alcohol, and finally the intensity of the yellow color was measured at 425 nm in a spectrophotometer and curcumin content is calculated (Sadasivam and Manickam, 2002).

The percentage of curcumin present in the samples was calculated using the following formula

$$\text{Curcumin content} = \frac{A425 \times 0.0025 \times \text{volume made up} \times \text{dilution factor} \times 100}{0.42 \times \text{weight of the sample} \times 1000}$$

Curcumin analysis steps

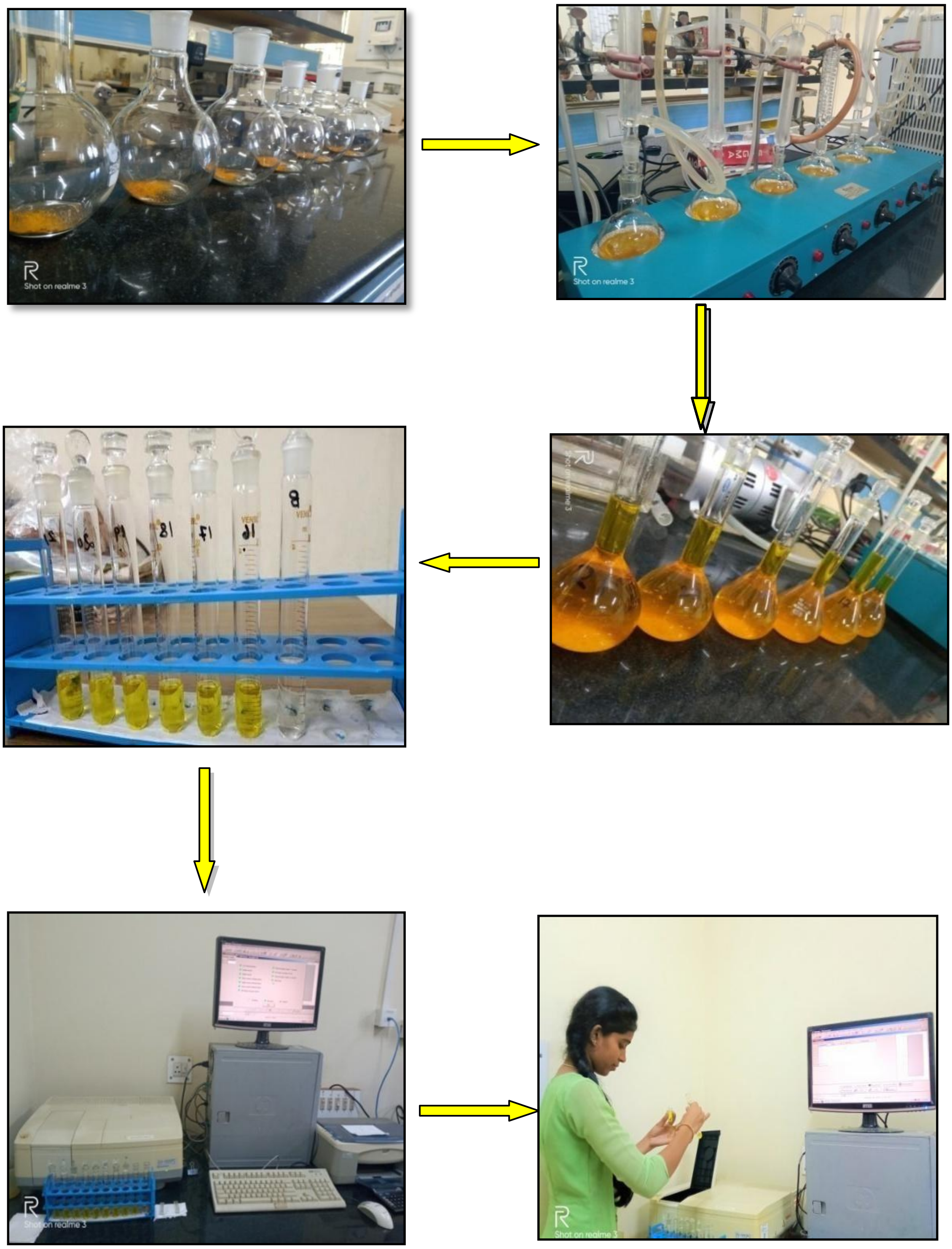


Plate.4. Curcumin content analysis

Results

4. RESULTS

This study entitled "Harvesting stages and chitosan sprays on curcumin yield in turmeric *(Curcuma longa* L.)" was undertaken during 2019-2020 in Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, to study the influence of chitosan sprays and stages of harvest on curcumin yield in turmeric genotypes. The genotypes include Sobha, Prathibha, and Wayanad local (Acc 23). The three stages of harvest were 210, 240 and 270 DAP. Foliar application of chitosan at a concentration of 1g L^{-1} along with water spray and absolute control was another treatment. Five rounds of foliar application of chitosan were given to the plants starting from 60 DAP to 180 DAP.Various growth parameters, yield characters and biochemical characters were recorded during the experimental period and statistically analysed. This chapter comprises of results of various parameters recorded during the experimental period.

MORPHOLOGICAL OBSERVATIONS

Influence of chitosan sprays on plant height of turmeric genotypes at various growth stages

There was a significant difference in plant height at various growth stages of turmeric genotypes when considered irrespective of chitosan spray. The genotype Wayanad local (Acc WCL 23) recorded significantly higher plant height in all growth stages *viz.*, 100, 120 and 150 DAP (94.49 cm, 127.70 cm and 140.20 cm, respectively). The lowest plant height was recorded by genotype Sobha in all growth stages (66.61 cm, 101.32 cm and 120.62 cm, respectively). The genotype Prathibha recorded a plant height of 89.35 cm, 116.30 cm and 129.32 cm, respectively at growth stages of 100, 120 and 150 DAP (Table 2).

There was no significant difference in plant height by chitosan spray at 1g L^{-1} when considered irrespective of genotypes during the initial stages of growth at 100 DAP and 120 DAP. But there was significant difference at 150 days after planting. The highest plant height was in plants sprayed with chitosan 1g L^{-1} (133.58 cm) and water sprayed plants (131.67 cm). Lowest plant height was noticed in absolute control (124.88 cm) (Table 2).

Interaction effect of genotypes and chitosan sprays had no significant influence on plant height of turmeric in all growth stages (Table 3).

Table 2. Influence of chitosan sprays on plant height of turmeric genotypes at various growth stages

Treatments	Plant height at 100 DAP (cm)	Plant height at 120 DAP (cm)	Plant height at 150 DAP (cm)
Genotypes			
Sobha	66.61^{c}	101.32^{c}	120.62^{c}
Prathibha	89.35^{b}	116.30^{b}	129.32^{b}
Wayanad local	94.49^{a}	127.70^{a}	140.20^{a}
SE	1.72	1.97	1.84
CD	4.87	5.59	5.22
Spraying Chitosan			
Chitosan spray	82.93	115.06	133.58^{a}
Water spray	86.13	117.37	131.67^{a}
Absolute control	81.41	112.90	124.88^{b}
SE	1.72	1.97	1.84
CD	NS	NS	5.22

Table 3. Interaction effect of genotype and chitosan spray on plant height at various growth stages

Genotype x Chitosan spray	Plant height at 100 DAP (cm)	Plant height at 120 DAP (cm)	Plant height at 150 DAP (cm)
Sobha x Chitosan spray	63.27	99.57	122.72
Sobha x Water spray	68.41	103.13	122.59
Sobha x Control	68.17	101.28	116.53
Prathibha x Chitosan spray	89.08	116.20	135.59
Prathibha x Water spray	92.32	120.42	127.63
Prathibha x Control	86.68	112.30	124.74
Wayanad local x Chitosan spray	96.44	129.42	142.43
Wayanad local x Water spray	97.67	128.56	144.81
Wayanad local x Control	89.37	125.12	133.37
CD	NS	NS	NS

Influence of chitosan spray on the number of leaves of turmeric genotypes at various growth stages

Number of leaves at 100, 120 and 150 DAP recorded significant variation in turmeric genotypes in all growth stages (Table 4) when considered irrespective of chitosan spray. At 100 DAP the genotype Prathibha recorded significantly higher number of leaves (7.87). The genotypes Wayanad local recorded higher numbers of leaves (8.65) at 120 DAP. At 150 DAP the genotype Prathibha (8.46) recorded significantly highest number of leaves. The number of leaves of Wayanad local was on par with highest (8.33) at 150 DAP.

There was no significant difference in number of leaves with respect to chitosan sprays during all growth stages (Table 4).

The interaction effect of genotypes and chitosan spray on number of leaves was also found to be statistically non-significant during all growth stages (Table 5).

Table 4. Influence of chitosan spray on number of leaves of turmeric genotypes at various growth stages

Treatments	Number of leaves at 100 DAP	Number of leaves at 120 DAP	Number of leaves at 150 DAP
Genotypes			
Sobha	7.37[c]	8.46[b]	8.18[c]
Prathibha	7.87[a]	8.46[b]	8.46[a]
Wayanad local	7.61[b]	8.65[a]	8.33[ab]
SE	0.08	0.05	0.06
CD	0.21	0.14	0.17
Spraying Chitosan			
Chitosan spray	7.60	8.56	8.31
Water spray	7.64	8.55	8.37
Absolute control	7.61	8.46	8.28
SE	0.08	0.05	0.06
CD	NS	NS	NS

Table 5. Interaction effect of genotype and chitosan spray on number of leaves of turmeric at various growth stages

Genotype x Chitosan spray	Number of leaves at 100 DAP	Number of leaves at 120 DAP	Number of leaves at 150 DAP
Sobha x Chitosan spray	7.27	8.41	8.13
Sobha x Water spray	7.40	8.57	8.28
Sobha x Control	7.45	8.41	8.12
Prathibha x Chitosan spray	7.83	8.53	8.41
Prathibha x Water spray	7.91	8.42	8.46
Prathibha x Control	7.87	8.43	8.48
Wayanad local x Chitosan spray	7.71	8.74	8.38
Wayanad local x Water spray	7.62	8.67	8.35
Wayanad local x Control	7.51	8.56	8.25
CD	NS	NS	NS

Influence of chitosan spray on number of tillers of turmeric genotypes at various growth stages

The number of tillers observed at 100, 120 and 150 DAP showed significant difference with respect to genotypes (Table 6). Among the genotypes, Wayanad local (Acc WCL 23) recorded highest number of tillers at 100, 120, 150 DAP (2.97, 3.59, 3.71, respectively) followed by Prathibha (2.73, 3.19, 3.36, respectively). The number of tillers recorded in Sobha was (2.31, 2.82 and 2.90, respectively).

Chitosan sprays had a significant influence on tillers production when considered irrespective of genotypes (Table 6). Chitosan sprayed plants exhibited a significant effect on tiller number at 120 DAP to 150 DAP. At 120 DAP significantly higher number of tillers was recorded in chitosan sprayed plants (4.11) followed by water spray (2.88) and control (2.60). Irrespective of genotypes chitosan treated plants had a significant increase in tiller production. At 150 DAP the significantly highest number of tiller were recorded in chitosan sprayed plants (3.78) followed by water spray and control (3.12, 3.07, respectively).

The interaction effect of genotypes and chitosan spray on number of tillers had significant effect at 120 DAP. The highest number of tillers was recorded in chitosan sprayed plants of genotype Wayanad local (Acc WCL 23) (4.93) followed by chitosan sprayed plants of Prathibha and Sobha (3.90 and 3.52, respectively). The interaction effect of genotypes and chitosan spray on number of tillers at 100 and 150 DAP was found non-significant (Table 7).

Table 6. Influence of chitosan spray on number of tillers of turmeric genotypes at various growth stages

Treatments	Number of tillers at 100 DAP	Number of tillers at 120 DAP	Number of tillers at 150 DAP
Genotypes			
Sobha	2.31[c]	2.82[c]	2.90[c]
Prathibha	2.73[b]	3.19[b]	3.36[b]
Wayanad local	2.97[a]	3.59[a]	3.71[a]
SE	0.07	0.08	0.07
CD	0.22	0.24	0.20
Spraying Chitosan			
Chitosan spray	2.67	4.11[a]	3.78[a]
Water spray	2.72	2.88[b]	3.12[b]
Absolute control	2.62	2.60[c]	3.07[b]
SE	0.07	0.08	0.07
CD	NS	0.24	0.20

Table 7. Interaction effect of genotype and chitosan spray on tiller production in turmeric at various growth stages

Genotype x Chitosan spray	Number of tillers at 100 DAP	Number of tillers at 120 DAP	Number of tillers at 150 DAP
Sobha x Chitosan spray	2.39	3.52[b]	3.33
Sobha x Water spray	2.41	2.64[de]	2.74
Sobha x Control	2.12	2.30[e]	2.61
Prathibha x Chitosan spray	2.72	3.90[b]	3.82
Prathibha x Water spray	2.62	2.92[cd]	3.01
Prathibha x Control	2.83	2.76[cd]	3.25
Wayanad local x Chitosan spray	2.90	4.93[a]	4.18
Wayanad local x Water spray	3.11	3.10[bc]	3.61
Wayanad local X Control	2.90	2.74[cd]	3.34
CD	NS	0.42	NS

Influence of chitosan spray on the girth of main tiller of turmeric genotypes at various growth stages

The girth of the main tiller observed at various growth stages was significant at 100 and 150 DAP (Table 8). At 100 DAP the highest girth was observed in genotypes Wayanad local and Prathibha (9.06 cm and 8.98 cm, respectively). The girth of tiller was also highest in the genotype Wayanad local (Acc WCL 23) (10.45 cm) at 150 DAP.

Girth of main tiller was found to be highest in genotype Wayanad local (Acc WCL 23) in all growth stages (9.06 cm, 10.00 cm and 10.45 cm, respectively) followed by Prathibha 8.98, 9.67, 9.93 cm, respectively. There was a significant variation in girth of the main tiller on chitosan application.

At 100 DAP the highest girth was noticed in plants sprayed with water (8.79 cm). Chitosan sprayed plants had a girth of (8.61cm) which was on par with water sprayed plants. At 120 DAP highest girth was in chitosan sprayed plants (10.34 cm). At 150 DAP significant difference in girth of main tiller was observed and the highest girth of the main tiller was noticed in chitosan sprayed plants (10.36 cm) and plants sprayed with water (10.00 cm) (Table 8).

The interaction effect of genotypes and chitosan spray on the girth of the main tiller was significant at 100 DAP. The chitosan sprayed plants of genotype Wayanad local recorded the highest girth of 9.41 cm at 100 DAP. The girth of plants of Prathibha sprayed with chitosan (9.10 cm), water (9.10 cm) and water sprayed plants of Wayanad local (9.36 cm) was on par (Table 9). There was no significant interaction between genotypes and chitosan with respect to the girth of the main tiller at 120 and 150 DAP (Table 9).

Table 8. Influence of chitosan spray on the girth of the main tiller in turmeric genotypes at various growth stages

Treatments	Girth of the main tiller at 100 DAP	Girth of the main tiller at 120 DAP	Girth of the main tiller at 150 DAP
Genotypes			
Sobha	7.66^{b}	9.56	9.45^{b}
Prathibha	8.98^{a}	9.67	9.93^{b}
Wayanad local	9.06^{a}	10.00	10.45^{a}
SE	0.11	0.14	0.17
CD	0.32	NS	0.48
Chitosan spray	8.61^{ab}	10.34^{a}	10.36^{a}
Water spray	8.79^{a}	9.57^{b}	10.00^{a}
Absolute control	8.29^{b}	9.36^{b}	9.47^{b}
SE	0.12	0.14	0.17
CD	0.33	0.41	0.48

Table 9. Interaction effect of genotypes and chitosan spray on girth of tillers in turmeric at various growth stages

Genotype x Chitosan spray	Girth of the main tiller at 100 DAP	Girth of the main tiller at 120 DAP	Girth of the main tiller at 150 DAP
Sobha x Chitosan spray	7.33^{f}	10.11	9.68
Sobha x Water spray	7.94^{de}	9.34	9.67
Sobha x Control	7.70^{ef}	9.23	9.02
Prathibha x Chitosan spray	9.10^{ab}	10.67	10.23
Prathibha x Water spray	9.10^{ab}	9.32	10.10
Prathibha x Control	8.76^{bc}	9.03	9.47
Wayanad local x Chitosan spray	9.41^{a}	10.25	11.19
Wayanad local x Water spray	9.36^{ab}	10.05	10.24
Wayanad local x Control	8.43^{cd}	9.83	9.93
CD	0.57	NS	NS

Influence of chitosan sprays on leaf area of turmeric genotypes at various growth stages

Leaf area of turmeric had a significant difference with respect to genotypes and growth stages of 100, 120, 150 DAP (Table 10). Leaf area of all genotypes were increased gradually from each stage of growth from 100 DAP to 150 DAP. Leaf area of genotype Sobha, Prathibha, Wayanad local was lowest at 100 DAP (375.86 cm^2, 466.98 cm^2, 529.06 cm^2, respectively). A gradual increase of leaf area was recorded at 120 DAP (555.00 cm^2, 571.76 cm^2, 657.38 cm^2, respectively) and at 150 DAP (596.81 cm^2, 631.73 cm^2 and 696.28 cm^2, respectively) by genotypes Sobha, Prathibha, Wayanad local (Acc WCL 23). Among the genotypes Wayanad local recorded highest leaf area in all growth stages of 100, 120 and 150 DAP (529.06 cm^2, 657.38 cm^2 and 696.28 cm^2, respectively).

The influence of chitosan spray on leaf area was non significant at all growth stages (Table 10).

The interaction effect of genotype and chitosan spray on leaf area was also non significant at all growth stages studied (Table 11).

Influence of chitosan spray on photosynthetic rate of turmeric genotypes

The photosynthetic rate was taken at 150 DAP. The Photosynthetic rate of turmeric genotypes varied significantly among genotypes and chitosan spray (Table 12). Significant variation in photosynthetic rate was noticed among the genotypes (Table 12). Highest photosynthetic rate was in Sobha (30.60 $\mu mol\ m^{-2}\ s^{-1}$) followed by Prathibha (29.92 $\mu mol\ m^{-2}\ s^{-1}$) and Wayanad local (25.92 $\mu mol\ m^{-2}\ s^{-1}$).

Foliar sprays of chitosan at 0.1 % at monthly intervals had an influence on photosynthetic rate in turmeric plants (Table 12). Photosynthetic rate was significantly high in chitosan sprayed plants (32.76 $\mu mol\ m^{-2}\ s^{-1}$) followed by water spray (28.81 $\mu mol\ m^{-2}\ s^{-1}$) and the lowest photosynthetic rate were observed in control (24.86 $\mu mol\ m^{-2}\ s^{-1}$).

The interaction effect of genotypes and chitosan spray on photosynthetic rate was found to be significant (Table 13). The highest photosynthetic rate was in chitosan sprayed plants of genotype Wayanad local (35.60 µmol m^{-2} s^{-1}) followed by water sprayed plants of Prathibha (32.73 µmol $m^{-2}s^{-1}$). The lowest photosynthetic rate was observed in the control plants of Wayanad local (15.96 µmol m^{-2} s^{-1}).

Table 10. Influence of chitosan sprays on leaf area of turmeric genotypes at various growth stages

Treatments	Leaf area 100 DAP (cm^2)	Leaf area 120 DAP(cm^2)	Leafarea 150 DAP(cm^2)
Genotypes			
Sobha	375.86[c]	555.00[b]	596.81[c]
Prathibha	466.98[b]	571.76[b]	631.73[b]
Wayanad local	529.06[a]	657.38[a]	696.28[a]
SE	13.09	18.16	9.07
CD	37.17	51.54	25.74
Spraying Chitosan			
Chitosan spray	447.41	604.91	642.86
Watrer spray	456.03	597.93	636.08
Absolute control	468.45	581.30	645.89
SE	13.09	18.16	9.07
CD	NS	NS	NS

Table 11. Interaction effect of genotypes and chitosan sprays on leaf area of turmeric at various growth stages

Genotype x Chitosan spray	Leaf area at 100 DAP (cm^2)	Leaf area at 120 DAP (cm^2)	Leaf area at 150 DAP (cm^2)
Sobha x Chitosan spray	347.71	569.07	611.22
Sobha x Water spray	369.40	555.24	573.08
Sobha x Control	410.48	540.70	606.16
Prathibha x Chitosan spray	463.10	571.58	631.90
Prathibha x Water spray	470.46	568.89	634.46
Prathibha x Control	467.40	574.83	628.83
Wayanad local x Chitosan spray	531.43	674.09	685.47
Wayanad local x Water spray	528.27	669.67	700.71
Wayanad local x Control	527.50	628.38	702.69
CD	NS	NS	NS

Table 12. Influence of chitosan sprays on photosynthetic rate of turmeric genotypes

Tretments	Photosynthetic rate ($\mu mol\ m^{-2}\ s^{--1}$)
Genotypes	
Sobha	30.60[a]
Prathibha	29.92[b]
Wayanad local	25.92[c]
SE	0.03
CD	0.09
Spraying Chitosan	
Chitosan spray	32.76[a]
Water spray	28.81[b]
Absoute control	24.86[c]
SE	0.03
CD	0.09

Table 13. Interaction effect of genotypes and chitosan sprays on photosynthetic rate of turmeric

Genotype x Chitosan spray	Photosynthetic rate ($\mu mol\ m^{-2}\ s^{--1}$)
Sobha x Chitosan spray	32.16[c]
Sobha x Water spray	27.50[e]
Sobha x Control	32.13[c]
Prathibha x Chitosan spray	30.53[d]
Prathibha x Water spray	32.73[b]
Prathibha x Control	26.50[f]
Wayanad local x Chitosan spray	35.60[a]
Wayanad local x Water spray	26.20[g]
Wayanad local x Control	15.96[h]
CD	0.17

Plate 5. Measurement of photosynthetic rate using IRGA

INFLUENCE OF GENOTYPES, HARVESTING STAGES AND CHITOSAN SPRAY ON RHIZOME CHARACTERS AT HARVEST

Influence of chitosan spray on length of primary rhizome of turmeric genotypes at various harvesting stages

There was significant difference in the length of the primary rhizome of three genotypes at various harvesting stage (Table 14). Significantly higher length of primary rhizome was recorded in Wayanad local (Acc WCL 23) and Sobha (11.07 cm and 10.68 cm, respectively). The primary rhizome length was lowest in genotype Prathibha (8.36 cm) when considered irrespective of harvesting stages and chitosan spray.

There was significant difference in the length of primary rhizome of turmeric genotypes in all three stages of harvest (Table 14). The highest length of primary rhizome was observed at 270 days after planting (10.58 cm) followed by 240 DAP (10.00 cm) and 210 DAP (9.53 cm). But, there was no significant difference in the length of primary rhizome of turmeric on chitosan application (Table 14). Though not significant, the highest length of primary rhizome was observed in chitosan sprayed plants (10.27 cm).

When the interaction effect between genotypes and harvesting stages was analysed, it was found to be significant (Table 15). The highest length of primary rhizome was in genotype Wayanad local (Acc WCL 23) at all stages of harvest *viz*., 210, 240 and 270 DAP (11.27 cm, 10.80 cm and 11.15 cm, respectively) and Sobha at 240 and 270 DAP (11.08 cm and 11.32 cm, respectively).

The interaction effect between genotypes and chitosan sprays was also significant in improving the length of primary rhizome in turmeric (Table 16). The genotype Sobha sprayed with chitosan at 1 g L^{-1}, exhibited the highest length of primary rhizome (11.48 cm). The primary length of rhizomes of genotype Wayanad local (Acc WCL 23) at three stages of harvest *viz.*, 210, 240 and 270 DAP was found to be on par (11.29 cm, 11.04 cm and 10.89 cm, respectively) But, the interaction effect of harvesting stages and chitosan was non-significant in improving length of the primary rhizome in turmeric (Table 17).

Influence of chitosan sprays on width of primary rhizome of turmeric genotypes at various harvesting stages

Significant difference was observed in width of the primary rhizome of three genotypes (Table 14). The genotype Prathibha recorded significantly highest width of primary rhizome (2.79 cm) followed by Wayanad local (Acc WCL 23) (2.53 cm). The lowest width of primary rhizome was in genotype Sobha (2.11 cm) (Table 14).

There was a significant difference in the width of primary rhizome. Irrespective of chitosan sprays and genotypes the highest width of primary rhizome was at 270 days after planting (3.19 cm) followed by 240 DAP (2.47 cm) and 210 DAP (1.79 cm) (Table 14).

Foliar sprays of chitosan significantly improved the width of primary rhizomes irrespective of genotypes and stage of harvest. The highest width of primary rhizome was observed in chitosan sprayed plants (2.59 cm) (Table 14).

The interaction effect between genotypes and harvesting stages had a significant difference in the width of primary rhizome in turmeric. The highest width of primary rhizome was obtained from turmeric genotype Prathibha harvested at 270 DAP (3.47cm) (Table 15).

The interaction effect between genotypes and chitosan sprays had no significant difference on the width of primary rhizome in turmeric (Table 16). The interaction effect of harvesting stages and chitosan was also non-significant in improving width of primary rhizome in turmeric (Table 17).

Influence of chitosan sprays on number of primary rhizome of turmeric genotypes at various harvesting stages

There was a significant difference in the number of primary rhizome at various harvesting stages and on application of chitosan (Table 14). There was a significant variation with respect to genotypes. The highest number of primary rhizomes was recorded in Wayanad local (6.78) and Prathibha (6.67) followed by Sobha (6.32). Significant difference in the number of primary rhizomes was noticed during the harvest stages (Table 14). The highest number of primary rhizomes was recorded at 270 days after planting (7.10) followed by 240 DAP (6.35) and 210 DAP (6.31).

The highest number of primary rhizomes was observed in rhizomes obtained from plants sprayed with chitosan at 1 g L^{-1} (7.32). The chitosan sprays had a significant influence on number of primary rhizomes (Table 14).

The interaction between genotypes and harvesting stages had a significant difference on the number of primary rhizomes per plant (Table 15). The highest number of primary rhizomes per plant, was obtained from turmeric genotype Prathibha (7.83) harvested at 270 DAP and followed by genotype Wayanad local harvested at 270 DAP (7.24) and Sobha harvested at 240 DAP (7.03).

There was no interaction between genotypes and chitosan sprays on number of primary rhizomes in turmeric (Table 16).

The interaction between harvest stages and chitosan spray had a significant difference on number of primary rhizomes in turmeric.The highest number of primary rhizomes per plant was obtained from chitosan sprayed plants harvested at 270 DAP (8.11) followed by plants harvested at 210 DAP (7.18) (Table17).

Influence of chitosan sprays on the number of secondary rhizomes of turmeric genotypes at various harvesting stages

There was a significant difference in the number of secondary rhizomes of three turmeric genotypes on application of elicitor chitosan (Table 14). Irrespective of the chitosan sprays and harvesting stages, rhizomes obtained from Wayanad local (Acc WCL 23) and Sobha had the highest number of secondary rhizomes (18.35 and 18.67, respectively). The lowest number of secondary rhizomes was observed in Prathibha (14.28).

But there was no significant variation with respect to stages of harvest (Table 14). Though not significant, the highest number of secondary rhizomes was noticed in plants harvested at 270 DAP (18.11).

A significant difference was observed on production of secondary rhizomes by chitosan spray at 1 g L^{-1} (Table 14). The highest number of secondary rhizomes was noticed in rhizomes obtained from chitosan sprayed plants (18.89) followed by control and water spray (16.39, 16.01, respectively).

The interaction effect between genotypes and harvesting stages had a significant difference on number of secondary rhizomes per plant (Table 15). The number of secondary rhizomes per plant was highest in rhizomes obtained from turmeric genotype, Sobha harvested at 270 DAP (20.89) and Wayanad local (Acc WCL 23) (20.33) at 240 DAP and Sobha harvested at 210 DAP (19.56). Wayanad local (Acc WCL 23) harvested at 270 DAP (18.22) was on par with the highest.

The interaction effect between genotypes and chitosan sprays (Table 16), harvesting stages and chitosan sprays (Table 17) had no significant difference on number of secondary rhizomes in turmeric.

Influence of chitosan sprays on number of mother rhizomes of turmeric genotypes at various harvesting stages

There was no significant difference in the number of mother rhizomes in the three genotypes studied. The stages of harvest also had no significant influence on number of mother rhizomes in turmeric (Table 14).

When the effect of chitosan spray on the number of mother rhizomes were studied irrespective of varietal differences and harvesting stages, the results revealed that foliar application of chitosan had a significant influence on the number of mother rhizomes. Chitosan at a concentration of 1 g L^{-1} significantly improved the number of mother rhizomes. The chitosan sprayed plants (1.58 $plant^{-1}$) were significantly superior than the plants subjected to water spray (1.33) and plants maintained as control without any spray (1.21) (Table 14).

The interaction effect of genotypes and harvesting stages on number of mother rhizome was significant (Table 15). The highest number of mother rhizome was obtained from Prathibha harvested at 210 DAP (1.56) and 240 DAP (1.53) and Wayanad local (Acc WCL 23) harvested at 210 DAP (1.51). Sobha harvested at 270 DAP (1.43), Wayanad local (Acc WCL 23) harvested at 240 (1.41) was on par with the highest.

The interaction effect of genotypes and chitosan on number of mother rhizomes was found to be significant. Significantly higher number of mother rhizomes was observed in the genotype Wayanad local (Acc WCL 23) sprayed with chitosan 1 g L^{-1} (1.84). Prathibha sprayed with chitosan 1 g L^{-1} (1.59) was on par with the highest.Whereas the number of mother rhizomes was only 1.30 and 1.14 in plants of Wayanad local given water spray and those maintained without any spray, respectively (Table 16). The interaction effect of harvesting stages and chitosan was significant in improving the number of mother rhizomes in turmeric (Table 17). Plants given chitosan spray (1 g L^{-1}) and harvested at 210 DAP, recorded the highest number of mother rhizomes (1.82) followed by rhizomes harvestd at 240 DAP (1.51).

Table 14. Influence of chitosan sprays on rhizome characters of turmeric genotypes at various harvesting stages

Treatments	Length of primary rhizome (cm)	Width of primary rhizome (cm)	Number of primary rhizomes	Number of secondary rhizome	Number of mother rhizomes
Genotypes					
Sobha	10.68[a]	2.11[c]	6.32[b]	18.67[a]	1.30
Prathibha	8.36[b]	2.79[a]	6.67[a]	14.28[b]	1.40
Wayanad local	11.07[a]	2.53[b]	6.78[a]	18.35[a]	1.43
SE	0.18	0.06	0.11	0.60	0.06
CD	0.50	0.16	0.33	1.73	NS
Harvesting stages					
210 DAP	9.53[b]	1.79[c]	6.31[b]	16.34	1.30
240 DAP	10.00[b]	2.47[b]	6.35[b]	16.84	1.41
270 DAP	10.58[a]	3.19[a]	7.10[a]	18.11	1.41
SE	0.18	0.06	0.11	0.60	0.06
CD	0.50	0.16	0.33	NS	NS
Spraying Chitosan					
Chitosan spray	10.27	2.59[a]	7.32[a]	18.89[a]	1.58[a]
Water spray	9.82	2.37[b]	6.28[c]	16.01[b]	1.33[b]
Absolute control	10.01	2.47[ab]	6.61[b]	16.39[b]	1.21[b]
SE	0.18	0.06	0.11	0.60	0.06
CD	NS	0.16	0.33	1.73	0.16

Table 15. Interaction effect of genotypes and harvesting stages on rhizome characters of turmeric

Genotype x Harvesting stage	Length of primary rhizome (cm)	Width of primary rhizome (cm)	Number of primary rhizomes	Number of secondary rhizome	Number of mother rhizomes
Sobha x 210 DAP	9.66^{b}	1.65^{d}	5.69^{d}	19.56^{a}	1.18^{bc}
Sobha x 240 DAP	11.08^{a}	1.78^{d}	7.03^{b}	15.57^{bcd}	1.30^{abc}
Sobha x 270 DAP	11.32^{a}	2.92^{b}	6.24^{cd}	20.89^{a}	1.43^{ab}
Prathibha x 210 DAP	7.67^{b}	1.83^{d}	6.33^{c}	12.98^{d}	1.56^{a}
Prathibha x 240 DAP	8.12^{b}	3.07^{b}	5.86^{cd}	14.62^{cd}	1.53^{a}
Prathibha x 270 DAP	9.28^{b}	3.47^{a}	7.83^{a}	15.24^{bcd}	1.11^{c}
Wayanad local x 210 DAP	11.27^{a}	1.88^{d}	6.91^{bc}	16.51^{bc}	1.51^{a}
Wayanad local x 240 DAP	10.80^{a}	2.56^{c}	6.18^{cd}	20.33^{a}	1.41^{ab}
Wayanad local x 270 DAP	11.15^{a}	3.17^{b}	7.24^{b}	18.22^{ab}	1.37^{abc}
CD	0.87	0.27	0.57	2.99	0.27

Table 16. Interaction effect of genotypes and chitosan spray on rhizome characters in turmeric

Genotype x Chitosan spray	Length of primary rhizome (cm)	Width of primary rhizome (cm)	Number of primary rhizomes	Number of secondary rhizomes	Number of mother rhizomes
Sobha x Chitosan spray	11.48[a]	2.30	6.79	20.46	1.32[c]
Sobha x Water spray	10.10[c]	1.96	5.98	17.56	1.33[bc]
Sobha x Control	10.47[bc]	2.09	6.19	17.99	1.26[c]
Prathibha x Chitosan spray	8.05[d]	2.87	7.48	15.44	1.59[ab]
Prathibha x Water spray	8.33[d]	2.70	6.33	13.27	1.38[bc]
Prathibha x Control	8.69[d]	2.80	6.22	14.13	1.23[c]
Wayanad local x Chitosan	11.29[ab]	2.62	7.69	20.78	1.84[a]
Wayanad local x Water spray	11.04[ab]	2.47	6.56	17.22	1.30[c]
Wayanad local x Control	10.89[abc]	2.52	6.09	17.07	1.14[c]
CD	0.87	NS	NS	NS	0.27

Table 17. Interaction effect of harvesting stages and chitosan spray on rhizome characters in turmeric

Harvesting stage x Chitosan spray	Length of primary rhizome (cm)	Width of primary rhizome (cm)	Number of primary rhizomes	Number of secondary rhizome	Number of mother rhizomes
210 DAP x Chitosan	9.74	1.85	7.18^{b}	16.58	1.82^{a}
210 DAP x Water spray	9.28	1.77	6.22^{c}	16.82	1.31^{bcd}
210 DAP x Control	9.58	1.74	5.53^{d}	15.64	1.11^{d}
240 DAP x Chitosan	10.48	2.56	6.67^{bc}	18.48	1.51^{b}
240 DAP x Water spray	9.96	2.32	6.07^{cd}	15.74	1.40^{bc}
240 DAP x Control	9.56	2.51	6.33^{c}	16.30	1.33^{bcd}
270 DAP x Chitosan	10.60	3.37	8.11^{a}	21.62	1.42^{bc}
270 DAP x Water spray	10.24	3.03	6.57^{c}	15.49	1.30^{bcd}
270 DAP x Control	10.92	3.16	6.64^{bc}	17.24	1.19^{cd}
CD	NS	NS	0.57	NS	0.27

INFLUENCE OF GENOTYPES, HARVESTING STAGES AND CHITOSAN SPRAY ON RHIZOME CHARACTERS OF TURMERIC

Influence of chitosan sprays on weight of mother rhizomes in turmeric turmeric genotypes at various harvesting stage

Significant difference in weight of mother rhizomes was obtained with respect to genotype and harvesting stages. The highest weight of mother rhizome was recorded in genotype Prathibha (59.15g), irrespective of harvesting stages and chitosan spray. The average weight of mother rhizomes of Sobha and Wayanad local (Acc WCL 23) was 38.95 g and 48.13 g per plant, respectively (Table 18).

Harvesting of turmeric at 240 DAP and 270 DAP was significantly superior in recording a higher weight of mother rhizome (52.03, 51.68 g, respectively) when considered irrespective of genotype and chitosan sprays. Harvest at 210 days, resulted in an average weight of 42.52 g (Table 18).

Though not statistically significant, the effect of chitosan spray on weight of mother rhizome per plant was high in plants received chitosan spray (51.24 g), irrespective of genotypes and harvesting stages (Table 18).

The interaction effect between genotypes and harvesting stages on weight of mother rhizome was statistically significant (Table 19). Significantly higher weight of mother rhizome was observed in turmeric genotype Prathibha harvested at 240 DAP (70.60 g) followed by 270 DAP (58.88 g).

The interaction effect between genotype and chitosan sprays had no significant effect on weight of mother rhizome of turmeric (Table 20). Interaction effect of harvesting stages and chitosan spray was also non-significant in improving weight of mother rhizome in turmeric (Table 21).

Influence of chitosan sprays on weight of primary rhizome in turmeric genotypes at various harvesting stage

The genotypes exhibited a significant difference in the weight of primary rhizome. The highest weight of primary rhizome was recorded in Wayanad local (Acc WCL 23) (24.96 g) and Sobha (24.41 g) followed by Prathibha 22.61g (Table 18).

Harvest at 270 DAP was significantly superior in improving the weight of primary rhizome (27.29 g), irrespective of genotypes and chitosan sprays, followed by harvest at 240 DAP resulting in an average weight of primary rhizome 23.45 g. (Table 18).

When the influence of chitosan sprays were analysed irrespective of genotypes and harvesting stages, it was revealed that foliar application of chitosan had a significant influence in improving the weight of primary rhizome. Chitosan at a concentration of 1 g L^{-1} significantly improved the weight of primary rhizome (25.72 g). This was significantly superior to the rhizomes obtained from plants maintained as control without any spray (23.68 g) and water spray (22.57g) (Table 18).

The interaction between genotypes, stages of harvest on weight of primary rhizome was found to be significant. The highest weight of primary rhizome was obtained from turmeric genotype, Sobha harvested at 270 DAP (28.61 g), Prathibha harvested at 270 DAP (26.90 g) and Wayanad local (Acc WCL 23) harvested at 240 DAP and 270 DAP (26.37, 26.38, respectively) (Table 19).

Interaction effect between genotypes and chitosan sprays (Table 20), harvesting stages and chitosan sprays (Table 21) had no significant influence on weight of primary rhizome in turmeric.

Influence of chitosan sprays on weight of secondary rhizome in turmeric genotypes at various harvesting stages

A significant difference in the weight of secondary rhizome was observed with respect to genotypes. Highest weight of secondary rhizome was recorded in Prathibha (4.74 g) and Sobha (4.63 g). The Wayanad local (Acc WCL 23) had a weight of 4.48 g which was the lowest (Table 18).

Irrespective of genotypes and chitosan sprays turmeric harvested at 270 DAP was significantly superior in improving the weight of secondary rhizome (5.94 g) followed by 240 DAP, resulting in a weight of 4.56 g. Early harvesting *i.e.*, at 210 DAP, resulted in significantly lower weight of secondary rhizome (3.35 g) when compared to other harvesting stages (Table 18).

Though not statistically significant, the highest weight of secondary rhizome was obtained from plants sprayed with chitosan at a concentration of 1 g L^{-1} resulting in an average weight of 4.68 g (Table 18).

The interaction between genotypes and harvesting stages was statistically significant on the weight of secondary rhizome (Table 17). Prathibha harvested at 270 DAP (6.17 g) was superior followed by Sobha and Wayanad local (Acc WCL 23) harvested at 270 DAP (6.01) (Table 19).

But, the interaction effect between "genotypes and harvesting stages‟ and harvesting stages and chitosan sprays‟ had no significant influence on the weight of secondary rhizome in turmeric (Table 20 and 21).

Influence of chitosan sprays on fresh weight of rhizome per plant of turmeric genotypes at various harvesting stages

The genotypes exhibited a significant difference in average fresh yield of rhizome obtained from single plant irrespective of harvesting stage and chitosan spray. The highest fresh rhizome weight was obtained in Wayanad local (Acc WCL 23) (255.86 g plant^{-1}) and Sobha (246.01 g plant^{-1}) followed by Prathibha (236.71 g plant^{-1}) (Table 18).

Turmeric harvested at 270 DAP was significantly superior in improving the fresh rhizome weight per plant (266.52 g plant^{-1}), irrespective of genotypes and chitosan sprays. This was followed by harvest at 240 DAP, resulting in an average yield of 247.42 g plant^{-1}. Early harvesting *i.e.*, at 210 DAP, resulted in significantly lower yield (224.63 g plant^{-1}) when compared to other harvesting stages (Table 18).

When the effect of chitosan sprays on fresh weight of rhizome was analysed irrespective of genotypes and harvesting stages, it was clear that foliar application of chitosan had a significant influence in improving yield in turmeric. Chitosan at a concentration of 1 g L^{-1} improved the fresh rhizome yield per plant, resulting in an average rhizome yield of 273.18 g plant $^{-1}$. This was significantly superior to the yield obtained from plants subjected to water spray (230.62 g plant^{-1}) and plants maintained as control without any spray (234.78 g plant^{-1}) (Table 18).

The interaction between genotypes and harvesting stages on fresh rhizome yield was statistically significant. Highest fresh rhizome yield was obtained from turmeric genotype, Wayanad local (Acc WCL 23) harvested at 270 DAP (269.25 g plant^{-1}), Prathibha at 270 DAP (262.13 g plant^{-1}) and Sobha at 240 and 270 DAP (263.25, 268.19 g plant^{-1}, respectively) (Table 19).

The interaction effect between genotypes and chitosan sprays was non-significant. However, chitosan sprayed plants of genotype Wayanad local (Acc WCL 23) exhibited highest rhizome yield of 281.76 g per plant followed by Sobha (277.26 g plant^{-1}) (Table 20).

There was a significant difference in fresh weight of rhizome per plant with respect to chitosan sprays and harvesting stages. Plants given chitosan spray (1 g L^{-1}) and harvested at 270 DAP (287.04 g $plant^{-1}$) and 240 DAP (279.85 g $plant^{-1}$) recorded the highest fresh weight rhizome. Plants maintained as control (270.58 g $plant^{-1}$) and harvested at 270 DAP was on par with highest (Table 21).

When fresh yield per plant was analysed in details with considering the all tresatment combination, interaction effect between genotypes and chitosan sprays and harvesting stages had a significant difference in fresh yield of rhizome in turmeric (Table 22). The highest rhizome yield per plant was obtained from chitosan sprayed plants of genotype Wayanad local harvested at 210 DAP (V3H1C1) (314.01 g $plant^{-1}$) and Sobha harvested at 240 DAP (V1H2C1) (311.25 g $plant^{-1}$). The chitosan sprayed plants of genotype Prathibha harvested at 270 DAP was onpar with the highest (V2H3C1) (297.55 g $plant^{-1}$).

Influence of chitosan sprays on dry weight of rhizome per plant in turmeric genotypes at various harvesting stages

There was a significant difference in dry yield per plant with respect to genotypes, harvesting stages and chitosan spray.The highest dry rhizome yield per plant was obtained from genotype Wayanad local (Acc WCL 23) (46.98 g $plant^{-1}$), when considered irrespective of harvesting stages and chitosan spray. Other genotypes *viz*., Sobha and Prathibha yielded an average of 42.68 g and 41.84 g dry rhizome yield per plant, respectively (Table 18).

Turmeric harvested at 240 DAP and 270 DAP was significantly superior in improving the dry rhizome yield per plant (48.13 and 45.48 g $plant^{-1}$, respectively), irrespective of varietal effect and chitosan sprays. Early harvesting *i.e*., at 210 DAP, resulted in significantly lowest dry rhizome yield (37.89 g $plant^{-1}$) when compared to other harvesting stages (Table 18).

Foliar application of chitosan had a significant influence in improving dry yield in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the dry rhizome yield per plant, resulting in an average dry rhizome yield of 49.48 g $plant^{-1}$.

This was significantly superior to the yield obtained from plants subjected to water spray (40.73 g plant^{-1}) and plants maintained as control without any spray (41.29 g plant^{-1}) (Table 18).

The interaction effect of genotypes and harvesting stages revealed that, except Sobha and Prathibha harvested 210 DAP, all other treatment combinations are superior in improving dry yield per plant. Dry rhizome yield of genotype Wayanad local was 46.31g, 50.01 g and 44.62 g plant^{-1} when rhizomes harvested at 210, 240 and 270 DAP, respectively. The genotype Sobha recorded a dry yield of 48.06, 47.17 g plant^{-1} when harvested at 240 DAP and 270 DAP respectively. The genotype Prathibha recorded dry weight of 46.33 g plant^{-1} when harvested at 240 DAP and 44.64 g plant^{-1} at 270 DAP (Table 19).

The interaction effect of genotypes and chitosan spray, harvesting stages and chitosan spray was found non-significant (Table 20 and 21).

Influence of chitosan sprays on curing per cent of turmeric genotypes at various harvesting stages

There was a significant difference in curing percent with respect to genotypes, harvesting stages and chitosan spray. Among the genotypes Wayanad local recorded highest curing per cent of 17.23%. Other genotypes *viz*., Sobha and Prathibha recorded a curing per cent of 15.73% and 15.30% respectively (Table 18). Turmeric harvested at 240 DAP was found to be significantly superior in improving the curing percent (16.56%) followed by 270 DAP (16.03%), irrespective of genotypes and chitosan sprays. Harvesting at 210 days, resulting in an average curing percent of 15.66%, which was significantly lower when compared to other harvesting stages (Table 18).

Foliar application of chitosan had a significant influence in improving curing per cent in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the curing percent (16.29 %). This was significantly superior to the curing percent obtained from plants subjected to water spray (16.12%) and plants maintained as control without any spray (15.83%) (Table 18).

The interaction effect of harvesting stage and genotypes was found statistically significant. Curing per cent was significantly high in genotype Wayanad local harvested at 240 DAP (17.71 %) (Table 19).

Interaction effect between genotypes and chitosan sprays had a significant difference in curing per cent of turmeric. Wayanad local which received a spray of chitosan 1 g L^{-1} exhibited highest curing per cent of 17.31 % (Table 20).

Interaction effect of harvesting stages and chitosan was also significant in improving curing per cent in turmeric. Plants harvested at 240 DAP and received chitosan spray was found to have the highest curing per cent (17.09%) (Table 21).

Interaction effect of genotypes, harvesting stages and chitosan sprays on curing percent of turmeric were analysed, and significant difference were noticed between the treatment combinations. The genotype Wayanad local with chitosan sprays harvested at 240 DAP (V3H2C1) was found to have a highest curing percent (18.44%) (Table 22).

Table 18. Influence of chitosan sprays on rhizome characters of turmeric genotype at various harvesting stages

Treatment	Weight of mother rhizome (g)	Weight of primary rhizome (g)	Weight of secondary rhizome(g)	Fresh rhizome weight per plant (g)	Dry rhizome weight per plant (g)	Curing percentage (%)
Genotypes						
Sobha	38.95[c]	24.41[a]	4.63[a]	246 .01[a]	42.68[b]	15.73[b]
Prathibha	59.15[a]	22.61[b]	4.74[a]	236.71[b]	41.84[b]	15.30[c]
Wayanad local	48.13[b]	24.96[a]	4.48[b]	255.86[a]	46.98[a]	17.23[a]
SE	1.80	0.63	0.05	3.89	1.48	0.003
CD	5.12	1.79	0.13	11.00	4.20	0.01
Harvesting stages						
210 DAP	42.52[b]	21.23[c]	3.35[c]	224.63[c]	37.89[b]	15.66[c]
240 DAP	52.03[a]	23.45 [b]	4.56[b]	247.42[b]	48.13[a]	16.56[a]
270 DAP	51.68[a]	27.29[a]	5.94[a]	266.52[a]	45.48[a]	16.03[b]
SE	1.80	0.63	0.05	3.89	1.48	0.003
CD	5.12	1.79	0.13	11.00	4.20	0.01
Spraying Chitosan						
Chitosan spray	51.24	25.72[a]	4.68	273.18[a]	49.48[a]	16.29[a]
Water spray	47.26	22.57[c]	4.56	230.62[b]	40.73[b]	16.12[b]
Absolute control	47.73	23.68[b]	4.60	234.78[b]	41.29[b]	15.83[c]
SE	1.80	0.63	0.05	3.89	1.48	0.003
CD	NS	1.79	NS	11.00	4.20	0.01

Table 19. Interaction effect of genotypes and harvesting stages on rhizome characters in turmeric

Genotype x Harvesting stage	Weight of mother rhizome (g)	Weight of primary Rhizome (g)	Weight of secondary rhizome (g)	Fresh rhizome weight per plant (g)	Dry rhizome weight per plant (g)	Curing percentage (%)
Sobha x 210 DAP	31.67^{d}	22.64^{b}	3.36^{f}	206.58^{d}	32.81^{b}	15.52^{g}
Sobha x 240 DAP	34.88^{d}	21.98^{b}	4.51^{e}	263.25^{a}	48.06^{a}	15.89^{e}
Sobha x 270 DAP	50.29^{bc}	28.61^{a}	6.01^{b}	268.19^{a}	47.17^{a}	15.77^{f}
Prathibha x 210 DAP	47.96^{c}	18.92^{c}	3.36^{f}	209.12^{d}	34.56^{b}	14.79^{i}
Prathibha x 240 DAP	70.60^{a}	22.01^{b}	4.70^{d}	238.88^{c}	46.33^{a}	16.07^{d}
Prathibha x 270 DAP	58.88^{b}	26.90^{a}	6.17^{a}	262.13^{a}	44.64^{a}	15.04^{h}
Wayanad local x 210 DAP	47.92^{c}	22.13^{b}	3.34^{f}	258.20^{ab}	46.31^{a}	16.68^{c}
Wayanad local x 240 DAP	50.03^{bc}	26.37^{a}	4.46^{e}	240.15^{bc}	50.01^{a}	17.71^{a}
Wayanad local x 270 D AP	45.86^{c}	26.38^{a}	5.64^{c}	269.25^{a}	44.62^{a}	17.29^{b}
CD	8.87	3.11	0.22	19.17	7.27	0.02

Table 20. Interaction effect of genotypes and chitosan spray on rhizome characters in turmeric

Genotype x Chitosan spray	Weight of mother rhizome (g)	Weight of primary rhizome (g)	Weight of secondary rhizome (g)	Fresh rhizome weight per plant (g)	Dry rhizome weight per plant (g)	Curing percentage (%)
Sobha x Chitosan spray	41.24	27.14	4.75	277.26	48.08	15.96[c]
Sobha x Water spray	36.12	22.22	4.55	225.12	39.13	15.47[g]
Sobha x Control	39.49	23.86	4.58	235.64	40.83	15.75[d]
Prathibha x Chitosan spray	61.94	23.38	4.80	260.52	46.65	15.62[f]
Prathibha x Water spray	58.49	22.12	4.72	224.33	39.44	15.71[e]
Prathibha x Control	57.00	22.33	4.71	225.28	39.42	14.56[h]
Wayanad local x Chitosan	50.54	26.64	4.50	281.76	53.71	17.31[a]
Wayanad local x Water spray	47.15	23.38	4.42	242.41	43.61	17.18[b]
Wayanad local x Control	46.70	24.86	4.51	243.42	43.61	17.19[b]
CD	NS	NS	NS	NS	NS	0.02

Tabl 21. Interaction effect of harvesting stages and chitosan spray on rhizome characters in turmeric

Harvesting stage x Chitosan	Weight of mother rhizome (g)	Weight of primary rhizome (g)	Weight of secondary rhizome (g)	Fresh rhizome weight per plant (g)	Dry rhizome weight per plant (g)	Curing percentage (%)
210 DAP x Chitosan	43.28	22.55	3.47	252.66^{b}	43.73	15.58^{h}
210 DAP x Water spray	43.65	20.52	3.30	215.98^{de}	36.48	15.60^{h}
210 DAP x Control	40.62	20.62	3.29	205.26^{e}	33.46	15.80^{f}
240 DAP x Chitosan	54.24	24.84	4.63	279.85^{a}	52.07	17.09^{a}
240 DAP x Water spray	49.38	22.16	4.49	233.93^{bcd}	43.08	16.88^{b}
240 DAP x Control	52.48	23.36	4.55	228.49^{cd}	49.25	15.71^{g}
270 DAP x Chitosan	56.21	29.77	5.96	287.04^{a}	52.64	16.22^{c}
270 DAP x Water spray	48.73	25.04	5.90	241.95^{bc}	42.63	15.88^{e}
270 DAP x Control	50.10	27.07	5.97	270.58^{ab}	41.15	15.99^{d}
CD	NS	NS	NS	19.17	NS	0.02

Table 22. Interaction effect of genotypes, harvesting stages and chitosan spray on Fresh rhizome weight and curing per cent of turmeric genotypes

Treatments	Fresh rhizome weight (g plant^{-1})	Curing per cent (%)
V1H1C1	233,39^{fghi}	15.8^{m}
V1H1C2	194.03^{j}	15.03^{s}
V1H1C3	192.33^{j}	15.72^{n}
V1H2C1	311.25^{a}	16.04^{k}
V1H2C2	245.55^{defg}	6.08^{j}
V1H2C3	232.95^{fgh}	15.56^{o}
V1H3C1	287.16^{abc}	16.05^{k}
V1H3C2	235.79^{fgh}	15.28^{p}
V1H3C3	281.64^{abc}	15.97^{l}
V2H1C1	210.6^{hij}	14.29^{v}
V2H1C2	214.71^{ghij}	14.96^{t}
V2H1C3	202.07^{ij}	14.92^{u}
V2H2C1	273.43^{bcd}	16.78^{i}
V2H2C2	227.67^{fghi}	16.96^{h}
V2H2C3	215.54^{ghij}	14.48^{w}
V2H3C1	297.55^{ab}	15.17^{r}
V2H3C2	230.61^{fghi}	15.21^{q}
V2H3C3	258.24^{cdef}	14.73^{v}
V3H1C1	314.00^{a}	16.03^{k}
V3H1C2	239.2^{efgh}	16.8^{i}
V3H1C3	221.4^{ghij}	17.2^{e}
V3H2C1	254.87^{cdef}	18.44^{a}
V3H2C2	228.59^{fghi}	17.6^{b}
V3H2C3	237.00^{fgh}	17.08^{g}
V3H3C1	276.42^{bcd}	17.45^{c}
V3H3C2	259.47^{cdef}	17.15^{f}
V3H3C3	271.87^{bcde}	17.28^{d}
CD	11.69	0.03

INFLUENCE OF CHITOSAN SPRAYS ON YIELD AND QUALITY PARAMETERS OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Influence of chitosan sprays on dry weight of rhizome per plot (kg plot^{-1}) of turmeric genotypes at various harvesting stages

Influence of chitosan sprays on Fresh weight of rhizome per plot (kg plot^{-1}) of turmeric genotypes at various harvesting stages

Significant difference was observed in fresh yield of rhizome per plot with respect to genotypes, harvesting stages and chitosan spray (Table 23) The highest fresh rhizome yield per plot was recorded in Wayanad local (Acc WCL 23) (9.68 kg plot^{-1}), irrespective of harvesting stages and chitosan spray. Other genotypes *viz*., Sobha and Prathibha yielded an average of 7.86 kg and 7.98 kg of fresh rhizome per plot, respectively (Table 23).

Harvesting of turmeric at 270 DAP and 240 DAP was found to be significantly superior in improving the fresh rhizome yield per plot (8.98 kg, 8.82 kg plot^{-1}, respectively) irrespective of genotypes and chitosan sprays. Early harvesting *i.e*., at 210 DAP resulted in significantly lowest yield (7.72 kg plot^{-1}) when compared to other harvesting stages (Table 23).

Foliar application of chitosan had a significant influence in improving yield in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the fresh rhizome yield per plot (9.43 kg plot^{-1}). This was significantly superior than the yield obtained from plants subjected to water spray (7.91 kg plot^{-1}) and plants maintained as control without any spray (8.18 kg plot^{-1}) (Table 23).

The interaction effect between genotypes and harvesting stages, genotypes and chitosan spray and harvesting stages and chitosan spray on fresh yield per plot was found non significant (Table 24, 25 and 26, respectively).

Influence of chitosan sprays on projected fresh yield per hectare (t ha^{-1}) of turmeric genotypes at various harvesting stages

Fresh yield per hectare was significantly higher in Wayanad local (Acc WCL 23) (32.27 t ha^{-1}**)**, followed by Prathibha (26.62 t ha^{-1}**)** and Sobha (26.22 t ha^{-1}**)** irrespective of harvesting stages and chitosan spray (Table 23).Turmeric harvested at 240 (29.40 t ha^{-1}) and 270 DAP (29.95 t ha^{-1}) was found to be significantly superior in improving the fresh yield per hectare, irrespective of genotypes and chitosan sprays. Harvesting at 210 days after planting resulted in an average yield of (25.74 t ha^{-1}) which was found to be significantly lower when compared to other harvesting stages (Table 23).

Foliar application of chitosan had a significant influence in improving yield in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved fresh yield per hectare resulting in an average rhizome yield of (31.45 t ha^{-1}). This was significantly superior than the yield obtained from plants subjected to water spray (26.39 t ha^{-1}) and plants maintained as control without any spray (27.26 t ha^{-1}) (Table 23).

The interaction effect between genotypes and harvesting stages, genotypes and chitosan spray and harvesting stages and chitosan spray on fesh yield per hectare was found non-significant (Table 24, 25 and 26).

Influence of chitosan sprays on dry weight of rhizome per plot (kg plot^{-1}) of turmeric genotypes at various harvesting stages

Highest dry rhizome yield per plot was recorded in Wayanad local (Acc WCL 23) (1.77 kg plot^{-1}), irrespective of harvesting stages and chitosan spray. Other genotypes *viz*., Sobha and Prathibha yielded an average of 1.37 kg and 1.38 kg of dry rhizome per plot, respectively (Table 23).

Harvest of turmeric at 270 DAP and 240 DAP was significantly superior in improving the dry rhizome yield per plot (1.66, 1.57 kg plot^{-1}, respectively) irrespective of varietal effect and chitosan sprays. Harvesting at 270 (1.57 kg plot^{-1}) and 240 DAP (1.66 kg plot $^{-1}$) was found to be superior in terms of dry yield per plot.

Early harvesting *i.e.*, at 210 DAP, resulted in significantly lowest dry yield (1.30 kg plot^{-1}) when compared to other harvesting stages (Table 23).

Foliar application of chitosan had a significant influence in improving dry rhizome yield in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the dry rhizome yield per plot resulting in an average rhizome yield of 1.71 kg plot $^{-1}$(Table 23).

The interaction effect between genotypes and harvesting stages, genotypes and chitosan spray and harvesting stages and chitosan spray on dry yield per plot was found non- significant (Table 24, 25 and 26).

Influence of chitosan sprays on dry rhizome yield per hectare (t ha^{-1}) of turmeric genotypes at various harvesting stages

The highest projected dry rhizome yield was recorded in Wayanad local (Acc WCL 23) (5.91 t ha^{-1}) followed by Prathibha (4.61 t ha^{-1}) and Sobha (4.58 t ha^{-1}) irrespective of harvesting stages and chitosan spray (Table 23).

Harvesting of turmeric at 240 DAP and 270 DAP significantly superior in improving the dry rhizome yield per hectare (5.23, 5.53 t ha^{-1}, respectively), irrespective of varietal effect and chitosan sprays (Table 23).

Foliar application of chitosan had a significant influence in improving dry yield in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the dry rhizome yield per hectare resulting in an average dry rhizome yield of 5.71 t ha^{-1}. This was significantly superior than the yield obtained from plants subjected to water spray (4.57 t ha^{-1}) and plants maintained as control without any spray (4.82 t ha^{-1}) (Table 23).

The interaction effect between genotypes and harvesting stages, genotypes and chitosan spray, harvesting stages and chitosan spray on dry yield per hectare was found non significant (Table 24, 25 and 26).

Influence of chitosan sprays on curcumin content (%) of turmeric genotypes at various harvesting stages

The highest average curcumin content was recorded in genotype Prathibha (4.36%) followed by Wayanad local (Acc WCL 23) (4.21%). The lowest curcumin was in Sobha (3.98 %) when analysed irrespective of harvesting stages and chitosan spray (Table 23).

Harvest of turmeric at 270 DAP (4.33%) and 240 (4.34%) was significantly superior in improving the curcumin content, irrespective of genotypes and chitosan sprays. Harvest at 210 days, resulting in an average curcumin of 3.87 % and was found to be the lowest when compared to the curcumin content obtained from harvest after 240 and 270 DAP (Table 23).

Foliar application of chitosan had a significant influence on improving curcumin content of turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the curcumin content (4.81%) followed by plants subjected to water spray (3.90%) and plants maintained as control without any spray (3.84%) (Table 23).

Interaction effect of genotypes and harvesting stages had a significant influence on the curcumin content. The highest curcumin content was obtained from turmeric genotype Wayanad local (Acc 23) harvested at 270 DAP (4.58%), Prathibha harvested at 240 DAP (4.68%) and Sobha harvested at 240 DAP(4.57%) followed by Sobha harvested at 270 DAP (4.32 %) and Wayanad local (Acc WCL 23) and Prathibha harvested at 210 DAP (4.27, 4.29 %, respectively) (Table 24).

Interaction effect between genotypes and chitosan sprays had a significant difference in curcumin content. Plants of genotype Wayanad local which received foliar spray of chitosan at 1 g L^{-1} exhibited highest curcumin content of 4.99 %. It was followed by genotypes Prathibha and Sobha which received chitiosan spray at 1 g L^{-1} (4.72 and 4.72 %, respectively) (Table 25).

Interaction effect of harvesting stages and chitosan was also significant with respect to curcumin content in turmeric. Plants given chitosan spray (1 g L^{-1}) and harvested at 240 DAP, recorded highest curcumin content 5.02%. This was followed by chitosan sprayed plants harvested at 270 DAP and 210 DAP (4.77 and 4.63%, respectively) (Table 26).

The results of analysis of interaction effect of genotypes, harvesting stages and foliar spray of chitosan on curcumin content of turmeric considering all the treatment combinations is given in Table 27. Significantly highest curcumin content of 5.26 % was observed in the treatment combinations of genotype Sobha sprayed with chitosan spray 1 g L^{-1} and harvested at 240 DAP (V1H2C1), Prathibha with chitosan spray 1 g L^{-1} and harvested at 240 DAP (V2H2C1) (5.14%), Wayanad local with chitosan spray of 1 g L^{-1} and harvested at 270 DAP (V3H3C1) (5.20%) and 210 DAP (V3H1C1) (5.11%).

Influence of chitosan sprays on curcumin yield (kg ha^{-1}) of turmeric genotypes at various harvesting stages

The highest average curcumin yield was recorded in genotype Wayanad local (275.41 kg ha^{-1}) followed by Sobha (233.75 kg ha^{-1}) and Prathibha (233.73 kg ha^{-1}). Harvesting of turmeric at 270 DAP (273.91 kg ha^{-1}) and 240 (263.70 kg ha^{-1}) was significantly superior in improving the curcumin yield. Chitosan at a concentration of 1 g L^{-1} significantly improved the curcumin yield (316. 72 kg ha^{-1}) followed by plants subjected to water spray (215.20 kg ha^{-1}) and plants maintained as control without any spray (211.48 kg ha^{-1}) (Table 23).

Interaction effect of genotypes and harvesting stages for curcumin yield recorded significant difference. The highest curcumin yield was obtained from turmeric genotype, Wayanad local harvested at 270 DAP (313.72 kg ha^{-1}) followed by Sobha harvested at 240 DAP (284.45 kg ha^{-1}), 270 DAP (269.21 kg ha^{-1}) and Prathibha at harvested at 240 DAP (267.58 kg ha^{-1}) (Table 24).

Interaction effect between genotypes and chitosan sprays had a significant difference in curcumin yield. Plants of genotype Wayanad local which received a spray of chitosan 1 g L^{-1} exhibited highest curcumin yield of 355.21 kg ha^{-1} followed by genotype Sobha which received chitiosan spray (309.65 kg ha^{-1}) (Table 25).

Interaction effect between harvesting stage and chitosan sprays had a significant difference in curcumin yield. The highest curcumin yield of 350.55 kg ha^{-1} was recorded by rhizomes obtained from chitosan sprayed plants which was harvested at 240 DAP followed by harvested at 270 DAP (326.27 kg ha^{-1}) (Table 26).

When curcumin yield per hectare was analysed in detail by considering all the treatment combinations of genotypes, harvesting stages and chitosan sprays, the highest curcumin yield was obtained from genotype Sobha sprayed with chitosan and harvested at 240 DAP (V1H2C1) (385.16 kg ha^{-1}) and Wayanad local sprayed with chitosan 1 g $L^{-1}$and harvested at 210 DAP (378.54 kg ha^{-1}). The curcumin content of Wayanad local sprayed with chitosan and harvested at 270 DAP (V3H3C1) (367.88 kg ha^{-1}) was found on par with the highest curcumin yield, followed by genotype Prathibha with chitosan spray and harvested at 240 DAP (V2H2C1) (345.27 kg ha^{-1}) Table 27).

Influence of chitosan sprays on disease sevearity of leaf spot.

The incidence of leaf spot in turmeric crop in the experimental plot was observed in the month of November. Disease scoring was done to know the disease severity.

There was no significant difference in disease severity among the genotypes.. But, the chitosan sprays of 1 g L^{-1} on turmeric exhibited the least per cent of disease incidence (23.82%). The disease severity in water spraed plants was 28.04 % and in plants without any spray was 29.68 % (Table 28).

Table 23. Influnece of genotypes and chitosan sprays on yield characters in turmeric at various harvesting stages

Treatments	Fresh rhizomeyield per plot (kg plot^{-1})	Projected fresh yield (t ha^{-1})	Dry rhizome yield per plot (kg plot^{-1})	Projected dry rhizome yield (t ha^{-1})	Curcumin content (%)	Projected curcumin yield (kg ha^{-1})
Genotypes						
Sobha	7.86^{b}	26.22^{b}	1.37^{b}	4.58^{b}	3.98^{c}	233.75^{b}
Prathibha	7.98^{b}	26.62^{b}	1.38^{b}	4.61^{b}	4.36^{a}	233.73^{b}
Wayanalocal	9.68^{a}	32.27^{a}	1.77^{a}	5.91^{a}	4.21^{b}	275.41^{a}
SE	0.37	1.21	0.07	0.22	0.034	3.86
CD	1.04	3.45	0.19	0.62	0.10	10.96
Harvesting stages						
210 DAP	7.72^{b}	25.74^{b}	1.30^{b}	4.33^{b}	3.87^{b}	205.28^{b}
240 DAP	8.82^{a}	29.40^{a}	1.57^{a}	5.23^{a}	4.34^{a}	263.70^{a}
270 DAP	8.98^{a}	29.95^{a}	1.66^{a}	5.53^{a}	4.33^{a}	273.91^{a}
SE	0.37	1.21	0.07	0.22	0.034	3.86
CD	1.04	3.45	0.19	0.62	0.10	10.96
Spraying Chitosan						
Chitosan spray	9.43^{a}	31.45^{a}	1.71^{a}	5.71^{a}	4.81^{a}	316.21^{a}
Water spray	7.91^{b}	26.39^{b}	1.37^{b}	4.57^{b}	3.90^{b}	215.20^{b}
Absolute control	8.18^{b}	27.26^{b}	1.44^{b}	4.82^{b}	3.84^{c}	211.48^{b}
SE	0.37	1.21	0.07	0.22	0.034	3.86
CD	1.04	3.45	0.19	0.62	0.10	10.96

Table 24. Interaction effect of genotypes and harvesting stages on yield characters in turmeric

Genotype x Harvesting stage	Fresh rhizome yield per plot (kg plot^{-1})	Projected fresh rhizome yield (t ha^{-1})	Dry rhizome yield per plot (kg plot^{-1})	Projected dry rhizome yield (t ha^{-1})	Curcumin content (%)	Projected curcumin yield (kg ha^{-1})
Sobha x 210 DAP	6.75	22.50	1.07	3.58	3.05^{e}	147.59^{e}
Sobha x 240 DAP	8.11	27.05	1.45	4.86	4.57^{a}	284.45^{b}
Sobha x 270 DAP	8.73	29.10	1.59	5.33	4.32^{b}	269.21^{b}
Prathibha x 210 DAP	7.28	24.28	1.20	4.00	4.29^{b}	194.81^{d}
Prathibha x 240 DAP	8.38	27.96	1.40	4.69	4.68^{a}	267.58^{b}
Prathibha x 270 DAP	8.28	27.60	1.54	5.14	4.10^{c}	238.80^{c}
Wayanad local x 210 DAP	9.13	30.45	1.62	5.42	4.27^{b}	273.45^{d}
Wayanad local x 240 DAP	9.96	33.21	1.85	6.16	3.78^{d}	239.06^{c}
Wayanad local x 270 DAP	9.94	33.15	1.84	6.15	4.58^{a}	313.72^{a}
CD	NS	NS	NS	NS	0.17	19.0

Table 25. Interaction effect of genotypes and chitosan sprays on yield characters in turmeric

Genotype x Chitosan spray	Fresh rhizome yield per plot (kg plot^{-1})	Projected fresh rhizome yield (t ha^{-1})	Dry rhizome yield per plot (kg plot^{-1})	Projected dry rhizome yield (t ha^{-1})	Curcumin content (%)	Projected curcumin yield (kg ha^{-1})
Sobha x Chitosan spray	8.69	28.97	1.51	5.05	4.72^{b}	309.65^{b}
Sobha x Water spray	7.56	25.22	1.31	4.39	3.61^{e}	189.17^{g}
Sobha x Control	7.34	24.48	1.30	4.33	3.61^{e}	202.43^{fg}
Prathibha x Chitosan spray	8.74	29.16	1.55	5.20	4.72^{b}	283.78^{c}
Prathibha x Water spray	7.39	24.66	1.22	4.09	4.15^{c}	215.46^{ef}
Prathibha x Control	7.81	26.04	1.36	4.54	4.20^{c}	201.95^{f}
Wayanad local x Chitosan	10.87	36.23	2.06	6.89	4.99^{a}	355.21^{a}
Wayanad local x Water spray	8.79	29.31	1.57	5.26	3.94^{d}	240.97^{d}
Wayanad local x Control	9.38	31.28	1.67	5.59	3.71^{e}	230.04^{de}
CD	NS	NS	NS	NS	0.17	19.0

Table 26. Interaction effect of harvesting stages and chitosan sprays on yield characters in turmeric

Harvesting stage x Chitosan	Fresh rhizome yield per plot (kg $plot^{-1}$)	Projected fresh rhizome yield (t ha^{-1})	Dry rhizome yield per plot (kg $plot^{-1}$)	Projected dry rhizome yield (t ha^{-1})	Curcumin content (%)	Projected curcumin yield (kg ha^{-1})
210 DAP x Chitosan spray	8.42	28.09	1.45	4.85	4.63^{b}	271.82^{c}
210 DAP x Water spray	7.24	24.14	1.22	4.07	3.63^{d}	184.43^{f}
210 DAP x Control	7.50	25.00	1.22	4.07	3.34^{e}	159.59^{g}
240 DAP x Chitosan spray	9.47	31.58	1.73	5.76	5.02^{a}	350.55^{a}
240 DAP x Water spray	8.17	27.24	1.38	4.60	4.00^{c}	231.10^{d}
240 DAP x Control	8.81	29.39	1.60	5.34	4.01^{c}	209.45^{e}
270 DAP x Chitosan spray	10.40	34.67	1.95	6.51	4.77^{b}	326.27^{b}
270 DAP x Water spray	8.33	27.78	1.51	5.05	4.06^{c}	230.07^{d}
270 DAP x Control	8.22	27.40	1.51	5.04	4.17^{c}	265.38^{c}
CD	NS	NS	NS	NS	0.17	19.0

Table 27. Interactin effect of genotypes, chitosan spary on curcumin content and cucumin yield of turmeric genotypes at various harvesting stages

Treatments	Curcumin content (%)	Curcumin yield (kg ha^{-1})
V1H1C1	4.23^{ef}	228.78^{ghijk}
V1H1C2	2.53^{i}	108.00^{n}
V1H1C3	2.39^{i}	105.98^{o}
V1H2C1	5.26^{a}	385.16^{a}
V1H2C2	4.11^{f}	238.01^{ghi}
V1H2C3	4.33^{cde}	230.19^{ghij}
V1H3C1	4.66^{b}	315.00^{cd}
V1H3C2	4.2^{ef}	221.50^{ijklmn}
V1H3C3	4.11^{f}	271.13^{ef}
V2H1C1	4.56^{bcd}	210.15^{ijklmn}
V2H1C2	4.11^{f}	$193.63l^{mn}$
V2H1C3	4.21^{def}	180.67^{n}
V2H2C1	5.14^{a}	345.27^{bc}
V2H2C2	4.57^{bc}	258.80^{fg}
V2H2C3	4.34^{cdef}	198.66^{jklm}
V2H3C1	4.47^{bcde}	295.93^{de}
V2H3C2	3.77^{g}	193.95^{lmn}
V2H3C3	4.06^{fg}	226.51^{ghijkl}
V3H1C1	5.11^{a}	378.54^{a}
V3H1C2	4.27^{bcdef}	251.67^{fgh}
V3H1C3	3.44^{h}	192.13^{mn}
V3H2C1	4.66^{b}	321.21^{cd}
V3H2C2	3.33^{h}	196.49^{klmn}
V3H2C3	3.36^{h}	199.49^{jklmn}
V3H3C1	5.20^{a}	367.88^{ab}
V3H3C2	4.21^{ef}	274.76^{ef}
V3H3C3	4.34^{cdef}	298.52^{de}
CD	0.29	32.89

Table 28. Influence of chitosan sprays on leaf spot disease severity of turmeric genotypes at various growth stages

Genotypes	Disease sevearity (%)
Sobha	26.44
Prathibha	28.13
Wayanad local	26.98
SE	0.83
CD	NS
Spraying Chitosan	
Chitosan spray	23.82[c]
Water spray	28.04[b]
Absolute control	29.68[a]
SE	0.83
CD	4.09


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 6. Sobha harvested at 210 Days after planting


Harvested rhizomes of Chitosan 1 g L-1


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 7. Prathiba harvested at 210 Days after planting


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 8. Wayanad local harvested at 210 Days after planting

Harvested rhizomes of Chitosan 1 g L

Harvested rhizomes of Water spray

Harvested rhizomes of Control

Plate 9. Sobha harvested at 240 Days afeter planting


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 10. Prathibha harvested at 240 Days afeter planting

Harvested rhizomes of Chitosan 1 g L^{-1}

Harvested rhizomes of Water spray

Harvested rhizomes of Control

Plate 11. Wayanad local harvested at 240 Days afeter planting


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 12. Sobha harvested at 270 Days afeter planting


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate 13. Prathibha harvested at 270 Days afeter planting


Harvested rhizomes of Chitosan 1 g L^{-1}


Harvested rhizomes of Water spray


Harvested rhizomes of Control

Plate .14 Wayanad local harvested at 270 Days afeter planting

Discussion

5. DISCUSSION

The study entitled “Harvesting stages and chitosan sprays on curcumin yield in turmeric (*Curcuma longa* L.)” is an attempt to find out the effect of chitosan spray and stages of harvest on curcumin yield of three turmeric genotypes. This chapter contains the discussion of the results obtained.

INFLUENCE OF CHITOSAN SPRAYS ON PLANT HEIGHT OF TURMERIC GENOTYPES AT VARIOUS GROWTH STAGES

Plant height was observed at three growth stages, *viz.*, 100, 120, 150 DAP. Significant difference in plant height over each stage of harvest was observed. The plant height differs significantly at each growth stage (Fig.2). Among the genotypes, Wayanad local (Acc WCL 23) recorded significantly highest plant height in all growth stages followed by Prathibha (Fig. 2). The growth rate from 100 DAP to 150 DAP was highest for the genotype Sobha (81.08%) followed by Wayanad local (Acc WCL 23) (48.38%) and Parthibha (44.73%). Similar variations in plant height were found by Bahl *et al*. (2014) in turmeric, a wide variability in plant height among the evaluated accessions were noticed. Shanmugasundaram *et al*. (2000) took 15 turmeric genotypes and evaluated the plant height and observed the significant variation in plant height.Venugopal and Pariari (2017). Jilani *et al.* (2012), Kumar *et al.* (2015), Sadanand *et al*. (2019), Venkatesh (1994), Kandiannan *et al*. (2012) also recorded similar variation in plant height amog the turmeric genotypes. Patil *et al*. (1995) evaluated the performance of eight turmeric cultivars for their plant height and found that plant height differs with the cultivars.

Similar results were observed by Dinkar *et al*. (2012), Kumar *et al*. (2019) noticed that plant height varied significantly with varieties. This difference can be due to the genetic composition of the genotype with influence of environment.

There was a significant difference of plant height at 150 days after planting by the chitosan sprays. Foliar sprays of chitosan significantly improved the plant height irrespective of genotypes (Fig. 3). The highest plant height was recorded in chitosan sprayed plants (133.58 cm) followed by water spray (131.67cm). The lowest plant height was recorded in absolute control (124.88 cm) (Fig. 3).

Anusuya and Sathiyabama, 2016 recorded increased plant height of turmeric due to the foliar sprays of chitosan in regular intervals of 30 days in turmeric. Similar results were recorded by Thengumpally (2019) in kasturi turmeric the chitosan sprayed plants were recorded highest plant height. Salachna and Zawadzinska (2014) observed higher plant height in chitosan treated plants of freesia. Mondal *et al*. (2012) observed increased plant height of okra by chitosan application. El-Miniawy *et al*.(2013) recorded foliar sprays of chitosan resulted in increase in height of the plant in strawberry, this increase is may be due to the increasing total carbohydrates in the crowns can be probable reason for plant height increment. Increase in plant height as a result of chitosan application was recorded by Farouk *et al*. (2012) in cowpea, Van *et al*. (2013) in coffee, Mondal *et al*. (2011) in Indian spinach, Sheikha and Al-Malki (2011) in common bean.

Fig.2. Plant height of turmeric genotypes at various growth stages

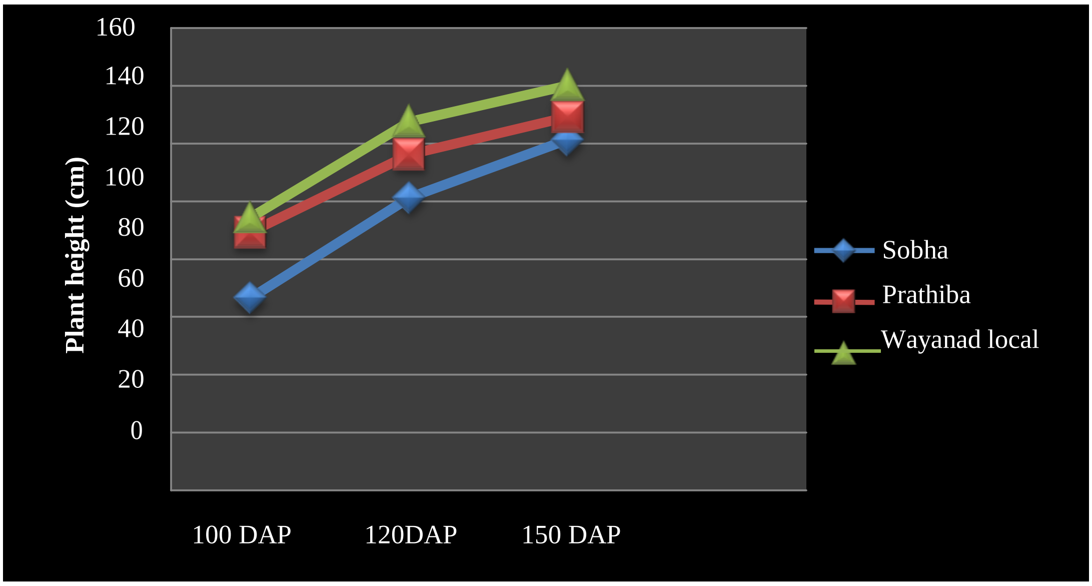
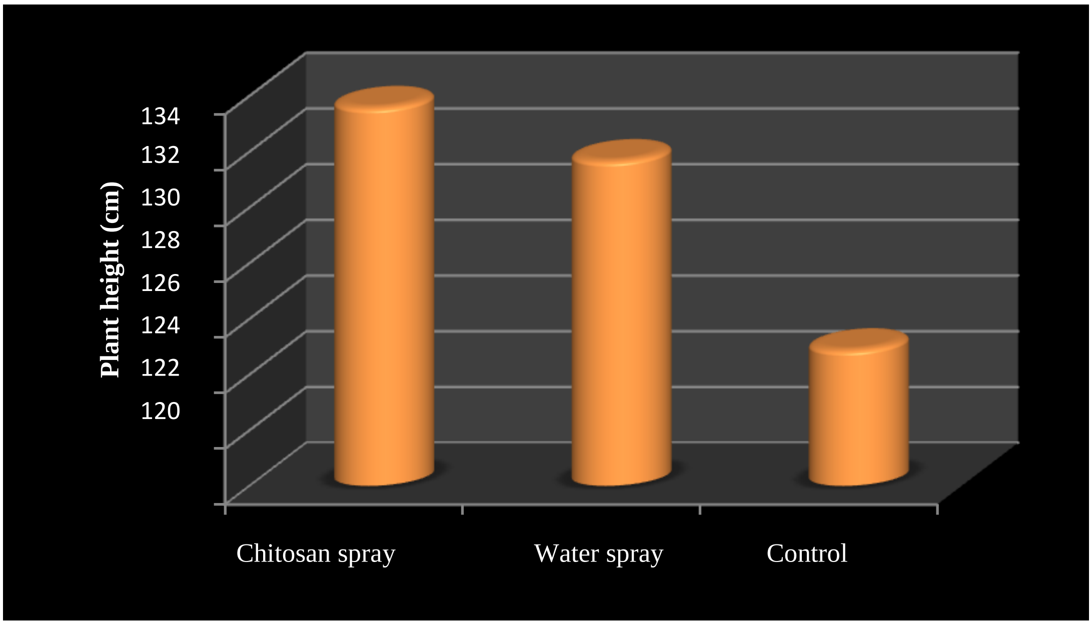


Fig. 3. Influence of chitosan sprays on plant height of turmeric at 150 DAP



INFLUENCE OF CHITOSAN SPRAYS ON NUMBER OF LEAVES OF TURMERIC GENOTYPES AT VARIOUS GROWTH STAGES

Number of leaves per plant was recorded in Sobha, Prathibha, Wayanad local (Acc WCL 23) at three different growth stages and significant variation was observed (Fig. 4). At 100 DAP genotype Prathibha recorded highest number of leaves (7.87), At 120 DAP Wayanad local recorded highest number of leaves 8.65, at 150 DAP, and the highest number of leaves were recorded by genotype Prathibha (8.46) and genotype wayanad local was found on par with the highest (8.33). Significant difference in the number of leaves was noticed due the genetic difference of varieties.

Variations in the number of leaves of turmeric were recorded by vijayan (2015) in different genotypes of turmeric at three different stages of growth of 160, 200, 240 DAP in various cultivars. Significant variations in leaf number were exhibited at each stage of growth of the three genotypes, Sobha, Prathibha and wayanad local. Among the three stages of plant growth, lowest number of leaves was noticed at 160 DAP in Sobha (8.70) Prathibha (13.64) and Wayanad local (Acc WCL 23) (8.80). Highest number of leaves were recorded at 200 DAP in Sobha, Prathibha, Wayanad local (Acc WCL 23) (10.28, 15.94, 10.54, respectively). But later at 240 DAP there was a reduction in leaf number of all genotypes were noticed.

Dodamani (2015) recorded the number of leaves in turmeric genotypes at 30, 90, 150, 180 DAP and results found that number of leaves differs significantly in all genotypes with the growth stages. The minimum number of leaves was at 30 DAP and ranged from 2.18 - 4.12. The highest number of leaves was at 180 DAP which ranged from 10.61 – 18.63.

Bahl *et al*. (2014) evaluated 84 accessions from different localities. Number of leaves showed a wide range of variations due to different accessions.

Kandiannan *et al*. (2012) recorded variation in number of leaves among the varieties, Prathibha recorded more number of leaves (24.6) and lower numbers of leaves recorded in Rajendra Sonia (16.1) at 150 DAP.

After evaluating thirty three genotypes, the genotype TPR-2 exhibited more number of leaves per plant (28.34) and TMZ-2 exhibited less number of leaves per plant (11.82). The growth parameter number of leaves plant^{-1} had a significant difference due to the genotypes (Luiram *et al*., 2018).

INFLUENCE OF CHITOSAN SPRAYS ON NUMBER OF TILLERS IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Number of tillers in Sobha, Prathiba and Wayanad local (Acc WCL 23) was recorded at three growth stages. Tiller production was increased with the growth stages. Significant improvement of tillers over a growth period was noticed.The genotype Wayanad local (Acc WCL 23) recorded significantly higher number of tillers, followed by Prathiba and lower number of tillers was observed in genotype Sobha during various growth stages. Tiller production varied with genotypes and growing stages (Fig.5).

Similar results were recorded by Vijayan (2015) in turmeric. The number of tillers was recorded at three stages at 160, 200 and 240 DAP. The highest number of tillers was recorded at 240 days after planting (2.74), which was on par with 200 days after planting (2.73). Lowest number of tillers was recorded after 160 days after planting (2.61).

Tiller production varied with the varieties as recorded by Kandiannan *et al.* (2012) after evaluating 11 cultivars of turmeric. More number of tillers was in Rasmi (3.8) and lesser tillers were noticed in Suranjana (2.8).

Venkatesha (1994) studied tiller production of 10 cultivars. The BSR-1 cultivar had a significantly higher number of tillers (7.0) followed by cultivar CO-1 (5.36) and lower number of tillers was recorded in Waigon (3.56). Shanmugasundaram *et al*. (2000) selected fifteen turmeric genotypes and evaluated the growth characters. Number of tillers after 6 months after planting was highest in Kanthi (4.88), which was on par with Roma (4.68). Least number of tillers was in VK-5 (1.65).

Venugopal and Pariari (2017) noticed the plant growth characters varied with varieties. Highest number of tillers was noticed in Rajendra sonia (2.77) and Duggirala had least number of tillers. Luiram *et al*. (2018) found genotype TPR-2 as highest number of tillers (3.48), which was on par with TAS-10 (3.45) and TNL-2 recorded lowest (1.12) number of tillers after 165 days after planting. Sadanand *et al* (2019) evaluated turmeric genotypes tiller production was recorded. Higher number of tillers was recorded in Pratibha (3.5), and lower number of tillers was recorded in Megha Haldi (2.12). High heritability was observed for number of tillers (Vinodhini *et al*., 2018) and supported by Vimal *et al*. (2018). Numbers of tillers are considered as one of the selection character for turmeric (Rajalakshmi *et al*., 2013).

Irrespective of genotypes, chitosan sprays at 0.1% recorded higher number of tillers at 120 DAP and 150 DAP. At 150 DAP Chitosan sprayed plants recorded highest number of tillers (3.78), this was followed by water spray (3.12). Lowest number of tillers was in absolute control (3.07) as shown in (Fig.6). Similar findings were recorded by Manoj (2017). Highest number of tillers was observed in chitosan sprayed plants at 0.01% concentration.

When interaction effects were analyzed chitosan sprayed plants of genotype Wayanad local exhibited higher number of leaves at 120 DAP (4.93).

Fig.4 Number of leaves of turmeric genotypes at various growth stages

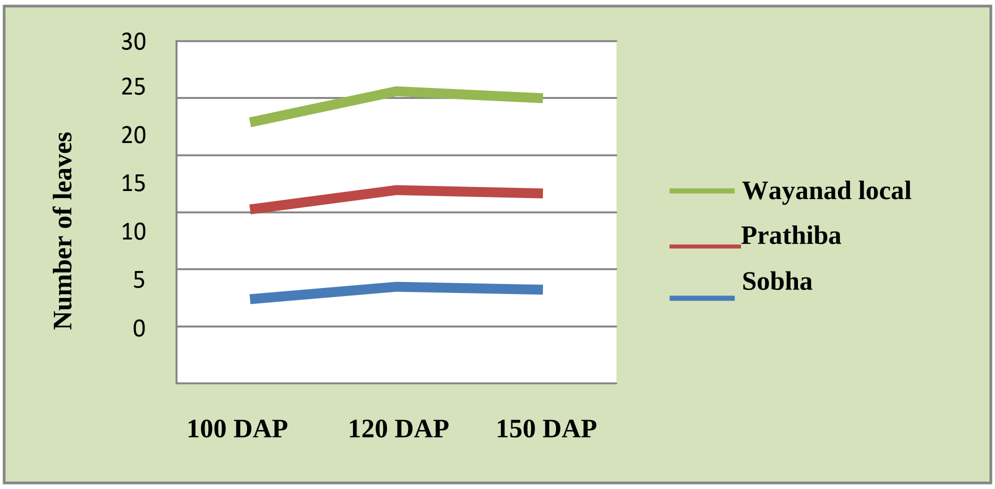


Fig.5 Tillers production at various growth stages of turmeric genotypes

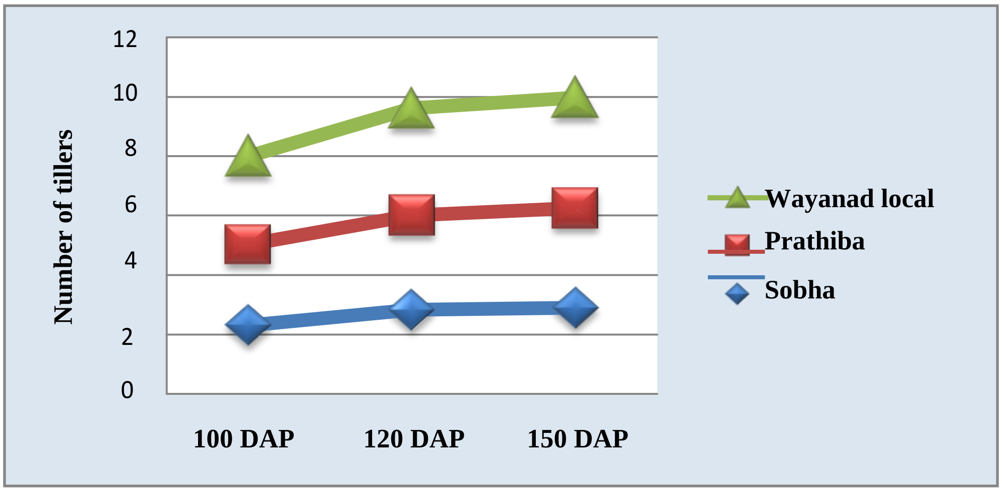
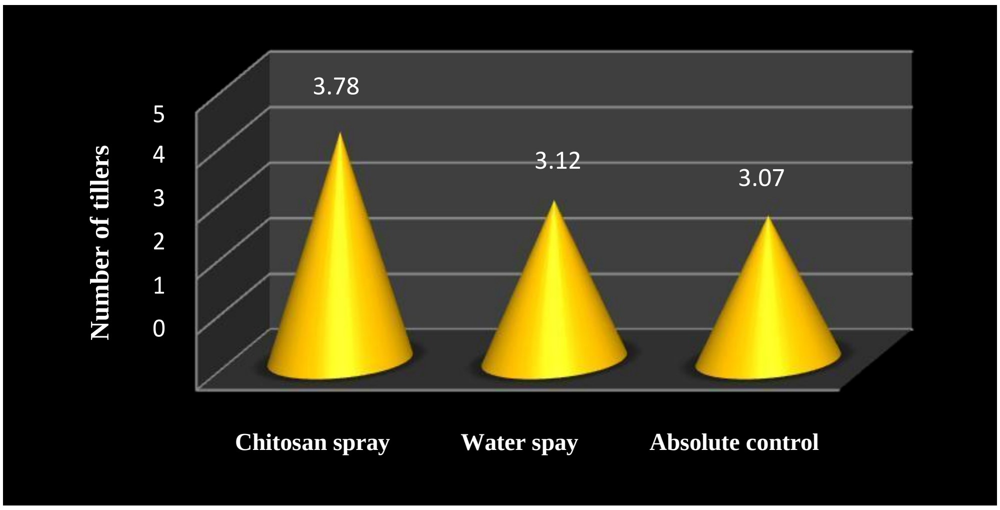


Fig.6.Influenceof chitosan sprays on number of tillers at 150 DAP



INFLUENCE OF CHITOSAN SPRAY ON GIRTH OF MAIN TILLER OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Main tiller girth of Sobha, Prathiba, Wayanad local (Acc WCL 23) was observed at three growth stages *viz.,* 100, 120 and 150 DAP. Girth of the main tiller increased with each growth stage. Higher girth was noticed at 150 DAP in all genotypes. Wayanad local (Acc WCL 23) recorded significantly higher main tiller girth (10.45 cm) followed by Prathiba and Sobha (9.93 cm and 9.45 cm, respectively) at 150 DAP (Fig.7).

Girth of tiller differs significantly with respect to genotypes and growth stages, Similar results were recorded by Dodamani (2015) on stem girth of main tillers at 30, 90,150,180 DAP. Girth increased from 30 DAP to 180 DAP. The highest stem girth was recorded in Co-1 (6.28 cm) and least girth of pseudostem was noticed in CO-2 (5.34 cm) at 180 DAP. Sekhon (2012) recorded varied main tiller girth among the selected 40 genotypes. The girth ranged from 9.04 cm – 28.70 cm among the genotypes. The highest girth was in ST10 -27 (28.70 cm) and lowest in ST10-33 (9.04 cm). Supporting results was recorded by Vinodhini (2018) by evaluating 55 genotypes the observed tillers girth varied from 4.88 cm - 9.56 cm among the varieties.

Singh *et al.* (2010) recorded maximum heritability with moderate genetic advance for plant girth. Vinodhini *et al*. 2018 recorded that pseudo stem girth had high heritability with genetic advance.

INFLUENCE OF CHITOSAN SPRAYS ON LEAF AREA OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Leaf area of Sobha, Prathiba, and Wayanad local (Acc WCL 23) was recorded at 100 DAP, 120 DAP, and 150 DAP. Leaf area increased gradually from 100 DAP to 150 DAP. Leaf areas at 100 DAP in Sobha, Prathiba, and Wayanad local (Acc WCL 23) was 375.86 cm^2, 466.98 cm^2, and 529.06 cm^2, respectively. At 120 DAP leaf area was 555.00 cm^2, 571.76 cm^2, and 657.38 cm^2 in genotypes Sobha, Prathiba, and Wayanad local (Acc WCL 23), respectively. Highest leaf area was observed at 150 DAP. Wayanad local (Acc WCL 23) had a highest leaf area at 150 DAP (696.28 cm^2) followed by Prathiba (631.72 cm^2). Leaf area was least in genotype Sobha (596.81cm^2). The leaf area differs by the growth stages and by genotypes (Fig.8).Dodamani (2015) recorded similar findings after evaluating leaf area of 18 genotypes of turmeric at 30, 90, 150 and 180 DAP. Leaf area was highest at 180 days after planting. Genotype C0 -1 (541.8 cm^2) had a highest leaf area and it was on par with CLI -325 (526.3 cm^2). The lowest leaf area was observed in CO-2 (454 cm^2). Satish *et al.* (1997) studied leaf area in different cultivars at 175 days after planting. Among them Bangalore Local recorded highest leaf area (515.6 cm^2), followed by Sangli (440.2 cm^2). Lowest leaf area was recorded in cultivar Rajapuri (308.2cm^2)

Fig.7. Girth of main tiller of turmeric genotypes at various growth stages

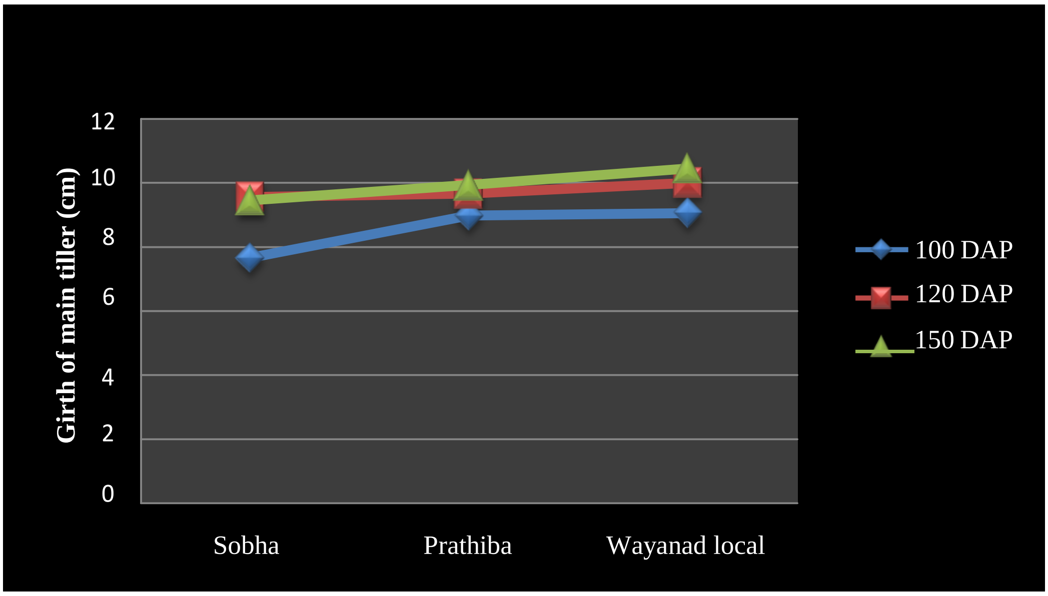
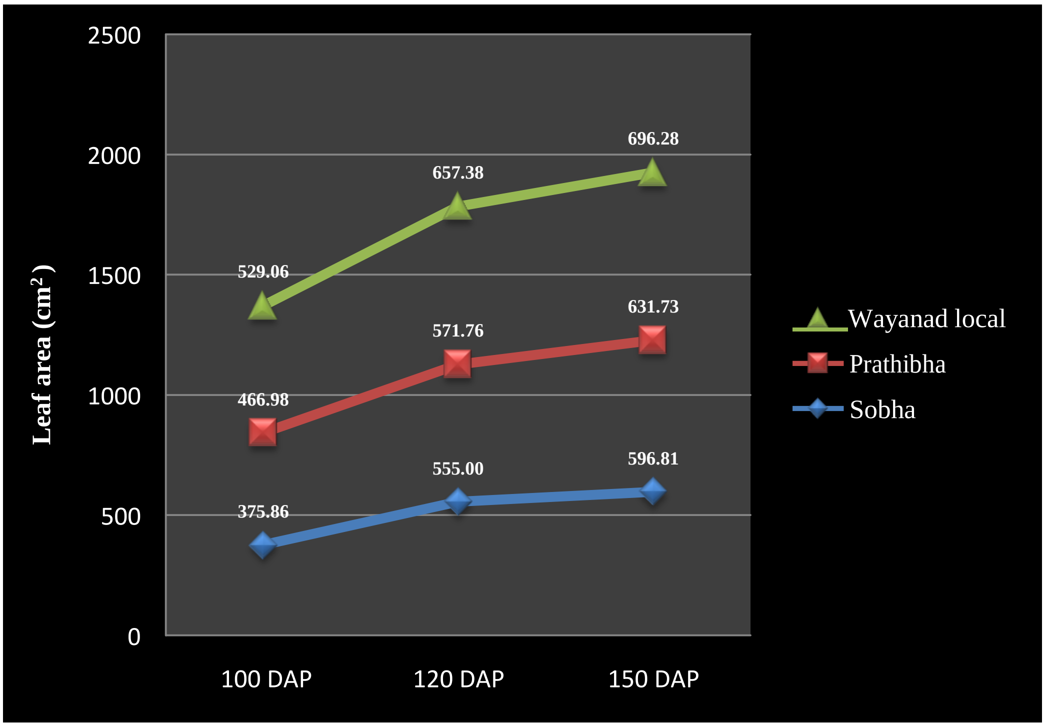


Fig.8. Leaf area of turmeric genotypes at various growth stages



INFLUENCE OF CHITOSAN SPRAYS ON PHOTOSYNTHETIC RATE OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

There was significant variation in photosynthetic rate of turmeric with genotypes. Sobha had the highest photosynthetic rate (30.60 µmol m^{-2} s^{-1}) followed by Prathiba (29.92 µmol m^{-2} s^{-1}). Lowest photosynthetic rate was in Wayanad local (Acc WCL 23) (25.92 µmol m^{-2} s^{-1}) (Fig. 9).

Photosynthetic rate was highest in chitosan sprayed plants. Foliar sprays of chitosan at 0.1% at monthly intervals increased photosynthetic rate in plants significantly. Photosynthetic rate of 32.76 µmol m^{-2} s^{-1} was recorded in chitosan treated plants. It was the highest among other treatments followed by water spray (28.81 µmol m^{-2} s^{-1}). Least photosynthetic rate was recorded in control (24.86 µmol m^{-2} s^{-1}) (Fig.10).

Similar reports of chitosan on increasing photosynthetic rate were found in kasturi turmeric by Thengumpally (2019). Two foliar sprayings of chitosan increased the photosynthetic rate.

Supporting results of increased photosynthetic rate by chitosan treatment was recorded in wheat by Zeng and Luo (2012). Increase in the chlorophyll content of chitosan treated plants was observed to have influence photosynthetic rate. Similar increase in photosynthetic rate of coffee was found by Van *et al*. (2013) due to increased chlorophyll. Salachna and Zawadzinska, (2014) also recorded enhanced chlorophyll (13%) leads to increase photosynthetic rate in freesia, when freesia corms were treated with chitosan at 0.5%. Similar reports were found in okra (Mondal *et al*., 2012).

Fig.9. Photosynthetic rate of turmeric genotypes

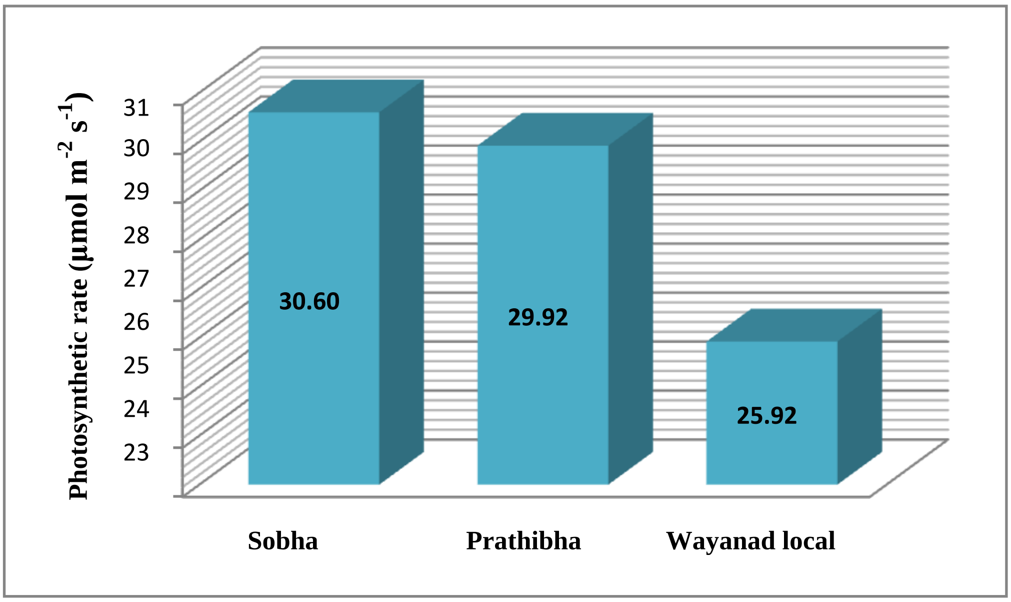
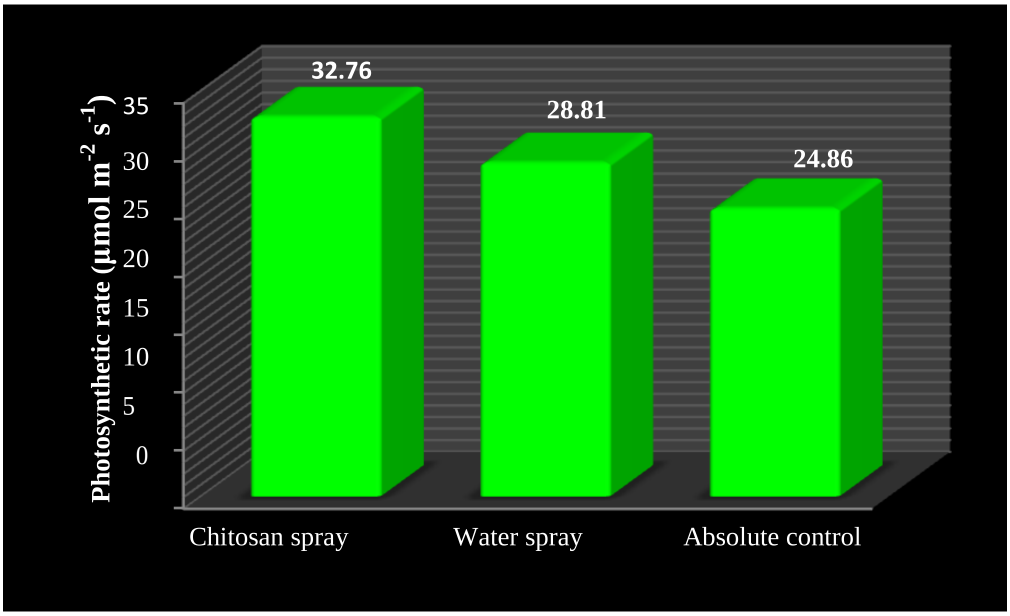


Fig.10. Influence of chitosan sprays on photosynthetic rate of turmeric



INFLUENCE OF CHITOSAN SPRAYS ON THE LENGTH OF PRIMARY RHIZOMES OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Length of primary rhizome in Sobha, Prathiba and Wayanad local (Acc WCL 23) differed significantly. Among the genotypes Wayanad local (Acc WCL 23) and Sobha recorded significantly higher length of primary rhizome (11.07 cm and 10.68, respectively) (Fig.11).

Vinodhini (2018) recorded similar findings in turmeric by evaluating different genotypes. Length of primary rhizome varied from 3.40 cm to 11.00 cm. Length of primary rhizome is governed by additive genes and it can be inherited by selection. Venugopal and Pariar (2017) evaluated five turmeric cultivars and recorded variation in primary rhizome length from 4.55 cm to 6.36 cm. Kumari *et al* (2014) observed primary rhizome length variation from 5.20 cm to 11.83 cm after evaluating ten genotypes. Anu (2019) found primary rhizome length ranging from 6.49 cm to 12.69 cm in turmeric. Dodamani (2015) evaluated 18 genotypes and found primary rhizome length varying from 4.20 cm to 5.79 cm.

Length of primary rhizome was recorded at three harvest stages *viz.*, 210, 240 and 270 DAP, observed significant difference at each stage of harvest (Fig.12). The highest length of primary rhizome was recorded at 270 DAP (10.58 cm) followed by 240 DAP (10.00 cm) and 210 DAP (9.53 cm) (Fig.12). The primary rhizome length increased with rhizome development. Simlar difference in the rhizome development with respect to growth was obserced by Hailemichael *et al.*, 2016 and found that rhizome development increase with growth stage. The highest length of primary rhizome was in genotype Wayanad local (Acc WCL 23) at all growth stages of harvest *viz.*, 210, 240 and 270 DAP (11.27 cm, 10.80 cm, 11.15 cm, respectively) and Sobha at 240 and 270 DAP (11.08 and 11.32 cm, respectively). There was no significant difference in length of primary rhizome of turmeric on chitosan application. But, the genotype Sobha sprayed with chitosan at 1g L^{-1} exhibited the highest length of primary rhizome (11.48 cm).

Fig.11. Length of primary rhizomes in turmeric genotypes

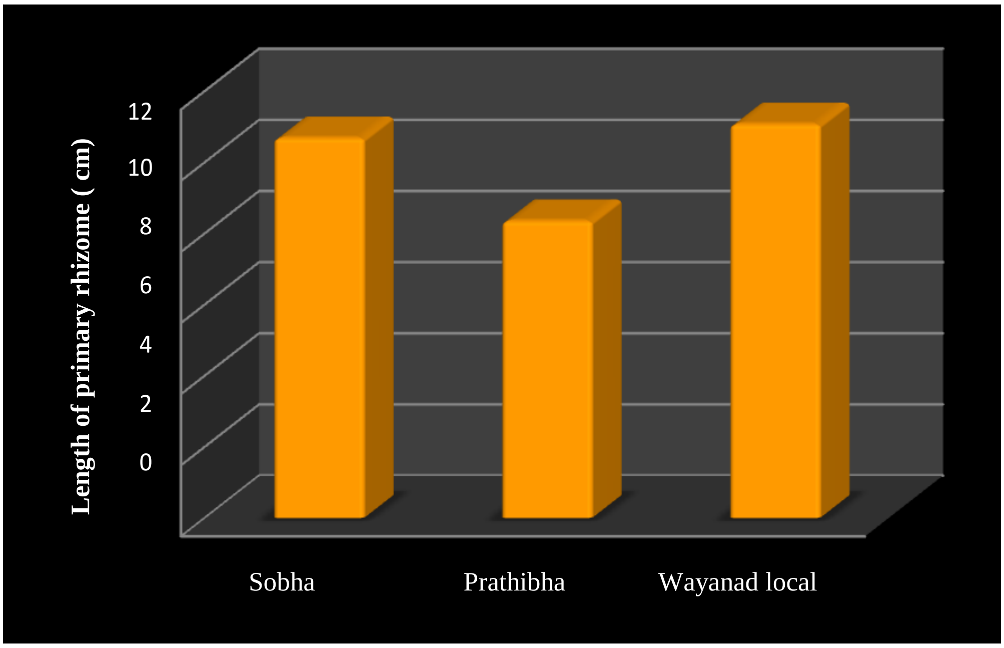
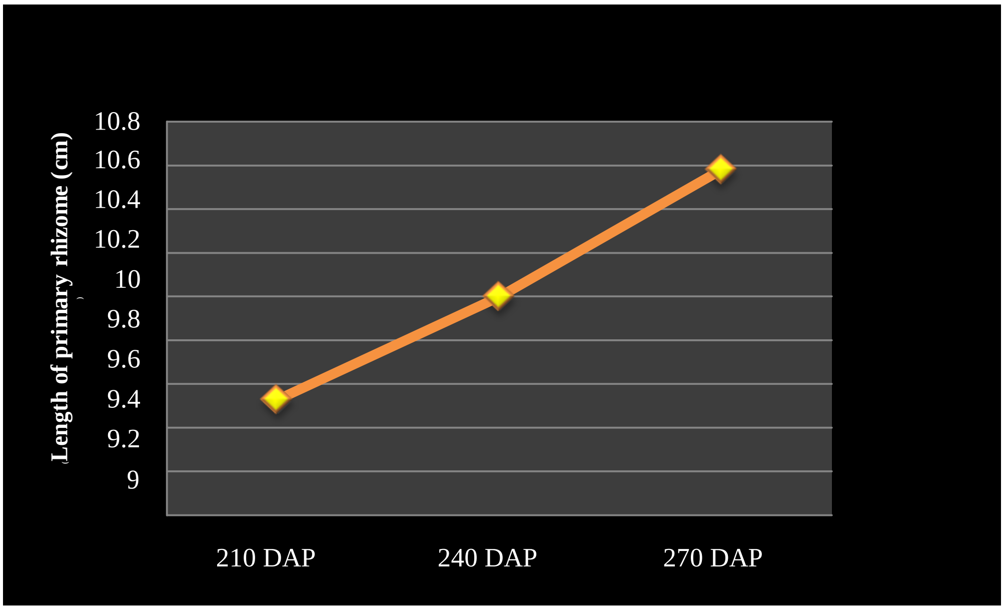


Fig.12. Influence of harvesting stages on length of primary rhizome.



INFLUENCE OF CHITOSAN SPRAYS ON WIDTH OF PRIMARY RHIZOMES OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Genotypes recorded variability in the width of primary rhizome (Fig.13).The highest width of primary rhizome was recorded in Prathiba (2.79 cm) followed by Wayanad local (Acc WCL 23) (2.53 cm) (Fig.13). Anu (2019) noticed variability among the accessions for width of primary rhizome, the width of primary rhizome ranged from 1.44 cm to 3.08 cm and Prathibha (3.08 cm) recorded highest width.

While analyzing the interaction effect, it is clear that, the highest width of primary rhizome was obtained from turmeric genotype Prathibha harvested at 270 DAP (3.47 cm).

The width of primary rhizome was highest at 270 DAP (3.19cm) followed by 240 DAP (2.47 cm) and the lowest width of primary rhizome was at 210 DAP (1.79 cm). Hailemichael *et al.* (2016) evaluated turmeric rhizomes by using different accessions with five harvesting stages and recorded that rhizome development increase with growth stage (Fig.14).

Chitosan sprays at 1g L^{-1} were found to increase the width of the primary rhizome. Chitosan sprayed plants recorded the highest width of primary rhizome (2.59 cm) followed by absolute control (2.47 cm) and water spray (2.37 cm) (Fig.15). Anasuya and Sathyabama (2016) recommended chitosan foliar application to increase the yield in turmeric. Width of primary rhizome, one of the yield contributing characters, can be increased by chitosan sprayings.

Fig.13. Width of primary rhizome in turmeric genotypes

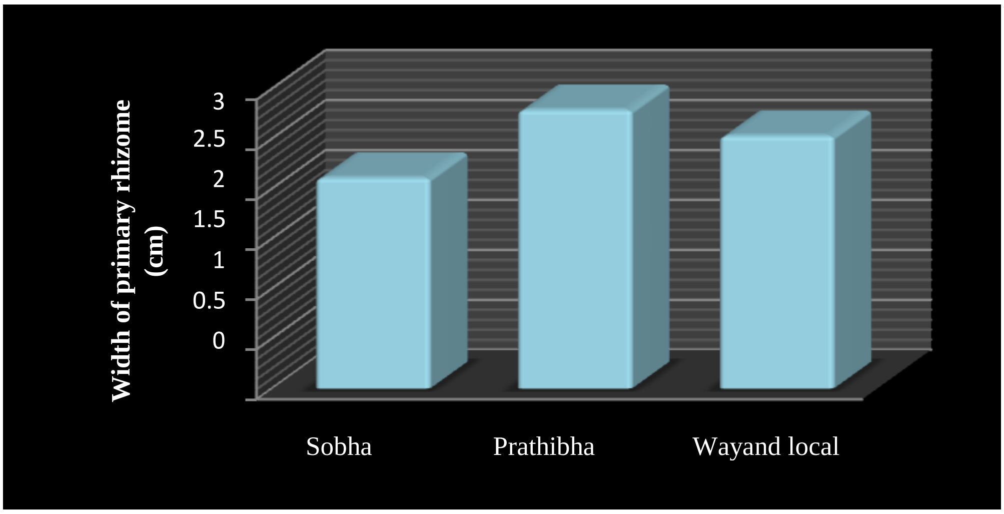


Fig.14. Influence of harvesting stages on width of primary rhizome

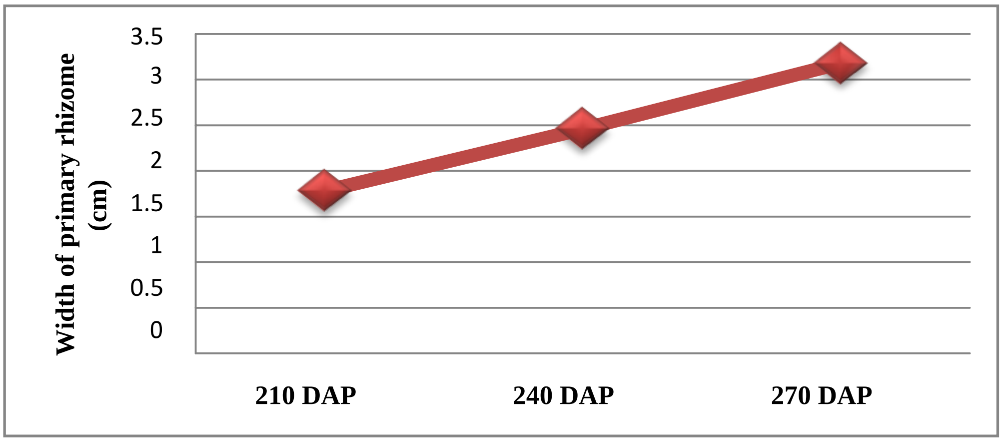
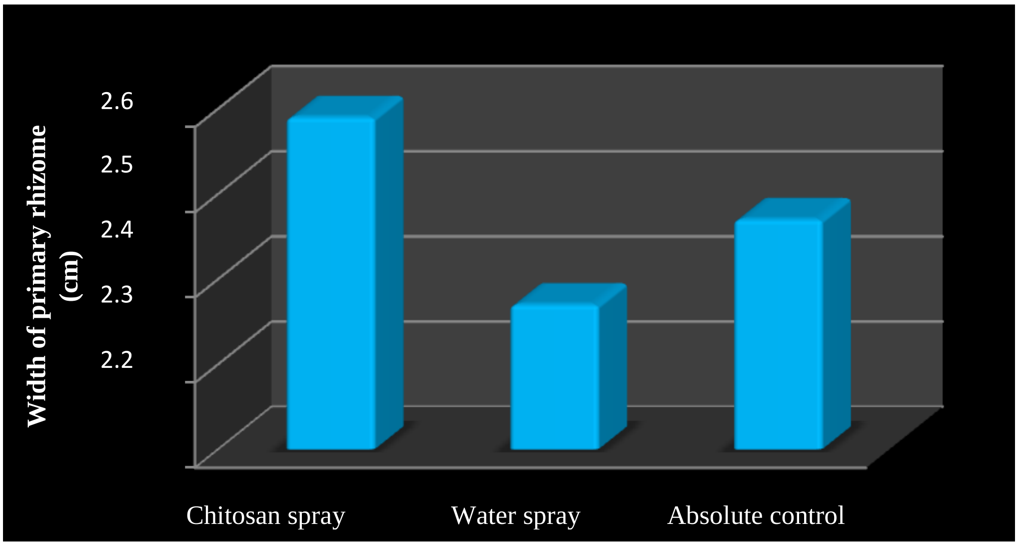


Fig.15. Influence of chitosan sprays on width of primary rhizome



INFLUENCE OF CHITOSAN SPRAYS NUMBER OF PRIMARY RHIZOMES OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

There was a significant variation with respect to genotypes, the highest number of primary rhizomes was recorded in Wayanad local (Acc WCL 23) (6.78) and Prathibha (6.67), followed by Sobha (6.32) (Fig.16). Similar results were noticed by Anu (2019) number of primary rhizome was found to be highest for the accession WCL 23 (7.33) and lowest in WCL 3 (3.87). Bandhopadhya *et al*., 2015 observed the highest number of primary rhizomes in TCP 70 (6.33). Venugopal and Pariari (2017) noticed the highest number of primary rhizome in genotypes Rajendra Sonia (6.81) and Suguna (6.69).

The primary rhizomes count differed significantly at each stage of harvest in all genotypes. Significant improvement in the number of primary rhizomes with the harvest stage was noticed (Fig.17). Among the different harvest stages, 270 DAP recorded significantly higher number of primary rhizomes (7.10) followed by 240 DAP (6.35). The lowest number of primary rhizomes was at 210 DAP (6.31).

Kumar and gill (2009) also recorded significant improvement in the number of primary rhizomes in different harvest dates. Delayed harvest increased the number of primary rhizomes due to the long growth period and may be due to more nutrients absorption.

There was a significant difference by the chitosan spray at 0.1 % on number of primary rhizomes per plant. Foliar sprays of chitosan significantly improved the number of primary rhizomes irrespective of genotypes (Fig 18). The highest primary rhizome count was recorded in chitosan sprayed plants (7.32) followed by control (6.61) (Fig.18).

Similar results were found by Manoj (2017) in turmeric. Chitosan spray at 100 ppm concentration at three foliar sprays at monthly intervals from 120, 150 and 180 DAP had the highest number of primary rhizomes. Thengumpally (2019) recorded that foliar sprays of chitosan at 0.25 % and 0.3 % on kasthuri had the highest number of primary rhizomes. Anasuya and Sathyabama (2016) observed that chitosan sprays had an influence on the number of nodes. Highest number of nodes was observed by chitosan spray.

When the interaction effects were observed, the highest number of primary rhizomes per plant was obtained from turmeric genotype Prathibha (7.83) harvested at 270 DAP. The highest number of primary rhizomes per plant was obtained from chitosan sprayed plants harvested at 270 DAP (8.11).

Fig 16. Number of primary rhizomes in turmeric genotypes

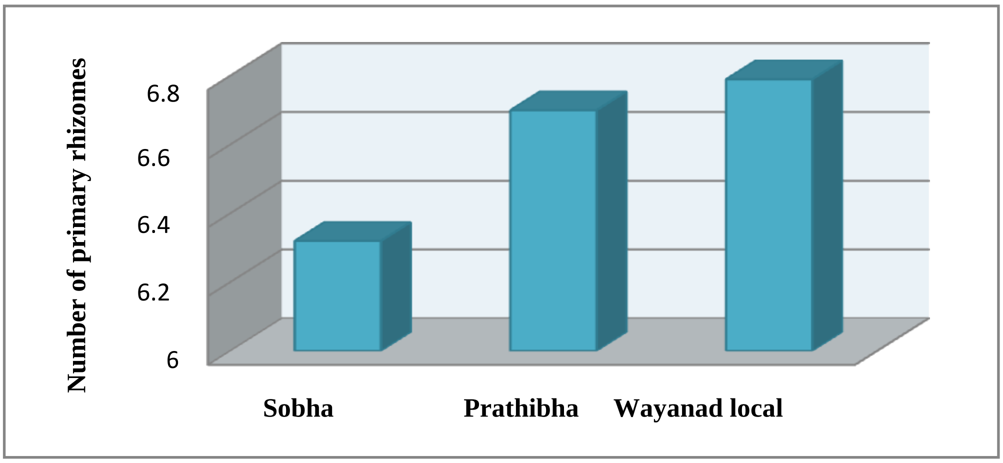


Fig.17. Influence of harvesting stages on number of primary rhizomes

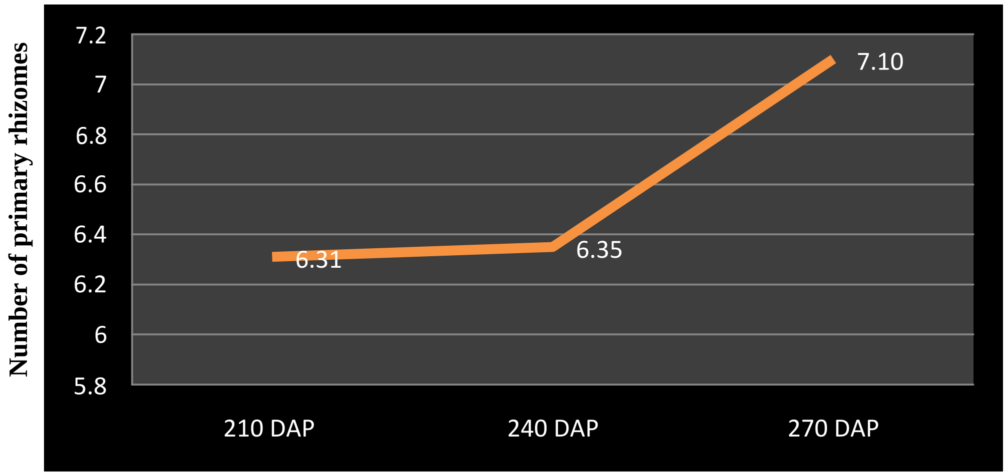
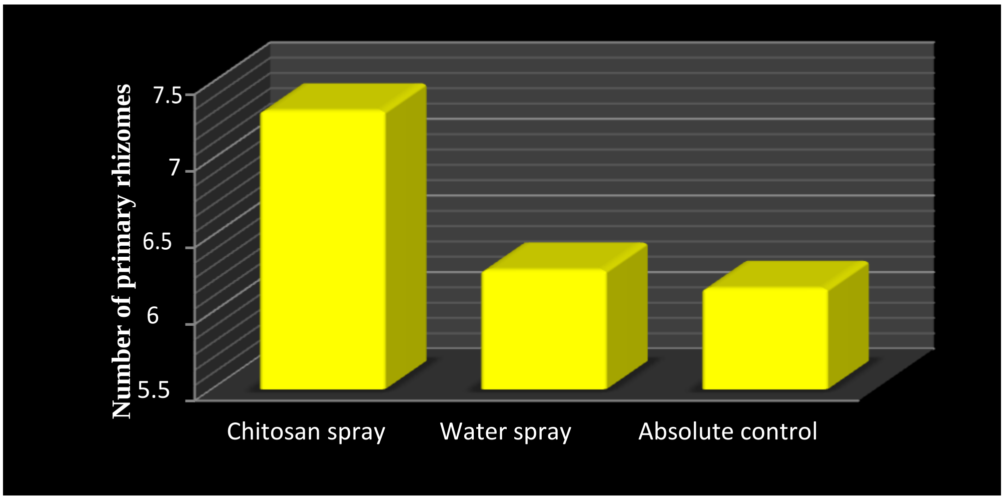


Fig.18. Influence chitosan sprays on number primary rhizomes



INFLUENCE OF CHITOSAN SPRAYS ON NUMBER OF SECONDARY RHIZOMES IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

It was observed that the production of number of secondary rhizomes varied with genotypes. The highest number of secondary rhizomes was recorded in Sobha (18.67) and Wayanad local (Acc WCL 23) (18.35) followed by Prathibha (14.28) (Fig. 19). Variability in the production of secondary rhizomes was observed. Similar results were recorded by (Vinodhini, 2018), number of secondary rhizome production in 55 genotypes ranged from 2 to 19. Sadanad *et al*., 2019 observed that secondary rhizome production varied with the turmeric cultivars. Sinkar *et al*., 2005, Tiwari, 2014, Vimal *et al*., 2018, Anu (2019) and Latha *et al*., 1995 observed varietal difference in production of secondary rhizomes.

There was a significant difference in secondary rhizomes at the time harvest. Foliar sprays of chitosan significantly improved the secondary rhizomes count irrespective of genotypes (Fig.20). The highest number of secondary rhizomes was recorded in chitosan sprayed plants (18.89) followed by control (16.39) and water spray (16.01) (Fig.20). Similar results of increased secondary rhizomes were recorded by Manoj (2017) in turmeric. Chitosan sprays at regular intervals of 30 days on turmeric resulted in increased number of secondary rhizomes at the time of harvest

Fig. 19. Number of secondary rhizomes in turmeric genotypes

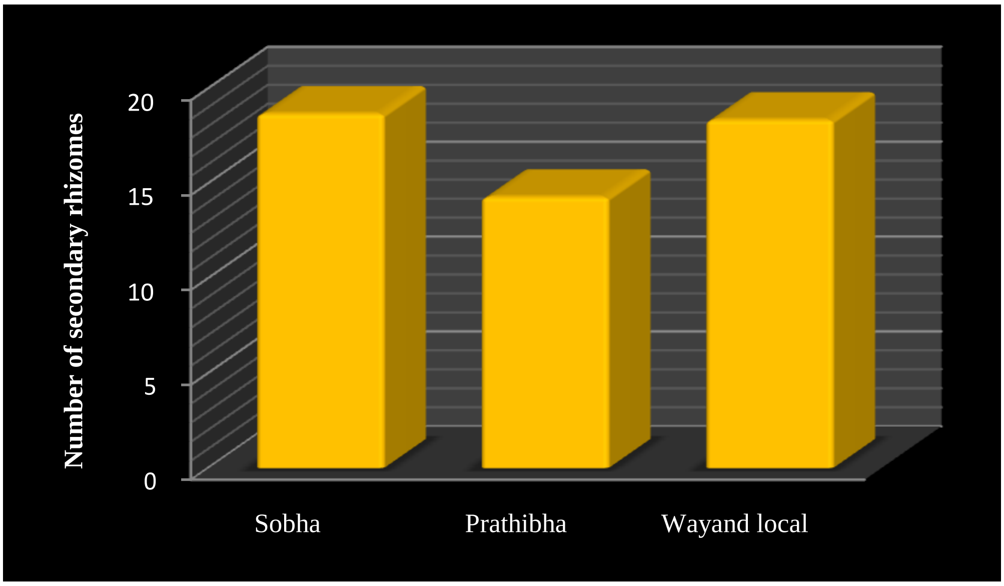
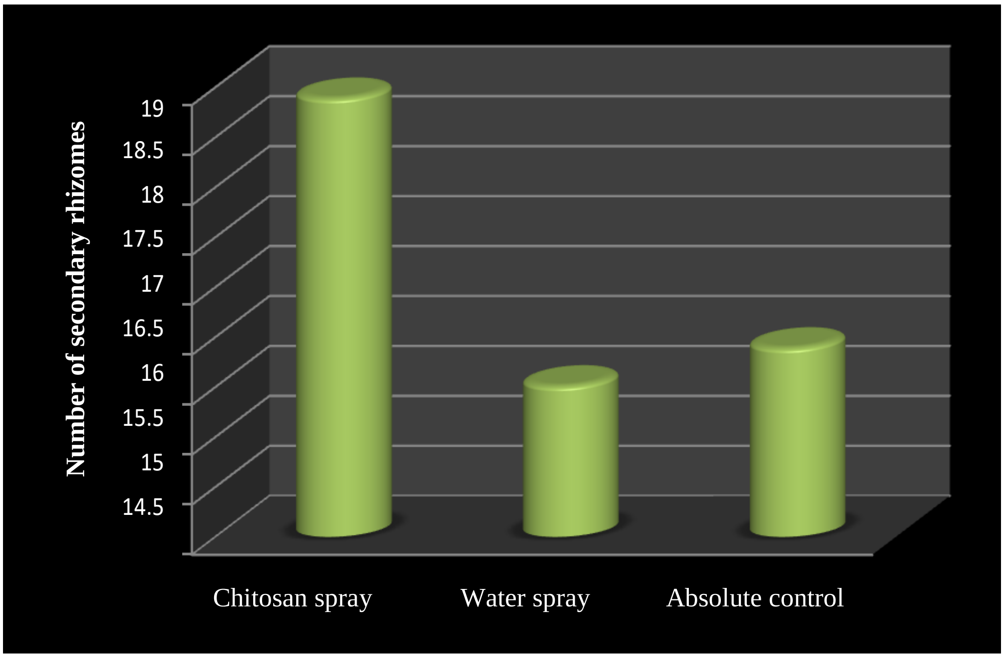


Fig. 20. Influence of chitosan sprays on number of secondary rhizomes in turmeric



INFLUENCE OF CHITOSAN SPRAYS ON NUMBER OF MOTHER RHIZOMES OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Significant difference was observed in the number of mother rhizomes by chitosan spray at 0.1%. Number of mother rhizomes noticed in chitosan sprayed plants was 1.58 followed by 1.33 in water spray and 1.21 in control (1.21) (Fig.21).

Manoj (2017) also recorded significant increase in the number of mother rhizomes at the time harvest in chitosan sprayed plants at a concentration of 100 ppm.

INFLUENCE OF CHITOSAN SPRAYS ON WEIGHT OF MOTHER RHIZOMES OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Weight of mother rhizome was recorded in genotypes Sobha, Prathiba and Wayanad local (Acc WCL 23). The weight of mother rhizome differs significantly with respect to genotypes (Fig.22). Among the genotypes Prathibha had bigger mother rhizomes and recorded significantly higher weight (59.15 g) followed by Wayanad local (Acc WCL 23) (48.13 g). The lowest weight of mother rhizome was noticed in the genotype Sobha (38.95 g).

Similar results were recorded by Sadanad *et al*. (2019) after evaluated ten turmeric genotypes. The variability in the weight of mother rhizome was due to varietal difference and heritability. Aarthi et *al*. (2018) evaluated 15 genotypes of turmeric and found variability in the weight of mother rhizomes. Reports of Piride *et al*. (2007), and Mishra and Singh (2017) also concur with the present findings.

Weight of mother rhizome was recorded at three harvest stages *viz*., 210, 240 and 270 DAP. Significant difference in the weight of mother rhizome of turmeric was observed at the time of harvest. Highest weight of mother rhizome was observed at 270 and 240 DAP (51.68, 52.03 g, respectively) and weight of mother rhizome was lowest at 210 DAP (42.52 g). Increase in the weight of mother rhizome with delay in harvest was noticed (Fig.23).Kumar and gill (2009) also recorded increase in weight of mother rhizome with delay in harvest. Plants with a longer growth period help them to absorb more nutrient resulting in increased weight of turmeric.

Fig. 21. Influence of chitosan sprays on number of mother rhizomes in turmeric

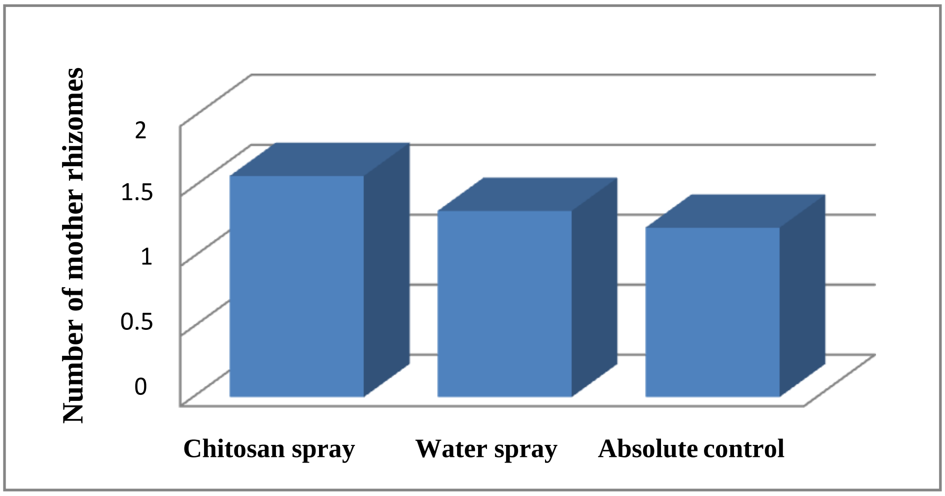


Fig. 22. Weight of mother rhizome in turmeric genotypes

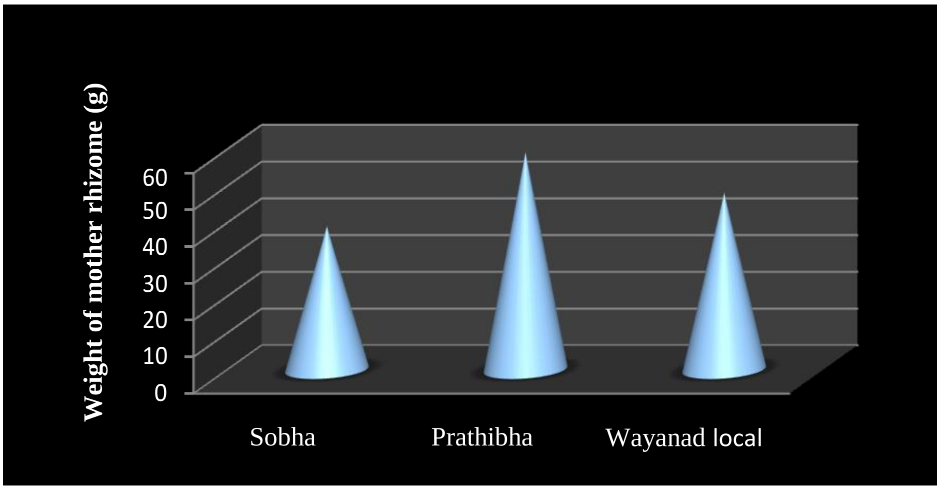
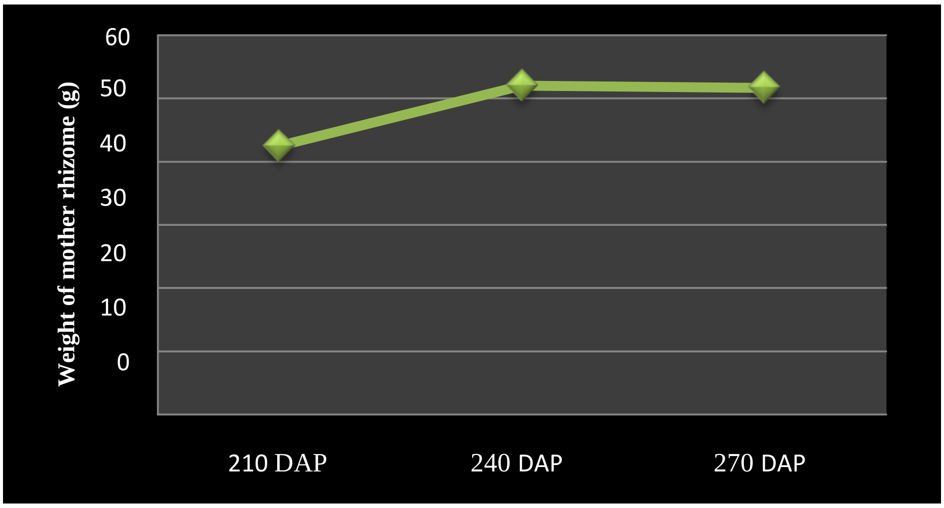


Fig.23. Influence of harvesting stges on weight of mother rhizome



5.13. INFLUENCE OF CHITOSAN SPRAYS ON THE WEIGHT OF PRIMARY RHIZOMES IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

The genotypes exhibited a significant difference in the weight of primary rhizome. The highest weight of primary rhizome was recorded in Wayanad local (24.96 g) and Sobha (24.41 g), irrespective of harvesting stages and chitosan spray. Anu (2019) recorded highest primary rhizome weight in accession WCL 24 (26.67 g) and lowest in WCL 5 (10.67 g). Singh *et al*. (2003) observed variability in turmeric rhizomes with respect to weight of primary rhizome and stated that the weight of primary rhizome can be used to select the best genotype.

Weight of primary rhizome was recorded at 210, 240 and 270 DAP. Significant difference in weight of primary rhizome was observed at the time of harvest. The highest weight of primary rhizome was at 270 DAP (27.29 g) followed by 240 DAP (23.45 g). The lowest weight of primary rhizome was observed at 210 DAP (21.23 g). Increase in the weight of primary rhizome was observed at the final harvest (Fig.24). Kumar and Gill (2009) also found increase in weight of primary rhizome with delay in harvest. When harvest was delayed, plants had a long growth period and absorb more nutrient resulting in increased weight of rhizome (Fig.24).

Weight of primary rhizome was highest in the rhizomes sprayed with chitosan (25.72 g) (Fig.25). Control and water spray recorded primary rhizome weight of (23.68, and 22.57 g, respectively). Manoj (2017) recorded that, by spraying chitosan in regular intervals on turmeric plants results in an increase in the weight of mother rhizome.

Fig.24. Influence of harvesting stages on weight of primary rhizome

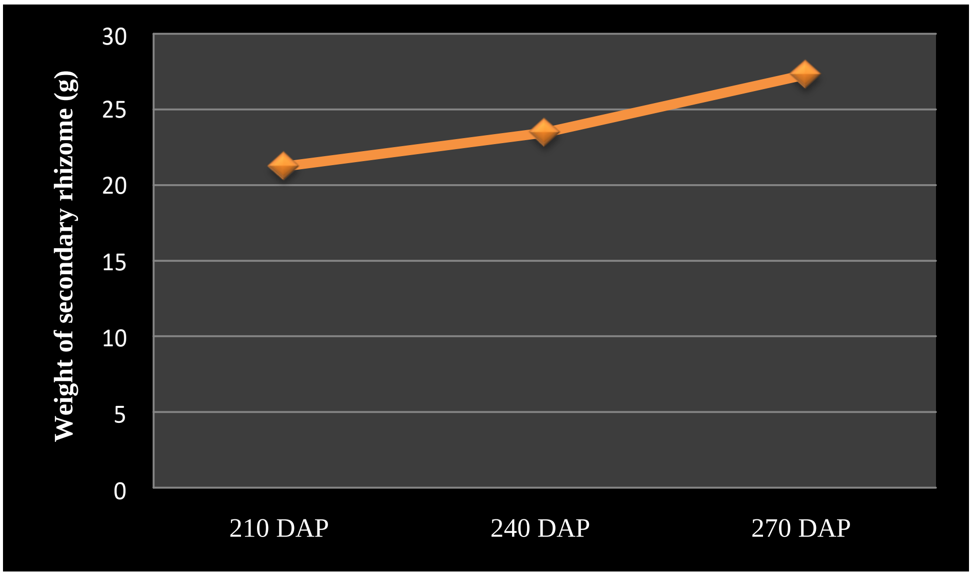
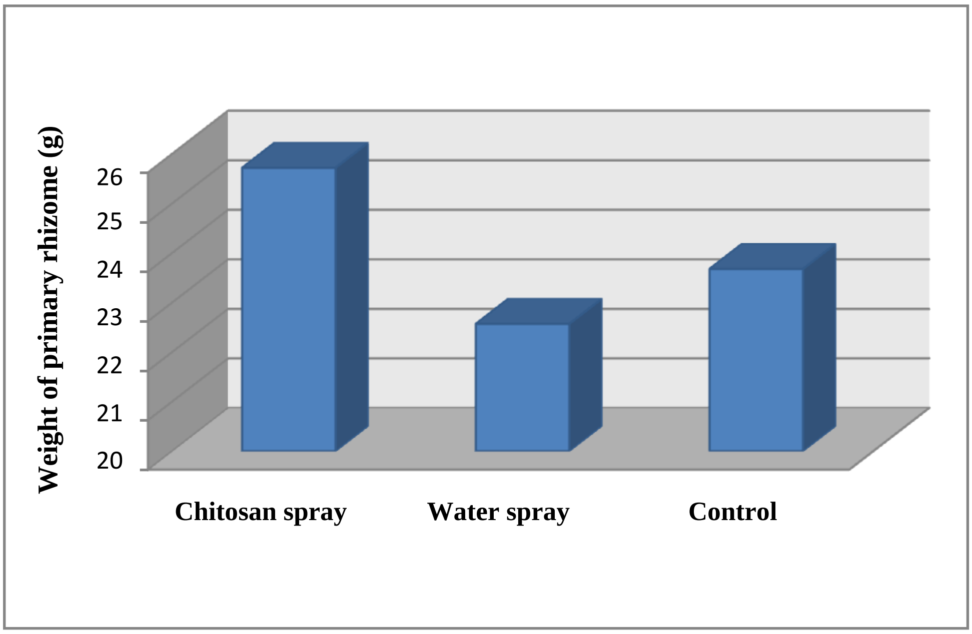


Fig.25. Influence of chitosan sprays on weight of primary rhizome in turmeric



5.14. INFLUENCE OF CHITOSAN SPRAYS ON WEIGHT OF SECONDARY RHIZOMES IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

Weight of secondary rhizome was recorded in Sobha, Prathiba and Wayanad local (Acc WCL 23). The weight of secondary rhizome differs significantly with respect to genotypes (Fig.26). Among the genotypes Prathibha and Sobha had the highest weight of secondary rhizome (4.74, and 4.63 g, respectively). The lowest weight of secondary rhizome was noticed in the genotype Wayand local (4.48 g). Variability in weight of secondary rhizomes was due to varietal difference. Anu (2019) also observed variability in weight of secondary rhizomes between the varieties. Sadanad *et al*., 2019 observed varietal difference in weight of secondary rhizome due to heritability.

Weight of secondary rhizome was observed at 210, 240, 270 DAP. The weight of secondary rhizome differs significantly with each stage of harvest (Fig.27). Highest weight of secondary rhizome was observed at 270 DAP (5.94 g) followed by 240 DAP (4.56 g). Lowest weight of secondary rhizome was noticed at 210 DAP (3.35 g). Similar results were recorded by Kumar and Gill (2009) by recording significant variation in the weight of secondary rhizomes at different harvest dates.

Fig.26. Weight secondary rhizome in turmeric genotypes

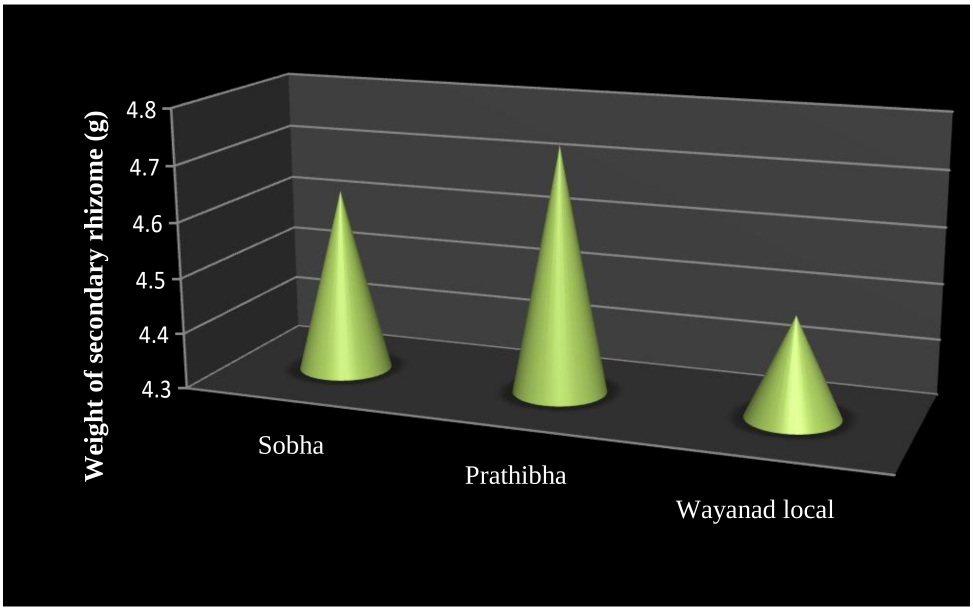
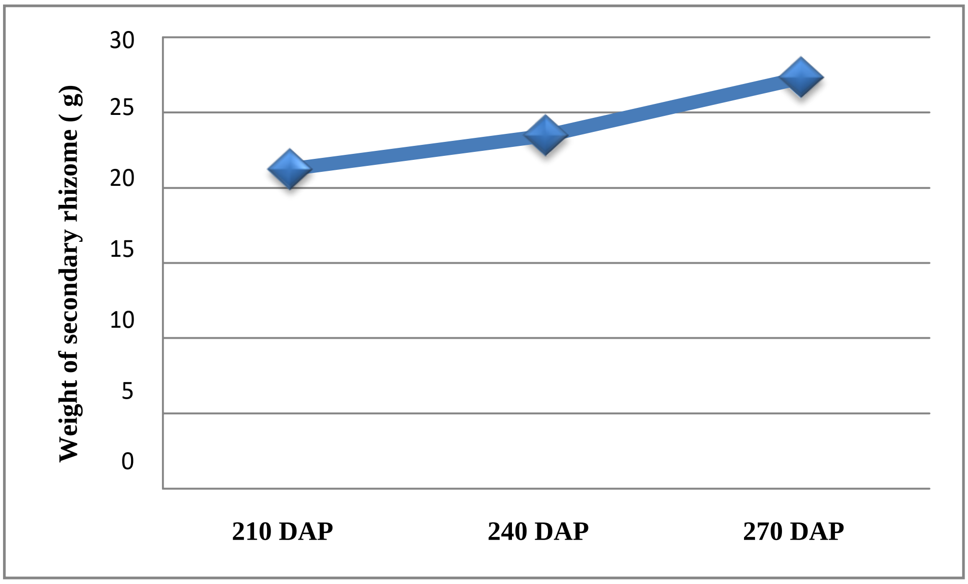


Fig.27. Influence of harvesting stages on weight of secondary rhizome



5.15. INFLUENCE OF CHITOSAN SPRAYS ON FRESH WEIGHT OF RHIZOME PER PLANT IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

There was a significant difference in fresh weight of rhizome obtained from a single plant irrespective of harvesting stage and chitosan spray. The highest fresh rhizome yield was obtained in Wayanad local (255.86 g plant-^{1}), and Sobha (246.71 g plant^{-1}) followed by Prathibha (236.71g) (Fig.28). Anu (2019) also observed variability in fresh weight of plant in various accessions of turmeric and recorded that fresh weight per plant was highest in accession WLC 23 (350.08 g plant-^{1}) and WCL 24 (350.33 g plant-^{1}). Lowest fresh weight was observed in WCL 16 (116.05 g plant-^{1}). Luiram *et al*., 2018 evaluated 32 genotypes and observed that fresh weight of the rhizomes ranged from 150.7 – 374.47 g plant-^{1}. Fresh rhizomes yield per plant determines the economic value (Aarti *et al*., 2018).

There was a significant difference in fresh weight of rhizome per plant at different stages of harvest. Fresh weight of rhizome per plant differed significantly at each stage of harvest. The highest fresh weight of rhizome per plant was observed at 270 DAP (266.52 g plant $^{-1}$) and 240 DAP (247.42 g plant^{-1}) (Fig.29). The interaction effect between genotypes and harvesting stages on fresh rhizome yield was statistically significant. Highest fresh rhizome yield was obtained from turmeric genotype, Wayanad local (Acc WCL 23) harvested at 270 DAP (269.25 g plant^{-1}), Prathibha at 270 DAP (262.13 g plant^{-1}) and Sobha at 240 and 270 DAP (263.25, 268.19 g plant^{-1}, respectively).

The rhizomes obtained from chitosan sprayed plants recorded highest fresh rhizome weight (273.18 g plant-^{1}) (Fig.30). Similar results were recorded by Vijayan (2015). The yield per plant in evaluated genotypes was found to be highest at final harvest of 240 DAP and lowest at 160 DAP. Asghari *et al*. (2009) observed influence of harvesting stages on fresh weight per plant. Crop harvests were done from 2 – 10 months at 2 months interval. Fresh weight per plant was highest at the final harvest.

Results revealed that fresh weight per plant increase with delay in harvesting. Hossain (2010) and Mishra and Singh (2017) also recorded similar results in turmeric.

Irrespective of genotypes and harvesting stages there was a significant increase in the fresh weight of rhizome per plant by chitosan sprays. The chitosan treated plants had a 273.18 g fresh weight per plant, which was found to be the superior. This was followed by water spray (230.62 g $plant^{-1}$) and control (234.78 g $plant^{-1}$) (Fig.30).

Similar results were recorded by Anusuya and Satiyabama (2016) in turmeric. Chitosan spray at 0.1 % had a yield increase up to 60 per cent than the control. Thengumpally (2019) found significant yield improvement in Kasthuri turmeric by foliar spray of chitosan at 3 g L^{-1}. Salachna and Zawadzinska (2014) treated freesia corms with chitosan 0.5 per cent before planting, which resulted in an increase of corm weight by 31.6 per cent.

The interaction between genotypes and harvesting stages on fresh rhizome yield was statistically significant. Highest fresh rhizome yield was obtained from turmeric genotype, Wayanad local (Acc WCL 23) harvested at 270 DAP (269.25 g $plant^{-1}$), Prathibha at 270 DAP (262.13 g $plant^{-1}$) and Sobha at 240 and 270 DAP (263.25, 268.19 g $plant^{-1}$, respectively)

The interaction effect between genotypes and chitosan sprays was non-significant. However, chitosan sprayed plants of genotype Wayanad local (Acc WCL 23) exhibited highest rhizome yield of 281.76 g per plant followed by Sobha (277.26 g $plant^{-1}$).

There was a significant interaction effect of fresh weight of rhizome per plant with respect to chitosan sprays and harvesting stages. Plants given chitosan spray (1 g L^{-1}) and harvested at 270 DAP (287.04 g $plant^{-1}$) and 240 DAP (279.85 g $plant^{-1}$) recorded the highest fresh weight rhizome. Plants maintained as control (270.58 g $plant^{-1}$) and harvested at 270 DAP was on par with highest.

Other factors like growing condition can also be the reason for the yield difference Srikrishnah and Sutharsan, (2015) observed the performance of turmeric under different shade levels. The treatments consisted of, open field condition and shade levels of 50%, 70% and 80%. Among the shade levels and open condition, the yield performance of turmeric was highest in 50% shade level and also observed reduced yield in plants under open condition. The plants under open condition may receive higher radiation level leading to destruction of photosynthetic pigments resultin in reduced yield. When plants are in heavy shade of 70% and 80%, solar radiation received by the plants may not be sufficient for optimum photosynthesis.

Fig.28. Fresh weight of turmeric genotypes

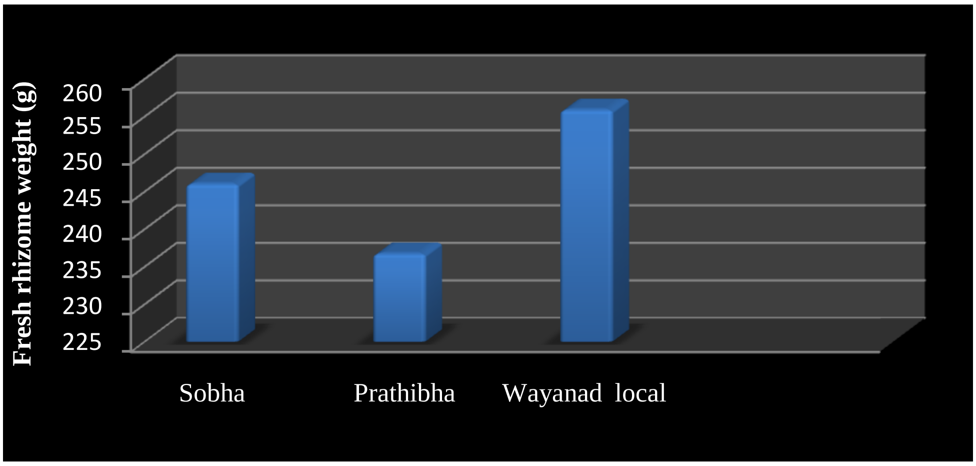


Fig.29 Influence of harvesting stages on fresh weight of turmeric genotypes

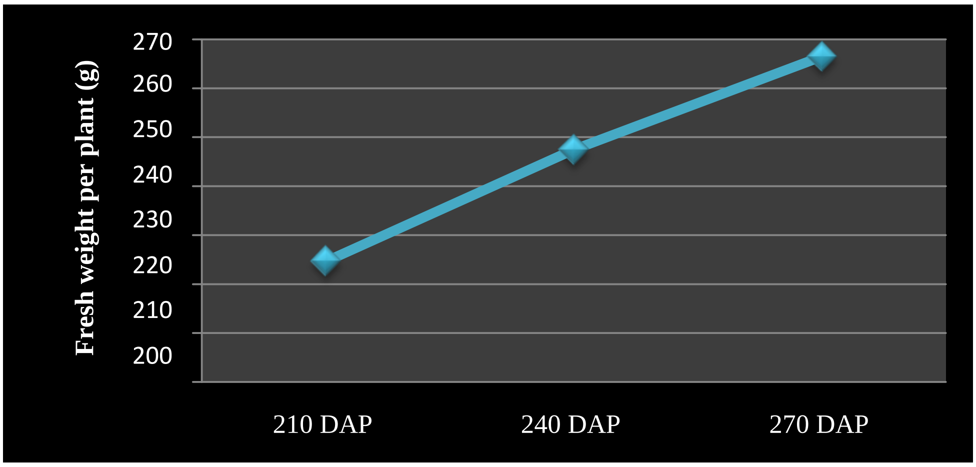
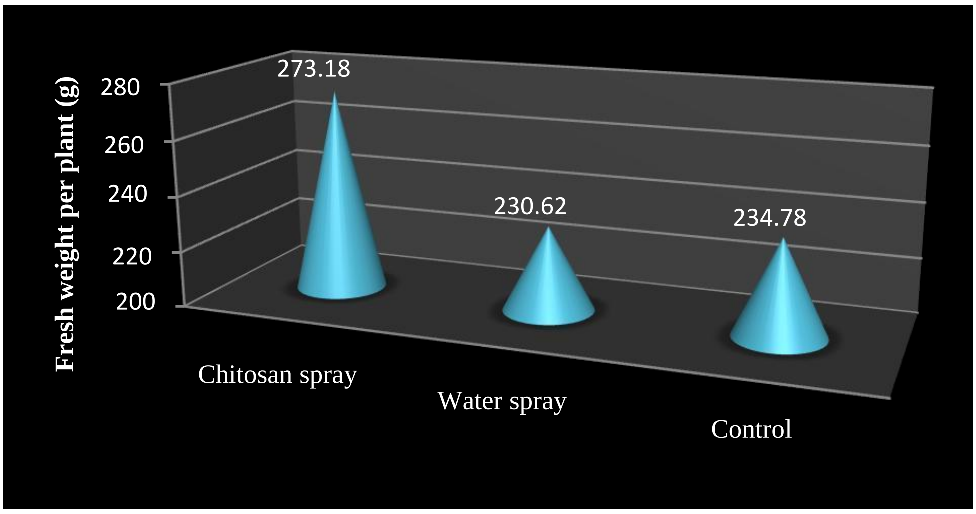


Fig.30. Influence of chitosan sprays on fresh rhizome weight of turmeric



5.16. INFLUENCE OF CHITOSAN SPRAYS ON DRY WEIGHT OF RHIZOMES IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

There was a significant difference in dry weight of rhizome per plant of turmeric genotypes. The dry weight of rhizome per plant differed significantly with turmeric genotypes. The highest dry weight of rhizome per plant was observed in Wayanad local (Acc WCL 23) (46.98 g plant-^{1}), followed by Sobha and Prathibha (41.84, and 46.98 g plant-^{1}, respectively). The dry weight per plant was having a significant difference between the genotypes (Fig.31)

Dry yield per plant varied significantly among the accessions (Anu 2019). Dry weight per plant was highest for the Wayanad - 23 (61.74 g plant^{-1}) and lowest was in Wayanad local - 16 (20.46 g plant^{-1}). Vijayan (2015) also observed significant difference in dry rhizome yield per plants with varieties. Highest dry weight per plant was observed in genotype Kedaram (119.06 g) and lowest was in Suguna (38.50 g). Krishna *et al*., 2019 aslo observed variability in dry rhizome per plant between the genotypes (41.38 to 123.14 g plant^{-1}).

The harvesting stages had a significant influence in dry weight of rhizome per plant (Fig.32). The highest dry weight of rhizome per plant was observed at 270 and 240 DAP (45.48 and 48.13 g plant^{-1}, respectively). The lowest dry weight per plant was noticed at 210 DAP (37.89 g). The dry weight of plant was increased with the duration of the crop.

Dry yield per plant was recorded by evaluating 12 genotypes of turmeric at 160, 200 and 240 DAP (Vijayan, 2015). Dry rhizome yield per plant was found to be highest at the last stage of harvest *i.e*., 240 DAP.

Narendrabhai (2012) studied the variability in yield by using thirty genotypes of turmeric. The variation in dry yield per plant ranged from 20.02 to 63.98. The highest dry yield per plant was observed in the genotype NVST 6 (63.98 g) and lowest for the genotype Dahod (20.02 g).

There was a significant increase in dry weight of rhizome per plant due to chitosan sprays. The highest dry weight of rhizome was observed in chitosan sprayed plants (49.48 g plant^{-1}) followed by control and water spray (41.29 and 40.73 g plant^{-1}, respectively) (Fig.33).Satiyabama *et al*. (2016) found foliar spray of chitosan at 1 g to increase dry yield of rhizome in turmeric. Thengumpally (2019) found that foliar spray of chitosan at a concentration of 3 g L^{-1} had the highest dry rhizome yield in kasthuri turmeric.

Fig.31. Dry weight of rhizome in turmeric genotypes

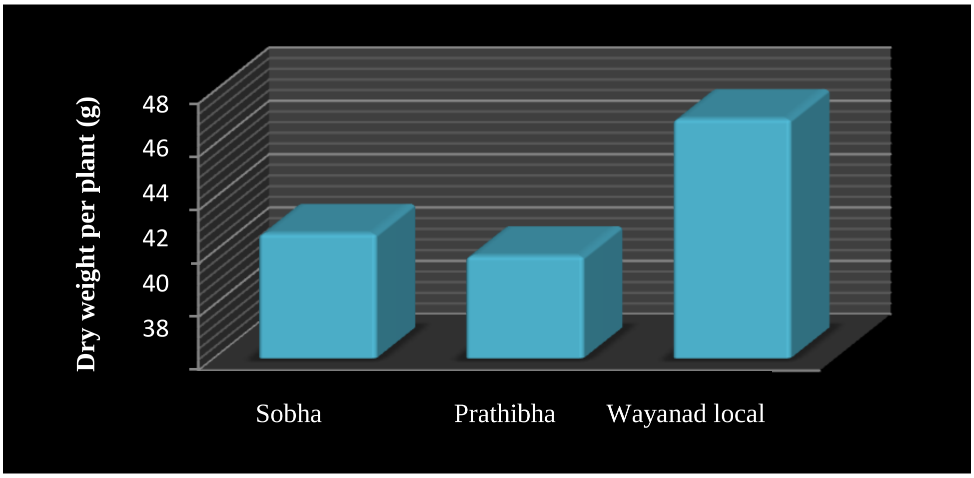


Fig.32. Influence of harvesting stages on dry weight of turmeric rhizome

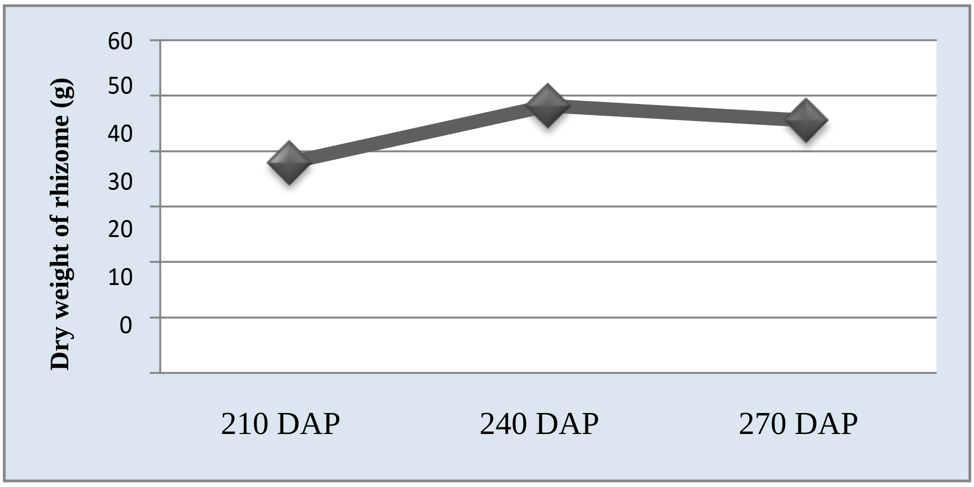
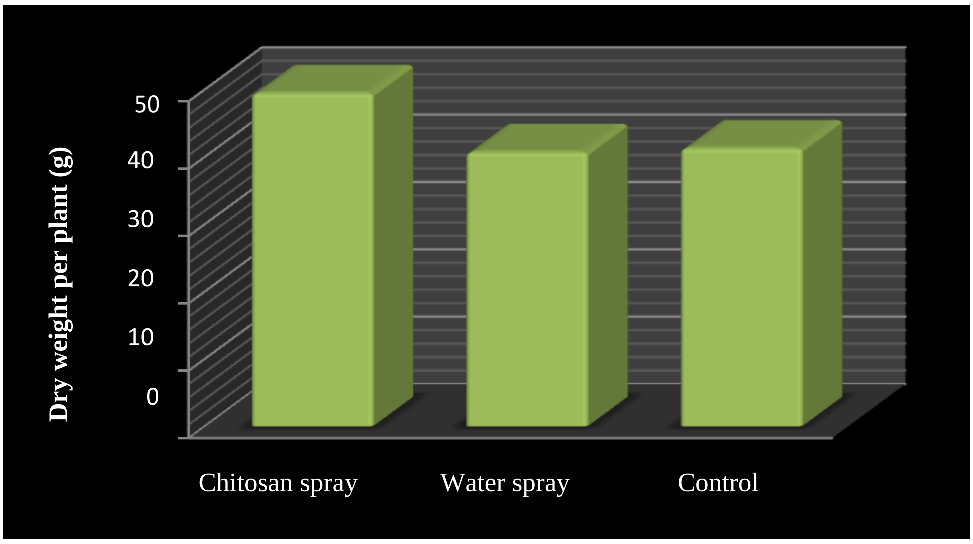


Fig.33. Influence of chitosan spray on dry weight of turmeric rhizome.



5.17. INFLUENCE OF CHITOSAN SPRAYS ON FRESH YIELD PER PLOT IN TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

There was a significant difference on fresh rhizome yield per plot with respect to turmeric genotypes. Significantly higher fresh rhizome yield per plot was obtained from genotype Wayanad local (Acc WCL 23) (9.68 kg plot $^{-1}$) followed by Prathibha and Wayanad local (Acc WCL 23) (7.98, and 7.86 kg plot^{-1}, respectively). The variation in yield of turmeric was due to the varietal difference (Fig.34).

Vijayan (2015) evaluated 12 genotypes and significant difference was observed in fresh rhizome yield per plot (3m^2) with respect to the genotypes. The highest yield per plot was recorded by genotype Sudarsana (18.45 kg plot $^{-1}$) and lowest in Suvarna (6.38 kg plot $^{-1}$). Anu (2019) also recorded variation in the fresh yield per plot between the genotypes. Highest fresh yield per plot was observed in WCL 25 (9.69 kg plot^{-1}) and lowest fresh yield per plot in the genotype WCL 8 (2.17 kg plot^{-1}) obtained from plot of (3m^2). Dodamani (2015) observed a difference in fresh yield per plot with respect to varieties. Kandiannan (2015) evaluated eleven turmeric genotypes and found fresh rhizome yield varying from 7.5 kg to 17.0 kg. The highest yield per plot was obtained from Rajendra Sonia (17 kg plot^{-1}) the lowest yield per plot was obtained from genotype Rasmi (7.5 kg plot^{-1}).

Sinkar *et al.,* (2005) evaluated the performance of 21 turmeric genotypes and found significant varietal difference regarding yield. The yield was found to be lowest in CA-64 (3.14 kg plot^{-1}) and highest in Salem (11.99 kg plot^{-1}). The yield variation might be due to the phenotypic and genotypic coefficient of variation, genetic advance and heritability.

Significant increase in fresh rhizome yield per plot of turmeric was observed at the time of harvest. Increase in the yield of turmeric with the delay in harvest was observed. The highest fresh rhizome yield per plot was observed at 270 and 240 DAP (8.98 and 8.82 kg plot $^{-1}$, respectively). Lowest weight of fresh yield per plot was observed at 210 DAP (7.72 kg plot $^{-1}$) (Fig.35).

Yield improvement was observed with delay in harvest. Similar findings were recorded by Vijayan (2015). The highest fresh rhizome yield per plot was at last harvest carried out 240 DAP (12.09 kg plot $^{-1}$), and lowest was at first harvest done at 160 DAP (4.14 kg plot $^{-1}$). Cooray *et al*. (1988) found harvesting after 9 months of planting as the best for turmeric. Kumar and Gill (2009) found increase in weight of fresh rhizome with delay in harvest of the crop. This might be due to the absorption of more nutrients resulting in increased weight.

There was a significant influence in the yield of turmeric by chitosan spray at0.1 %. Foliar sprays of chitosan at regular intervals of 30 days on turmeric resulted in higher yield. The highest fresh rhizome yield per plot was obtained from chitosan sprayed plants (9.43 kg plot $^{-1}$) followed by control (8.18 kg plot $^{-1}$) and water spray (7.91 kg plot $^{-1}$) (Fig.36).

Chitosan spray at 0.1 % at monthly intervals significantly increased the fresh yield of turmeric rhizome by 60 per cent (Satiyabama *et al.* 2016). Thengumpally (2019) found highest yield of kasthuri turmeric sprayed with chitosan. Salachna and Zawadzinska (2014) found that freesia corms treated with chitosan at 0.5 per cent before planting increased corm weight by 31.60 per cent.

Chitosan enhanced yield in wheat (Zeng and Luo, 2012), in okra (Mondal *et al.* 2012), in cucumber, (Shehata *et al.* 2012), in tomato, (Sathiyabama *et al*., 2015) and in strawberry (El-Miniawy *et al.* 2013).

Fig. 34. Fresh yield per plot in turmeric genotypes

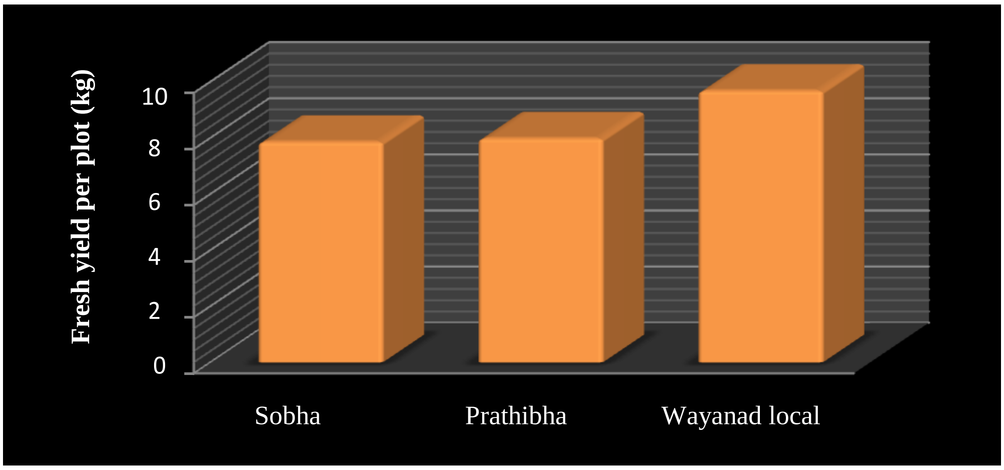


Fig. 35. Influence of harvesting stages on fresh rhizome yield per plot

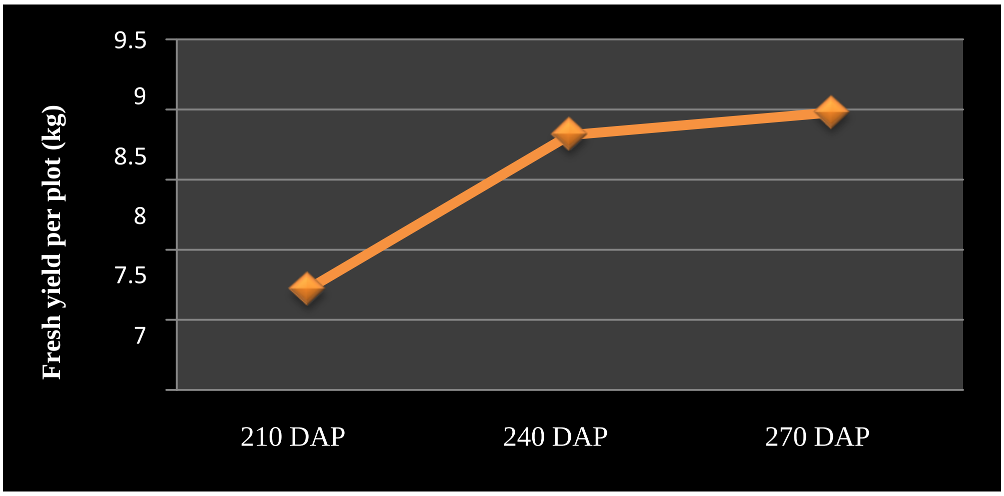
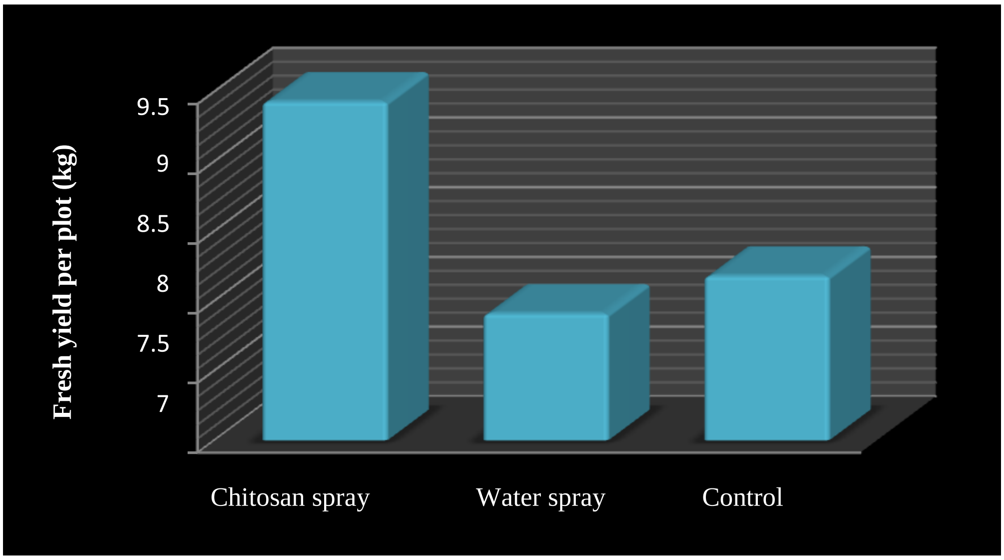


Fig. 36. Influence of chitosan spay on fresh rhizome yield per plot



5.18. INFLUENCE OF CHITOSAN SPRAYS ON DRY RHIZOME YIELD PER PLOT OF TURMERIC GENOTYPES AT VARIOUS HARVESTING STAGES

The dry rhizome yield per plot differed significantly with respect to varieties. The highest dry yield per plot was observed in genotype Wayanad local (Acc WCL23) (1.77 kg plot $^{-1}$) followed by Prathibha and Wayanad local (Acc WCL 23) (1.38,1.37 kg plot $^{-1}$, respectively) (Fig.37).

Anu (2019) also recorded significant difference in dry yield per plot in various turmeric accessions. Dry weight per plot was highest for the genotype Wayanad local - 25 (1.67 kg plot^{-1}) and lowest for Wayanad local 23 (1.6 kg plot^{-1}). Dry rhizome yield per plant significantly differed with genotypes and was highest yield was in the genotype Kedaram (3.28 kg plot -^{1}) and lowest in Suguna (0.98 kg plot$^{-1)}$ (Vijayan, 2015).

The highest dry rhizome yield per plot was observed at 270 and 240 DAP (1.66, and 1.57 kg plot $^{-1}$, respectively) and lowest was at 210 DAP (1.30 kg plot $^{-1}$). The dry weight per plot improved with the delay in harvest (Fig.38).

Similar results were observed by Vijayan (2015) by evaluating 12 genotypes of turmeric at different dates of harvest. Dry weight per plot increased in all genotypes. Highest dry weight per plot was obtained at final harvest of 240 DAP (1.72 kg plot^{-1}). The lowest was in 160 DAP (0.47 kg plot $^{-1}$). Hossaian (2010) noticed an increase in dry weight by delaying harvest till turmeric shoots dried completely.

Chitosan spray at 0.1 % had a significant influence on increasing the dry yield of turmeric. Foliar sprays of chitosan at regular intervals of 30 days in turmeric resulted in higher dry yield (Fig.39). The highest dry rhizome yield per plot was observed in chitosan sprayed plants (1.71 kg plot $^{-1}$) followed by control (1.44 kg plot^{-1}) and water spray (1.37 kg plot^{-1}) (Fig.39). Thengumpally (2019) found that chitosan sprays at 2.5 g L^{-1} at 3 to 5 months after planting in Kasthuri turmeric resulted in an increase in dry weight.

Fig. 37. Dry rhizome yield per plot in turmeric genotypes

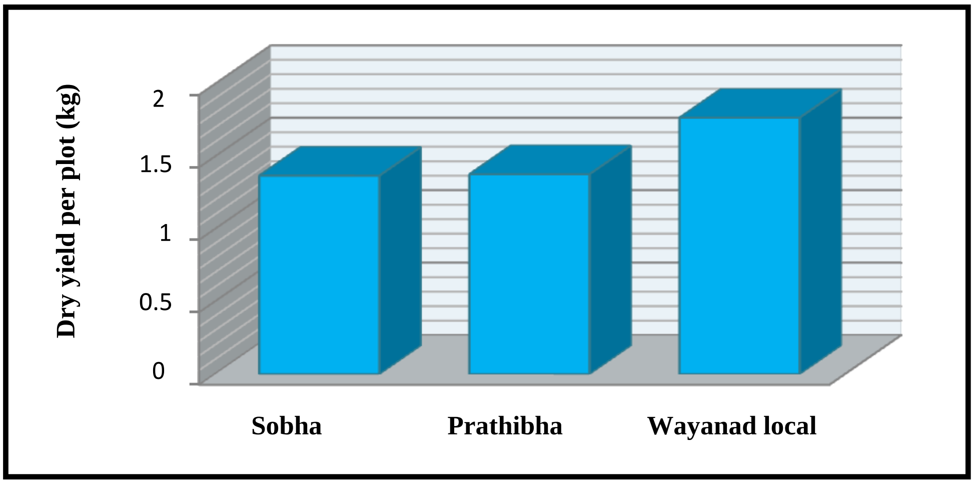


Fig. 38. Influence of harvesting stages on dry yield per plot

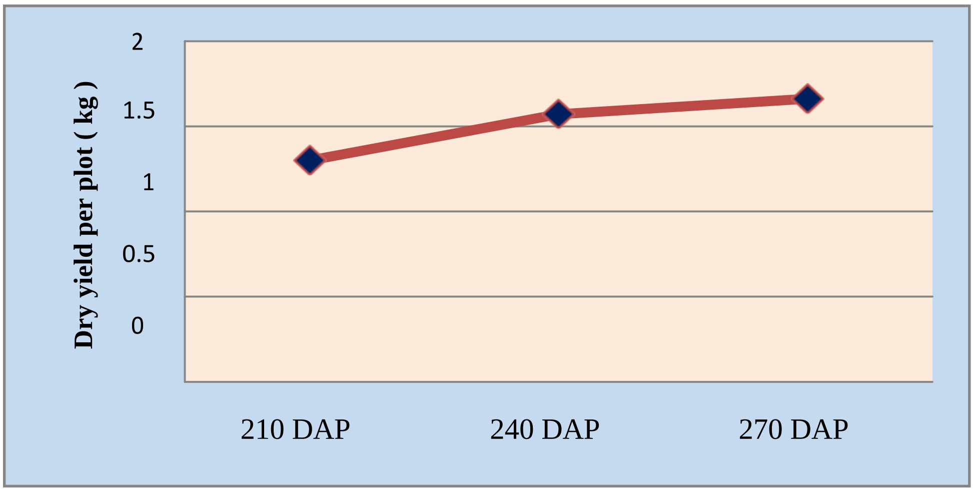
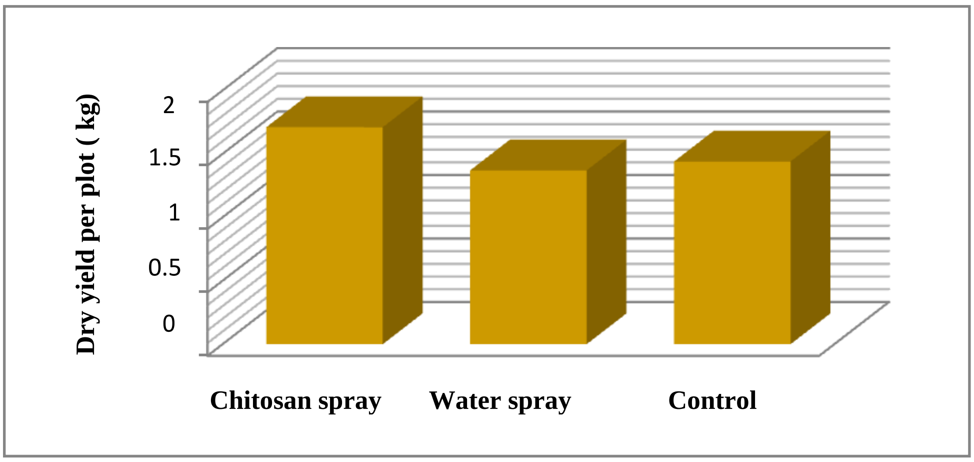


Fig. 39. Influence of chitosan spray on dry yield per plot



INFLUENCE OF CHITOSAN SPRAYS AND HARESTING STAGES ON CURING PER CENT OF TURMERIC GENOTYPES.

Among the genotypes Wayand local recorded highest curing percet of 17.23%, followed by Sobha (15.73 %) and lowest in Prathibha (15.30 %) (Fig.40). Similar results were recorded by Patil *et al.* (1995). The variations in curing per cent between the varieties may be due to genetic factors.

Harvest at 240 DAP was found to be significantly highest curing percent (16.56 %) followed by 270 DAP (16.03 %), and lowest curing per cent was at 210 days (Fig.41). Hossain (2010) noticed improvement of curing per cent by delaying the harvest.

Foliar application of chitosan had a significant influence in improving curing per cent in turmeric (16.29 %) compared to other plants subjected to water spray (16.12%) and plants maintained as control without any spray (15.83) (Fig.42). Satiyabama *et al*. (2016) found foliar spray of chitosan at 1 g L^{-1} positively influence dry weight of rhizome in turmeric.

Interaction effect of genotypes, harvesting stages and chitosan spray on curing of turmeric

When the interaction effect of genotype, harvesting stages and chitosan spray on curing per cent of turmeric was analysed, significantly superior curing per cent was observed in Wayanad local (Acc WCL 23) sprayed with chitosan and harvested at 240 DAP. This treatment combination was significantly superior than all other treatments. The lowest curing percentage was observed in Prathibha harvested without any spray (14.48) (Fig.43).

Fig.40. Curing per cent in turmeric genotypes

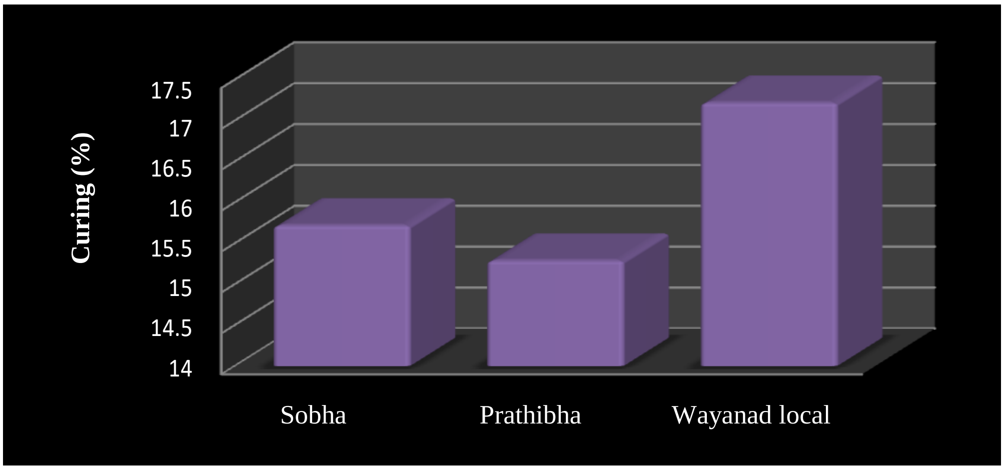


Fig. 41.Influence of harvesting stages on curing per cent of turmeric rhizome

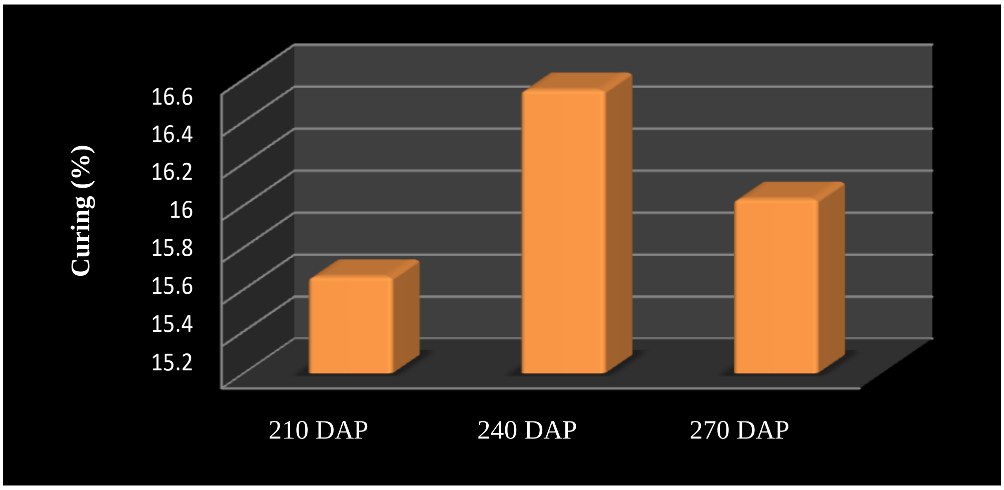


Fig. 42.Influence of chitosan spray on curing per cent of turmeric rhizome

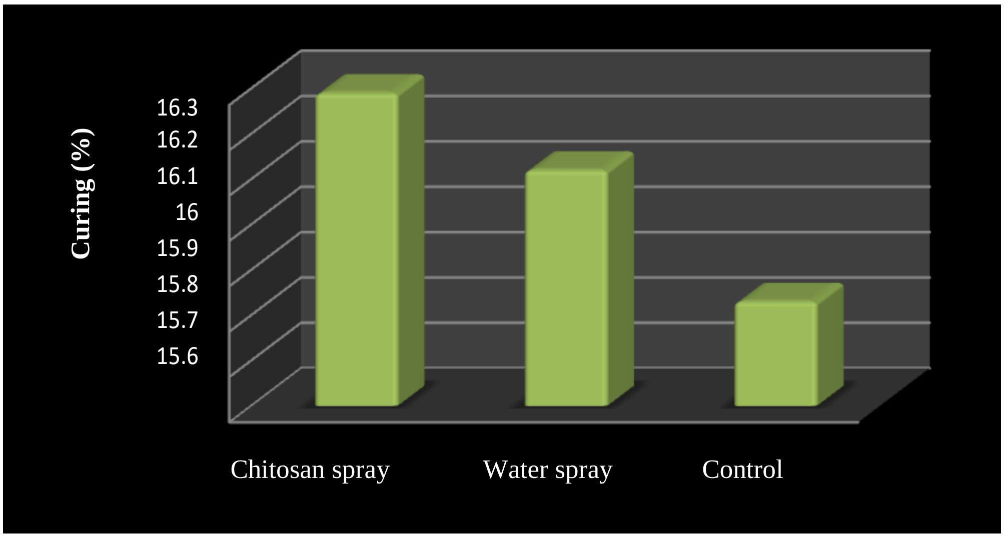
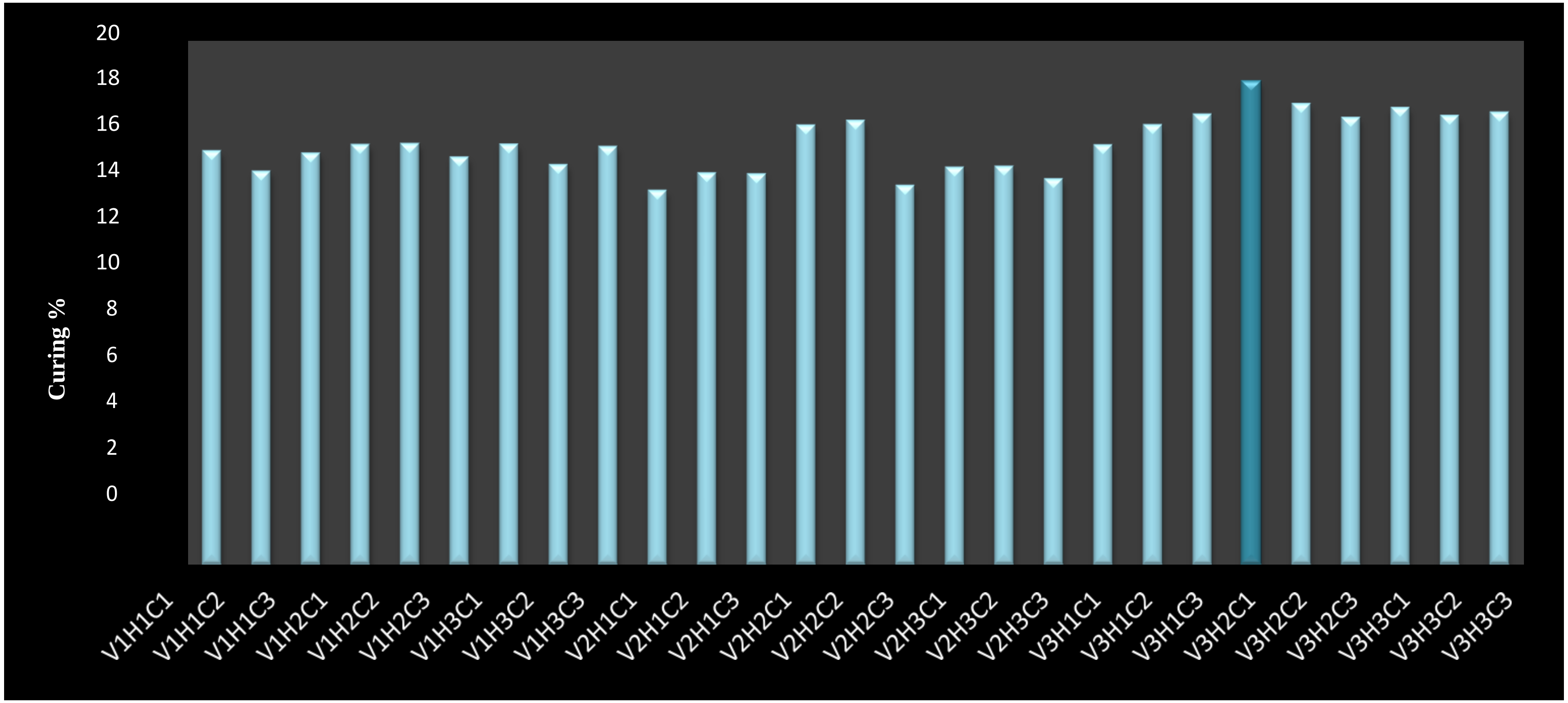


Fig. 43 Interaction effect of genotypes, harvesting stages and chitosan spray on curing of turmeric.



V1- Sobha
V2- Prathibha
V3 –Wayanad local (Acc WCL 23)

C1- Chitosan Spray 1g L^{-1}
C2- Water spray
C3- Control

H1- Harvest at 210 DAP
H2- Harvest at 240 DAP
H3 – Harvest at 270 DAP

A COMPRIHENCEIVE COMPARISON OF INTERACTION EFFECT OF HARVESTING STAGES AND CHITOSAN SPRAYS ON FRESH YIELD PER HECTARE OF TURMERIC GENOTYPES

When the fresh yield per ha was compared at various harvesting stages, it was found that Yield from genotype Wayanad local at 210 DAP was 30.45 t ha^{-1} and the yield at 270 DAP was 33.15 t ha^{-1} (Fig. 44). Yield increased by 8.86% over a period of 60 days. Yield improvement in Sobha from 210 DAP to 270 DAP was 29.33%, and in Prathibha it was 13.67 %. Hence, the yield improvement in Wayanad local (Acc WCL 23) (8.86%) over a period of 60 days was comparatively low, indicating its early maturing habit.

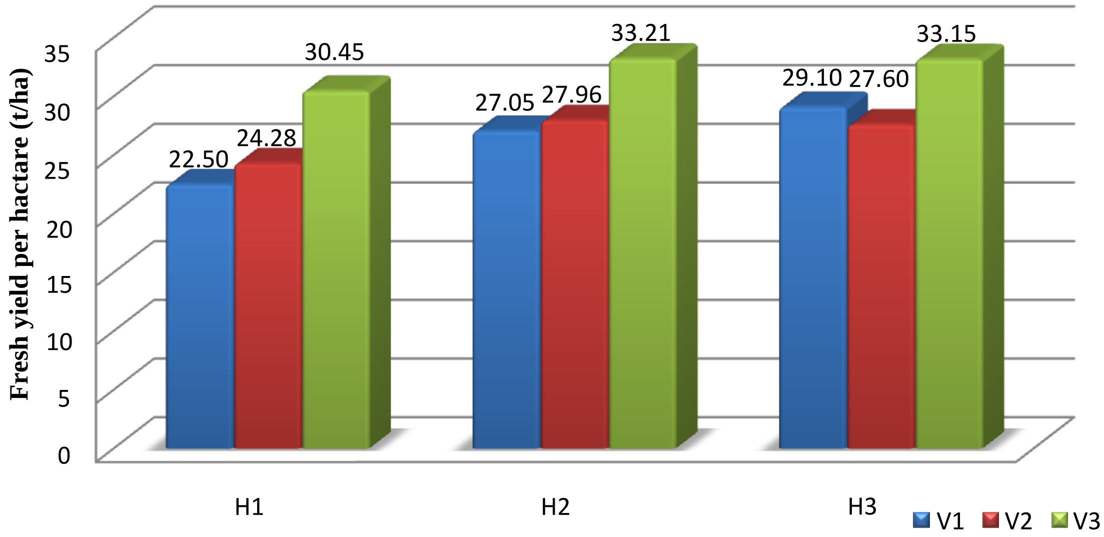
Interaction effect of genotypes and chtiosan on fresh yield per hectare

In all genotypes, chitosan sprayed plants recorded higher yield than absolute control. It is evident from Fig.45 that the per cent increase in yield upon chitosan spray of Sobha was (18.34 %,) Prathibha (11.98%) and wayanad local (15.82%) (Fig.45).

Interaction effect of harvesting stages and chitosan sprays on fresh turmeric yield per hectare.

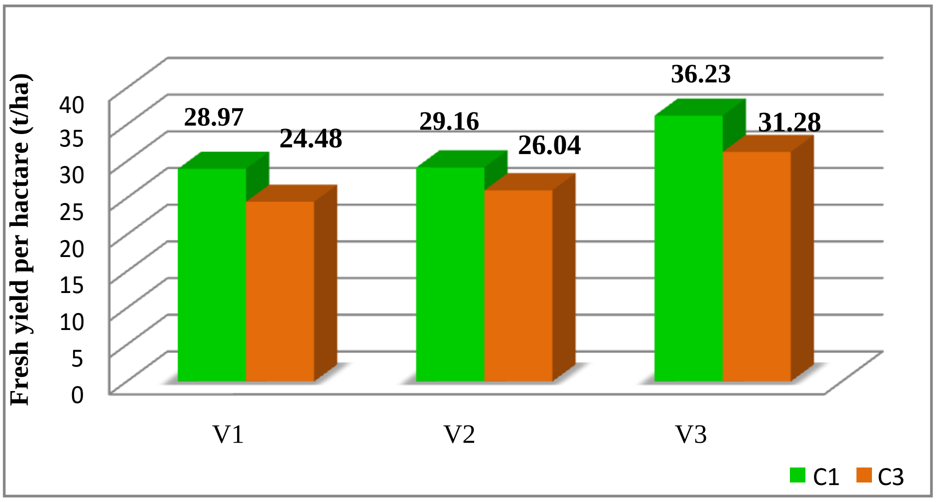
When the influence of chitosan spray on yield of turmeric at different harvesting stages was analysed, it was clear that increase in yield due to chitosan spray was more pronounced when harvested at 270 DAP, recording 26.53% increase in fresh yield (Fig.46).

Fig.44. Interaction effect of harvesting stages and genotypes on fresh yield per hectare.



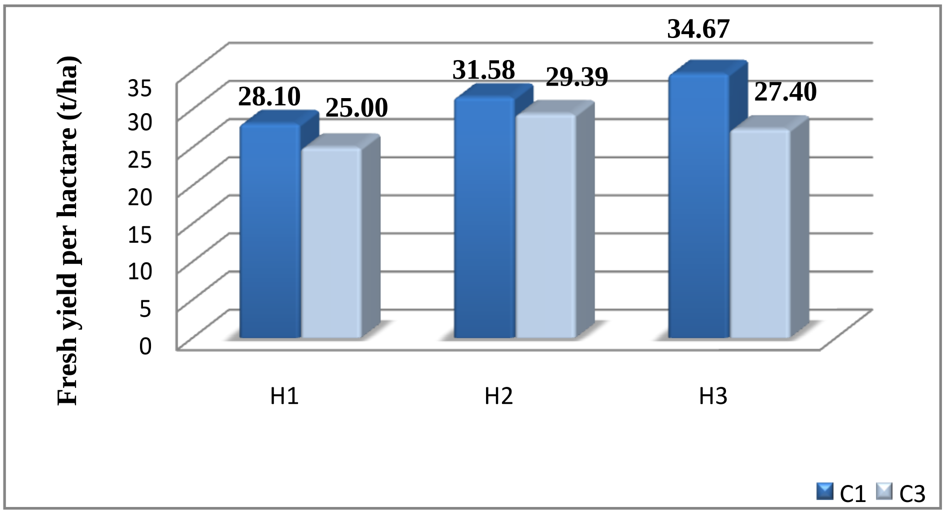
V1- Sobha	H1- Harvest at at 210 DAP
V2- Prathibha	H2- Harvest at 240 DAP
V3- Wayanad local	H3- Harvest at 270 DAP

Fig.45. Interaction effect of genotypes and chtiosan on fresh yield per hectare.



V1- Sobha	C1- Chitosan Spray
V2- Prathibha	C3- Control
V3- Wayanad local	

Fig 46. Interaction effect of harvesting stages and chitosan sprays on fresh turmeric yield per hectare



H1- Harvest at at 210 DAP	C1- Chitosan Spray
H2- Harvest at 240 DAP	C3- Control
H3- Harvest at 270 DAP	

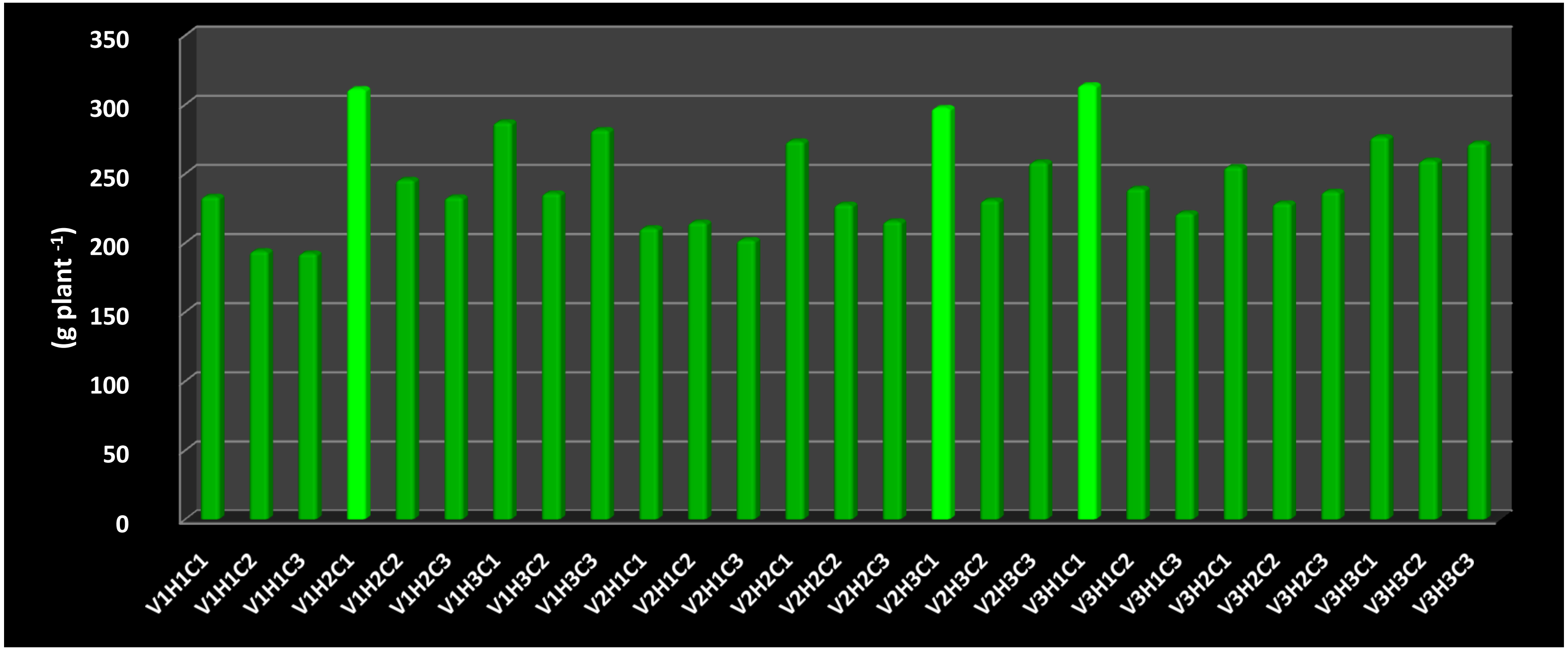
5.21. INTERACTION EFFECT OF GENOTYPES, HARVESTING STAGES AND CHITOSAN SPRAY ON FRESH YIELD PER PLANT IN TURMERIC

When fresh yield per plant was analysed considering all the treatment combinations, interaction effect between genotypes, chitosan sprays and harvesting stages had a significant difference in fresh yield of rhizome in turmeric. The highest rhizome yield per plant was obtained from chitosan sprayed plants of genotype Wayanad local harvested at 210 DAP (V3H1C1) (314.01 g plant^{-1}) and Sobha harvested at 240 DAP (V1H2C1) (311.25 g plant^{-1}). The chitosan sprayed plants of genotype Prathibha harvested at 270 DAP was onpar with the highest (V2H3C1) (297.55 g plant^{-1}) (Fig.47).

In all the above treatments chitosan sprayed plants are showing best performance in terms of fresh yield per plant. Anasuya and sathyabama (2016) opined that the yield improvement is due to the growth parameters such as Plant height and number of leaves plant $^{-1}$. The foliar application of chitosan has found to have higher source and sink relation as evident from morphometric characters like Plant height, Number of tillers, Girth of main tiller which found improved upon chitosan spray and has reflected in yield. In the present study chitosan sprayed plants exhibited the highest photosynthetic rate. Mathews (2018) noticed the ginger plants with highest photosynthetic rate found to have highest yield. Chitosan sprays increased the plant immunity and chitosan is having various defence mechanisms against the disease (Satiyabama *et al*., 2014). In the present study the disease severity of leaf spot was siginificantly reduced by chtosan sprays due to the reduced disease the yield was increase.

The chitosan showed stimulating effect of growth parameters, physiological parameters, and also showed the various defence mechanisam during the growth and development of plant this charcters were correlated with the higher fresh rhizome yield in turmeric resuted improved width of primary rhizome (2.59 cm), number of primary rhizomes (7.32), number of secondary rhizomes (18.89), number of mother rhizomes (1.58), weight of primary rhizomes (25.72g), fresh weight per plant (273.18), dry rhizome weight per plant (49.48) was noticed.

Fig. 47. Interaction effect of genotypes, harvesting stages and chitosan spray on fresh yield per plant in turmeric



V1- Sobha
V2- Prathibha
V3 –Wayanad local (Acc WCL 23)

C1- Chitosan Spray 1g L^{-1}
C2- Water spray
C3- Control

H1- Harvest at 210 DAP
H2- Harvest at 240 DAP
H3 – Harvest at 270 DAP

5.22. A COMPREHENSIVE COMPARISON OF INTERACTION EFFECT OF HARVESTING STAGES AND CHITOSAN SPARAY ON CURCUMIN CONTENT OF TURMERIC GENOTYPES.

The highest curcumin content was recorded in genotype Prathibha (4.36 %) followed by Wayanad local (Acc WCL 23) (4.21%). The lowest curcumin was in Sobha (3.98 %) when analysed irrespective of harvesting stages and chitosan spray (Fig.48) Similar results of variability in curcumin content with respect to turmeric accessions was noticed by Anu (2019) by evaluating the different accessions WCL-5 (10.18 %) was recorded highest curcumin content, lowest was in WCL 9 (3.70 %). Similar variations in curcumin content were observed by Vijayan (2015) in turmeric. The variations may due to the effect of genotype and environment (Krishna *et al*., 2019).

Harvesting of turmeric at 270 DAP (4.33%) and 240 (4.34%) was significantly superior in improving the curcumin content.Harvesting at 210 days, resulting in an average curcumin of 3.87% and was found to be the lowest when compared to the curcumin content obtained from 240 and 270 DAP(Fig.49).

Similar results of variability in curcumin content by stage of harvest were recorded by Kumar and Gill (2009) improvement in curcumin content was noticed with delayed harvest. The turmeric harvested at 307 days after planting as last stage of harvest recorded highest curcumin content (2.98%). The curcumin content was lowest in first harvest at 187 DAP (1.81%). Vijayan (2015) recorded highest curcumin content at 240 DAP (6.05 %) and the lower curcumin content was at 160 DAP (5.18%) observed the variations in curcumin content with different stages of harvest. The curcumin content affected by rhizome maturity (Cooray *et al*., 1988).

Foliar application of chitosan had a significant influence in improving curcumin content in turmeric. Chitosan at a concentration of 1 g L^{-1} significantly improved the curcumin content (4.81%) followed by plants subjected to water spray (3.90%) and plants maintained as control without any spray (3.84%) (Fig 50).Similar improvement of curcumin content by foliar sprayings of chitosan was recorded by Anasuya and sathyabama (2016) foliar sprayings of Chitosan recorded 4-fold increase in curcumin content when compared to the plants maintained as control. Similar improvement of curcumin content was found by Manoj (2017) in turmeric by chitosan sprays. Garcia and Plaza (2013) observed a positive charge of chitosan on some specific biological and physiological activities Chitosan acts as tool to improve the phenolic contents. Chitosan treatmented grapes tend to increase the poly phenol level. Gorelick *et al*., 2015 recorded Withaferin A content in chitosan treated plants by 69% than the plants maintained as control. Chitosan foliar spray at 100 mg l^{-1} is effective in improving the artimisin compound in *Artemisia annua* L(Lei *et al*., 2011). Menthol in *Mentha piperita* was increased by chitosan (Chang *et al.,* 1998). Chitosan treatment effect on physiochemical properties and its biological properties were investigated by Kim *et al*. (2005) on sweet basil.

Fig.48 .Curcumin content in turmeric genotypes

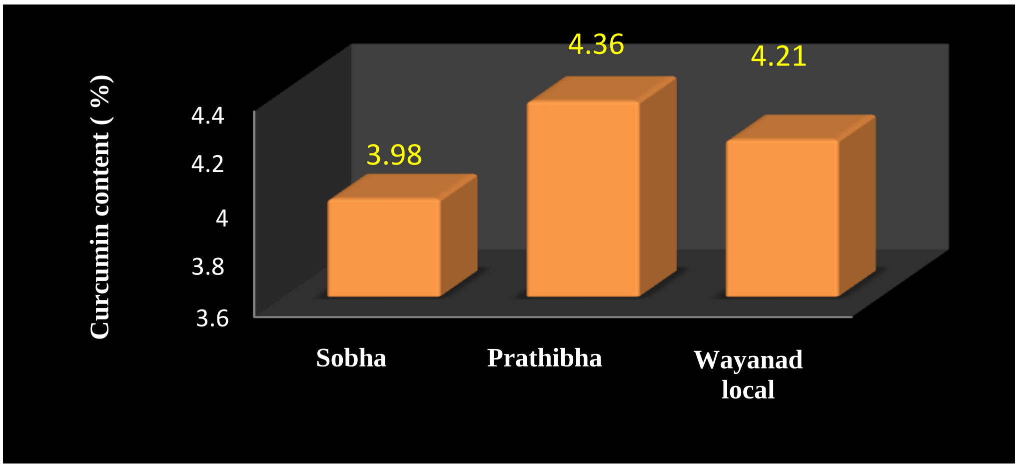


Fig.49. Influence of harvesting stages on curcumin content

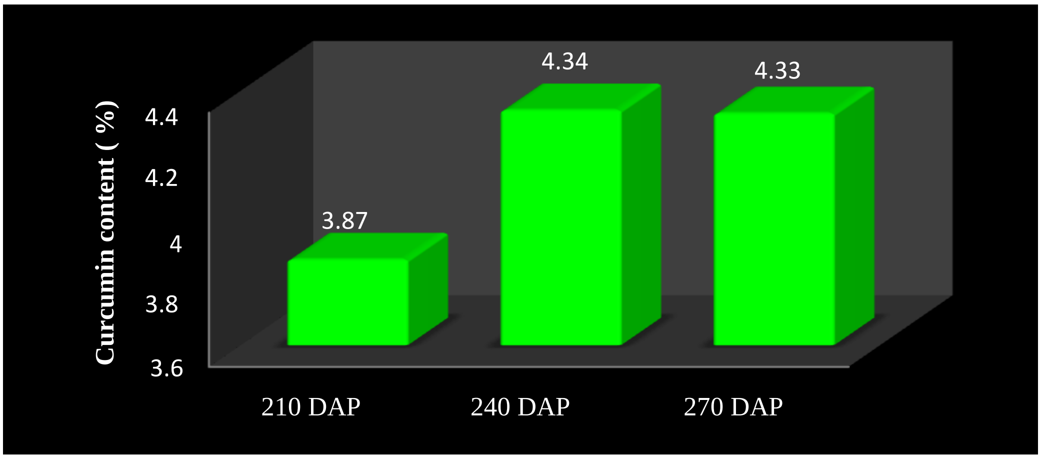
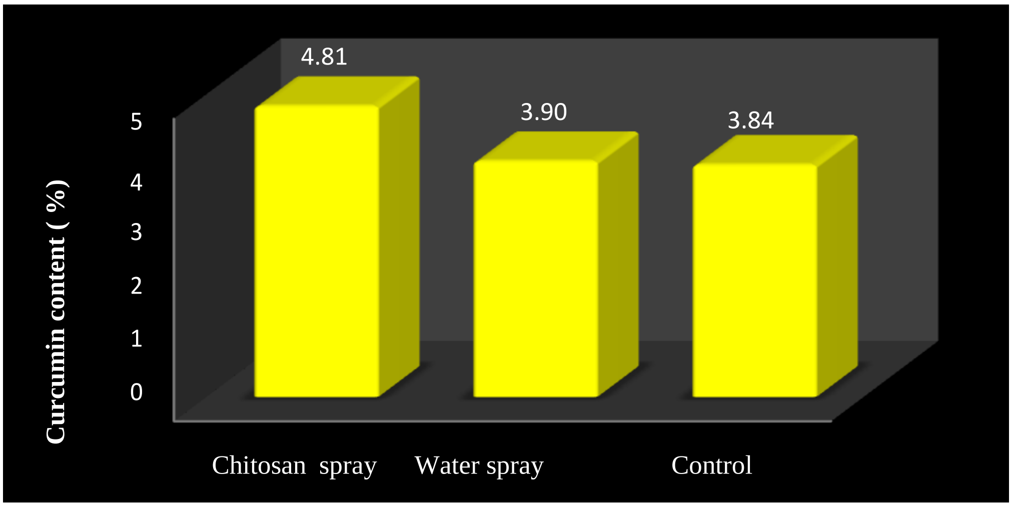


Fig.50.Influence of harvesting stages on curcumin content



5.23. INTERACTION EFFECT OF GENOTYPES, HARVESTING STAGES AND CHITOSAN SPRAY ON CURCUMIN CONTENT (%)

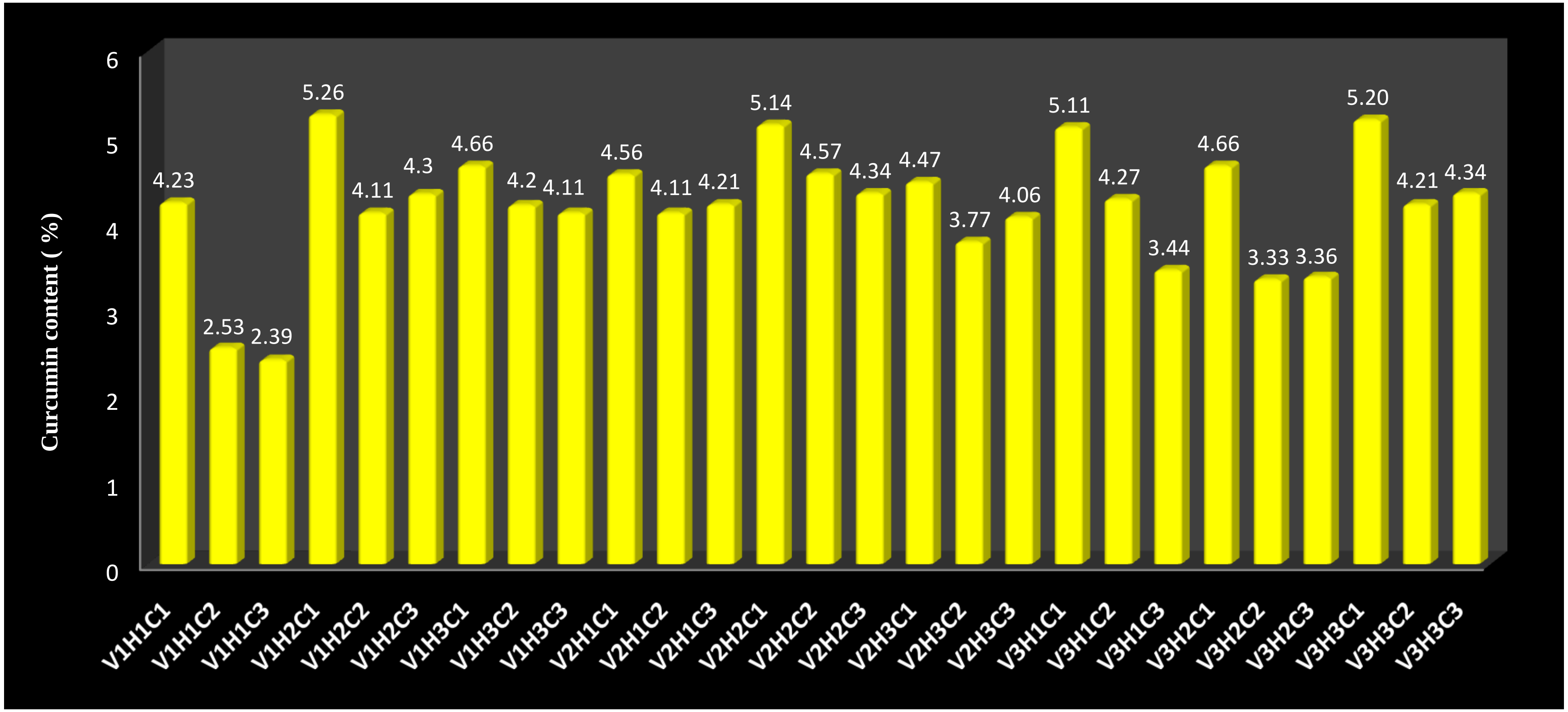
When curcumin content of genotypes was analysed in detail considering all the treatment combinations, interaction effect between genotypes, harvesting stages and chitosan sprays was found to be significant (Fig.51). Significantly higher curcumin content was obtained from the treatment combinations involving genotype Sobha sprayed with chitosan 1 g L^{-1} and harvested at 240 DAP (5.26%), variety Wayanad local with chitosan 1 g L^{-1} and harvested at 270 DAP (5.2%) and 210 DAP (5.11 %) and Prathibha sprayed with chitosan 1g$L^{-1}$and harvested at 240 DAP (5.14) (Fig .51).

Similar results of variability in curcumin content by stage of harvest were recorded by Kumar and Gill (2009) improvement in curcumin content was noticed with delayed harvest. The turmeric harvested at 307 days after planting as last stage of harvest recorded highest curcumin content (2.98%). The curcumin content was lowest in first harvest at 187 DAP (1.81%). Vijayan (2015) recorded highest curcumin content at 240 DAP (6.05 %) and the lower curcumin content was at 160 DAP (5.18 %) observed the variations in curcumin content with different stages of harvest.

Other factors lke environment also plays major role on curcumin content. Hossain *et al*. (2009) noticed variation of curcumin content in different shade levels. The plants maintained under shade level of 27-41 % recorded increased curcumin content when compared to the open condition and stated that turmeric under partial shade can perform better when comapared to open condition. Padmapriya *et al*., (2017) conducted an experiment at Tamil Nadu Agricultural University with 40 treatment combinations of fertilizers in genotype CL147. The shade level of 25–30 per cent was maintained and compared with open condition and found curcumin content to be influenced by shade levels. The treatment combinations under the shade level of 25 – 30% performed better than the plants maintained under open condition. Highest curcumin content (5.57%) was recorded in the rhizomes obtained from shade and lowest curcumin content (3.84 %) was recorded in open condition.

Kumar et *al (*2018) experimented to evaluate the influence of shade on curcumin content of turmeric by adopting agroforestry system and observed positiveresponse of curcumin in shade compared to open conditions. Turmeric under *Diospyrus embryophytum* recorded highest curcumin (4.12%). Lowest curcumin content was observed in open condition (3.11%). This suggests that curcumin synthesis, translocation and assimilation are influenced by shade.

Fig.51. Interaction effect of genotypes, harvesting stages and chitosan spray on curcumin content (%)



V1- Sobha
V2- Prathibha
V3 –Wayanad local (Acc WCL 23)

C1- Chitosan Spray 1g L^{-1}
C2- Water spray
C3- Control

H1- Harvest at 210 DAP
H2- Harvest at 240 DAP
H3 – Harvest at 270 DAP

Interaction effect of genotypes and harvesting stages on curcumin yield (kg/ha)

Interaction between genotypes and harvesting stages for curcumin yield recorded significant difference. The highest curcumin yield was obtained from turmeric genotype, Wayanad local (Acc WCL 23) harvested at 270 DAP (313.72 kg/ha) followed by Sobha harvested at 240 DAP (284.45 kg ha^{-1}) and Prathibha at harvested at 240 DAP (267.58 kg ha^{-1}). When yield improvement of curcumin from first harvest to the last stage of harvest was considered. The yield improvement was highest in Sobha (82.40%).The Prathibha and wayanad local recorded yield improvement of (33.57%, 14.73%, respectively) (Fig.52).

Interaction effect of harvesting stages and chitosan sprays on curcumin yield

Interaction effect of harvesting stages and chitosan was significant in improved curcumin yield was rhizomes obtained from chitosan spray (1 g L^{-1}) and harvested at 240 DAP, recorded highest curcumin yield 350.55 kg ha^{-1} followed by chitosan sprayed plants harvested at 270 DAP (326.27 kg ha^{-1}). The curcumin yield improvement by foliar sprayings of chitosan was more pronounced at rhizomes harvested at 210 DAP (70.32%) followed by 240 DAP (67.32%) lowest was at 210 DAP (22.56%) (Fig.53)

Interaction effect of genotypes and chitosan sprays on curcumin yield

Interaction effect between genotypes and chitosan sprays had a significant difference in curcumin yield. Plants of genotype Wayanad local (Acc WCL 23) which received a spray of chitosan 1 g L^{-1}, exhibited highest curcumin yield of 355.21 kg ha^{-1}. It was followed by genotype Sobha which received chitiosan spray at 1g L^{-1} (309.65 kg ha^{-1}) (Fig.54). The curcumin yield improvement by foliar sprayings of chitosan was more pronounced in Sobha (52.96%) followed by Wayanad local (Acc WCL 23) (45.71) and Prathibha (40.52%) (Fig.54).

5.24.4. Interaction effect of genotypes, harvesting stages and chitosan spray on curcumin yield (kg/ha)

When curcumin yield per hectare was analysed in detail by considering all the treatment combinations of genotypes, harvesting stages and chitosan sprays, the highest curcumin yield was obtained from genotype Sobha sprayed with chitosan and harvested at 240 DAP (V1H2C1) (385.16 kg ha^{-1}) and Wayanad local sprayed with chitosan 1 g $L^{-1}$and harvested at 210 DAP (378.54 kg ha^{-1}). The curcumin ontent of Wayanad local sprayed with chitosan and harvested at 270 DAP (V3H3C1) (367.88 kg ha^{-1}) was found on par with the highest curcumin yield followed by genotype Prathibha with chitosan spray and harvested at 240 DAP (V2H2C1) (345.27 kg ha^{-1}) (Fig.55).

The treatment V1H2C1 and V3H1C1 performed as best treatment combination by exhibiting highest fresh weight, curcumin content and curmin yield.

Fig.52. Interaction effect of genotypes and harvesting stages on curcumin yield (kg/ha)

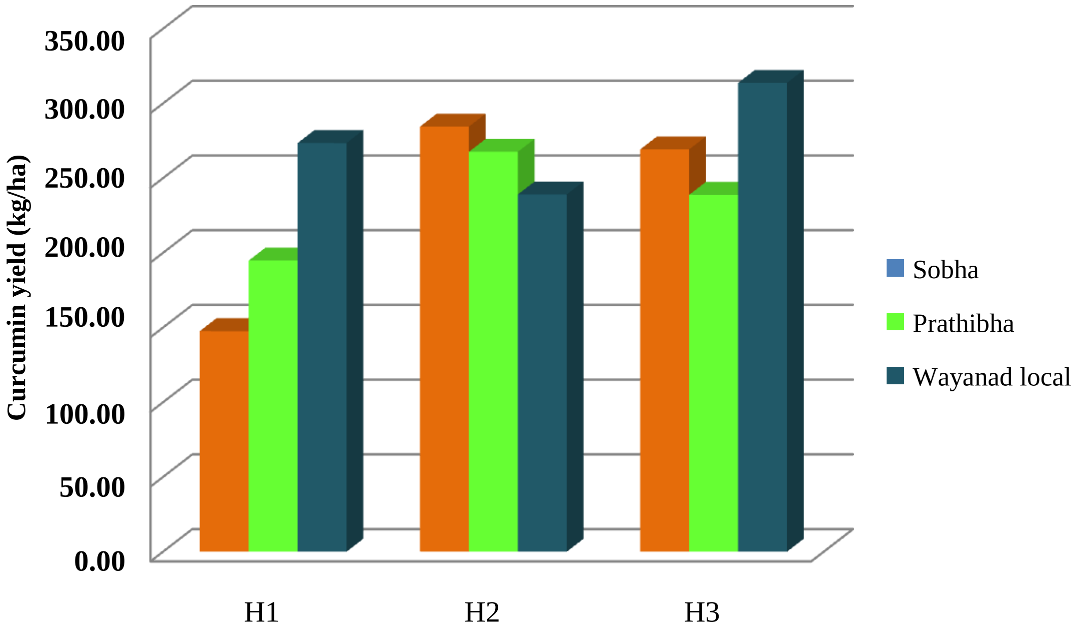


Fig.53. Interaction effect of harvesting stages and chitosan sprays on curcumin yield

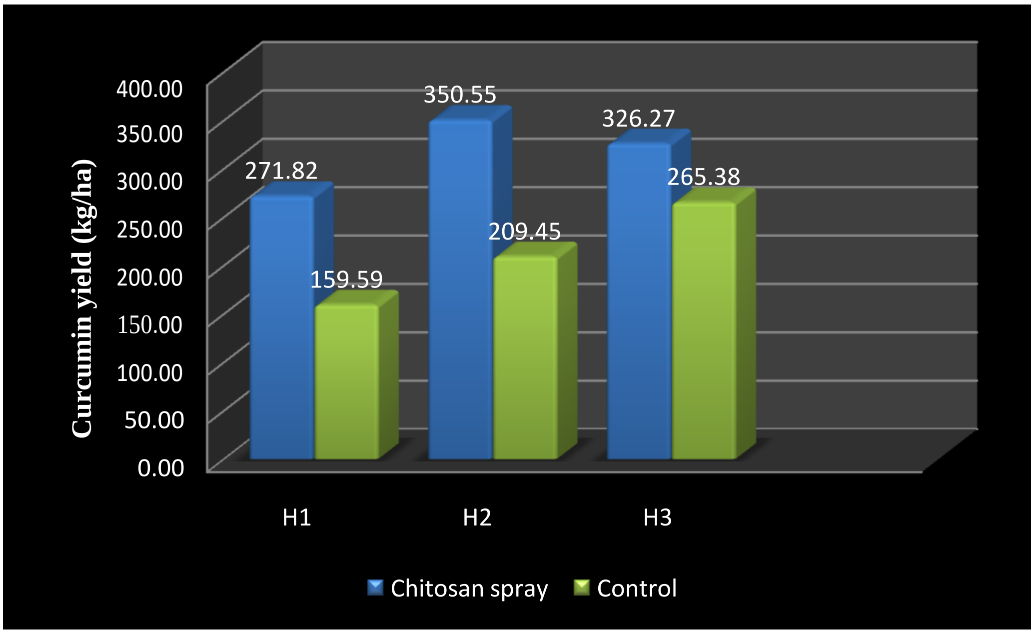


Fig.54. Interaction effect of genotypes and chitosan sprays on curcumin yield

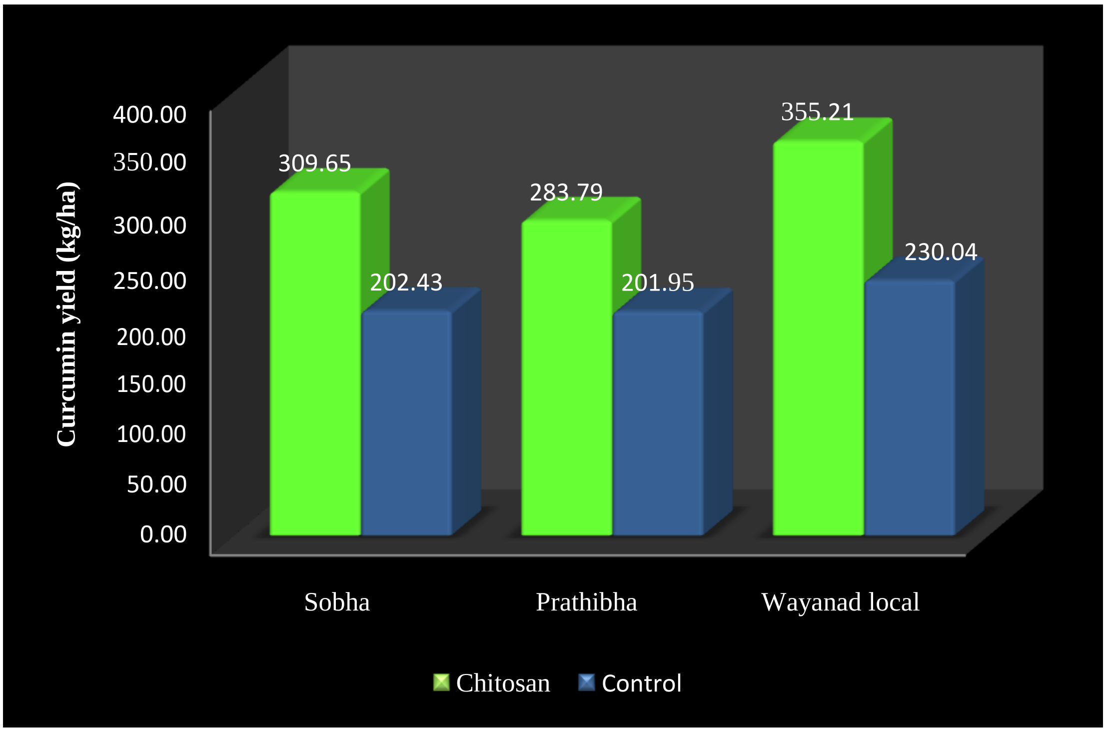
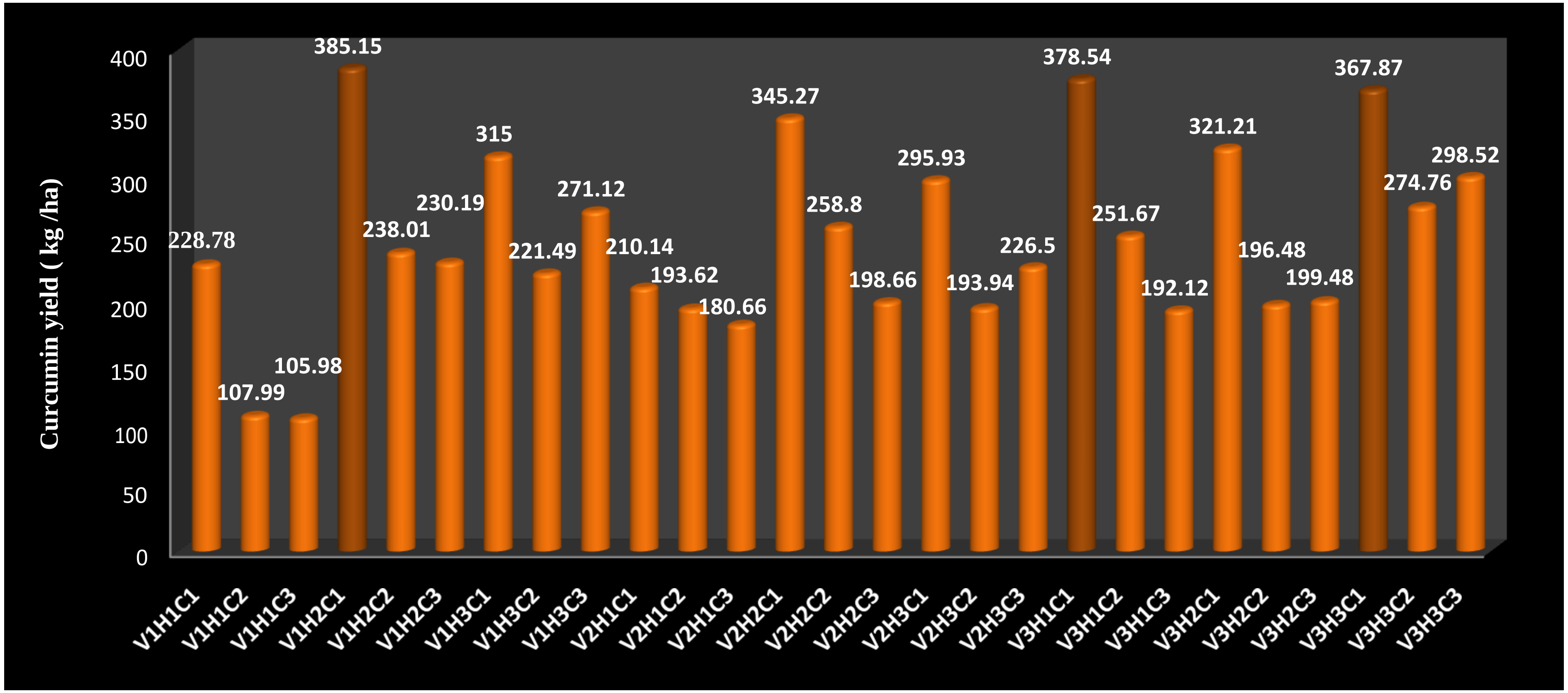


Fig.55. Interaction effect of genotypes, harvesting stages and chitosan spray on curcumin yield (kg/ha)



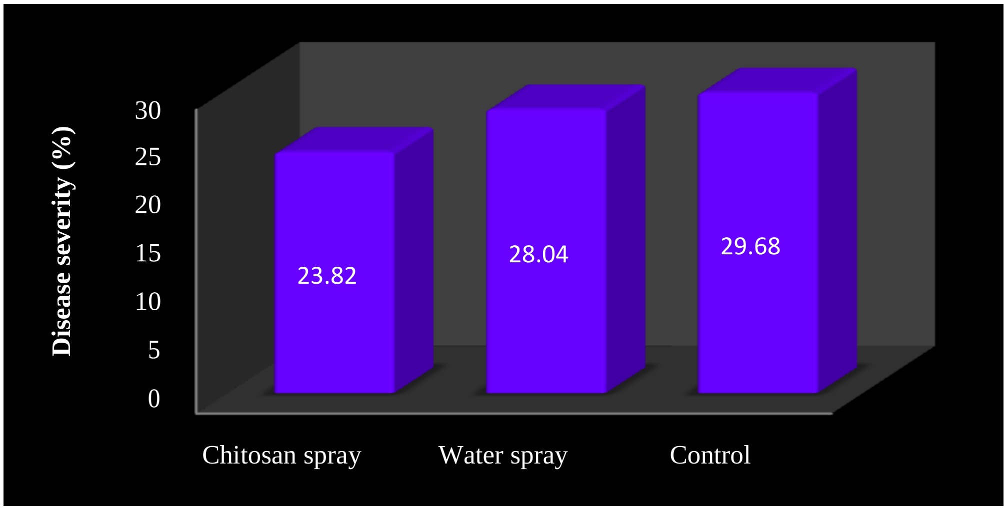
V1- Sobha V2- Prathibha V3 –Wayanad local (Acc WCL 23)	C1- Chitosan Spray 1g/L C2- Water spray C3- Control	H1- Harvest at 210 DAP H2- Harvest at 240 DAP H3 – Harvest at 270 DAP

5.25. INFLUENCE OF CHITOSAN SPRAYS ON DISEASE SEVERITY OF LEAF SPOT

The chitosan sprays of 1 g L^{-1} on turmeric exhibited the least per cent of disease incidence (23.82%). The disease severity in water sprayed plants was 28.04 % and in plants without any spray was 29.68 % (Fig 56).

A Chitosan sprayed plant enhances the compounds like beta-1, 3-glucanase and chitinase which are related to proteins (Satiyabama *et al*., 2014). Phenyl alanine ammonia lyase a defense enzyme in plant is enhanced by the chitosan (Ali *et al*., 2012; Kim *et al*., 2005). Chitosan induces resistance against pathogens by producing the gens of pathogenesis related *viz.,* glucanase and chitinase (Pichyangkura and Chadchawan, 2015). Chitosan sprays promotes the formation of defence related proteins like poly phenol oxidase (PPO) and peroxidase (PO) this might help to resitruct the pathogenic fungi and bacteria entry in to the plant (Anusuya and Satiyabama, 2016).

Fig.56. Influence of Chitosan sprays on leaf spot disease



Summary

6. SUMMARY

The present study entitled, "Harvesting stages and chitosan sprays on curcumin yield in turmeric (*Curcuma longa*.L) was carried out in Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during April 2019 to March 2020.The main objective of this study was to evaluate rhizome and curcumin yield of turmeric genotypes as influenced by harvesting stage and foliar application of chitosan spray.

The experiment was laid out in factorial RBD. It comprised of 27 treatments combinations with 3 replications. Treatment combinations consiste of three popular genotypes, three different harvesting stages and foliar sprays of biostimulant chitosan at 1g L^{-1}. The genotypes used were V1-Sobha (released by Kerala Agricultural University), V2-Prathibha (released by Indian Institute of Spice Research) and V3-Wayanad local accession (WCL -23), an accession identified as superior in the previous study of Department of Plantation Crops and Spices. Harvesting was carried out at H1- 210, H2- 240 and H3- 270 Days After Planting (DAP). Foliar sprays of chitosan at a concentration at 1 g L^{-1} (C1) was given at monthly interval starting from 60 days after planting to 180 days after planting and water sprayed plants (C2) and plants without any spray (C3) were maintained as control. The influence of treatments and treatment combinations were analysed by evaluating the growth, yield and quality parameters at different stages of harvest. The salient findings of the study are summarized here under in this chapter.

The morphological observations were recorded at 100, 120 and 150 DAP. The genotype Wayanad local recorded significantly higher plant height in all growth stages *viz*., 100, 120 and 150 DAP (94.49 cm, 127.70cm, and 140.20 cm, respectively). The plants sprayed with chitosan (133.58 cm) recorded highest plant height and it was on par with the plant heights observed in plants sprayed with water (131.67 cm).

The genotypes Wayanad local recorded highest numbers of tillers at 100,120,150 DAP (2.97, 3.59 and 3.71, respectively). The number of tillers at 120

DAP was superior in plants sprayed with chitosan 1g L^{-1} (4.11). At 100 and 150 DAP, the highest number of leaves was observed in Prathibha (7.87 and 8.46 respectively). But at 120 DAP, Wayanad local recorded the highest number of leaves (8.65). Girth of the main tiller was found to be the highest in Wayanad local in all growth stages studied (9.06 cm, 10.00 cm and 10.45 cm).

Leaf area was found to be highest in genotype Wayanad local at all growth stages.The highest value was at 150 DAP (696.28 cm^2). But chitosan spray had no significant influence on leaf area. Photosynthetic rate was found to be highest in genotype Sobha (30.60 µmol m^{-2} s^{-1},) followed by Prathibha (29.92 µmol $m^{-2}s^{-1}$). Chitosan sprayed plants exhibited the highest photosynthetic rate (32.76 µmol m^{-2} s^{-1}). When the interaction effect of chitosan and genotypes was considered, the highest photosynthetic rate was observed in genotype Wayanad local (35.60 µmol m^{-2} s^{-1}) sprayed with chitosan 1g L^{-1}

Harvesting stages and chitosan spray of 1g L^{-1} had a significant influence on rhizome characters of turmeric genotypes. Significantly highest primary rhizome length was obsereved in Wayanad local and Sobha (11.07cm and 10.68 cm, respectively). Harvesting at 270 DAP significantly increased the length of primary rhizome (10.58 cm).Prathibha recorded significantly higher width of primary rhizome (2.79 cm) followed by Wayanad local (2.53 cm).The highest width of rhizomes was noticed when harvested at 270 DAP (3.19 cm). Regarding the chitosan sprays, highest width of primary rhizome was observed from plants sprayed with chitosan (2.59 cm)

The highest number of primary rhizomes was obtained in genotype Wayanad local (6.78) followed by Prathibha (6.67) and Sobha (6.32). The highest number of primary rhizomes was observed in the rhizomes harvested at 270 DAP (7.10). Chitosan spray at 1g L^{-1} had a significant influence number of primary rhizomes (7.32). The number of secondary rhizomes was found to be significantly high in Sobha (18.67) and Wayanad local (18.35). Chitosan at a concentration of 1 g L^{-1} improved the number of secondary rhizomes (18.89) and mother rhizomes (1.58).

The genotype Wayanad local (24.96 g) and Sobha (24.41 g) were found to have a highest weight of primary rhizome. Turmeric harvested at 270 DAP was found to be significantly superior in improving the weight of primary rhizome (27.29 g). The foliar application of chitosan had a significant influence in improving weight of primary rhizome (25.72 g). Highest weight of mother rhizome was observed in Prathibha (59.15 g). The highest weight of secondary rhizome was recorded by Prathibha (4.74 g) and Sobha (4.63).

There was a significant difference in fresh weight of rhizome per plant. The highest fresh weight of rhizome was obtained from genotype Wayanad local (255.86 g plant^{-1}) and Sobha (246.01 g plant^{-1}). The rhizomes harvested at 270 DAP recorded the highest fresh rhizome (266.52 g plant^{-1}) Chitosan at a concentration of 1 g L^{-1} significantly improved the fresh rhizome yield per plant (273.18 g plant^{-1}).

Highest dry rhizome yield per plant was recorded in the genotype Wayanad local (46.98 g plant^{-1}). Harvesting at 240 DAP and 270 DAP was found effective in getting a good dry yield (48.13 and 45.48 g plant^{-1}, respectively). Chitosan at a concentration of 1 g L^{-1} significantly improved the dry rhizome yield per plant, resulting in an average dry rhizome yield of 49.48 g plant^{-1}.

Significant difference was observed in fresh and dry yield of rhizome per plot and projected fresh and dry rhizome yield per hectare with respect to genotypes, harvesting stages and foliar spray of chitosan. The highest fresh rhizome yield per plot and yield per hectare was recorded in Wayanad local (9.68 kg plot^{-1} and 32.27 t ha^{-1}, respectively). Rhizomes when harvested at 270 DAP and 240 DAP was found to be significantly superior in improving the fresh rhizome yield per plot (8.98 and 8.82 kg plot^{-1}, respectively) and fresh rhizome yield per hectare (29.95 and 29.40 t ha^{-1}, respectively). Foliar application of chitosan had a significant influence on yield in turmeric.Chitosan at a concentration of 1 g L^{-1} significantly improved the fresh rhizome yield per plot and per hectre (9.43 kg plot^{-1} and 31.45 t ha^{-1}, respectively).

The projected dry yield per hectare was the highest in genotype Wayanad local (5.71 t ha^{-1}) .The rhizomes harvested at 270 DAP and 240 DAP was found to be significantly superior in improving the dry rhizome yield per hectre (5.23 and 5.53 t ha^{-1}, respectively).The chitosan sprayed plants recorded the highest dry rhizome yield of 5.71 t ha^{-1} and found superior.

The highest curing percent was recorded in Wayanad local (17.23 %), and with respect to harvest stage of turmeric, rhizome harvested at 240 DAP (16.56 %) was found to be significantly superior.Plants sprayed with chitosan at a concentration of 1 g L^{-1} significantly improved the curing percent (16.29%).

The rhizomes harvested at 270 DAP, recorded highest length of primary rhizome (10.58 cm), width of primary rhizome(3.19cm), number of primary rhizomes (7.10), weight of mother rhizome (51.68), weight of primary rhizome (27.29g), weight of secondary rhizomes (5.94 g), fresh weight per plant (266.52 g $plant^{-1}$), dry weight per plant (45.48 g $plant^{-1}$), fresh rhizome yield per plot (8.98 kg $plot^{-1}$), dry rhizome yield per plot (1.66 kg $plot^{-1}$) and also curcumin content (4.34%).

The genotype Wayanad local was found to have hghest in length in primary rhizome (11.07cm), number of primary rhizomes (6.78), weight of primary rhizomes (24.96 g), Fresh weight per plant (255.86 g $plant^{-1}$), dry weight per plant (46.98 g), curing percent (17.22%), fresh yield per plot (9.68 kg $plot^{-1}$) and dry rhizome yield per plot (1.77kg $plot^{-1}$).curcumin yield (275.41 kg ha^{-1}).

Chitosan at a concentration of 1 g L^{-1} significantly improved width of primary rhizome (2.59 cm), number of primary rhizomes (7.32), number of secondary rhizomes (18.89), number of mother rhizomes (1.58), weight of primary rhizomes (25.72 g), fresh weight per plant (273.18), dry rhizome weight per plant (49.48 g), fresh rhizome yield per plot (9.43 kg $plot^{-1}$) and dry rhizome yield per plot (1.71 kg $plot^{-1}$), curcumin content (4.81%) and curcumin yield(316.21kg ha^{-1}).

When projected fresh yield per hectare was critically analysed with interaction effect, Wayanad local at 210 DAP yielded 30.45 t ha^{-1} and the yield at stages 270 DAP was only 33.15t ha^{-1}, contributing to 8.86% increase in yield over a period of 60 days. While the yield improvement in from 210 DAP to 270 DAP was 29.33% in Sobha and 13.62 % in Prathibha. Hence the higher yield of Wayanad at

210 DAP indicates the instinct early maturing habit of genotype Wayanad local.

In the present study, the major active constituent curcumin exhibited a significant difference due to the influence of factors like genotypes, stage of harvest and chitosan sprays. However, highest curcumin was in genotype Prathibha (4.36%) followed by Wayanad local (4.21%). Harvesting of turmeric at 270 DAP (4.33 %) and 240 DAP (4.34%) was found to be significantly influencing the curcumin content. The foliar application of chitosan at a concentration of 1 g L^{-1} significantly improved the curcumin content (4.81%). The results of analysis of interaction effect of genotypes, harvesting stages and foliar spray of chitosan on curcumin content of turmeric considering all the treatment combinations, Significantly highest curcumin content of 5.26 % was observed in the treatment combinations of genotype Sobha sprayed with chitosan 1 g L^{-1} and harvested at 240 DAP (V1H2C1), Prathubha with chitosan spray chitosan 1 g L^{-1} and harvested at 240 DAP (V2H2C1) (5.14 %), Wayanad local with chitosan 1 g L^{-1} and harvested at 270 DAP (V3H3C1) (5.20%) and 210 DAP (V3H1C1) (5.11%).

When curcumin yield per hectare was analysed in detail by considering all the treatment combinations of genotypes, harvesting stages and chitosan sprays, the highest curcumin yield was obtained from genotype Sobha sprayed with chitosan and harvested at 240 DAP (V1H2C1) (385.16 kg ha^{-1}) and Wayanad local sprayed with chitosan 1 g $L^{-1}$and harvested at 210 DAP (V3H1C1) (378.54 kg ha^{-1}). The curcumin yield of Wayanad local sprayed with chitosan and harvested at 270 DAP (V3H3C1) (367.88 kg ha^{-1}) was found on par with the highest curcumin yield followed by genotype Prathibha with chitosan spray and harvested at 240 DAP (V2H2C1) (345.27 kg ha^{-1}).

The chitosan showed stimulating effect of growth parameters, physiological parameters, and also showed the various defence mechanisam during the growth and development of plant this charcters were correlated with the higher fresh rhizome yield in turmeric resuted yield improvement . Hence the present study revealed that foliar application of chitosan at 1g L^{-1} is effective in enhancing the weight of fresh rhizome in turmeric. Chitosan sprayed plants of all genotypes found superior in weight of fresh rhizome. Harvesting at 240 and 270 days after planting are equally good in getting higher weight of fresh rhizome and curcumin. The best combinations for superior fresh rhizome yield per plant were V1H2C1 and V3H1C1.The fresh yield from combination V2H2C1 was on par with the superior. The best combinations for superior curcumin content was V1H2C1 (5.26 %) V2H2C1 (5.14 %) V3H1C1 (5.11) and V3H3C1 (5.20%) and best treatment combinations for curcumin yield were V1H2C1 (385.16 kg ha^{-1}) and V3H1C1 (378.54 kg ha^{-1}). The yield from V3H3C1 (367.88 kg ha^{-1}) was found on par with the highest curcumin yield. The curcumin yield from V2H2C1 (345.27 kg ha^{-1}) was found on par with V3H3C1 (367.88 kg ha^{-1}). The treatment V1H2C1 and V3H1C1 performed as best treatment combination for yield and quality by exhibiting highest fresh weight, curcumin content and curmin yield.

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HARVESTING STAGES AND CHITOSAN SPRAYS ON CURCUMIN YIELD IN TURMERIC (*Curcuma longa* L.)

by

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ABSTRACT OF THESIS

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Abstract

Turmeric (*Curcuma longa* L.) the golden spice, is highly valued as a medicinal plant. The major active constituent of turmeric is curcumin. The curcumin content varies with the agro climatic regions, cultivars, agronomic practices and the stages of harvest. The present study entitled 'Harvesting stages and chitosan sprays on curcumin yield in turmeric *(Curcuma longa* L.)' to identify the influence of chitosan sprays and stages of harvesting on curcumin yield of turmeric genotypes.

There were twenty seven treatment combinations of genotypes, harvesting stages and foliar application of chitosan. Among the turmeric genotypes Wayanad local (Acc WCL 23) was found superior in morphological characteristics like plant height (94.49 cm, 127.70 cm, 140.20 cm, respectively), number of tillers (2.97, 3.59 and 3.71, respectively) and leaf area (529.06 cm^2, 657.38 cm^2 and 696.28 cm^2, respectively) in all the three growth stages of plant at 100, 120 and 150 Days After Planting (DAP). The foliar sprays of chitosan at 1g L^{-1} at monthly interval had a pronounced in morphological characters like plant height (133.58 cm), number of tillers (3.78) and girth of tillers (10.36 cm) at 150 DAP. However, the interaction effect of turmeric genotypes and foliar application of chitosan on morphological characters was found non significant. The photosynthetic rate was found higher in turmeric genotype, Wayanad local sprayed with chitosan (35.60 μmol $m^{-2}s^{-1}$). The lowest disease sevearity index for leaf spot was remarkable in chitosan sprayed plants (23.82%).

The rhizome characters like length of primary rhizome and number of secondary rhizomes were found to be significantly high in Sobha (10.68 cm and 18.67 cm, respectively) and Wayanad local (11.07 cm and 18.35, respectively). The genotype Prathibha was found superior in width of rhizome (2.79 cm). The highest number of primary rhizomes was recorded in genotype Wayanad local (6.78) and Prathibha (6.67). When the main effect of harvesting stages were analysed, harvesting at 270 DAP was found superior in improving length, width and number of primary rhizome (10.58 cm, 3.19 cm and 7.10 cm, respectively). Chitosan sprayed plants recorded highest number (7.32) and width (2.59 cm) of primary rhizomes.

Among the turmeric genotypes Wayanad local (255.86 g plant^{-1}) and Sobha (246.01 g plant^{-1}) recorded highest fresh rhizome weight. The rhizome harvested at 270 DAP recorded the highest fresh rhizome weight (266.52 g plant^{-1}). Chitosan at a concentration of 1g L^{-1} significantly improved the fresh rhizome yield per plant (273.18 g plant^{-1}). From the interaction effect it was evident that the fresh rhizome yield per plant was significantly superior in chitosan sprayed plants of Wayand local (314.00 g plant^{-1}) harvested at 210 DAP (V3H1C1) and in chitosan sprayed plants of Sobha (311.25 g plant^{-1}) harvested at 240 DAP (V1H2C1). The treatment combination V2H3C1- Prathibha sprayed with chitosan and harvested at 270 DAP was found on par (297.55 g plant^{-1}). The chitosan sprayed plants of Wayanad local (18.44 %) harvested at 240 DAP (V3H2C1) recorded highest curing percentage.

The curcumin content was significantly high in Prathibha (4.36 %). Harvesting of turmeric at 240 DAP (4.34 %) and 270 DAP (4.33 %) was found to be significantly superior in the curcumin content. Chitosan sprays significantly improved the curcumin content (4.81%). When influence of genotypes, harvesting stages and chitosan spray on curcumin content was analysed in detail, the treatment combinations of V1H2C1 - chitosan sprayed plants of Sobha harvested at 240 DAP (5.26%), V2H2C1- Prathiba at 240 DAP with chitosan sprays (5.14%), V3H1C1- Chitosan sprayed plants of Wayanad local harvested at 210 DAP (5.11%) and V3H3C1- Wayanad local harvested at 270 DAP (5.20%) were found superior. The curcumin yield improvement by foliar sprayings of chitosan was more pronounced in Sobha (52.96%) followed by Wayanad local (Acc WCL 23) (45.71%) and Prathibha (40.52%). Significantly higher curcumin yield was obtained from the treatment combinations involving genotype Sobha sprayed with chitosan 1 g L^{-1} and harvested at 240 DAP (V1H2C1) - (385.16 kg ha^{-1}) and Wayanad local (Acc WCL 23) sprayed with chitosan 1 g L^{-1} and harvested at 210 DAP (V3H1C1) - (378.54 kg ha^{-1}).

However, foliar application of chitosan at 1g L^{-1} is effective in enhancing the weight of fresh rhizome, curcumin content and curcumin yield in turmeric. Harvesting at 240 and 270 days after planting are equally good in getting higher weight of fresh rhizome and curcumin.