RAPID MULTIPLICATION OF KASTHURI TURMERIC (*Curcuma aromatica* Salisb.) THROUGH MINISETT TECHNIQUE AND NURSERY MANAGEMENT

By

ASWATHY T. S

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THESIS

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VELLAYANI, THIRUVANANTHAPURAM - 695 522

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DECLARATION

I hereby declare that this thesis entitled **"RAPID MULTIPLICATION OF KASTHURI TURMERIC (*Curcuma aromatica* Salisb.) THROUGH MINISETT TECHNIQUE AND NURSERY MANAGEMENT"** is 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.

Vellayani

Date: 11-11-2015

Aswathy T.S

(2013-12-112)

CERTIFICATE

Certified that this thesis, entitled **"RAPID MULTIPLICATION OF KASTHURI TURMERIC (*Curcuma aromatica* Salisb.) THROUGH MINISETT TECHNIQUE AND NURSERY MANAGEMENT"** is a record of research work done independently by Ms. Aswathy T.S (2013-12-112) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani

Date: 11-11-2015

Dr. P.C. Jessykutty
Chairperson, Advisory committee
Associate Professor
Dept. of Plantation crops and Spices,
College of Agriculture, Vellayani

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Vellayani *Aswathy T.S*

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LIST OF ABBREVIATIONS

%	Per cent
AOAC	Association of Official Agricultural Chemist
BA	Benzyl adenine
B:C ratio	Benefit-Cost ratio
CD	Critical Difference
CGR	Crop Growth Rate
cm	Centimetre
cm^2	Square centimetre
cv.	Cultivar
DAS	Days After Sowing
DAP	Days After Planting
day^{-1}	Per day
et al.	And others
Fig	Figure
g	Gram
$g\ m^{-2}$	Gram per metre square
HI	Harvest Index
Kg	Kilogram
$kg\ ha^{-1}$	Kilogram per hectare
LAI	Leaf Area Index
L^{-1}	Per litre
m	Metre
m^2	Square metre
mts	Minutes
MAP	Months After Planting
NAR	Net Assimilation Rate
NS	Non-significant
NVEE	Non-volatile ether extract
ppm	Parts per million
ºC	Degree Celsius
$t\ ha^{-1}$	Tonnes per hectare
V/W	Volume by Weight
Viz.	Namely
WAP	Weeks after planting

INTRODUCTION

1. INTRODUCTION

Curcuma aromatica Salisb. known as kasthuri turmeric (kasthuri manjal in Malayalam), is a valued cosmetic cum medicinal plant. It has vast ethno botanical value, already known in India as a tonic, carminative, antidote to snake bite, astringent and is used for bruises, corns and sprains. Kasthuri turmeric has been widely used as an effective skin care cosmetic in ayurvedic medicines (Sasikumar, 2000). It is also used externally in the treatment of various skin diseases like scabies owing to its antifungal and antimicrobial activity (Kirtikar and Basu, 1978). Rhizomes of *Curcuma aromatica* are also used in medicines as a stomachic, carminative and emmenagogue, and recently as a health food in Japan (Kojima *et al*., 1998). The essential oil obtained from kasthuri turmeric has been reported to have antifungal and antimicrobial activity and is used in the treatment of early stages of cervical cancer (Asolkar *et al*., 1992).

In spite of the multifarious applications and good export potential of the crop, its cultivation has not become wide spread and is getting slowly depleted from cultivation due to various reasons. The ignorance about the true identity of the crop is one of the major reasons for the decline in cultivation of this crop. Detailed study conducted in the Department of Plantation Crops and Spices helped to identify true kasthuri turmeric accessions through morphological, physiological, anatomical, biochemical and RAPD techniques (Alex, 2005).

Limited availability and high cost of planting materials are other constraints for commercial cultivation of true kasthuri turmeric. The traditional method of propagation using 15 g rhizome pieces competes with its availability for cosmetic manufacture and at the same time makes the cultivation expensive for large scale production. In kasthuri turmeric, the sprouting, vigour and viability hold a direct relationship with size of planting material. Identification of better pre-sprouting treatments may be helpful in sprouting smaller pieces of seed rhizomes thereby reducing the quantity of the costly seed rhizome.

Although there are reports of minisett technique of propagation in tuber crops and yams, so far very little work has been done in spices and medicinal crops. Use of pro-tray seedlings in turmeric has been recommended by TNAU when the cost of seed rhizome is higher (TNAU, 2012). In an on farm trial conducted by KVK, Dharmapuri, it has been reported that the use of protray seedlings reduced seed cost by an average of 15 percent and reduced the cost of cultivation while the yield and BCR was on par with that of seed rhizome planting.

In this emerging world of fashion and enlightened market products, kasthuri turmeric will have good demand and the soil and the climate of the state are ideal for its large-scale commercial cultivation. In this context, standardization of a propagation technique and nursery management for kasthuri turmeric permitting rapid multiplication of limited quantities of planting materials can pave the way for commercial cultivation and better utilization of this valuable underexploited crop and it will be a boon to the farming community.

Considering these factors, the present investigation was undertaken to standardize the minisett technique of macro propagation in kasthuri turmeric by:

1. Finding out the best pre-sprouting treatment/treatments for the minisetts.
2. Finding out the best media for the pro- tray seedlings.
3. Finding out the optimum age of transplanting of pro-tray seedlings and their field evaluation.
4.Working out the economics of cultivation of different treatments so as to formulate a cost effective propagation technique for commercial cultivation of kasthuri turmeric.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Kasthuri turmeric (*Curcuma aromatica* Salisb.) is a medicinal and aromatic plant with multiple uses. It has vast ethno botanical value, already known in India as tonic, carminative, antidote to snake bite, astringent and used for bruises, corns and sprains. Paste of rhizome with milk is used for blood dysentery and stomach ache. Juice of *C. aromatica* is given for curing indigestion and rheumatism.

Even though, kasthuri turmeric has got wide range of application, it is getting slowly depleted from cultivation due to various reasons. The ignorance about the true identity of the crop is the major reason for the decline in the cultivation of this crop. This also makes it easy for the vendors to sell any turmeric in the disguise of kasturi turmeric by many vendors. Easily available *Curcuma zedoaria* Roxb. (Manjakoova) is the common *Curcuma* spp. sold at an exorbitant price as kasthuri turmeric by many vendors (Sasikumar, 2000)

Though there are reports about minisett technique practices in tuber crops and yams, so far very little work has been standardized for spices and in medicinal crops. Hence, literature of minisett technique, response of crops to size of planting material, different plant growth regulators for better sprouting, organic manures for nursey seedling raising, optimum age at transplanting and their effect on growth, yield and quality of turmeric, yams, vegetables, black pepper and ginger are specifically reviewed in this chapter.

2.1. Minisett Technique

In the late 1970s, the "minisett technique" was developed for the production of seed tubers separated from the production of ware yam. The technique utilizes a small (20-50g) part of a whole non-dormant tuber containing periderm and some cortex parenchyma (Okoli, 1982).

Four different minisett sizes (15, 30, 45 and 60g) were tried in *Dioscorea alata* and *D. rotundata*. Minisetts weighing 60g was found to be superior. However the performance of mini-setts weighing 30g was found to be on par with 45g minisett (George, 1990).

Okwuowulu (1992) studied the influence of varying minisett weights, intra-row spacing, sites and weather condition on yield of ginger cv.Taffin-giwa. He observed that small seed rhizome weighing 3g can give potential setts. Using mini-setts stimulated complete harnessing of food reserve in mother rhizome.

In the conventional method of planting the recommended seed rate for kasthuri turmeric is 1500 kg ha^{-1}(Jayachandran, 2011). Maintenance of such a huge amount of seed rhizomes for annual planting is expensive and labour intensive.

Use of pro-tray seedlings in turmeric has been recommended by TNAU when the cost of seed rhizome is higher (TNAU, 2012). In an on farm trial conducted by KVK, Dharmapuri, it has been reported that the use of protray seedlings reduced seed cost by an average of 15 percent and reduced the cost of cultivation while the yield and BCR was on par with to seed rhizome planting. When seed rhizomes are sown directly in the field, they require 20-30 days to sprout and another 30 days to produce two to three leaves. Within 20 days such growth is attained in the rapid method and hence advantage of saving about 40 days of duration in the open field thus avoiding one weeding (Senapathy, 2011).

2.2. Effect of Size of Rhizome and Plant Growth Regulators on Sprouting.

Hussain and Said (1967) reported that in turmeric the use of larger size rhizomes resulted in significantly higher sprouting and fresh yield than smaller size rhizomes or from whole or divided central rhizomes. In an experiment to economise the planting material in elephant foot yam, four sizes of planting bits (250,500,750 and 1000 g) were used. It was shown that the sprouting was delayed when the planting material was too small (KAU, 1983).

Banana suckers weighing more than 390, 220-390 and 30-100g were planted in nursery beds. Sprouting percentage after 45 days, plant height from 30 to 150 days and size after removal from nursery beds were recorded for each grade. In all the cases best results were obtained with suckers weighing 220-390 g or more than 390 g (Hernandez *et al*., 1988).

In a rapid multiplication trial in turmeric, minisetts weighing of 5g took the lowest number of days to sprout (17.7 days) and obtained the highest fresh rhizome yield of 296.7g (Okoro *et al*., 2009).

Higher Benzyl adenine concentrations (50 and 100 mg L^{-1}) broke dormancy and enhanced sprouting in both rhizome halves of achimenes when they were soaked in four different concentrations of benzyl adenine solution for 8, 16 and 24hr (Vlahos, 1985).

Furutani *et al*., (1985) and Furutani and Nagao (1986) demonstrated that ethephon stimulated shoot production of edible ginger whether it was applied to the foliage or to the rhizomes.

Soaking of rhizomes, of turmeric cultivar Co1 and BSR1 in 0.2 per cent potassium nitrate recorded early germination, enhanced sprouting percentage and seedling vigour. Finger rhizomes were found early sprouting than mother rhizome (Balashanmugam and Vanangamudi, 1992).

In edible ginger, 250 ppm ethylene for 15 minutes increased the number of shoots and number of roots, which suggested a dormancy-breaking response (Sanewski *et al*., 1996).

Cytokinins are involved in branching, cell division, and juvenility. They are occasionally used to stimulate axillary shoot development (Dole and Wilkins, 1999).

Cytokinins are known to induce bud break on many kinds of plants on both aerial and below-ground parts (Criley, 2001). Pre-plant bulb (crown, corm, rhizome, tuber, bulblet etc.) soaks may also be an effective method of applying cytokinins.

2.3. Effect of Organic Manure Mixtures on Seedling Growth

Organic manures contain more or less all the nutrient elements required for plant growth. The quality of nursery potting medium is important to the successful growing of plants in containers (Bunt, 1988).

While a wide range of crop residues, organic wastes and other industrial by-products could be used as organic growing medium, preference of any should largely be determined by considerations of availability, economics, physical and chemical characteristics (Akanbi *et al*., 2002).

2.3.1.1. Effect of vermicompost

Vadiraj *et al.* (1992) observed that application of vermicompost as potting mixture for cardamom gives significant increase in growth characters. Vermicomposting is the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat as much as their own body weight per day. The excreta or casting of earthworms are rich in nutrients (N, P, K, Ca and Mg) and also in bacterial and actinomycete population (Gaur and Sadasivam, 1993). Krishnakumar *et al*. (1994) reported better growth and development of seedlings in cardamom nursery by the use of vermicompost in potting medium.

Vermicompost is a potential source of readily available plant nutrients, growth enhancing substances and a number of beneficial microorganisms like nitrogen fixing, phosphorus solubilizing and cellulose decomposing organisms and can substitute or complement chemical fertilizers. It also contains various amino acids and minerals which humidified the organic matter and surrounding soil and act as a bio fertilizer for plants (Shanbhag, 1999).

Vermicompost was found to improve soil texture and porosity, thus, facilitating root respiration and growth. Whenever the vermicompost is more than 25 percent in a media mixture, higher shoot growth and subsequently higher leaf area were observed in subabul seedlings (Biradar *et al*. 2001).

Vermicompost is rich in major and minor nutrients. It also has a high bacterial count of 10^{10} consisting of phosphate solubilisers, nitrobacter, actinomycetes, fungi, rhizobium etc. and is free from all pathogens. Vermicompost is a good source of GA_3, IAA and cytokinins (Yadav and Yadav, 2003).

Mixture of coir pith compost and vermicompost was the ideal medium registering cent per cent survival rate of in-vitro raised plants. The good water holding capacity coupled with optimal porosity could have helped the plantlets to establish better in this medium (Shameena, 2012).

2.3.1.2. Effect of coirpith

Coir pith is a light fluffy refuse obtained during the separation of coir fibre from coconut husk. Normally about 10,000 husk yield one tonne of coir fibre and another one tonne of coir pith as a waste material (Nagarajan *et al*., 1985). He also observed that coir pith is having about 533 per cent of maximum water holding capacity. As coir pith is found to contain appreciable amount of K, studies revealed that 50 per cent of K fertilizer could be saved by its application and would be available for plants over the years (Singh *et al*., 2002).

2.3.1.3. Effect of Trichoderma

The mode of action of *Trichoderma viride* is competition, antibiosis hyperparasitism, hyphal coiling, hyphal penetration, production of lytic enzymes, induced resistance, plant growth promotion etc. The competition for carbon and nitrogen by *T. harzianum* suppressed the infection of *Fusarium oxysporum* for sp. *melonis* (Sivan and Chat, 1989) on several crops through competition. Antibiotics like trichodermin, dermadin, trichoviridin, viridian etc. are produced by *Trichoderma*. Mycoparasitism relies on the production of mycoparasite for the lysis of cell walls. *Trichoderma* induces plant growth like increased germination, early emergence, fresh and dry weight of roots, shoots, root length, yield and flowering.

Prasath *et al.* (2014) study the effect of different combinations of soil-less coir pith based nursery mixtures on rooting and growth of black pepper cuttings in the nursery. Among the different nursery media combinations, coir pith with *Trichoderma* and vermicompost recorded significantly higher growth parameters.

2.4. Effect of Rhizome Size on Growth of the Plant

In colocasia Bourke and Perry (1976) observed that longer seed setts showed larger leaf areas. Such plants produced more suckers plant $^{-1}$ during the early growth itself.

Lyonga (1979) reported that in tannia, the optimum weight of planting sett and planting density were 400-500 g and 10,000 plant ha^{-1}. In amorphophallus, the plant height and canopy sizes were less when smaller planting bits were used (KAU, 1983).

A two year old field trial with ginger cultivar ‘Gorubathan’ revealed that the use of longest rhizome (40g) at planting gave the greatest plant height, number of leaves per clump and rhizome yield (Senguptha *et al*., 1986).

In another study Patel *et al*. (1988) observed that, in banana, the use of large fresh suckers induces early and vigorous vegetative growth which resulted in early and concentrated harvests.

Studies in Kerala (Jayachandran, 1989) for three seasons showed that mini-seed ginger rhizome possessing one healthy viable bud and weighing 5-7g produced normal plants with an average of 17 tillers plant^{-1} an average yield of 180 g plant^{-1}.

Korla *et al*. (1989) used four sizes of rhizomes for planting. They compared the rhizome bits weighing 5-10 g, 10-15,15-20 and 20-25 g in a three year trial with *Zingiber officinale* cv Local Dharja under Solan conditions. He observed no significant difference in responses between 10-15 g and 15-20 g for number of tillers, leaf breadth, rhizome length and breadth, yield plant^{-1} and yield plot^{-1}.

Sarker *et al.* (2001) reported that plants from the larger seeds were longer and had larger number of tillers on rice plant.

2.5. Effect of Transplanting Age on Growth of the Plant

The optimal choice of transplant age or growth stage plays a significant economic role because such transplants begin yielding faster.

Elmstrom (1973) hypothesized that increased yields for watermelon transplants as compared to direct seeded watermelons may be due to more extensive root growth of the transplanted crop early in the season, which allowed the transplants to better use water and nutrients.

Planting of young tomato transplants (3-4 weeks) require a longer growing period for obtaining an optimal yield. When planting older transplants (7-9 weeks) their yield is early (Palamakumbura, 1987).

Patil and Borse (1980) observed that transplanted cut rhizome seedling gave the highest plant height in turmeric. An experiment was conducted (Kumar *et al*., 2000) to study the effect of cultural practices and transplant age (90, 60 or 30 days old) on growth and yield of ginger raised through transplants. It was concluded that 90-day-old transplants had higher pseudo stem length, number of leaves, leaf growth and yield compared to other transplant ages.

Jankauskieneour *et al.* (2013) also reported that tomatoes transplanted of older age were taller and had more leaves than seedlings transplanted at their younger age. Hasandokht and Nosrati (2010) reported that the older the cucumber transplants, the larger their total yield.

Higher establishment success in cashew was reported when seedlings raised in small bags are best transplanted at 6-weeks after sowing. It also increases vigour as well as yield (Yeboah *et al*., 2015).

2.6. Effect of Rhizome Size on Yield

In southern Nigeria Envy (1967) found that increasing the seed sett size of tannia from small (43.71 g) to large size (156-185 g) lead to an increase in yield. It is reported that in ginger, larger rhizomes weighing 150 g with 4-6 buds gave higher yield compared to smaller ones of 60 g with two buds (Randhawa *et al*., 1972).

Experiments showed that in tapioca both the tuber size and number of tuber per plant were maximum when 30 cm long setts were used. Longer setts (25-30 cm) compared to cuttings of 8-10 cm gave higher yields. Studies in Brazil revealed close correlation between cutting length and early maturity. Using full length stem has some advantages such as ease of planting, early harvest good yield and good quality (Thampan, 1979).

Trials conducted in turmeric revealed that whole rhizomes were the best planting material for realizing the maximum yield of green turmeric (KAU, 1981).

Studies at Vellayani revealed that mother rhizome can be detached from the growing ginger plant at 3-4 months maturity without adverse effects to the plant (Jayachandran *et al*., 1982).

In amorphophallus, experiments (KAU, 1983) showed that the highest yield of 40.12 t ha^{-1} was obtained with planting bits of size 1 kg. This was on par with the bit of 750 g combined with farmyard manure and urea application. Bits weighing 250 g produced the lowest yield at all manurial levels.

Yield of green and cured turmeric rhizome was significantly influenced by the weight of planting material used. Rhizome weighing 60g at 10 x 20 cm spacing planted in mid-May gave maximum yield (KAU, 1984a).

Experiments with Costus showed that the yield of rhizome was proportionally higher when heavier planting material was used (KAU, 1984b).

Maximum yield of 94.7 t ha^{-}1 with a corm weight of 5.28 kg was obtained in amorphophallus when seed corm of 1 kg size was used as planting material (Ashokan *et al*., 1984; Sen *et al.*, 1984).

Variation in seed size caused significant differences in yield of *Dioscorea esculenta* (KAU, 1989c). Seed material weighing 130 g produced a yield of 28.6 t ha^{-1} while 50 g seed material produced only 10.43 t ha^{-1}

In banana large corms were significantly superior to small corms. But there was no significant variation between medium and large corms (Baghel, 1987).

An experiment was conducted (Ahmed *et al*., 1988) to study the effect of seed size and spacing on the yield of ginger. Rhizomes weighing 10, 11-20 and 21-30 g were planted at 15-20 cm or 25 cm in rows of 45 cm apart. The highest yield of 13.42 t ha^{-1} was obtained with the largest rhizomes plated at 25cm spacing gave only 5.41 t ha^{-1}.

A seed corm size cum spacing trail in amorphophallus, four seed corm sizes (250,500,750 and 1000 g) and three spacing (50x50,75x75 and 100x100 cm) were the treatments. Results showed that 1000 g seed corm was significantly superior. Effect of seed size was evident only on lower spacing (50x50 cm). The highest yield of 77.2 t ha^{-1} was recorded by 750 g corm with 50x50 cm spacing (KAU, 1989b).

In *Acorus calamus* the yield of fresh rhizome was always higher (Philip *et al*., 1992) for a larger planting material (6 cm with top) compared to smaller planting material (3 cm top).

2.6. Effect of Rhizome Size on Quality of the Product

Studies conducted in Kerala Agricultural University (1984b) with *Costus* showed that the yield of rhizome and diosgenin content were proportionately higher when heavier planting material were used.

Variation in seed size caused significant difference in yield of *Dioscorea esculenta*. Seed size had no influence on any of the quality characters such as protein, starch and crude fibre (KAU, 1989 c).

The essential oil from five *Curcuma* spp including *C.domestica* and *C.aromatica* were analysed by Zwaving and Bos (1992). The results showed that

C.domestica yielded 3.50 percent and *C. aromatica* yielded 9.40 percent of essential oil.

2.7. Economics of Cultivation

Use of pro-tray seedlings in turmeric has been recommended by TNAU when the cost of seed rhizome is higher (TNAU, 2012). In an on farm trial conducted by KVK, Dharmapuri, it has been reported that the use of protray seedlings reduced seed cost by an average of 15 percent and reduced the cost of cultivation while the yield and BCR was on par with to seed rhizome planting.

MATERIALS AND METHODS

2. MATERIALS AND METHODS

Studies on “Rapid multiplication of kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management” was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2014-2015. The objective of the study was to standardize minisett method of macro propagation and nursery techniques for rapid mass multiplication of kasthuri turmeric which has high cosmetic as well as medicinal value.

The details of the materials used and methods adopted for the study are presented in this chapter.

3.1. SEED MATERIAL AND VARIETY

The planting material used was original kasthuri turmeric collected from identified farmers in Neyyattinkara Taluk and also from Instructional farm, College of Agriculture, Vellayani.

3.2. SEASON

The experiment was conducted during May 2014 to February 2015.

3.3. EXPERIMENT

The experiment was conducted in two phases.

3.3.1. Phase I Standardization of Minisett Technique

For the propagation study, rhizome bits with two nodes (S_1) (approximate weight- 5g) and three nodes (S_2) (approximate weight -7g) was prepared from the primary fingers of kasthuri turmeric (Plate.1). Both the 2 node and 3 node rhizome

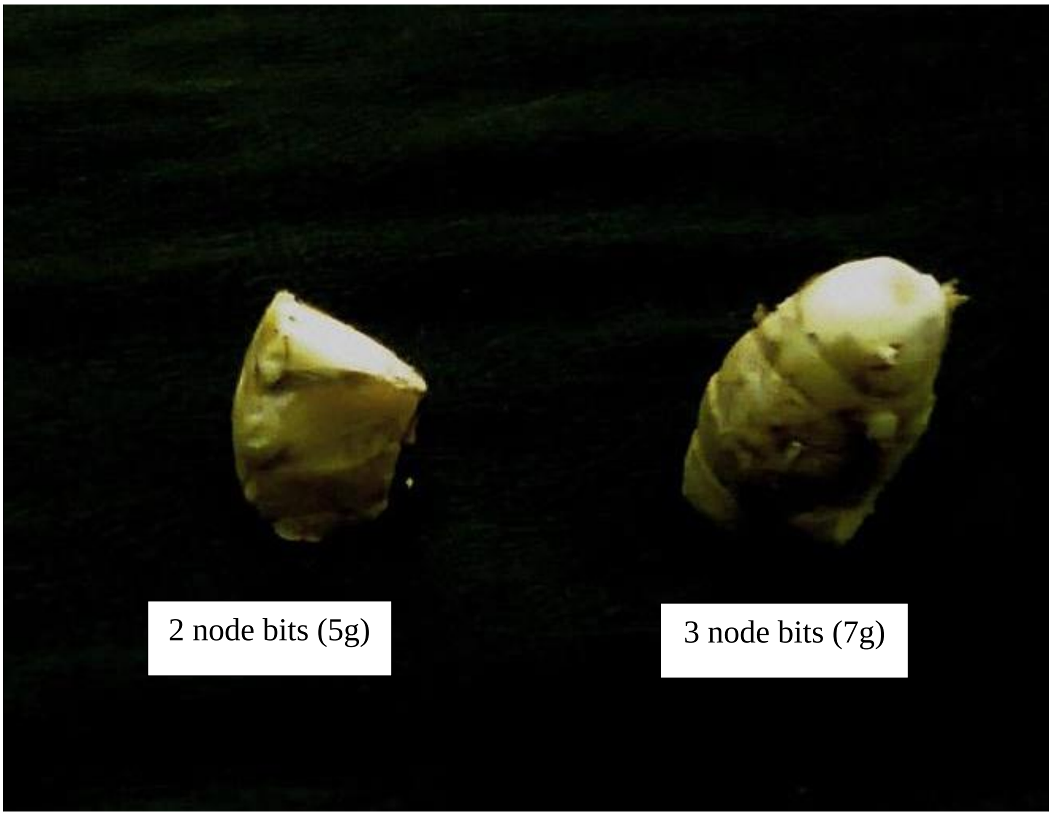


Plate.1. Rhizome bits with different sizes prepared from primary fingers of *Curcuma aromatica* Salisb.

bits were subjected to different pretreatments with chemicals/growth regulators to find out better sprouting treatments. The pre-soaked rhizome bitswere kept in air tight gunny bags for a week in a protected space for sprouting. Number of rhizome bits sprouted were recorded daily for a period of one week. Best treatment was selected based on the sprouting percentage.

3.3.1.1. Minisett size

S1: Rhizome bit with two nodes

S2: Rhizome bit with three nodes

3.3.1.2. Pre- sprouting treatments

T1: Soaking rhizome bits in Benzyl adenine 25 ppm for 24 hrs

T2: Soaking rhizome bits in Benzyl adenine 50 ppm for 24 hrs

T3: Soaking rhizome bits in Benzyl adenine 100 ppm for 24 hrs

T4: Soaking rhizome bits in Ethrel 125ppm for 30 mts

T5: Soaking rhizome bits in Ethrel 250ppm for 15 mts

T6: Soaking rhizome bits in 0.2% KNO_3 for 30 mts

T7: Soaking rhizome bits in Urea 5g L^{-1} for 30 mts (farmer's practice)

T8: Control (no presoaking treatment)

Design : CRD

Treatment combinations : 16

Replication : 5

3.3.2. Phase II Standardization of Nursery Technique

3.3.2.1. Standardization of Media

Both two node (S_1) and three node (S_2) sprouted rhizome bits from best pre sprouting treatments were planted separately in pro-trays of 5 cm diameter plug holes filled with coir pith and three different organic manures viz., cowdung, vermicompost and neemcake in 1:1 ratio and *Trichoderma* in 25:1 ratio. The pro-trays were kept in a shade house and irrigated regularly.

Treatments

M_1 –Coir pith + Cowdung + *Trichoderma*

M_2 –Coir pith + Vermicompost + *Trichoderma*

M_3 –Coir pith + Neem cake + *Trichoderma*

Design : Factorial CRD

Treatment combinations : 6

S_1M_1 : 2 Node rhizome bit+ Coir pith + Cowdung + *Trichoderma*

S_1M_2 : 2 Node rhizome bit + Coir pith + Vermicompost + *Trichoderma*

S_1M_3 : 2 Node rhizome bit + Coir pith + Neem cake + *Trichoderma*

S_2M_1 : 3 Node rhizome bit + Coir pith + Cowdung + *Trichoderma*

S_2M_2 : 3 Node rhizome bit + Coir pith +Vermicompost + *Trichoderma*

S_2M_3 : 3 Node rhizome bit + Coir pith +Neemcake + *Trichoderma*

Replication : 5

3.3.2.2. Standardization of Age at Transplanting

To find out the optimum stage at transplanting, seedlings along with the soil plug were transplanted to raised beds in the main field at a spacing of 30 x 30 cm, at 30th, 45th and 60th days after sowing (DAS) in pro-trays. Thereafter the plants were maintained as per package of practice recommendation of KAU. The neem cake media was found to be inferior and the emergence of seedlings in that media was much less and decaying of rhizome bits was noticed at the nursery stage. So it was excluded from further field experiment.

The field experiment was laid out (Fig.1) with the following technical programme:

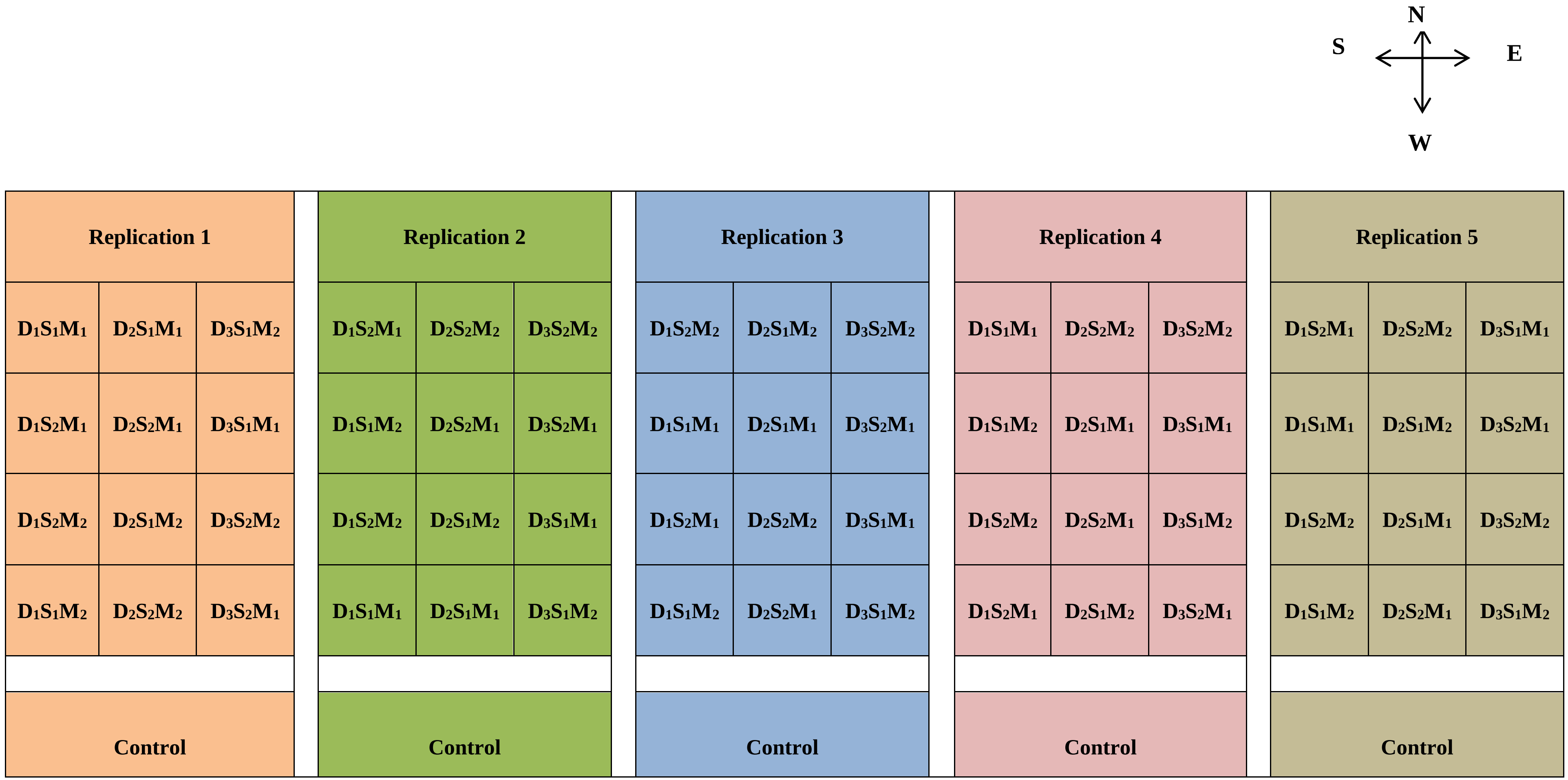
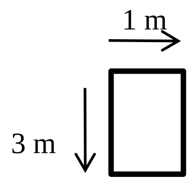


Fig.1. Lay out of the experimental field



Design : 3 x 4 Split plot+1 control

Replication : 5

Plot size : 3 x 1m

No.of plots : 65

Main plot treatments – 3
D_1 : 30 days after

D_2 : 45 days after sowing

D_3 : 60 days after sowing

Sub plot treatments – 5

S_1M_1 : 2 Node rhizome bit + Coir pith + Cowdung + *Trichoderma*

S_1M_2 : 2 Node rhizome bit + Coir pith + Vermicompost + *Trichoderma*

S_2M_1 : 3 Node rhizome bit + Coir pith + Cowdung + *Trichoderma*

S_2M_2 : 3 Node rhizome bit + Coir pith + Vermicompost + *Trichoderma*

Control: Conventional planting (rhizome bits with 15 g size, KAU)

3.4. Location

The field experiments were conducted at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala. The area is situated at 8° 30' North latitude and 76° 54' East longitude at an altitude of 29 m above MSL.

3.5. Soil

The soil of the experimental site is red loam and belongs to Vellayani series which comes under the Order Oxisol.

3.6. Applications of Manures and Fertilizers

Apply FYM or organic manure @ 10-15t $ha^{-1}$and fertilizers @100:50:50 N: P_2O_5: K_2O kg ha^{-1}. Entire P_2O_5 as basal dose and N and K_2O in two equal splits at planting and two months after planting.

3.7 After Cultivation

Hand weeding, earthing up and mulching were done 2 and 4 MAP respectively. The crop was raised as rainfed but with need based lifesaving irrigations.

3.8 Plant Protection

Pest and disease incidence was recorded periodically and timely plant protection measures were taken.

3.9 Harvesting

The crop was harvested when the above ground portions were completely dried up and the rhizome yield were recorded at the time of harvest.

3.10. Observations

Five observational plants per replication were taken from each treatment and the plants were tagged for taking biometric observations at bimonthly intervals starting from second to sixth months after planting. One bed per treatment is maintained for destructive sampling. The yield and yield components were recorded and biochemical analysis were made only during harvest.

3.10.1. Sprouting percentage

The number of rhizome bits sprouted were counted for a period of one week and expressed as percentage.

3.10.2. Growth Characters in the Nursery and in the Main Field.

3.10.2.1. Plant Height

The height of the plants was measured from the base of the main pseudo stem to the tip of the top most leaf and was expressed in cm.

3.10.2.2. Number of Leaves

Number of leaves were determined by counting the number of leaves at weekly interval.

3.10.2.3. Length of Leaves

The maximum length of leaves was measured at weekly interval and the mean length expressed in cm.

3.10.2.4. Breadth of Leaves

The maximum breadth of leaves were measured at weekly interval and the mean length expressed in cm.

3.10.2.5. Number of Tillers

Numbers of tillers were determined by counting the number of aerial shoots arising around a single plant.

3.10.2.6. Number of Roots.

The plants were uprooted from 2 MAP and maximum number of roots was counted and mean length expressed in cm.

3.10.2.7. Root Length

The plants were uprooted with whole rhizome and maximum length of roots were measured and the mean length expressed in cm.

3.10.2.8. Length of Primary Rhizome.

The plants were uprooted with whole rhizome and maximum length of primary rhizome were measured and the mean length expressed in cm.

3.10.2.9. Length of Secondary Rhizome.

The plants were uprooted with whole rhizome and maximum length of secondary rhizome were measured and the mean length expressed in cm.

3.10.2.10. Girth of Primary Rhizome.

Girth of primary rhizome was measured at bimonthly intervals from 2MAP

3.10.2.11. Girth of Secondary Rhizome.

Girth of secondary rhizome was measured at bimonthly intervals from 2MAP

3.10.2.12. Fresh Weight of Rhizome.

The fresh rhizome yield from each treatment was recorded by destructive sampling at bimonthly intervals and expressed in g plant^{-1}

3.10.2.13. Rhizome Spread

The horizontal spread of rhizome was measured at bimonthly intervals from 2MAP and expressed in cm.

3.10.2.14. Dry Weight of Rhizome.

The fresh rhizome was washed, chopped and allowed to dry under sun for three days. It was then kept in hot air oven at 70-80˚C till constant weight obtained and the dry rhizome yield was expressed in g plant^{-1}.

3.10.3. Physiological Characters

3.10.3.1. Net Assimilation Rate (NAR)

Net Assimilation Rate (NAR) was calculated and expressed in g m^{2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)(A_1 + A_2)/2}$$

Where,

W_2- total dry weight of the plant in g at time t_2

W_1- total dry weight of the plant in g at time t_1

$(t_2 - t_1)$ = time interval in days

A_2 = Leaf area (cm^2) at time t_2

A_1 = Leaf area (cm^2) at time t_1

3.10.3.2. Crop Growth Rate

Crop Growth Rate (CGR) was calculated using the formula and expressed as g $m^{-2}day^{-1}$

$$CGR = NAR \times LAI$$

NAR- Net assimilation rate
LAI- Leaf Area Index

3.10.3.3. Leaf area index (LAI)

Leaf area index was calculated at bimonthly intervals from 2 MAP. Five sample plants were randomly selected for each treatment and number of leaves on each plant were counted. Maximum length and width of leaves from all the sample plants were recorded separately and leaf area was calculated based on length and breadth method.

$$LAI = \frac{\text{Sum of leaf area of N sample (cm}^2\text{)}}{\text{Area of land covered by N plants (cm}^2\text{)}}$$

3.10.3.4. Stomatal Count

Stomatal count refers to the number of stomata per unit area of leaf. Stomatal frequency was recorded for both upper and lower surface of three randomly selected leaves from each replication. Leaf imprints were prepared for the purpose using adhesive,"Quick fix ". It was uniformly applied on the surface of leaf and after five minutes the dried membrane was carefully peeled off and mounted on a microscopic slide with a drop of water. The stomata were observed and counted using 40X objective and 10X eyepiece. The field of the microscope was measured using a stage micrometer and the number of stomata per unit area was calculated (Taylor *et al.*, 1997)

3.10.3.5. Bulking Rate

The bulking rate in rhizome was worked out at bimonthly intervals from 2 MAP on the basis of increase in dry weight of rhizome and expressed in g/plant/day.

$$BR = \frac{W_2 - W_1}{T_2 - T_1}$$

W_2- dry weight of rhizome at a time t_2

W_1- dry weight of rhizome at a time t_1

3.10.3.6. Harvest index (HI)

Harvest index was calculated during harvest as the ratio of dry weight of rhizome to the dry weight of whole plant.

$$HI = \frac{Y\ econ}{Y\ biol}$$

Where, Y econ - total dry weight of rhizome

Y biol - total dry weight of plant

3.10.4. Yield and Yield Components

3.10.4.1. Rhizome Yield Plot^{-1} - Fresh

The fresh rhizome yield of observational plants from each treatment was recorded at the time of harvest and the mean expressed in g plot^{-1}.

3.10.4.2. Rhizome Yield Plot^{-1} – Dry

The fresh rhizomes were washed, chopped and allowed to dry under sun for three days. It was then kept in hot air oven at 70°C till constant weight was obtained and the dry rhizome yield was expressed in g plot^{-1}.

3.10.5. Biochemical Characters

Biochemical analysis was done at the time of harvest.

3.10.5.1. Volatile Oil

Coarsely ground powder of dried rhizome was used for estimating volatile oil. The method adopted was hydro distillation using Clevenger distillation apparatus for three hours. The oil content was expressed in percentage (V/W) on dry weight basis.

3.10.5.2. Non Volatile Ether Extract

Non-volatile ether extract (NVEE) was estimated according to AOAC (1973) and expressed as percentage on dry weight basis.

3.10.5.3. Oleoresin

Finely ground powder of dried rhizome was used for estimating oleoresin. The method adopted was solvent extraction using Soxhelt apparatus for 1 hour. The content was expressed in percentage (V/W) on dry weight basis.

3.11. Incidence of Pest and Disease

Incidence of pests and diseases were noted at regular intervals and timely control measures were taken.

3.12. Economics of Cultivation / B: C ratio

The economics of cultivation was worked out after taking into account the cost of cultivation and prevailing market price of kasthuri turmeric. For calculating the cost, the different variable cost items like planting materials, manures, plant protection items, irrigation, labour charges etc. were considered at existing market rate during 2014-2015.

The net income was calculated as follows:

Net income (Rs ha^{-1}) = Gross income – Cost of cultivation.

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.13. Statistical Analysis

Data generated from the experiment were subjected to statistical analysis applying ANOVA technique and significance tested by ‘F’ test (Snedecor and Cochran, 1975). In the case where the effects were found to be significant, CD was calculated using standard techniques.

RESULTS

4. RESULTS

The study entitled, "Rapid multiplication of kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2013-2015. The data collected from the field experiment were statistically analysed and the results are presented in this chapter.

4.1. SPROUTING PERCENTAGE

The data recorded 1 week after pre-treatment of rhizome bits (Table.1) suggest that both the size of rhizome bits used as well as the pre-treatments given significantly influenced sprouting.

Rhizome bits with 3 node showed better sprouting (72.52 %) than 2 node bits (64.12 %). Among the pre-treatments, soaking 3 node rhizome bits in benzyl adenine 100 ppm (T_3S_2) recorded the highest sprouting (95.60 %) followed by benzyl adenine 50 ppm (T_2S_2, 91.20 %) and benzyl adenine 25 ppm (T_1S_2, 88.60 %) and was significantly superior to all the other treatments (Plate.2). Treatments with Urea 5g per litre (T_7S_2, 79.00 %), Ethrel 125 ppm (T_4S_2, 61.80 %) and 250 ppm (T_5S_2, 51.20 %) were also found to be significant. The pre-treatment using 0.2% KNO_3 (T_7S_2, 45.80 %) gave the lowest sprouting which was on par with control (no pre-soaking treatment) (T_8S_2, 54.00 %).

In the case of 2 node bits, soaking rhizome bits in benzyl adenine 100 ppm (T_3S_1) recorded the highest sprouting (89.20 %) followed by benzyl adenine 50 ppm (T_2S_1, 84.80 %) and benzyl adenine 25 ppm (T_1S_1, 79.80 %). Treatments with Urea 5g per litre (T_7S_2, 67.80 %), Ethrel 125 ppm (T_4S_2, 50.00 %) and 250 ppm (T_5S_2, 53.60 %) were also found to be significant. The pre-treatment using 0.2% KNO_3 (T_7S_1, 40.40 %) gave the lowest sprouting.

The data revealed that size of the rhizome bits as well as pre-treatment with growth regulators/ chemicals significantly enhances sprouting of rhizome bits.

Table.1. Effect of pre-treatments and rhizome bit size on sprouting percentage.

Treatment	Sprouting percentage	
	S_1	S_2
T_1(BA 25 ppm for 24 hrs)	79.80 (8.93)	88.60 (9.41)
T_2(BA 50ppm for 24 hrs)	84.80 (9.20)	91.20 (9.54)
T_3(BA 100 ppm for 24 hrs)	89.20 (9.44)	95.60 (9.77)
T_4(Ethrel 125 ppm for 30 mts)	50.00 (7.07)	61.80 (7.86)
T_5(Ethrel 250 ppm for 15 mts)	51.20 (7.15)	53.60 (7.31)
T_6(0.2% KNO_3 for 30 mts)	40.40 (6.35)	45.80 (7.66)
T_7(Urea 5 g L^{-1} for 30 mts)	67.80 (8.23)	79.00 (8.88)
T_8(No pre-soaking treatment)	47.40 (6.88)	54.00 (7.34)
Mean size	64.12 (7.93)	72.52 (8.93)
CD (0.05)	1.657	

(Figures in parentheses denote transformed values)

a. BA 100 ppm for 24 hrs

b. BA 50 ppm for 24 hrs

c. BA 25 ppm for 24 hrs

Plate 2. Sprouted rhizome bits of *Curcuma aromatica* Salisb after pre-treatments

4.2. STANDARDIZATION OF MEDIA

Perusal of the data revealed that morphological characters like plant height, number, length and breadth of leaves, number, length and girth of roots were found to be influenced by the different media combination as well as the size of the rhizome bits. The growth parameters recorded in various treatments differed according to the nursery mixture used with the best in the treatment M_2 (Vermicompost + Coirpith + *Trichoderma*) compared to M_1 (Cowdung + Coirpith + *Trichoderma*) media combination (Plate.3 and 4).

The neem cake media was found to be inferior and the emergence of seedlings in that media was much less and decaying of rhizome bits was noticed. Different concentration of neem cake was also tried but the result was the same. The initial inhibition of nitrification process might be the reason for poor establishment of seedlings in that media. So it was excluded from further field experiment.

4.2.1. Morphological Characters of the Seedlings

4.2.1.1. Seedling Height (cm)

As observed in Table. 2, the size of the rhizome bits as well as the media combination significantly influenced height as observed by the steady increase in seedling height throughout the observational period.

Among the rhizome bits used, S_2 (3 node bit) recorded the highest seedling height compared to S_1 (2node bit) in all the 8^{th} week of observation starting from 4.92 cm in the first week to 26.89 cm in the eight week. Among the media combination, M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded higher seedling height starting from 4.00 cm at first week to 25.52 cm at the eight week and was significantly different from M_1(Cowdung + Coirpith + *Trichoderma*) combination which recorded the lowest seedling height (4.00 cm to 25.33 cm) during the observational period.

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coirpith + *Trichoderma*)

3 A. Pro-trays with nursery mixtures

3 B. Germination of sprouted bits

Plate.3. Germinating rhizome bits in media combination

Plate 4. Experimental view of *Curcuma aromatica* Salisb seedlings in pro-trays

Table.2. Effect of media and rhizome bit size on seedling height (cm) in *Curcuma aromatica* Salisb.

Treatments	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Rhizome size								
S_1	3.09	6.83	10.15	13.20	15.38	18.68	20.85	23.96
S_2	4.92	9.14	11.66	15.19	18.33	20.95	23.79	26.89
Media								
M_1	4.00	7.84	10.75	14.16	16.81	19.72	22.22	25.33
M_2	4.00	8.13	11.06	14.22	16.89	19.91	22.41	25.52
Interaction effects								
s_1m_1	3.15	6.75	10.16	13.16	15.40	18.61	20.81	23.96
s_1m_2	3.02	6.91	10.13	13.23	15.36	18.75	20.88	23.97
s_2m_1	4.86	8.93	11.33	15.17	18.22	20.83	23.63	26.71
s_2m_2	4.98	9.34	11.99	15.21	18.43	21.07	23.94	27.08
CD (0.05)								
Rhizome size(S)	0.106	0.203	0.156	0.059	0.106	0.164	0.175	0.147
Media(M)	0.106	0.203	0.156	0.059	0.106	0.164	0.175	0.147
sxm	0.167	0.296	0.174	0.102	0.138	0.326	0.238	0.220

media (s_2m_2) recorded maximum seedling height and it ranges from 4.98 cm in the first week to 27.08 cm in the eight week and was on par with s_2m_1 at first, fourth and sixth WAP. Seedlings of 2 node rhizome bits planted in M_2 (Vermicompost + Coirpith + *Trichoderma*) media (s_1m_2) recorded the lowest seedling height (3.02 cm to 23.97 cm) during the observational period and it was on par with 2 node rhizome bits planted in M_1 (Cowdung + Coirpith + *Trichoderma*) (s_1m_1) (3.15 cm to 23.96 cm).

4.2.1.2. Number of Leaves

Table.3.shows the influence of rhizome size and media on number of leaves in the nursery. Unfurling of leaves was noticed only from 2nd WAP

Among the rhizome bits used, S_2 (3 node bit) recorded the maximum number of leaves (1.24 to 2.94) compared to S_1 (1.04 to 2.78) starting from second to eight week of observation. Among the media combination, M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded more number of leaves starting from 1.22 at first week to 2.48 at the 7th week and was on par with M_1 (Cowdung + Coirpith + *Trichoderma*) media combination 4th week onwards. After 7th week there was no significant difference among the number of leaves in both the media.

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum number of leaves and it ranges from 1.36 in the first week to 2.96 in the eight week and was on par with 3 node rhizome bits planted in M_1 media (s_2m_1) at 3rd , 4th ,5th and 7th WAP. Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_2) recorded the lowest number (1.04 to 2.74) during the observational period and it was on par with seedlings from 2 node rhizome bits planted in M_1 media (s_1m_1) (1.00 to 2.80).

4.2.1.3. Length of Leaves (cm)

The influence of rhizome size and media on leaf length became significant 3 WAP only as observed in Table. 4. Among the rhizome bits used, S_2 (3 node

Table.3. Effect of media and rhizome bit size on number of leaves in *Curcuma aromatica* Salisb. seedlings.

Treatments	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Rhizome size							
S_1	1.04	1.28	1.37	1.70	2.18	2.16	2.78
S_2	1.24	1.48	1.60	2.04	2.58	2.74	2.94
Media							
M_1	1.06	1.28	1.44	1.86	2.26	2.42	2.86
M_2	1.22	1.48	1.53	1.88	2.50	2.48	2.86
Interaction effects							
s_1m_1	1.00	1.20	1.36	1.68	2.04	2.20	2.80
s_1m_2	1.04	1.36	1.38	1.72	2.32	2.12	2.76
s_2m_1	1.12	1.36	1.52	2.04	2.48	2.64	2.92
s_2m_2	1.36	1.60	1.68	2.04	2.68	2.84	2.96
CD (0.05)							
Rhizome size (S)	0.006	0.150	0.114	0.106	0.159	0.129	0.118
Media(M)	0.006	0.150	0.114	0.106	0.159	0.129	0.118
sxm	0.148	0.242	0.212	0.212	0.166	0.259	0.161

Table. 4. Effect of media and rhizome bit size on length of leaves (cm) in *Curcuma aromatica* Salisb. seedlings

Treatments	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Rhizome size							
S_1	3.55	4.88	5.75	6.26	7.17	8.68	10.80
S_2	4.26	5.01	5.72	6.54	7.15	9.10	11.23
Media							
M_1	3.85	5.03	5.81	6.38	7.21	8.88	11.07
M_2	3.96	4.86	5.66	6.42	7.11	8.9	10.96
Interaction effects							
S_1M_1	3.52	4.58	5.36	5.90	6.80	8.02	10.46
S_1M_2	3.58	4.88	5.48	6.14	6.88	8.42	11.00
S_2M_1	4.18	5.14	5.96	6.62	7.42	9.34	11.14
S_2M_2	4.34	5.18	6.14	6.94	7.54	9.78	11.46
CD (0.05)							
Rhizome size (S)	0.499	0.223	0.170	0.247	0.254	0.286	0.344
Media (M)	NS	0.417	0.410	0.389	0.374	0.494	0.161
s x m	0.499	0.223	0.170	0.247	0.254	0.286	0.344

bit) recorded the maximum length of leaves and it ranges from 4.26 cm to 11.23 cm from first week to eight week which was significantly superior than S_1 (2 node bit) in all the eight weeks of observation.

Among the media combination, there was no significant difference regarding the length of leaves in both the media, eventhough M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded the highest leaf length starting from 3.96 cm in the first week to 10.96 cm in the 8^{th} week. M_1 (Cowdung + Coirpith + *Trichoderma*) combination which recorded the lowest length (3.85 cm to 10.07 cm) during the observational period.

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum length of leaves and it ranges from 4.34 cm in the first week to 11.46 cm in the eight week which was on par with seedlings of 3 node rhizome bits planted in M_1 media (s_2m_1). Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_1) recorded the lowest length (3.52 cm to 10.46 cm) during the observational period and it was on par with 2 node rhizome bits planted in M_2 media (s_1m_2) (3.58 cm to 11.00 cm).

4.2.1.4. Breadth of Leaves (cm)

The data (Table.5) revealed that breadth of leaves was not influenced by the size of rhizome bits as well as the media combination used. However among the rhizome size, S_2 (3 node bit) recorded maximum breadth (1.95 cm to 6.07 cm) and among the media M_2 (Vermicompost + Coirpith + *Trichoderma*) shows maximum value of 1.77 cm to 6.13 cm.

The interaction effect was found to be significant only at 4^{th} and 5^{th} WAP. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum breadth of leaves during 4^{th} and 5^{th} WAP (3.74 cm and 4.34 cm) which was on par with seedlings of 3 node rhizome bits planted in M_1 media (s_2m_1) (3.54 and 4.12). Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_1) recorded the lowest breadth of leaves in all the stages of observation.

Table. 5. Effect of media and rhizome bit size on breadth of leaves (cm) in *Curcuma aromatica* Salisb. Seedlings

Treatments	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Rhizome size							
S_1	1.72	2.97	3.37	4.05	4.69	5.25	6.05
S_2	1.95	3.07	3.64	4.23	4.74	5.27	6.07
Media							
M_1	1.9	2.96	3.45	4.09	4.65	5.24	5.99
M_2	1.77	3.08	3.56	4.19	4.78	5.28	6.13
Interaction effects							
S_1M_1	1.90	2.92	3.36	4.06	4.62	5.22	5.94
S_1M_2	1.54	3.02	3.38	4.04	4.68	5.26	6.04
S_2M_1	1.90	3.00	3.54	4.12	4.76	5.28	6.06
S_2M_2	2.00	3.14	3.74	4.34	4.80	5.28	6.20
CD (0.05)							
Rhizome size (S)	0.385	0.182	0.167	0.129	0.147	0.114	0.147
Media (M)	0.385	0.182	0.167	0.129	0.147	0.114	0.147
s x m	NS	NS	0.267	0.198	NS	NS	NS

4.2.1.5. Number of Roots

The influence of rhizome size and media on number of roots became significant 4 WAP as observed in Table.6.

Among the rhizome bits used, S_2 (3 node bit) recorded the maximum number of roots and it ranges from 3.1 to 7.81 from first week to eight week which was significantly superior to S_1 (2 node bit) and it recorded a value of 2.8 to 6.9 during the observational period.

Among the media combination, M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded maximum number of roots starting from 3.00 in the 2^{nd} week to 7.5 in the 8^{th} week. M_1 (Cowdung + Coirpith + *Trichoderma*) combination which recorded the lowest number (2.9 to 7.21) during the observational period

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum number of roots and it ranges from 3.4 in the 2^{nd} week to 8.00 in the 8^{th} week which was significantly different from all the other treatments. Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_1) recorded the lowest number of roots (3.00 to 6.80) during the observational period (Plate.5A)

4.2.1.6. Length of roots (cm)

As observed in Table.7, the size of the rhizome bits as well as the media combination significantly influenced length of roots throughout the observational period.

Among the rhizome bits used, S_2 (3 node bit) recorded the maximum length of roots and it ranges from 2.01 cm to 7.4 cm from 2^{nd} week to 8^{th} week which was significantly superior than S_1 (2 node bit) and it recorded a value of 1.58 cm to 7.09 cm during the observational period.

Among the media combination, M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded maximum length of roots starting from 1.86 in the 2^{nd} week to 7.34 cm in the 8^{th} week. M_1 (Cowdung + Coirpith + *Trichoderma*)

Table. 6. Effect of media and rhizome bit size on no. of roots in *Curcuma aromatica* Salisb.seedlings

Treatments	2nd week	4th week	6th week	8th week
Rhizome size				
S_1	2.8	5.56	6.39	6.9
S_2	3.1	6.45	7.25	7.81
Media				
M_1	2.9	5.75	6.56	7.21
M_2	3	6.26	7.08	7.5
Interaction effects				
s_1m_1	3.00	5.40	6.40	6.80
s_1m_2	2.60	5.720	6.56	6.96
s_2m_1	2.80	6.10	6.90	7.62
s_2m_2	3.40	6.80	7.62	8.00
CD (0.05)				
Rhizome size (S)	0.509	0.321	0.231	0.006
Media (M)	0.509	0.321	0.231	0.006
sxm	NS	0.267	0.343	0.120

Table. 7. Effect of media and rhizome bit size on length of roots (cm) in *Curcuma aromatica* Salisb. seedlings

Treatments	2nd week	4th week	6th week	8th week
Rhizome size				
S_1	1.58	2.8	4.26	7.09
S_2	2.01	3.04	4.9	7.4
Media				
M_1	1.73	2.85	4.54	7.15
M_2	1.86	2.99	4.62	7.34
Interaction effects				
s_1m_1	1.48	2.74	4.18	7.04
s_1m_2	1.68	2.86	4.34	7.14
s_2m_1	1.98	2.96	4.90	7.26
s_2m_2	2.04	3.12	4.90	7.54
CD (0.05)				
Rhizome size (S)	0.184	0.135	0.244	0.223
Media (M)	0.184	0.135	0.244	0.223
sxm	0.255	0.216	0.361	0.315

Combination which recorded the lowest number (1.73 cm to 7.15 cm) during the observational period.

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum length of roots (2.04 cm to 7.54 cm) and was on par with seedlings from 3 node rhizome bits planted in M_1 media (s_2m_1) (1.98 cm to 7.26 cm). Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_1) recorded the lowest length of roots (1.48 cm to 7.04 cm) during the observational period.

4.2.1.7. Girth of Roots

As observed in Table. 8, the size of the rhizome bits as well as the media combination significantly influenced girth of roots throughout the observational period.

Among the rhizome bits used, S_2 (3 node bit) recorded the maximum girth of roots and it ranges from 0.022 cm to 0.39 cm from 2nd week to 8th week which was significantly superior than S_1 (2 node bit) and it recorded a value of 0.012 cm to 0.351 cm during the observational period.

Among the media combination, M_2 (Vermicompost + Coirpith + *Trichoderma*) recorded maximum girth of roots starting from 0.019 cm in the 2nd week to 0.381 cm in the 8th week. M_1 (Cowdung + Coirpith + *Trichoderma*) combination which recorded the lowest girth (0.015 cm to 0.36 cm) during the observational period.

The interaction effect was also found to be significant. Seedlings of 3 node rhizome bits planted in M_2 media (s_2m_2) recorded maximum girth (0.026 cm to 0.318 cm) and was on par with seedlings of 3 node rhizome bits planted in M_1 media (s_2m_1) (0.018 cm to 0.296 cm). Seedlings of 2 node rhizome bits planted in M_1 media (s_1m_1) recorded the lowest value (0.012 cm to 0.302 cm) during the observational period.

Table. 8. Effect of media and rhizome bit size on girth of roots (cm) in *Curcuma aromatica* Salisb. seedlings

Treatments	2^{nd} week	4^{th} week	6^{th} week	8^{th} week
Rhizome size				
S_1	0.012	0.218	0.318	0.351
S_2	0.022	0.267	0.358	0.39
Media				
M_1	0.015	0.24	0.328	0.36
M_2	0.019	0.245	0.348	0.381
Interaction effects				
S_1M_1	0.012	0.120	0.220	0.302
S_1M_2	0.012	0.140	0.216	0.304
S_2M_1	0.018	0.206	0.260	0.296
S_2M_2	0.026	0.224	0.274	0.318
CD (0.05)				
Rhizome size(S)	0.009	0.026	0.016	0.012
Media (M)	0.011	0.022	0.019	0.024
s x m	0.009	0.026	0.016	0.012

4.3. STANDARDIZATION OF AGE AT TRANSPLANTING

Result of the experiment showed that the variation in transplanting age (Plate.5B and 6) and type of minisett seedlings had significant effect on morphological characters, physiological parameters and ultimately yield in kasthuri turmeric compared to conventional method of rhizome planting.

4.3.1. Morphological Characters in the Mainfield

4.3.1.1. Plant Height (cm)

Average height of the plant recorded at 2, 4 and 6 MAP is presented in the Table. 9.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the plant height at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest plant height followed by 45 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly superior plant height. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum plant height was associated with seedlings transplanted at 60 DAS (D_3) (49.09) and was significantly superior to all the other age at transplanting followed by seedlings transplanted at 45 DAS (D_2) (47.22) and seedlings transplanted at 30 DAS (D_1) (40.54). Among the type of seedlings, seedlings from 3 node rhizome bit planted in M_2 media (S_2M_2) (48.35) recorded the highest plant height which was on par with seedlings from 3 node rhizome bit planted in M_1 media (S_2M_1) (46.03) and control (48.20). Seedlings from 2 node rhizome bit planted in M_1 media (S_1M_1) (42.98) recorded the lowest plant height.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (50.44) was found to be best and was on par with seedlings of 3

Plate.5A. Root growth comparison

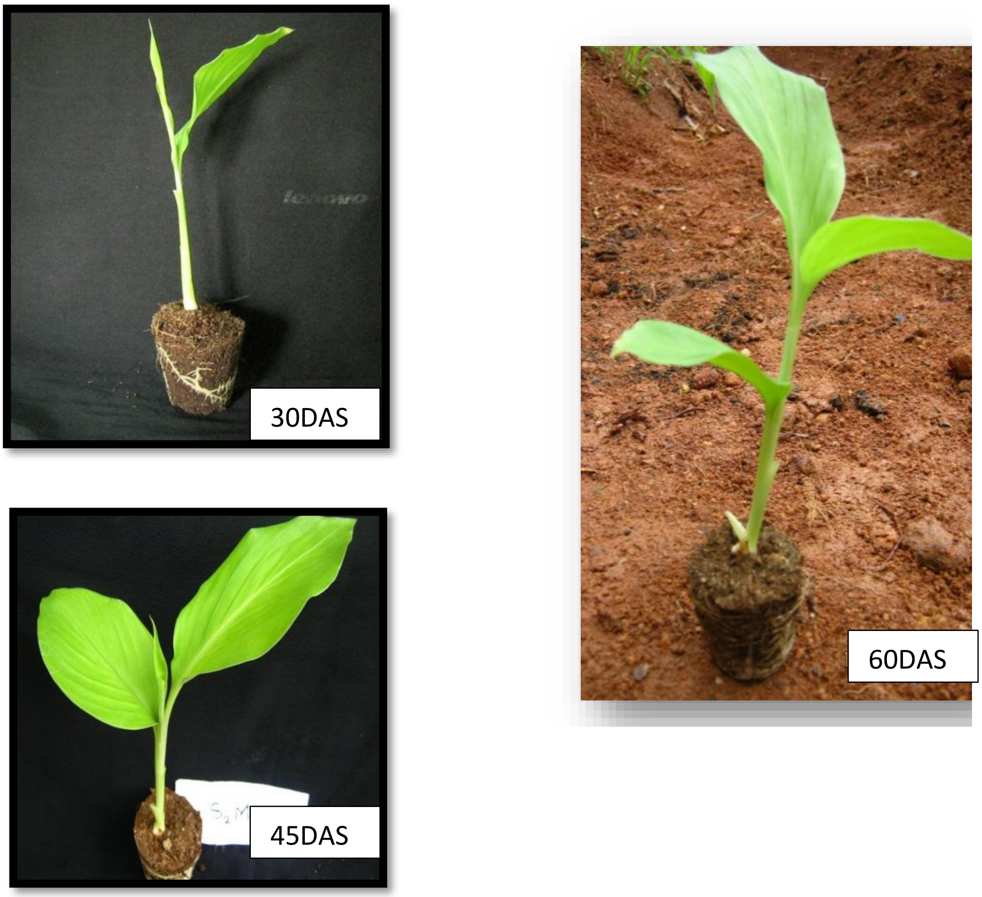


Plate. 5 B. Seedlings of different transplanting age

Plate. 5. Root growth comparison of seedlings in different media and seedlings of different ages.

Plate.6. General Field view

Table.9. Effect of age at transplanting and type of minisett seedlings on plant height (cm) in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	40.24	43.00	45.70	42.98	45.70	107.22	108.98	87.63	80.32	110.29	124.48	105.03
S_1M_2	35.70	49.52	50.10	45.10	94.88	104.46	110.50	103.28	95.32	105.04	119.36	106.57
S_2M_1	41.88	46.10	50.12	46.03	101.6	114.20	119.08	111.62	102.16	116.80	128.90	115.95
S_2M_2	44.36	50.26	50.44	48.35	101.8	109.90	118.80	110.19	107.34	118.86	132.38	119.52
Age at transplanting mean.	40.54	47.22	49.09		85.99	108.94	114.34		96.28	112.74	126.28	
Control(C)	48.20				106.58				118.19			
	SE	CD(0.05)			SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.915	2.983			0.701	2.286			1.203	3.922		
Minisett seedling (T)	0.864	2.469			0.789	2.255			0.895	2.559		
(D) x (T)	1.496	4.277			1.366	3.905			1.551	4.432		
T *Vs* C	S				S				S			

node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (50.12) and seedlings of 2 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_1m_2$) (50.10). The lowest plant height was recorded by seedlings of 2 node bit planted in M_2 media and transplanted at 30 DAS ($d_1s_1m_2$) (35.70).

At 4 MAP, the maximum plant height was associated with seedlings transplanted at 60 DAS (D_3) (114.34) and was significantly superior to all the other age at transplanting and was followed by seedlings transplanted at 45 DAS (D_2) (108.94) and seedlings transplanted at 30 DAS (D_1) (85.99). Among the type of seedlings, seedlings of 3 node bit planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (111.62) recorded the highest plant height which was on par with seedlings of 3 node bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (110.19) and significantly superior than control (87.63). Seedlings of 3 node bit planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (42.98) recorded the lowest plant height.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (119.08) was found to be best and was on par with seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (118.80) . The lowest plant height was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (45.70).

At 6MAP, the maximum plant height was associated with seedlings transplanted at 60 DAS (D_3) (126.28) and was significantly superior to all the other age at transplanting and was followed by seedlings transplanted at 45 DAS (D_2) (112.74) and seedlings transplanted at 30 DAS (D_1) (96.28). Among the type of seedlings, seedlings of 3 node bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (119.52) recorded the highest plant height which was on par with Control (118.19) and significantly superior to seedlings of 3 node bit planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1)

(115.95). Seedlings of 2 node bit planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (105.03) recorded the lowest plant height.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (132.38) was found to be best and was on par with seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (128.90). The lowest plant height was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (80.32). The comparison of type of minisett seedlings and control (plants from rhizomes of 15g size) was also found to be significant.

4.3.1.2. Number of Leaves

Average number of leaves of the plant recorded at 2, 4 and 6 MAP is presented in the Table. 10.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the number of leaves at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS (D_3) recorded the highest number of leaves followed by 45 (D_2) and 30 DAS (D_1). Among the type of seedlings, seedlings from 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly more number of leaves. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum number of leaves was associated with seedlings transplanted at 60 DAS (D_3) (7.05) and was on par with seedlings transplanted at 45 DAS (D_2) (7.04) and significantly different from seedlings transplanted at 30 DAS (D_1) (6.49). Among the type of seedlings, seedlings from 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (7.10) recorded the highest number of leaves which was on par with seedlings of 3 node rhizome bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1)

Table.10. Effect of age at transplanting and type of minisett seedlings on number of leaves in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	6.58	6.58	6.92	6.69	6.48	10.88	11.46	9.60	9.32	11.14	11.02	10.49
S_1M_2	6.12	7.10	7.00	6.74	7.12	11.56	11.52	10.06	9.18	11.56	11.50	10.74
S_2M_1	6.48	7.16	7.08	6.90	7.16	12.02	11.92	10.36	9.22	12.06	11.92	11.06
S_2M_2	6.78	7.34	7.20	7.10	7.64	11.60	11.72	10.32	9.38	11.68	12.12	11.06
Age at transplanting mean.	6.49	7.04	7.05		7.10	11.51	11.65		9.27	11.61	11.55	
Control(C)	6.94				10.02				11.04			
	SE	CD(0.05)			SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.099	0.322			0.085	0.276			0.064	0.207		
Minisett seedling (T)	0.095	0.271			0.124	0.354			0.089	0.254		
(D) x (T)	0.164	0.469			0.215	0.614			0.148	0.441		
T *Vs* C	S				S				S			

(6.90) and significantly different from control (6.94). Seedlings of 2 node rhizome bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (6.69) recorded the lowest number of leaves.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bits planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (7.34) was recorded the highest value and was on par with $d_3s_2m_2$ (7.20), $d_3s_2m_1$ (7.08), $d_3s_1m_2$ (7.00), $d_2s_2m_1$ (7.16) and $d_2s_1m_2$ (7.10). The lowest number was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (6.12).

At 4 MAP, the maximum number of leaves was associated with seedlings transplanted at 60 DAS (D_3) (11.65) which was on par with seedlings transplanted at 45 DAS (D_2) (11.51) and significantly superior to seedlings transplanted at 30DAS (D_1) (7.10). Among the type of seedlings, seedlings of 3 node rhizome bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (10.36) recorded the highest number of leaves which was on par with all the other seedlings except the seedlings of 2 node rhizome bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (9.60) which shows the lowest number of leaves.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted both in M_1 ($d_3s_2m_1$) (11.92) and M_2 media ($d_3s_2m_2$) (11.72) transplanted at 60 DAS was found to be on par. The lowest number was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_1$) (6.48).

At 6 MAP, the maximum number of leaves was associated with seedlings transplanted at 45 DAS (D_2) (11.61) which was on par with seedlings transplanted at 60 DAS (D_3) (11.55) and significantly superior to seedlings transplanted at 30 DAS (D_1) (9.27). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (11.06) recorded the maximum number of leaves which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (11.06) and Control (11.04). Seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (10.49) recorded the lowest number of leaves.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted both in M_1 media ($d_3s_2m_1$) (11.92) and M_2 media ($d_3s_2m_2$) (12.12) transplanted at 60 DAS was found to be on par. The lowest number was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (9.18). The comparison of type of minisett seedlings and control (plants from rhizomes of 15g size) was also found to be significant.

4.3.1.3. Number of Tillers

Average number of tillers per plant recorded at 2, 4 and 6 MAP is presented in the Table. 11.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the number of tillers at all growth stages. Control (plants from 15 g rhizome piece) recorded the maximum number of tillers in all the 3 stages of observation and its value was 0.54, 0.63 and 0.65 at 2, 4 and 6 MAP respectively. There was no significant difference among the seedlings which are transplanted at 45 and 60 DAS but differed significantly from seedlings which are transplanted at 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly more number of tillers. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) was the least in all the stages.

At 2 MAP, the maximum tiller production was associated with seedlings transplanted at 45 DAS (D_2) (0.37) which was on par with seedlings transplanted at 60 DAS (D_3) (0.33) and significantly superior to seedlings transplanted at 30 DAS (D_1) (0.28). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.38) recorded the

Table.11. Effect of age at transplanting and type of minisett seedlings on number of tillers in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	0.18	0.34	0.28	0.26	0.24	0.36	0.34	0.31	0.38	0.40	0.38	0.38
S_1M_2	0.40	0.32	0.26	0.32	0.26	0.34	0.36	0.32	0.38	0.37	0.38	0.37
S_2M_1	0.30	0.38	0.36	0.34	0.36	0.36	0.44	0.38	0.41	0.44	0.48	0.44
S_2M_2	0.26	0.46	0.44	0.38	0.38	0.46	0.52	0.45	0.44	0.54	0.56	0.51
Age at transplanting mean.	0.28	0.37	0.33		0.31	0.38	0.41		0.40	0.43	0.45	
Control(C)	0.54				0.63				0.65			
	SE	CD(0.05)			SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.020	0.064			0.011	0.037			0.015	0.050		
Minisett seedling (T)	0.030	0.085			0.015	0.042			0.012	0.034		
(D) x (T)	0.051	0.147			0.026	0.074			0.021	0.060		
T Vs C	S				S				S			

maximum number of tillers which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.34) and seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (0.32). Seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.28) recorded the lowest number of tillers.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (0.46) was recorded the highest value which was on par with seedlings of 3 node bit planted in M_1 media transplanted at 45 DAS ($d_2s_2m_1$) (0.38) and seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (0.36). The lowest number was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_1$) (0.18).

At 4 MAP, there was no significant difference among tiller production with respect to seedlings transplanted at 45 DAS (D_3) (0.38) and seedlings transplanted at 60 DAS (D_2) (0.41) but significantly superior to seedlings transplanted at 30 DAS (D_1) (0.31). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.45) recorded the maximum number of tillers which was significantly superior to all the treatments followed by seedlings of 3 node bit planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.38). The seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) recorded the lowest number (S_1M_1) (0.31) which was on par with seedlings from 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (0.32).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.52) recorded the highest value which was on par with $d_2s_2m_1$ (0.44) and seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS

($d_2s_2m_2$) (0.46). The lowest number was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_1$) (0.24).

At 6 MAP, there was no significant difference among tiller production with respect to seedlings transplanted at 45 DAS (D_3) (0.43) and seedlings transplanted at 60DAS (D_2) (0.45) but significantly superior to seedlings transplanted at 30DAS (D_1) (0.40). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.51) recorded the maximum number of tillers which was significantly superior to all the treatments followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.44). There was no significant difference among the seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.38) and M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (0.37) which was on par with each other.

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.56) recorded the highest value which was on par with seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (0.54).

4.3.1.4. Number of Roots

Average number of roots recorded at 2, 4 and 6 MAP is presented in the Table.12.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the number of roots at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest number of roots followed by 45 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly more number of roots. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) was the least in all the stages.

Table.12. Effect of age at transplanting and type of minisett seedlings on number of roots in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	5.40	7.46	7.90	6.92	10.38	16.52	16.72	14.54	11.09	17.06	17.32	15.16
S_1M_2	6.34	7.90	8.42	7.55	14.20	15.66	15.62	15.16	15.41	17.15	17.12	16.56
S_2M_1	7.00	8.46	9.14	8.20	19.90	22.70	21.60	21.40	20.76	22.96	24.20	22.64
S_2M_2	7.42	8.62	9.32	8.45	21.94	26.10	26.08	24.70	22.44	24.08	23.88	23.46
Age at transplanting mean.	6.54	8.11	8.69		16.60	20.24	20.00		17.43	20.31	20.63	
Control(C)	7.69				19.36				20.52			
	SE	CD(0.05)			SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.121	0.393			0.258	0.842			0.202	0.659		
Minisett seedling (T)	0.124	0.354			0.264	0.755			0.208	0.596		
(D) x (T)	0.215	0.613			0.458	1.308			0.361	1.032		
T *Vs* C	S				S				S			

At 2 MAP, the maximum number of roots was associated with seedlings transplanted at 60 DAS (D_3) (8.69) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (8.11) and seedlings transplanted at 30 DAS (D_1) (6.54). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (8.45) recorded the maximum number of roots which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (8.20). The lowest number of roots was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (6.92).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS($d_3s_2m_2$) (9.32) was recorded the highest value which was on par with seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (9.14). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (5.40).

At 4MAP, the maximum number of roots was associated with seedlings transplanted at 45DAS (D_2) (20.24) which was on par with seedlings transplanted at 60 DAS (D_3) (20.00) and significantly superior to seedlings transplanted at 30 DAS (D_1) (16.60). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (24.70) recorded the maximum number of roots which was significantly superior to all the other type of seedlings including control plants (19.36) and was followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (21.40). The lowest number of roots was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (14.54).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (26.10) was recorded the highest value which was on par with seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$)

(26.08). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (10.38).

At 6MAP, the maximum number of roots was associated with seedlings transplanted at 60 DAS (D_3) (20.63) which was on par with seedlings transplanted at 45 DAS (D_2) (20.31) and significantly superior to seedlings transplanted at 30 DAS (D_1) (17.43). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (23.46) recorded the maximum number of roots which was significantly superior to all the other type of seedlings including control plants (20.52) and was followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (22.64). The lowest number of roots was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (15.16).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_2s_2m_1$) (24.20) was recorded the highest value which was on par with 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (23.88). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (11.09). The comparison of seedlings and control was also found to be significant.

4.3.1.5. Length of Roots

Average length of roots recorded at 2, 4 and 6 MAP is presented in the Table 13.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the length of roots at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest root length which was on par with 45 DAS and significantly superior to 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) recorded the highest root length. The performance of

Table.13. Effect of age at transplanting and type of minisett seedlings on length of roots (cm) in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	8.36	8.60	8.82	8.59	10.06	10.47	10.43	10.32	12.14	12.83	12.83	12.60
S_1M_2	8.94	9.58	9.66	9.39	10.76	11.11	11.09	10.99	12.29	12.66	12.91	12.62
S_2M_1	9.84	10.68	10.48	10.33	11.64	12.58	12.80	12.34	12.67	13.21	13.24	13.04
S_2M_2	10.06	11.16	11.14	10.78	11.84	13.13	13.22	12.73	13.19	13.60	14.01	13.60
Age at transplanting mean.	9.30	10.00	10.02		11.08	11.82	11.88		12.57	13.07	13.25	
Control(C)	10.48				12.25				13.06			
	SE		CD(0.05)		SE		CD(0.05)		SE		CD(0.05)	
Transplanting age (D)	0.104		0.339		0.076		0.248		0.026		0.084	
Minisett seedling (T)	0.142		0.407		0.079		0.226		0.029		0.084	
(D) x (T)	0.246		0.704		0.137		0.392		0.051		0.145	
T Vs C	S				S				S			

seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum root length was associated with seedlings transplanted at 60 DAS (D_3) (10.02) which was on par with seedlings transplanted at 45 DAS (D_2) (10.00) and significantly superior than seedlings transplanted at 30 DAS (D_1) (9.30). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (10.78) recorded the maximum length of roots which was significantly superior to all the others. Seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (10.33) and control plants (C) (10.48) were on par. The lowest length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (8.59).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (11.16) was recorded the highest value which was on par with seedlings of 3 node bits planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (11.14). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (8.36).

At 4 MAP, the maximum length of roots was associated with seedlings transplanted at 60 DAS (D_3) (11.88) which was on par with seedlings transplanted at 45 DAS (D_2) (11.82) and significantly superior to seedlings transplanted at 30 DAS (D_1) (11.08). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (12.73) recorded the maximum root length which was significantly superior to all the other root length and was followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (12.34) and was on par with control plants (C) (12.25). The lowest root length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (10.32).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (13.22) was recorded the highest value which was on par with seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (13.13). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (10.06).

At 6 MAP, the maximum length of roots was associated with seedlings transplanted at 60 DAS (D_3) (13.25) which was significantly different from seedlings transplanted at 45 DAS (D_2) (13.07) and seedlings transplanted at 30 DAS (D_1) (12.57). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (13.60) recorded the maximum root length which was significantly superior to all the others and was followed by control plants (C) (13.06) which was on par with seedlings of 3 node bits planted in cowdung media (S_2M_1) (13.04). The lowest length of roots was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (12.60) and was on par with seedlings of 2 node bits planted M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (12.62).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (14.01) was recorded the highest value followed by seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (13.60). The lowest length was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (12.14). The comparison of seedlings and control was also found to be significant.

4.3.1.6. Length of Primary Rhizome

Average length of primary rhizomes recorded at 4 and 6 MAP is presented the Table 14.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the length of primary rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest primary rhizome length which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings from 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher primary rhizome length. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 4 MAP, the maximum length of primary rhizome was associated with seedlings transplanted at 45 DAS (D_2) (3.21) which was on par with seedlings transplanted at 60 DAS (D_3) (3.20) and significantly superior than seedlings transplanted at 30 DAS (D_1) (2.88). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.01) recorded the maximum length which was on par with control plants (C) (4.00) followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (3.41). The lowest primary rhizome length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (2.39).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (4.1) recorded the highest value which was on par with seedlings of 3 node bits planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (4.08). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (2.16). The comparison of seedlings and control was also found to be significant.

At 6 MAP, the maximum length of primary rhizome was associated with seedlings transplanted at 60 DAS (D_3) (7.20) which were significantly superior to seedlings transplanted at 45 DAS (D_2) (6.89) and 30 DAS (D_1) (6.62). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (7.50) recorded the maximum length of primary rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung +

Table.14. Effect of age at transplanting and type of minisett seedlings on length of primary rhizome (cm) in *Curcuma aromatica* Salisb.

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	2.16	2.52	2.50	2.39	5.86	6.44	6.76	6.35
S_1M_2	2.28	2.72	2.70	2.56	6.38	6.50	6.94	6.60
S_2M_1	3.22	3.50	3.52	3.41	7.06	7.12	7.32	7.16
S_2M_2	3.86	4.10	4.08	4.01	7.20	7.52	7.80	7.50
Age at transplanting mean.	2.88	3.21	3.20		6.62	6.89	7.20	
Control(C)	4.00				6.44			
	SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.019	0.063			0.077	0.250		
Minisett seedling (T)	0.045	0.128			0.073	0.210		
(D) x (T)	0.078	0.222			0.127	0.364		
T *Vs* Control	S				S			

Table.15. Effect of age at transplanting and type of minisett seedlings on length of secondary rhizome (cm) in *Curcuma aromatica* Salisb

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	1.04	1.17	1.23	1.14	2.90	3.06	3.14	3.03
S_1M_2	1.21	1.30	1.30	1.27	3.04	3.20	3.22	3.15
S_2M_1	1.30	1.35	1.33	1.33	3.30	3.30	3.96	3.52
S_2M_2	1.33	1.42	1.48	1.41	3.60	4.12	4.20	3.97
Age at transplanting mean.	1.22	1.31	1.33		3.21	3.42	3.63	
Control (C)	1.31				3.45			
	SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.012	0.039			0.028	0.090		
Minisett seedling (T)	0.017	0.047			0.038	0.109		
(D) x (T)	0.029	0.082			0.066	0.189		
T *Vs* Control	S				S			

Coirpith + *Trichoderma*) (S_2M_1) (7.16). The lowest primary rhizome length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (6.35) which were on par with control plants (C) (6.44)

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (7.80) was recorded the highest value which was on par with seedlings of 3 node bits planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (7.52). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (5.86). The comparison of seedlings and control was also found to be significant.

4.3.1.7. Length of Secondary Rhizome (cm)

Average length of secondary rhizomes recorded at 4 and 6 MAP is presented in the Table 15.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the length of secondary rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest secondary rhizome length which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher secondary rhizome length. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 4 MAP, the maximum length of secondary rhizome was associated with seedlings transplanted at 60 DAS (D_3) (1.33) which was on par with seedlings transplanted at 45 DAS (D_2) (1.31) and significantly superior than seedlings transplanted at 30 DAS (D_1) (1.22). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (1.41) recorded the maximum length of secondary rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1)

(1.33) which was on par with control plants (C) (1.31). The lowest secondary rhizome length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (1.14).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings from 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (1.48) recorded the highest value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (1.42). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (1.04). The comparison of seedlings and control was also found to be significant.

At 6 MAP, the maximum length of secondary rhizome was associated with seedlings transplanted at 60 DAS (D_3) (3.63) which were significantly superior to seedlings transplanted at 45 DAS (D_2) (3.42) and 30 DAS (D_1) (3.21). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (3.97) recorded the maximum length of secondary rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (3.52) which was on par with control plants (C) (3.45). The lowest secondary rhizome length was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.03).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (4.20) was recorded the highest value which was on par with seedlings of 3 node bits planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (4.12). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (2.90). The comparison of seedlings and control was also found to be significant.

4.3.1.8. Girth of Primary Rhizome (cm)

Average girth of primary rhizomes recorded at 4 and 6 MAP is presented in the Table 16.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the girth of primary rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest girth which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher girth of primary rhizome. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 4 MAP, the maximum girth was associated with seedlings transplanted at 60 DAS (D_3) (3.92) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (3.65) and seedlings transplanted at 30 DAS (D_1) (3.42). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.63) recorded the maximum girth of primary rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.21) which was on par with control plants (C) (4.30) . The lowest girth was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.24).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (4.86) was recorded the highest value which was on par with seedlings of 3 node bits planted in M_1 media transplanted at 60 DAS ($d_3s_2m_2$) (4.84). The lowest girth was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.16). The comparison of seedlings and control was also found to be significant.

Table.16. Effect of age at transplanting and type of minisett seedlings on girth of primary rhizome (cm) in *Curcuma aromatica* Salisb.

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	3.16	3.18	3.40	3.24	3.96	4.44	4.46	4.28
S_1M_2	3.28	3.42	3.48	3.39	4.70	5.06	5.20	4.98
S_2M_1	3.96	4.22	4.46	4.21	5.70	5.76	5.84	5.76
S_2M_2	4.20	4.86	4.84	4.63	6.18	6.74	7.02	6.64
Age at transplanting mean.	3.42	3.65	3.92		5.13	5.50	5.63	
Control(C)	4.3				5.66			
	SE	CD(0.05)			SE		CD(0.05)	
Transplanting age (D)	0.070	0.229			0.060		0.197	
Minisett seedling (T)	0.045	0.127			0.057		0.163	
(D) x (T)	0.077	0.221			0.099		0.283	
T *Vs* Control	S				S			

Table.17. Effect of age at transplanting and type of minisett seedlings on girth of secondary rhizome (cm) in *Curcuma aromatica* Salisb.

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	0.98	1.00	1.00	0.99	2.16	2.92	3.06	2.71
S_1M_2	0.98	1.08	1.04	1.03	2.72	3.08	3.10	2.96
S_2M_1	1.12	1.20	1.18	1.16	2.86	3.22	3.58	3.22
S_2M_2	1.2	1.25	1.28	1.24	3.36	3.58	3.92	3.62
Age at transplanting mean.	1.07	1.13	1.12		2.77	3.20	3.41	
Control(C)	1.19				3.41			
	SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.018	0.057			0.044	0.145		
Minisett seedling (T)	0.022	0.063			0.051	0.144		
(D) x (T)	0.038	0.109			0.088	0.250		
T *Vs* Control	S				S			

At 6 MAP, the maximum girth of primary rhizome was associated with seedlings transplanted at 60 DAS (D_3) (5.63) which were significantly superior to seedlings transplanted at 45 DAS (D_2) (5.5) and 30 DAS (D_1) (5.13). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (6.64) recorded the maximum girth followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (35.76) which was on par with control plants (C) (5.66). The lowest primary rhizome girth was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (4.28).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (7.02) was recorded the highest value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (6.74). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.96). The comparison of seedlings and control was also found to be significant.

4.3.1.9. Girth of Secondary Rhizome (cm)

Average girth of secondary rhizomes recorded at 4 and 6 MAP is presented in the Table 17.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the girth of secondary rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest girth which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher girth of secondary rhizome. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 4 MAP, the maximum girth of secondary rhizome was associated with seedlings transplanted at 45 DAS (D_3) (1.13) which was on par with seedlings transplanted at 45 DAS (D_2) (1.12) and significantly superior to seedlings transplanted at 30 DAS (D_1) (1.07). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (1.24) recorded the maximum girth of secondary rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (1.16) which was on par with control plants (C) (1.19) . The lowest girth was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.99) and was on par with seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (1.03). The interaction of age at transplanting and type of minisett seedling was found to be non-significant. The comparison of seedlings and control was also found to be significant.

At 6 MAP, the maximum girth of secondary rhizome was associated with seedlings transplanted at 60 DAS (D_3) (3.41) which were significantly superior to seedlings transplanted at 45 DAS (D_2) (3.20) and 30 DAS (D_1) (2.77). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (3.62) recorded the maximum girth of secondary rhizome followed by control plants (C) (3.41) and seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (3.22). The lowest girth was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (2.71).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (3.92) was recorded the highest value. The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (2.16). The comparison of seedlings and control was also found to be significant.

4.3.1.10. Fresh Weight of Rhizome (g plant^{-1})

Average fresh weight of rhizomes recorded at 2 and 4 MAP is presented in the Table 18.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the weight of fresh rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest fresh weight which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher rhizome weight. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum fresh weight of rhizome was associated with seedlings transplanted at 60 DAS (D_3) (23.45) which was on par with seedlings transplanted at 45 DAS (D_2) (23.23) and significantly superior than seedlings transplanted at 30 DAS (D_1) (21.94). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (25.68) recorded the maximum fresh weight of rhizome which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (25.00) and control plants (C) (25.64). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (19.44). The interaction of age at transplanting and type of minisett seedling was found to be non-significant. The comparison of seedlings and control was also found to be significant.

At 4 MAP, the maximum fresh weight of rhizome was associated with seedlings transplanted at 60 DAS (D_3) (67.56) which was on par with seedlings transplanted at 45 DAS (D_2) (67.46) and significantly superior to seedlings of 30 DAS (D_1) (63.55). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (71.14) recorded

Table.18. Effect of age at transplanting and type of minisett seedlings on fresh weight of rhizome (g plant $^{-1}$) in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	17.68	20.14	20.52	19.44	62.21	65.54	65.34	64.36
S_1M_2	20.30	22.06	21.78	21.38	61.61	65.40	65.20	64.07
S_2M_1	24.54	25.08	25.39	25.00	64.09	65.42	66.04	65.18
S_2M_2	25.26	25.66	26.14	25.68	66.28	73.48	73.68	71.14
Age at transplanting mean.	21.94	23.23	23.45		63.55	67.46	67.56	
Control(C)	25.64				70.35			
	SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.273	0.889			0.213	0.693		
Minisett seedling (T)	0.287	0.821			0.285	0.814		
(D) x (T)	0.497	1.422			0.493	1.410		
T Vs C	S				S			

the maximum fresh weight of rhizome followed by control plants (C) (70.35) and seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (65.18). The lowest fresh weight of rhizome was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (64.07).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (73.68) was recorded the highest value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (73.48). The lowest fresh weight was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_2$) (61.61). The comparison of seedlings and control was also found to be significant.

4.3.1.11. Rhizome Spread

Rhizome spread recorded at 2, 4 and 6 MAP is presented in the Table 19.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced rhizome spread at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest value followed by 45 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) recorded significantly higher value. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum rhizome spread was associated with seedlings transplanted at 60 DAS (D_3) (4.41) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (4.33) and seedlings transplanted at 30 DAS (D_1) (4.17). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.89) recorded the maximum rhizome spread followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.65) and control plants (C) (4.59).

Table.19. Effect of age at transplanting and type of minisett seedlings on rhizome spread in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	3.60	3.72	3.75	3.69	8.41	9.08	9.37	8.95	10.17	10.31	10.21	10.23
S_1M_2	3.84	4.11	4.22	4.06	8.84	9.57	9.59	9.34	10.25	10.64	10.57	10.48
S_2M_1	4.52	4.63	4.80	4.65	9.60	9.62	9.66	9.63	12.05	12.16	12.24	12.15
S_2M_2	4.73	4.85	4.87	4.82	9.52	9.63	9.76	9.64	12.12	12.65	12.53	12.43
Age at transplanting mean.	4.17	4.33	4.41		9.09	9.48	9.59		11.14	11.44	11.38	
Control(C)	4.59				9.39				11.56			
	SE	CD(0.05)			SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.010	0.032			0.037	0.122			0.022	0.073		
Minisett seedling (T)	0.014	0.041			0.033	0.095			0.029	0.083		
(D) x (T)	0.025	0.071			0.058	0.165			0.050	0.144		
T *Vs* C	S				S				S			

The lowest rhizome spread was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.69).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (4.87) recorded the highest value which was on par with seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (4.85). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.60).

At 4 MAP, the maximum rhizome spread was associated with seedlings transplanted at 60 DAS (D_3) (9.59) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (9.48) and seedlings transplanted at 30 DAS (D_1) (9.09). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (9.64) recorded the maximum rhizome spread which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung+Coirpith+*Trichoderma*) (S_2M_1) (9.63). The lowest rhizome spread was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (9.37) which were on par with control plants (C) (9.39).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_2s_2m_2$) (9.76) was recorded the highest value which was on par with seedlings from 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (9.66). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (8.41).

At 6 MAP, the maximum rhizome spread was associated with seedlings transplanted at 45 DAS (D_2) (11.44) which was on par with seedlings transplanted at 60 DAS (D_3) (11.38) and significantly superior to seedlings transplanted at 30 DAS (D_1) (11.14). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith+ *Trichoderma*) (S_2M_2) (12.43) recorded the maximum value which was significantly superior and was followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (12.15) and control plants (C) (20.52). The lowest rhizome spread was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (10.23).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (12.65) was recorded the highest value which was on par with seedlings of 3 node bit planted in the same media transplanted at 60 DAS ($d_3s_2m_2$) (12.53). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (10.17). The comparison of seedlings and control was also found to be significant.

4.3.1.12. Dry Weight of Rhizome (g plant^{-1})

Average dry weight of rhizomes recorded at 2 and 4 MAP is presented in the Table 20.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced the dry weight of rhizomes at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest dry weight which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher dry weight. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum dry weight of rhizome was associated with seedlings transplanted at 60 DAS (D_3) (7.03) which was on par with seedlings transplanted at 45 DAS (D_2) (6.97) and significantly superior than seedlings transplanted at 30 DAS (D_1) (6.58). Among the type of seedlings, seedlings of 3

Table.20. Effect of age at transplanting and type of minisett seedlings on dry weight of rhizome (g plant $^{-1}$) in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	5.30	6.04	6.15	5.83	18.66	19.66	19.60	19.30
S_1M_2	6.09	6.61	6.53	6.41	18.48	19.62	19.56	19.22
S_2M_1	7.36	7.52	7.61	7.50	19.22	19.62	19.81	19.55
S_2M_2	7.57	7.69	7.84	7.70	19.88	22.03	22.10	21.34
Age at transplanting mean.	6.58	6.97	7.03		19.06	20.23	20.27	
Control(C)	7.23				19.32			
	SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.082	0.267			0.064	0.207		
Minisett seedling (T)	0.086	0.246			0.085	0.244		
(D) x (T)	0.149	0.427			0.148	0.423		
T *Vs* C	S				S			

node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (7.7) recorded the maximum dry weight of rhizome which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (7.5) and superior than control plants (C) (7.23). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (5.83).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (7.84) recorded the highest value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (7.69). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (5.30). The comparison of seedlings and control was also found to be significant.

At 4 MAP, the maximum dry weight of rhizome was associated with seedlings transplanted at 60 DAS (D_3) (20.27) which was on par with seedlings transplanted at 45 DAS (D_2) (20.23) and significantly superior to seedlings 30 DAS (D_1) (19.06). Among the type of seedlings, seedlings from 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (21.34) recorded the maximum dry weight of rhizome followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (19.55) and control plants (C) (19.32). The lowest dry weight was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (19.22).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (22.10) was recorded the highest value which was on par with seedlings from 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (22.03). The lowest value was recorded by seedlings of 2 node bit planted in the same media transplanted at 30 DAS ($d_1s_1m_2$) (18.48). The comparison of seedlings and control was also found to be significant.

4.3.2. Physiological Characters

4.3.2.1. Net Assimilation Rate (NAR)

The results on effect of different age at transplanting and type of minisett seedlings on NAR are presented in the Table.21. Significant variations were observed with respect to NAR.

The perusal of the data revealed that age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest net assimilation rate (NAR) which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher value. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 60-120 DAP, the highest NAR was associated with seedlings transplanted at 60 DAS (D_3) (0.60) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (0.59) and seedlings transplanted at 30 DAS (D_1) (0.47). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.60) recorded the highest NAR which was followed by 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.57). Control plants (C) (0.56) and 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (0.56) were on par. The lowest value was observed in seedlings of 2 node bits planted in M_2 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.48).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.63) was recorded the highest value. The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS

Table.21. Effect of age at transplanting and type of minisett seedlings on Net Assimilation Rate (g day^{-1}) in *Curcuma aromatica* Salisb.

Type of minisett seedling	60-120DAP			Minisett seedling mean	120-180DAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	0.41	0.51	0.52	0.48	1.92	2.17	2.16	2.08
S_1M_2	0.44	0.61	0.62	0.56	2.08	2.11	2.19	2.13
S_2M_1	0.46	0.62	0.62	0.57	2.13	2.15	2.15	2.15
S_2M_2	0.55	0.62	0.63	0.60	2.07	2.17	2.22	2.15
Age at transplanting mean.	0.47	0.59	0.60		2.05	2.15	2.18	
Control(C)	0.56				2.12			
	SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.002	0.007			0.004	0.012		
Minisett seedling (T)	0.002	0.006			0.008	0.024		
(D) x (T)	0.003	0.010			0.015	0.042		
T *Vs* Control	S				S			

Table.22. Effect of age at transplanting and type of minisett seedlings on Crop Growth Rate (gm $^{-2}$day $^{-1}$) in *Curcuma aromatica* Salisb.

Type of minisett seedling	60-120DAP			Minisett seedling mean	120-180DAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	0.70	1.00	1.22	0.97	4.55	5.21	5.24	5.00
S_1M_2	0.97	1.35	1.38	1.23	5.05	5.66	8.65	6.45
S_2M_1	1.04	1.39	1.45	1.29	8.21	9.05	9.13	8.80
S_2M_2	1.28	1.40	1.46	1.38	8.30	9.06	9.88	9.08
Age at transplanting mean.	1.00	1.29	1.37		6.53	7.25	8.22	
Control (C)	1.34				8.52			
	SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.010	0.031			0.029	0.094		
Minisett seedling (T)	0.010	0.028			0.032	0.092		
(D) x (T)	0.017	0.048			0.056	0.159		
T *Vs* Control	S				S			

($d_1s_1m_1$) (0.41). The comparison of seedlings and control was also found to be significant.

At 120-180 DAP, the maximum NAR was associated with seedlings transplanted at 60 DAS (D_3) (2.18) which was on par with seedlings transplanted at 45 DAS (D_2) (2.15) and significantly superior to seedlings transplanted at 30 DAS (D_1) (2.05). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (2.15) recorded the maximum NAR which was on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (2.15). Control plants (C) (2.12) and 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (2.13) were on par. The lowest NAR was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (2.08).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (2.22) was recorded the highest value followed by seedlings from 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (2.17). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (1.92). The comparison of seedlings and control was also found to be significant.

4.3.2.2. Crop Growth Rate (CGR)

The results on effect of different age at transplanting and type of minisett seedlings on CGR are presented in the Table.22. Significant variations were observed with respect to CGR.

The perusal of the data revealed that the age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the maximum crop growth rate (CGR) which was significantly superior to seedlings transplanted at 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*)

(S_2M_2) produced significantly higher value. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 60-120DAP, the highest CGR was associated with seedlings transplanted at 60 DAS (D_3) (1.37) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (1.29) and seedlings transplanted at 30 DAS (D_1) (1.00). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (1.38) recorded the highest CGR which was followed by control plants (C) (1.34) and 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (1.29). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.97).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (1.46) recorded the highest value which was on par with seedlings of 3 node bit planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (1.45). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (0.41). The comparison of seedlings and control was also found to be significant.

At 120-180 DAP, the maximum CGR was associated with seedlings transplanted at 60 DAS (D_3) (8.22) followed by seedlings transplanted at 45 DAS (D_2) (7.25) and seedlings transplanted at 30 DAS (D_1) (6.53). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (9.08) recorded the maximum CGR followed by seedlings from 3 node bits planted in M_1 media (Cowdung + Coirpith+ *Trichoderma*) (S_2M_1) (8.80) and control plants (C) (8.52). The lowest CGR was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (5.00).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (9.88) was recorded the highest value followed by seedlings of 3 node bits planted in M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (9.13). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media 30 DAS ($d_1s_1m_1$) (4.55). The comparison of seedlings and control was also found to be significant.

4.3.2.3. Leaf Area Index (LAI)

Leaf Area Index recorded at 2, 4 and 6 MAP is presented in the Table 23.

The perusal of the data revealed that the different age at transplanting and type of minisett seedlings significantly influenced leaf area index at all growth stages. The age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the highest value followed by 45 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) recorded significantly higher value. The performance of seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 2 MAP, the maximum Leaf Area Index was associated with seedlings transplanted at 60 DAS (D_3) (2.24) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (2.20) and seedlings transplanted at 30 DAS (D_1) (2.16). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.89) recorded the maximum LAI and was on par with seedlings from 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (2.29) followed by control plants (C) (2.23). The lowest LAI was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (1.97).

The interaction of age at transplanting and type of minisett seedling was found to be non- significant. Even though seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (2.34) was recorded the highest value.

Table.23. Effect of age at transplanting and type of minisett seedlings on Leaf Area Index in *Curcuma aromatica* Salisb.

Type of minisett seedling	2MAP			Minisett seedling mean	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	1.88	1.97	2.07	1.97	2.36	2.40	2.50	2.42	3.88	3.78	4.02	3.89
S_1M_2	2.17	2.22	2.27	2.22	2.41	2.59	2.98	2.66	4.03	4.05	3.99	4.02
S_2M_1	2.26	2.29	2.30	2.29	3.59	4.27	4.25	4.03	4.77	5.13	5.27	5.05
S_2M_2	2.31	2.30	2.34	2.32	3.81	4.31	4.45	4.19	4.85	5.20	5.31	5.12
Age at transplanting mean.	2.16	2.20	2.24		3.04	3.39	3.54		4.38	4.54	4.65	
Control(C)	2.23				3.92				4.75			
	SE	CD (0.05)			SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.013	0.042			0.044	0.144			0.011	0.037		
Minisett seedling (T)	0.017	0.050			0.035	0.101			0.015	0.043		
(D) x (T)	0.030	0.086			0.061	0.175			0.026	0.074		
T *Vs* C	S				S				S			

At 4 MAP, the maximum LAI was associated with seedlings transplanted at 60 DAS (D_3) (3.54) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (3.39) and 30 DAS (D_1) (3.04). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.19) recorded the maximum value followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.03) which was on par with control plants (C) (3.92). The lowest LAI was observed in seedlings from 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (2.42).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings from 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (4.45) was recorded the highest value. The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (2.36).

At 6 MAP, the maximum LAI was associated with seedlings transplanted at 60 DAS (D_3) (4.65) which was followed by seedlings transplanted at 45 DAS (D_2) (4.54) and significantly superior to seedlings transplanted at 30 DAS (D_1) (4.38). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (5.12) recorded the maximum value which was significantly superior and was followed by seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (5.05) and control plants (C) (4.75). The lowest LAI was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.89).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (5.31) was recorded the highest value followed by seedlings of 3 node bit planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (5.20). The lowest number was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.88). The comparison of seedlings and control was also found to be significant.

4.3.2.4. Stomatal Frequency (Adaxial side)

Stomatal frequency (Adaxial side) recorded at 4 and 6 MAP is presented in the Table 24.

The perusal of the data revealed that there was no significant difference among different age at transplanting and type of minisett seedlings on stomatal frequency. However the seedlings which are transplanted at 45DAS recorded the highest value followed by 60 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) recorded significantly higher value.

At 4 MAP, the maximum stomatal frequency was associated with seedlings transplanted at 45 DAS (D_2) (1188.69) which was significantly superior to seedlings transplanted at 60 DAS (D_3) (1184.73) and seedlings transplanted at 30 DAS (D_1) (1184.30). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (1196.04) recorded the maximum stomatal frequency followed by control plants (C) (1190.29) and seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (1186.58). The lowest stomatal frequency was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (1179.13).

At 6 MAP, the maximum stomatal frequency was associated with seedlings transplanted at 45 DAS (D_2) (1445.35). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (2027.37) recorded the maximum value followed by control plants (C) (2025.24) and seedlings from 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (1252.63). The lowest stomatal frequency was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (1186.86).

Table.24. Effect of age at transplanting and type of minisett seedlings on stomatal frequency (Adaxial side) in *Curcuma aromatica* Salisb.

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	1181.97	1179.24	1192.61	1184.61	1184.11	1183.36	1193.12	1186.86
S_1M_2	1162.56	1188.23	1186.61	1179.13	1184.57	1193.47	1187.14	1188.39
S_2M_1	1183.38	1190.34	1186.02	1186.58	1191.57	1357.25	1209.06	1252.63
S_2M_2	1186.94	1196.96	1196.04	1193.31	2008.53	2047.34	2026.24	2027.37
Age at transplanting mean.	1184.30	1188.69	1184.73		1392.19	1445.35	1403.89	
Control(C)	1190.29				2025.24			
	SE	CD (0.05)			SE	CD (0.05)		
Transplanting age (D)	0.532	1.734			21.853	71.265		
Minisett seedling (T)	0.809	2.313			26.597	76.021		
(D) x (T)	1.402	4.007			46.068	131.672		
T *Vs* Control	NS				NS			

Table.25. Effect of age at transplanting and type of minisett seedlings on Stomatal frequency (Abaxial side) in *Curcuma aromatica* Salisb.

Type of minisett seedling	4MAP			Minisett seedling mean	6MAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	479.20	482.30	488.38	483.29	514.96	518.94	520.64	518.18
S_1M_2	486.48	489.48	489.24	488.40	512.44	516.52	522.00	516.98
S_2M_1	500.94	498.86	496.04	498.61	519.68	523.50	528.28	523.82
S_2M_2	509.62	503.62	504.66	505.96	525.76	529.76	531.66	529.06
Age at transplanting mean.	494.06	493.56	494.58		518.21	522.18	525.64	
Control(C)	501.18				525.92			
	SE	CD(0.05)			SE	CD (0.05)		
Transplanting age (D)	1.305	4.256			0.917	2.990		
Minisett seedling (T)	1.944	5.556			1.455	4.159		
(D) x (T)	3.367	9.624			2.521	7.204		
T *Vs* Control	NS				NS			

4.3.2.5. Stomatal Frequency (Abaxial side)

Stomatal frequency (Abaxial side**)** recorded at 4 and 6 MAP is presented in the Table.25. The perusal of the data revealed that there was no significant difference among different age at transplanting and type of minisett seedlings on stomatal frequency. However the seedlings which are transplanted at 45DAS recorded the highest value followed by 60 and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) recorded significantly higher value.

At 4 MAP, the maximum stomatal frequency was associated with seedlings transplanted at 60 DAS (D_3) (494.58) which was on par with seedlings transplanted at 45 DAS (D_2) (493.56) and seedlings transplanted at 30 DAS (D_1) (494.06). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (505.96) recorded the maximum stomatal frequency which was on par with control plants (C) (501.18). The lowest stomatal frequency was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (483.29).

The interaction of age at transplanting and type of minisett seedling was found to be non- significant. Even though seedlings from 3 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_2m_2$) (509.62) was recorded the highest value.

At 6 MAP, the maximum stomatal frequency was associated with seedlings transplanted at 60 DAS (D_3) (525.64). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (529.06) recorded the maximum value followed by control plants (C) (525.92) and seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (523.82). The lowest stomatal frequency was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (516.98) and was on par with 2 node bits planted in M_1 media (Cowdung + Coirpith +*Trichoderma*) (S_1M_1) (518.18).

The interaction of age at transplanting and type of minisett seedling was found to be non- significant. Even though seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (531.66) was recorded the highest value.

4.3.2.6. Bulking Rate

The results on effect of different age at transplanting and type of minisett seedlings on bulking rate were presented in the Table.26. Significant variations were observed with respect to bulking rate.

The perusal of the data revealed that the age at transplanting differed significantly and the seedlings which are transplanted at 60 DAS recorded the maximum bulking rate which was significantly superior to 45 DAS and 30 DAS. Among the type of seedlings, seedlings of 3 node rhizome bit planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) produced significantly higher value. The performance of seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) was the least in all the stages.

At 60-120 DAP, the highest bulking rate was associated with both the seedlings transplanted at 60 DAS (D_3) (0.35) and 45 DAS (D_2) (0.35) which was significantly superior to seedlings transplanted at 30 DAS (D_1) (0.33). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.37) recorded the maximum bulking rate which was followed by control plants (C) (0.36) and 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.35). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.33) which was on par with seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_1) (0.34)

The interaction of age at transplanting and type of minisett seedling was found to be non- significant. Even though seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.38) was recorded the highest value. The lowest number was recorded by seedlings of 2 node bit planted in M_1 media

Table.26. Effect of age at transplanting and type of minisett seedlings on Bulking rate (g day $^{-1)}$ in *Curcuma aromatica* Salisb.

Type of minisett seedling	60-120DAP			Minisett seedling mean	120-180DAP			Minisett seedling mean
	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)		30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	
S_1M_1	0.31	0.34	0.33	0.33	0.41	0.41	0.42	0.41
S_1M_2	0.33	0.34	0.34	0.34	0.41	0.41	0.45	0.43
S_2M_1	0.34	0.36	0.36	0.35	0.42	0.48	0.49	0.46
S_2M_2	0.35	0.37	0.38	0.37	0.42	0.50	0.50	0.47
Age at transplanting mean.	0.33	0.35	0.35		0.42	0.45	0.47	
Control(C)	0.36				0.44			
	SE	CD(0.05)			SE	CD(0.05)		
Transplanting age (D)	0.002	0.007			0.003	0.009		
Minisett seedling (T)	0.003	0.008			0.004	0.012		
(D) x (T)	0.005	0.015			0.007	0.020		
T *Vs* Control	S				S			

Table.27. Effect of age at transplanting and type of minisett seedlings on Harvest index in *Curcuma aromatica* Salisb.

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	0.402	0.450	0.430	0.427
S_1M_2	0.372	0.400	0.422	0.398
S_2M_1	0.432	0.570	0.570	0.524
S_2M_2	0.478	0.586	0.600	0.555
Age at transplanting mean.	0.421	0.502	0.506	
Control(C)	0.51			
	SE		CD(0.05)	
Transplanting age (D)	0.010		0.034	
Minisett seedling (T)	0.010		0.027	
(D) x (T)	0.017		0.048	
T *Vs* Control	S			

transplanted at 30 DAS ($d_1s_1m_1$) (0.31). The comparison of seedlings and control was also found to be significant.

At 120-180 DAP, the maximum bulking rate was associated with seedlings transplanted at 60 DAS (D_3) (0.47) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (0.45) and 30DAS (D_1) (0.42). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.47) recorded the maximum bulking rate which is on par with seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.46) followed by control plants (C) (0.44). The lowest bulking rate was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (0.41).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.50) and M_1 media transplanted at 60 DAS ($d_3s_2m_1$) (0.50) were on par. The lowest value was recorded by seedlings of 2 node bit planted in transplanted at 60 DAS (transplanted at 30 DAS ($d_1s_1m_1$) (0.41). The comparison of seedlings and control was also found to be significant.

4.3.2.7. Harvest Index

As observed in Table.27. Significant difference was found among different age at transplanting and type of minisett seedlings on harvest index. The age at transplanting differed significantly and the maximum harvest index was associated with seedlings transplanted at 60 DAS (D_3) (0.506) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (0.502) and seedlings transplanted at 30 DAS (D_1) (0.421). Among the type of seedlings, seedlings of 3 node bits planted in M_1 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (0.555) recorded the maximum harvest index which was significantly superior than seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (0.524) and control plants (C) (0.51). The lowest value was observed in seedlings of 2 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_1M_2) (0.427).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (0.60) recorded the maximum value which was on par with seedlings from 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (0.586). The lowest value was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (0.372). The comparison of seedlings and control was also found to be significant.

4.3.3. Yield

4.3.3.1. Fresh Yield (Kg plot $^{-1}$)

As observed in Table.28. Significant difference was found among different age at transplanting and type of minisett seedlings on fresh yield of rhizome (Plate.7).

The age at transplanting differed significantly and the maximum fresh yield was associated with seedlings transplanted at 60 DAS (D_3) (4.17) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (4.14) and seedlings transplanted at 30 DAS (D_1) (3.62). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.79) recorded the maximum fresh yield which was on par with control plants (C) (4.63) and significantly superior than seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.00). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.43).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (5.25) recorded the maximum value which was on par with

S_1M_1

S_1M_2

S_2M_1

S_2M_2

Control

Plate .7. Effect of age at transplanting and type of minisett seedlings on fresh rhizome yield in *Curcuma aromatica* Salisb.

Table.28. Effect of age at transplanting and type of minisett seedlings on fresh yield (Kg plot $^{-1}$) in *Curcuma aromatica* Salisb

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	3.23	3.51	3.56	3.43
S_1M_2	3.41	3.83	3.83	3.69
S_2M_1	3.88	4.06	4.06	4.00
S_2M_2	3.96	5.16	5.25	4.79
Age at transplanting mean.	3.62	4.14	4.17	
Control(C)	4.63			
	SE	CD(0.05)		
Transplanting age (D)	0.016	0.053		
Minisett seedling (T)	0.027	0.076		
(D) x (T)	0.046	0.132		
T *Vs* Control	S			

Table.29. Effect of age at transplanting and type of minisett seedlings on dry yield (Kg plot $^{-1}$) in *Curcuma aromatica* Salisb.

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	0.968	1.053	1.068	1.030
S_1M_2	1.023	1.150	1.149	1.108
S_2M_1	1.164	1.219	1.219	1.201
S_2M_2	1.189	1.549	1.576	1.438
Age at transplanting mean.	1.086	1.243	1.253	
Control(C)	1.35			
	SE	CD(0.05)		
Transplanting age (D)	0.005	0.016		
Minisett seedling (T)	0.008	0.023		
(D) x (T)	0.014	0.039		
T *Vs* Control	S			

seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (5.16). The lowest value was recorded by seedlings of 2 node bit planted in M_2 media transplanted at 30 DAS ($d_1s_1m_2$) (3.23). The comparison of seedlings and control was also found to be significant.

4.3.3.2. Dry Yield (Kg plot $^{-1}$)

As observed in Table.29. Significant difference was found among different age at transplanting and type of minisett seedlings on dry yield of rhizome.

The age at transplanting differed significantly and the maximum dry yield was associated with seedlings transplanted at 60 DAS (D_3) (1.253) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (1.243) and seedlings transplanted at 30 DAS (D_1) (1.086). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (1.438) recorded the maximum dry yield which was on par with control plants (C) (1.350) and significantly superior than seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (1.201). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung+Coirpith+ *Trichoderma*) (S_1M_1) (1.030).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (1.576) recorded the maximum value which was on par with seedlings of 3 node bits planted in M_2 media transplanted at 45 DAS ($d_2s_2m_2$) (1.549) . The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (0.968). The comparison of seedlings and control was also found to be significant.

4.3.3.3. Fresh Yield (t ha^{-1})

As observed in Table.30. Significant difference was found among different age at transplanting and type of minisett seedlings on fresh yield of rhizome.

Table.30. Effect of age at transplanting and type of minisett seedlings on fresh yield (t ha^{-1}) in *Curcuma aromatica* Salisb

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	10.765	11.698	11.866	11.443
S_1M_2	11.376	12.784	12.774	12.311
S_2M_1	12.939	13.548	13.547	13.345
S_2M_2	13.220	17.219	17.510	15.983
Age at transplanting mean.	12.075	13.812	13.924	
Control(C)	15.330			
	SE	CD(0.05)		
Transplanting age (D)	54.496	177.721		
Minisett seedling (T)	88.744	253.651		
(D) x (T)	153.709	439.337		
T *Vs* Control	S			

Table.31. Effect of age at transplanting and type of minisett seedlings on dry yield (t ha^{-1}) in *Curcuma aromatica* Salisb

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	3.228	3.508	3.558	3.431
S_1M_2	3.411	3.834	3.831	3.692
S_2M_1	3.880	4.062	4.063	4.002
S_2M_2	3.964	5.164	5.252	4.793
Age at transplanting mean.	3.621	4.142	4.176	
Control(C)	4.599			
	SE	CD(0.05)		
Transplanting age (D)	0.016	0.053		
Minisett seedling (T)	0.027	0.076		
(D) x (T)	0.046	0.131		
T *Vs* Control	S			

The age at transplanting differed significantly and the maximum fresh yield was associated with seedlings transplanted at 60 DAS (D_3) (13.924) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (13.812) and seedlings transplanted at 30 DAS (D_1) (12.075). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (15.983) recorded the maximum fresh yield which was significantly superior than control plants (C) (15.330) and seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (13.345). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (11.443).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (17.510) recorded the maximum value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (17.219) . The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (10.765). The comparison of seedlings and control was also found to be significant.

4.3.3.4. Dry Yield (t ha $^{-1}$)

As observed in Table.31. Significant difference was found among different age at transplanting and type of minisett seedlings on dry yield of rhizome.

The age at transplanting differed significantly and the maximum dry yield was associated with seedlings transplanted at 60 DAS (D_3) (4.176) which was significantly superior to seedlings transplanted at 45 DAS (D_2) (4.142) and seedlings transplanted at 30 DAS (D_1) (3.621). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.793) recorded the maximum dry yield which was on par with control plants (C) (4.599) and significantly superior than seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.00).

The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (3.431).

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (5.252) recorded the maximum value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (5.164) . The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.228). The comparison of seedlings and control was also found to be significant.

4.3.4. Quality Parameters

4.3.4.1. Volatile Oil

The data (Table.32.) revealed that volatile oil content was not influenced by different age at transplanting and type of minisett seedlings.

4.3.4.2. Non –Volatile Ether Extract.

As observed in Table.33. Significant difference was found among different age at transplanting and type of minisett seedlings on Non-volatile ether extract.

The age at transplanting differed significantly and the maximum NVEE was associated with seedlings transplanted at 60 DAS (D_3) (4.56) which was significantly superior to seedlings transplanted at 45DAS (D_2) (4.46) and seedlings transplanted at 30DAS (D_1) (4.28). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (4.85) recorded the maximum NVEE which was on par with control plants (C) (4.80) and significantly superior than seedlings of 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (4.85). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (4.12).

Table.32. Effect of age at transplanting and type of minisett seedlings on Volatile oil in *Curcuma aromatica* Salisb

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	5.13	5.13	5.14	5.13
S_1M_2	5.14	5.15	5.19	5.16
S_2M_1	5.17	5.15	5.18	5.17
S_2M_2	5.14	5.17	5.19	5.16
Age at transplanting mean.	5.14	5.15	5.17	
Control(C)	5.17			
	SE	CD(0.05)		
Transplanting age (D)	0.010	NS		
Minisett seedling (T)	0.007	NS		
(D) x (T)	0.012	NS		
T *Vs* Control	NS			

Table.33. Effect of age at transplanting and type of minisett seedlings on NVEE in *Curcuma aromatica* Salisb.

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	3.98	4.16	4.22	4.12
S_1M_2	4.14	4.12	4.28	4.18
S_2M_1	4.44	4.62	4.70	4.58
S_2M_2	4.56	4.96	5.04	4.85
Age at transplanting mean.	4.28	4.46	4.56	
Control(C)	4.80			
	SE	CD(0.05)		
Transplanting age (D)	0.029	0.095		
Minisett seedling (T)	0.029	0.082		
(D) x (T)	0.050	0.142		
T *Vs* Control	S			

The interaction of age at transplanting and type of minisett seedling was also significant. Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (5.04) recorded the maximum value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (4.96). The lowest value was recorded by seedlings of 2 node bit planted in M_1 media transplanted at 30 DAS ($d_1s_1m_1$) (3.98). The comparison of seedlings and control was also found to be significant.

4.3.4.3. Oleoresin

As observed in Table.34. Significant difference was found among different age at transplanting and type of minisett seedlings on oleoresin.

The age at transplanting differed significantly and the maximum oleoresin was associated with seedlings transplanted at 60 DAS (D_3) (9.89) which was on par with seedlings transplanted at 45 DAS (D_2) (9.86) and significantly superior to seedlings transplanted at 30 DAS (D_1) (9.73). Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) (S_2M_2) (9.96) recorded the maximum oleoresin which was on par with control plants (C) (9.90) and seedlings from 3 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_2M_1) (9.88). The lowest value was observed in seedlings of 2 node bits planted in M_1 media (Cowdung + Coirpith + *Trichoderma*) (S_1M_1) (9.68).

The interaction of age at transplanting and type of minisett seedling was found to be non-significant. Eventhough Seedlings of 3 node bit planted in M_2 media transplanted at 60 DAS ($d_3s_2m_2$) (10.02) recorded the maximum value which was on par with seedlings of 3 node bits planted in the same media transplanted at 45 DAS ($d_2s_2m_2$) (9.98). The comparison of seedlings and control was also found to be significant.

Table.34. Effect of age at transplanting and type of minisett seedlings on Oleoresin in *Curcuma aromatica* Salisb.

Type of minisett seedling	30DAS (D_1)	45DAS (D_2)	60DAS (D_3)	Minisett seedling mean
S_1M_1	9.64	9.64	10.14	9.68
S_1M_2	9.74	9.84	10.02	9.78
S_2M_1	9.66	9.98	10.10	9.88
S_2M_2	9.90	9.98	10.02	9.96
Age at transplanting mean.	9.73	9.86	9.89	
Control(C)	9.90			
	SE		CD(0.05)	
Transplanting age (D)	0.024		0.077	
Minisett seedling (T)	0.040		0.115	
(D) x (T)	0.070		0.199	
T *Vs* Control	S			

Table.35. Economics of cultivation in *Curcuma aromatica* Salisb.

Treatment	Fresh yield (t ha^{-1})	Gross income (Rs.)	Cost(Rs.)	Net income(Rs.)	B:C
$D_1S_1M_1$	10.76	645920	318868	327052	2.02
$D_1S_1M_2$	11.37	682560	321368	361192	2.12
$D_1S_2M_1$	12.93	776360	316468	459892	2.45
$D_1S_2M_2$	13.22	793200	318968	474232	2.48
$D_2S_1M_1$	11.69	701920	318868	383052	2.20
$D_2S_1M_2$	12.78	767040	321368	445672	2.38
$D_2S_2M_1$	13.54	812920	316468	496452	2.56
$D_2S_2M_2$	17.21	1033160	318968	714192	3.23
$D_3S_1M_1$	11.86	712000	318868	393132	2.23
$D_3S_1M_2$	12.77	766440	321368	445072	2.38
$D_3S_2M_1$	13.54	812840	316468	496372	2.56
$D_3S_2M_2$	17.51	1050600	318968	731632	3.29
Control	15.33	919800	307868	611932	2.98

4.4. INCIDENCE OF PEST AND DISEASES

Pest and disease incidence were recorded periodically and no serious pests and diseases were encountered. Incidence of stem borer (*Conogethes punctiferalis*) was noticed and plant protection measures were carried out by spraying 0.05 per cent Dimethoate.

4.5.. ECONOMICS OF CULTIVATION/ B: C RATIO

The economics of cultivation of kasthuri turmeric using minisett seedlings are given in Table 35. Among the thirteen treatments, $D_3S_2M_2$ recorded the highest gross income of Rs. 10,50,600 /- followed by $D_2S_2M_2$ (Rs. 10,33,160/-) and Control (Rs. 9,19,800 /-) whereas, the lowest gross income was recorded by $D_1S_1M_1$ (Rs. 6,45,920 /-). Highest cost of cultivation was incurred in the treatments $D_2S_1M_2$, $D_3S_1M_2$ and $D_1S_1M_2$ (Rs. 3, 21, 368 /-) whereas Control recorded the lowest cost of cultivation (Rs.3, 07,868/-).

Highest net income was obtained from $D_3S_2M_2$ (Rs. 7, 31,632 /-) followed by $D_2S_2M_2$ (Rs. 7, 14,192 /-), control (Rs. 6, 11, 932 /-), $D_2S_2M_1$ (Rs. 4, 96,452 /-) and $D_3S_2M_1$ (Rs. 4,96,372 /-). $D_1S_1M_1$ registered the lowest net income of Rs. 3,27,052 /-.

In the cost benefit analysis, treatment $D_3S_2M_2$ recorded the highest B: C ratio of 3.29 followed by $D_2S_2M_2$ (3.23). Better B:C ratios were also observed with treatments control, $D_3S_2M_1$, $D_2S_2M_1$, $D_1S_2M_2$, $D_1S_2M_1$ (2.98, 2.56, 2.56, 2.48 and 2.45 respectively) whereas, the $D_1S_1M_1$ recorded the lowest B:C ratio (1.77).

DISCUSSION

5. DISCUSSION

The present study entitled "Rapid multiplication of kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management" was undertaken to standardize minisett method of macro propagation and nursery techniques for rapid mass multiplication of kasthuri turmeric. The study included four different experiments viz., Standardization of pre- sprouting treatments, mini sett size, media for pro-tray seedlings and age at transplanting of pro-tray seedlings and their field level evaluation. The results of these experiments are discussed below.

5.1. STANDARDIZATION OF PRE-SPROUTING TREATMENTS

5.1.1. Sprouting percentage

The data recorded one week after pre-treatment of rhizome bits (Fig.2) suggest that both the size of rhizome bits used as well as the pre-treatments given significantly influenced sprouting. Rhizome bits with 3 node showed better sprouting (72.50 %) than 2 node bits (64.13 %). The increasing trend of sprouting with increasing weight of planting material was reported in banana (Hernandez *et al.*, 1988) and in turmeric (Hussain and Said, 1967). Higher content of reserve food material coupled with the presence of more viable buds in larger seed bits might have induced early sprouting and higher sprouting percentage.

Significant influence of pre-treatments with chemicals/growth regulators were also noticed in the sprouting of rhizome bits. Among the pre-treatments, soaking 3 node rhizome bits in benzyl adenine 100 ppm (T_3S_2) for 24 hrs recorded the highest sprouting (95.60 %) followed by 24 hr soaking of benzyl adenine 50 ppm (T_2S_2, 91.20 %). Breaking of dormancy and enhanced sprouting with higher concentrations (50 and 100 mg L^{-1}) of benzyl adenine has been reported in rhizome halves of achimenes as well as several bulbous and tuberous plants by Vlahos (1985). Cytokinins are known to induce bud break in many kinds of plants on both aerial and below-ground parts (Criley, 2001). Comparing all the

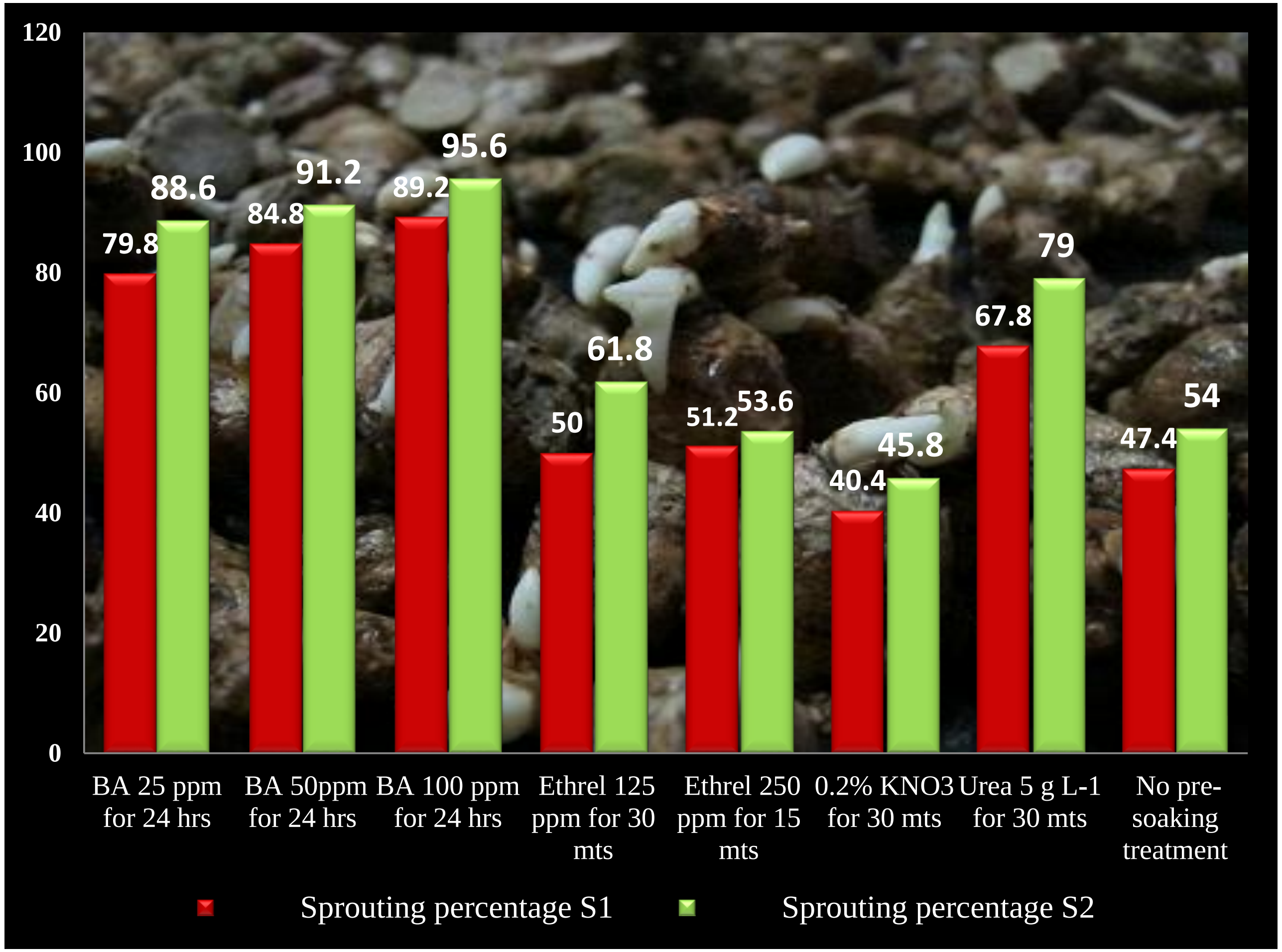


Fig. 2. Effect of different pre-treatments and rhizome bit size on sprouting percentage

other treatments the increase in sprouting percentage as a result of BA treatment might be due to optimum absorption of chemicals by rhizomes, which might have been further utilized for physiological processes to influence the sprouting parameters and also the increase in the quantum of alternate respiration in rhizomes due to these treatments.

5.2.STANDARDIZATION OF MEDIA

5.2.1. Morphological characters of the seedlings

From the study it was observed that the size of the rhizome bits as well as the media combination have influence on the morphological characters like plant height, number, length and breadth of leaves, number, length and girth of roots of the pro-tray seedlings.

The media combination M_2 (Vermicompost + Coirpith + *Trichoderma*) was found to be the best in enhancing the growth parameters of seedlings compared to M_1 (Cowdung + Coirpith + *Trichoderma*). In the above media, growth parameters such as rooting percentage, days to first leaf emergence, plant height, number of leaves, number of roots, and root length were significantly superior compared to M_1. Similar result was reported by Prasath *et al.* (2014) in black pepper nursery.

Plants with better root system obviously will give better growth of the plant. The ramified root system might have promoted better nutrient uptake and consequent improved growth attributes. It was observed that more number of leaves and roots was produced by seedlings of 3 node bit planted in M_2 (Vermicompost + Coirpith + *Trichoderma*) media than in M_1 (Cowdung + Coirpith + *Trichoderma***)** (Fig.3 and 4.). The above result is in conformity with the findings of Shameena (2012) who reported that in kasthuri turmeric mixture of coirpith compost and vermicompost was the ideal medium registering cent per cent survival rate of *in vitro* raised plants. The presence of plant growth promoting hormones and easy availability of nutrients in vermicompost, (Ushakumari, 2004) also might have contributed to the better growth characters observed in these

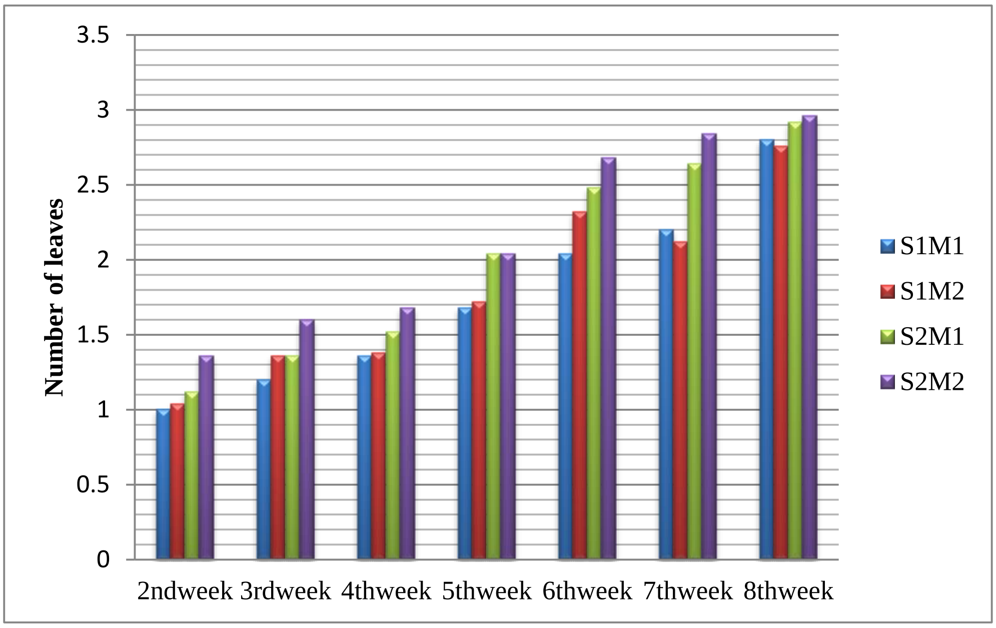


Fig. 3. Effect of media and rhizome bit size on number of Leaves in *Curcuma aromatica* Salisb seedlings in the nursery

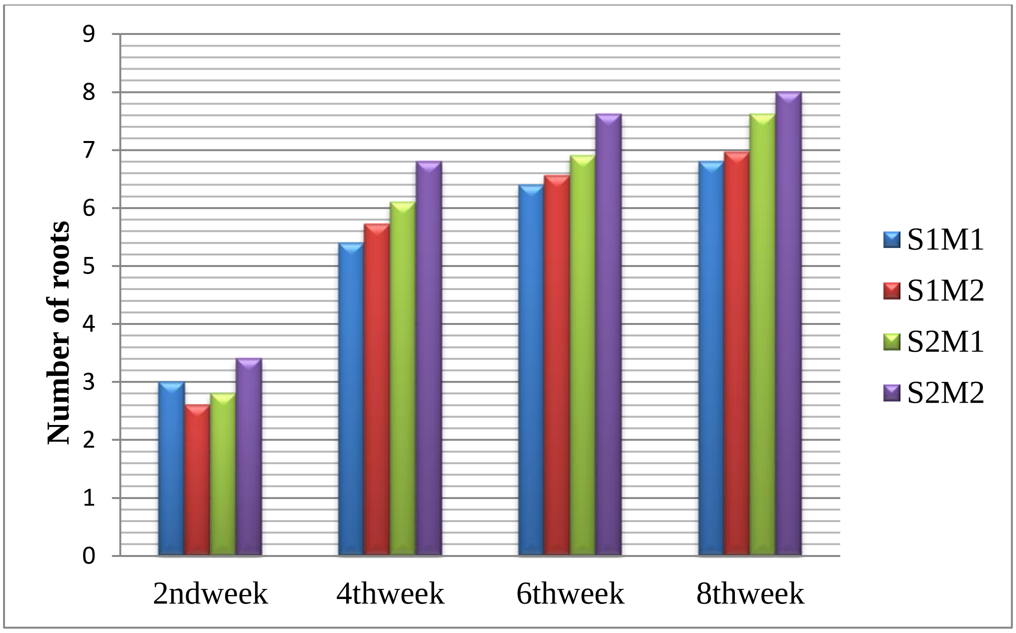


Fig. 4. Effect of media and rhizome bit size on number of roots *Curcuma aromatica* Salisb seedlings in the nursery.

seedlings. These results are also in conformity with the findings of Rakhee (2002) in turmeric, Sreekala (2004) in ginger, Sheeba (2004) in amaranthus and Santhosh Kumar (2004) in *Plumbago rosea.*

The significant influence of vermicompost as potting mixture in increasing growth characters of cardamom seedlings have been reported by Vadiraj *et al.* (1992) and Krishna Kumar *et al*. (1994). Where ever the vermicompost is more than 25 % in a media mixture, higher shoot growth and subsequently higher leaf area were observed in subabul seedlings as reported by Biradar *et al*., (2001). According to them the good water holding capacity coupled with optimal porosity could have helped the plantlets to establish better in this medium. Also, vermicompost in the potting medium might have stimulated the biochemical activity and nutrient cycling and thereby increase in the growth of vegetative characters.

Growing media are often formulated from a blend of different materials in order to achieve the ideal properties of the growth medium. Coirpith is the most commonly available material suitable for potting media preparation. Low density of coirpith coupled with good water holding capacity makes it a good potting media. Higher moisture retention capacity, porosity and nutrient status (Nagarajan *et al*., 1985) and better texture and porosity of coir pith (Singh *et al*., 2002) also attributed better growth. Similar results were reported by Siddagangaiah *et al*. (1996) in vanilla and Singh *et al*. (2003) in jojoba.

In the second experiment it was observed that compared to cowdung, application of vermicompost and *Trichoderma* to coir pith enhanced root initiation and root elongation. Besides, *Trichoderma* that colonizes the root system of seedlings might have helped in preventing infection by pathogens. It is hence presumed that all the above factors have contributed to the better seedling growth in this medium.

Another factor noticed in this experiment was that the morphological characters of the seedlings increased with increasing seed size. On the other hand, seedlings emergence was almost uniform irrespective of the size of seed rhizomes. Studies carried out in amorphophallus using different sized rhizome bits also revealed the same trend. Here also, plant height and canopy size were less when planting bits were smaller (KAU, 1983). Increase in plant height with increasing seed size has also been reported in ginger by Korla *et al.* (1989). Better seedling growth in the treatment S_2M_2 may be due to the stored food materials in the seed rhizome as well as the influence of media combination.

5.3. STANDARDIZATION OF AGE AT TRANSPLANTING

5.3.1. Morphological characters in the mainfield.

Result of the experiment showed that the variation in transplanting age of minisett seedlings had significant effect on their performance in the main field. These seedlings establish better in the field and their morphological characters, physiological parameters and ultimately yield was higher than that of conventional method of rhizome planting.

Comparing the morphological characters of the transplants with that of conventional rhizome planting (control) in the mainfield at 2, 4 and 6 MAP, it was observed that pro-tray seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($d_3s_2m_2$) established and grew well and their performance with regard to plant height, number of leaves, number and length of roots were significantly superior to seedlings of 2 node rhizome bits planted in M_1 (Cowdung + Coir pith + *Trichoderma*) media transplanted 30 DAS ($d_1s_1m_1$). In certain characters such as length and girth of primary and secondary rhizome it was on par with 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 45 DAS ($d_2s_2m_2$) and control plants. This observation gives us an inference that pro tray seedlings of kasthuri turmeric retained in the nursery for longer period and transplanted at a later stage performs better in the main field compared to those transplanted at early stage. Increase in plant height, pseudo stem length, number of leaves, leaf growth and yield was reported in 90-day-old transplants of ginger by Kumar *et al.* (2000). This result was also in conformity with cashew seedlings transplanted 6 weeks after sowing (Yeboah *et al.,* 2015).

The finding of Wurr *et al.,* (1986) that planting older transplants shortens the vegetative growth period of plants in the field and accelerates the plants entering the phase of generative initiation also supports this. The planting of seedlings with a ball of the media around the roots might have improved their survival and establishment in the field compared to control. In addition, seedlings raised in pro-trays have a well-developed root system contributing to better uptake of nutrient and water could be a reason for vigorous plant growth. The shoot with a larger leaf number and larger leaf size received a higher solar energy for photosynthesis, which ultimately resulted in a larger shoot biomass and it could be a reason for better morphological characters observed. This result is in agreement with the report of Sarker *et al*. (2001) on rice plant.

It was observed that the height of the transplanted minisett seedlings with that of conventional rhizome planting (control) was higher in the field at 2, 4 and 6 MAP (Fig.5 and 6). At the initial stage (2 MAP), in the mainfield control plants grow quickly because of the high amount of reserved nutrients. Later the seedlings from 3 node bits planted in M_2 media transplanted 45-60 DAS recorded superior performance with regard to plant height. Rapid establishment followed by better uptake of nutrients and water by the well developed root system could be the reason for the vigorous vegetative growth. However, as a whole, the plants from 2 node rhizome bits could not reach the plant height similar to that from 3 node bits (7g) and control plants.

Regarding the number of leaves, better leaf production was associated with seedlings raised using 3 node rhizome bits in M_2 (Vermicompost + Coirpith + *Trichoderma*) and in M_1 media (Cowdung + Coirpith + *Trichoderma*) and

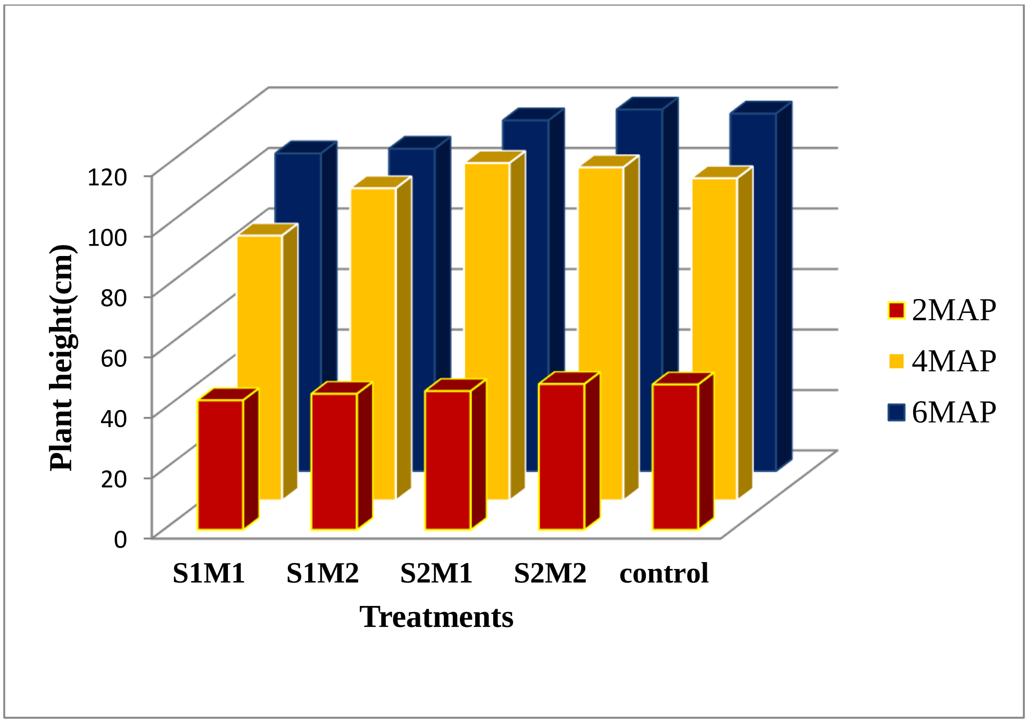


Fig.5. Effect of types of minisett seedlings on plant height (cm) in *Curcuma aromatica* Salisb at different growth stages in the mainfield.

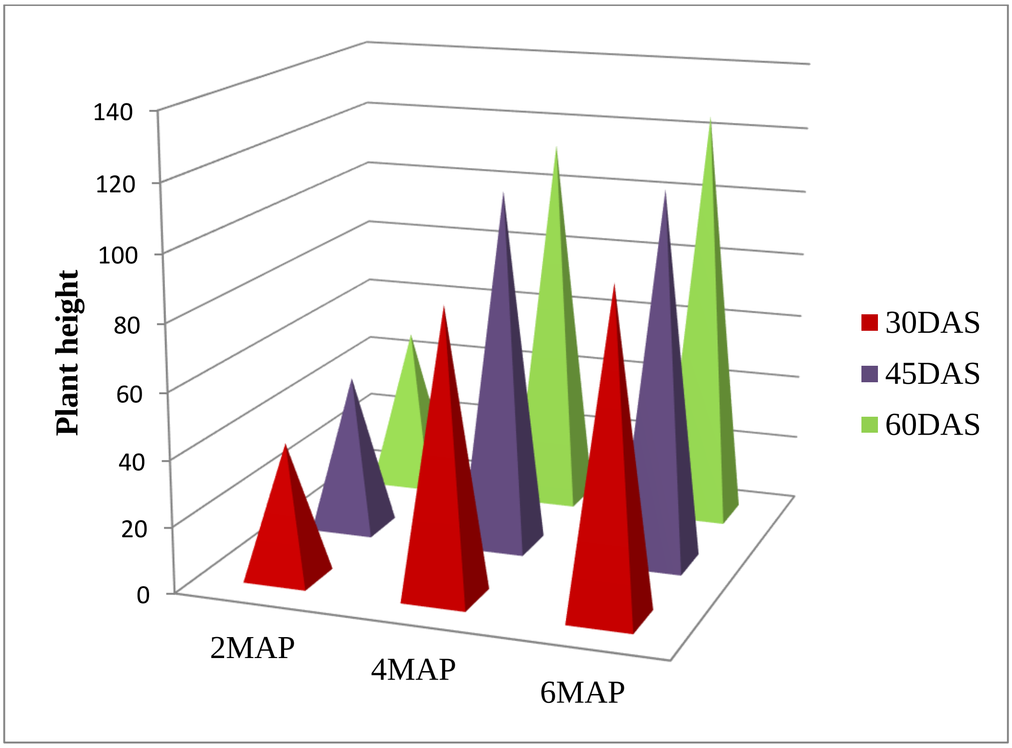


Fig.6. Effect of age at transplanting on plant height (cm) in *Curcuma aromatica* Salisb at different growth stages.

higher than seedlings raised using 2 node rhizome bits in M_1 media(Cowdung + Coirpith + *Trichoderma*) (Fig.7 and 8). At 2 MAP, the difference in the number of leaves was not large because the growth of the seedlings was almost uniform in the field and plants were applied a similar amount of nutrients, but leaf size was bigger in seedlings from 3 node bits. This result is in agreement with the report of Hossain *et al*. (2005) in turmeric. It was observed that the number of leaves in the control was less. This is because when seed rhizomes are sown directly in the field, they require 20-30 days to sprout and another 30 days to produce two to three leaves. Later at 4-6 MAP, the number of leaves increased because of the higher tiller number. This result was also in conformity with the findings of Senapathy (2011) in turmeric.

Regarding the tiller production, number of tillers per plant was more in control (plants from 15 g rhizome size) compared to minisett seedlings in all the 3 stages of observation (Fig.9 and 10). Tillers are produced from the axillary buds of the underground rhizomes and more the length of the rhizome more will be the possibility of increased tiller production. This can be the reason for less number of tillers in two node and three node bit seedlings. Deshmukh *et al.* (2005) also reported that in turmeric decrease in size of planting material significantly reduced tillers plant^{-1}. The present study also reveals that tiller production in kasthuri turmeric is influenced by rhizome sizes. Similar result was reported in cardamom (Bose *et al*., 1991) that planting of 20 cm long rhizome increased shoot number compared to small rhizome of 2.5 cm.

Contrary to this, Jayachandran (1989) reported that mini-seed ginger rhizome possessing one healthy viable bud and weighing 5-7 g produced normal plants with an average of 17 tillers per plant and an average yield of 180 g per plant. This result was also in conformity with the report of Korla *et al*. (1989) in ginger. They compared the rhizome bits weighing 5-10 g, 10-15 g, 15-20 g and 20-25 g in a three year trial and observed no significant difference in responses

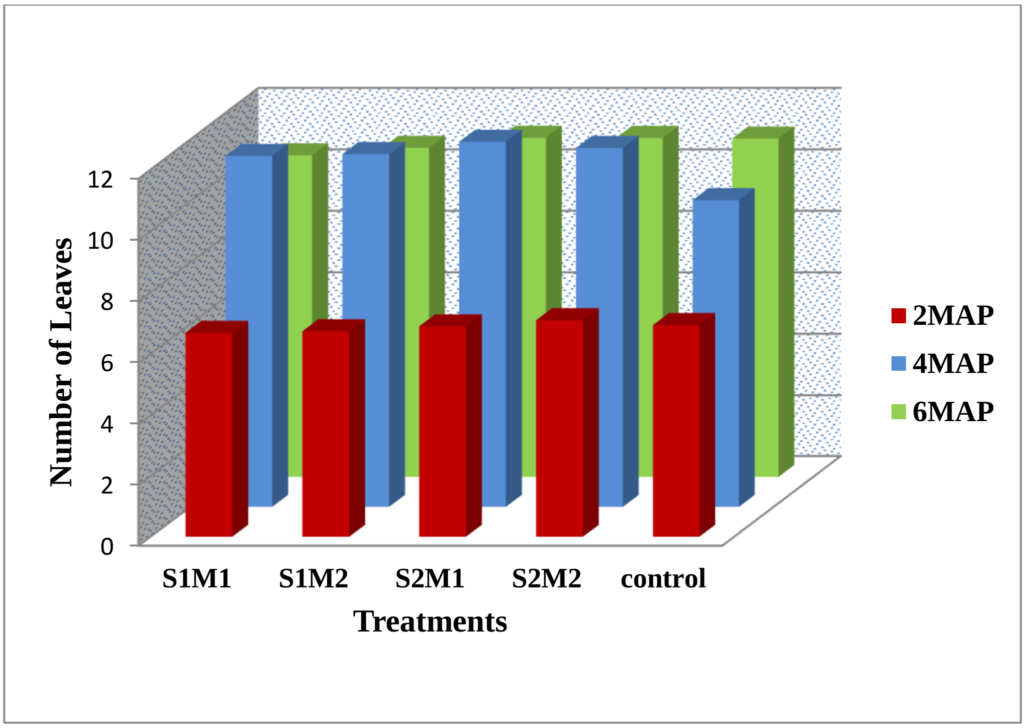


Fig.7. Effect of types of minisett seedlings on number of leaves in *Curcuma aromatica* Salisb at different growth stages in the mainfield.

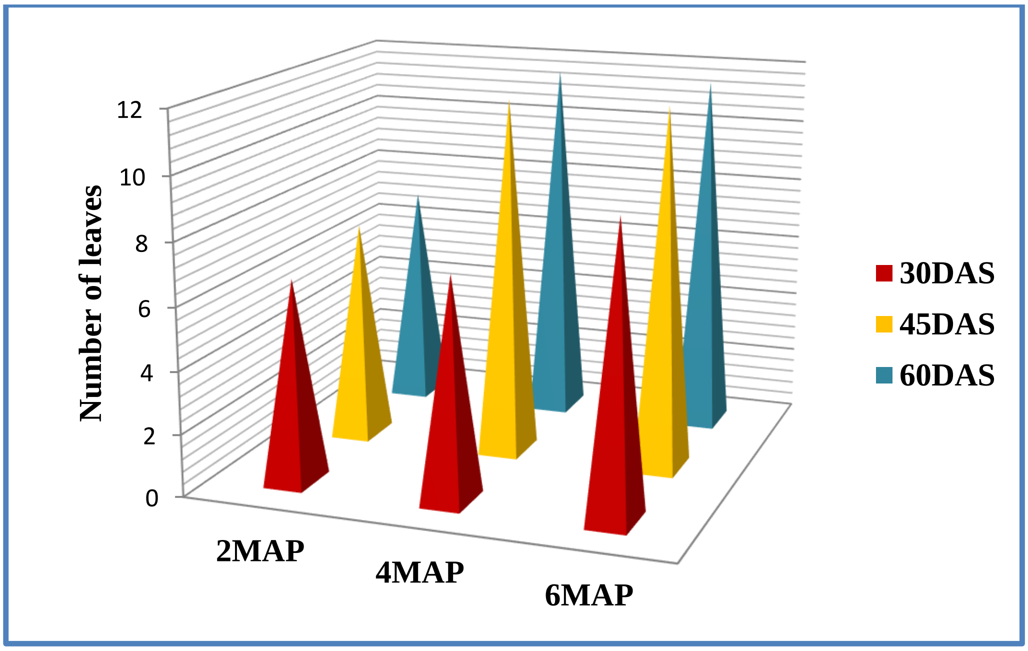


Fig.8. Effect of age at transplanting on Number of leaves in *Curcuma aromatica* Salisb at different growth stages.

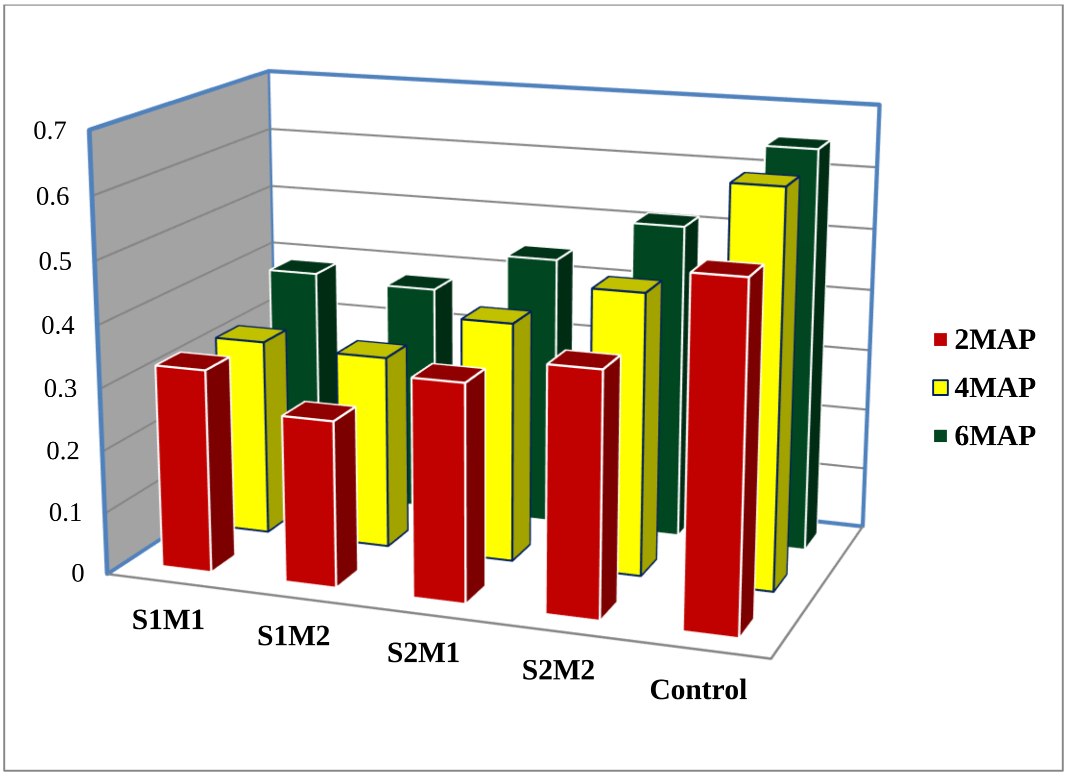


Fig.9. Effect of types of minisett seedlings on number of tillers in *Curcuma aromatica* Salisb at different growth stages in the mainfield.

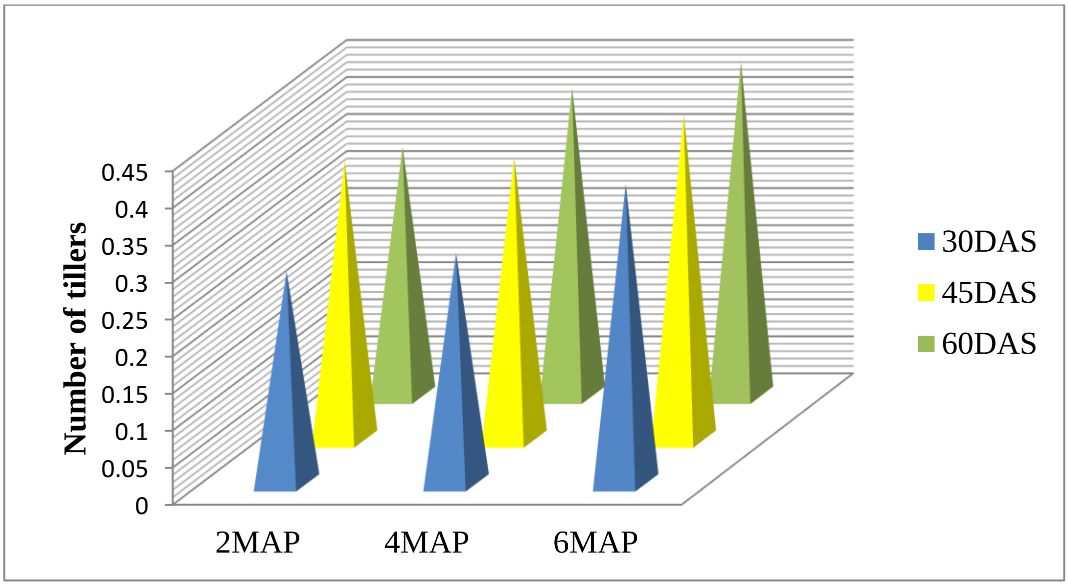


Fig.10. Effect of age at transplanting on number of tillers in *Curcuma aromatica* Salisb at different growth stages.

between 10-15 g and 15-20 g for number of tillers, leaf breadth, rhizome length and breadth, yield per plant and yield per plot.

On the other hand, age of seedlings does not seem to have any influence on tiller production. There was no significant difference among the pro-tray seedlings transplanted 45 ($d_2s_2m_2$) and 60 DAS ($d_3s_2m_2$) with respect to tiller production.

The seedlings which were transplanted 45 DAS and 60 DAS were superior and on par with regard to number of roots. Throughout the growth period, the performance of pro-tray seedlings raised from 3 node rhizome bit in M_2 (Vermicompost + Coirpith + *Trichoderma*) and transplanted at 45 ($d_2s_2m_2$) and 60 ($d_3s_2m_2$) DAS were on par. Compared to control plants, more number of roots were observed in seedlings of 3 node bits planted in M_2 (Vermicompost + Coirpith + *Trichoderma*) media (Fig.11 and 12). Production of more number of roots could be the effect of nursery mixture. The addition of vermicompost and *Trichoderma* to coir pith enhanced root initiation and root elongation in the nursey itself. Transplanting seedlings with better root system in the mainfield help in early establishment success and such plants have vigorous vegetative growth which ultimately leads to more number of roots. The performance of pro-tray seedlings raised from 2 node rhizome bits in M_1 media (Cowdung + Coirpith + *Trichoderma*) and transplanted at 30 DAS ($d_1s_1m_1$) was inferior.

It was observed that seedlings which were transplanted 45 DAS and 60 DAS were on par and superior compared to 30 DAS with regard to fresh and dry weight of rhizome. Presumably the increase in vegetative growth has contributed to the increase in rhizome yield of late transplanted pro-tray seedlings.

Generally larger the seed rhizome, higher will be the rhizome yield due to larger shoot biomass. However, as a whole, the yield was higher in the plants from 3 node rhizome bits planted in M_2 (Vermicompost + Coirpith + *Trichoderma*) media transplanted 45 ($d_2s_2m_2$) and 60 DAS ($d_3s_2m_2$) because they

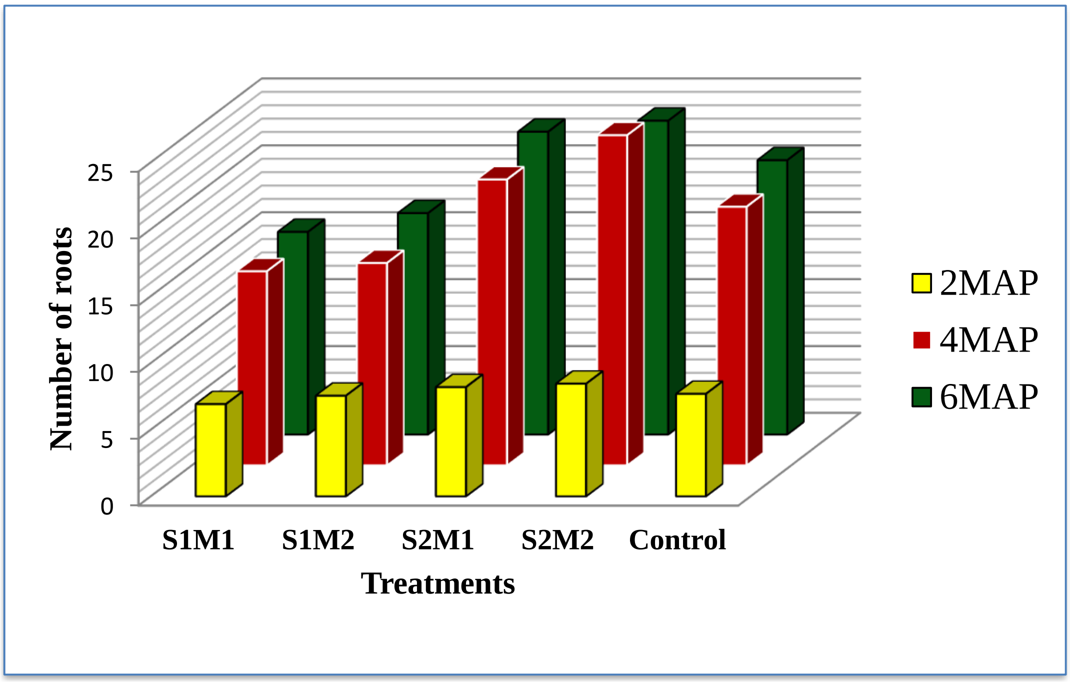


Fig.11. Effect of types of minisett seedlings on number of roots in *Curcuma aromatica* Salisb at different growth stages.

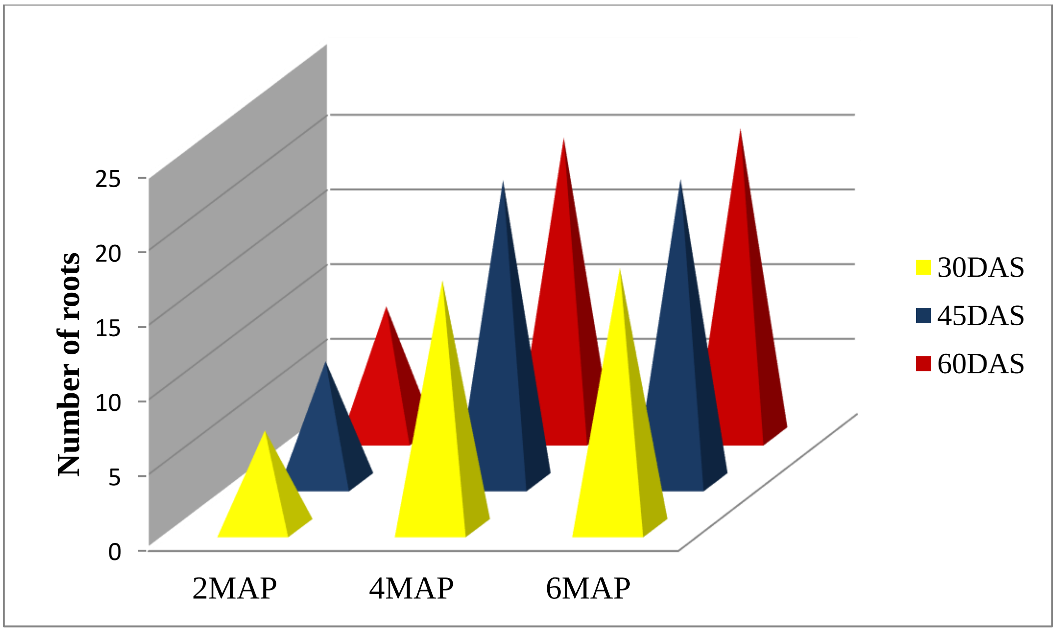


Fig.12. Effect of age at transplanting on number of roots in *Curcuma aromatica* Salisb at different growth stages.

had showed similar shoot growth as that of control plants. This result is in agreement with the reports of Hossain *et al.* (2000) and Ishimine *et al*. (2003) in turmeric. In addition, it was observed that pro-tray seedlings raised from 3 node rhizome bits produced secondary rhizome earlier and in a higher number, which ultimately increased the yield. Similar result was reported by Hossain *et al.* (2005) in turmeric.

5.3.2. Physiological characters

Comparing the physiological characters of the transplants with that of conventional rhizome planting (control) in the mainfield at 2, 4 and 6 MAP, it was observed that pro-tray seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($d_3s_2m_2$) recorded maximum leaf area index and crop growth rate and were superior to control plants and seedlings of 2 node rhizome bits planted in M_1 (Cowdung + Coir pith + *Trichoderma*) media transplanted 30 DAS ($d_1s_1m_1$). Throughout the growth period, the effect of pro-tray seedlings raised using 3 node rhizome bits in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 45 DAS ($d_2s_2m_2$) and 60 DAS ($d_3s_2m_2$) were on par with respect to crop growth rate and net assimilation rate. The enhanced leaf production coupled with more number of functional leaves retained per plant and higher photosynthetic area might have resulted in higher crop growth rate and net assimilation rate. The above result is in conformity with the findings of Arun kumar (2000) in amaranthus, Nihad (2005) in Chettikoduveli and Thakar Singh *et al*. (2006) in mustard. With regard to stomatal frequency no significant difference was noticed between transplanted seedlings and control plants at all growth stages observed.

Harvest index was the highest for seedlings transplanted 60 DAS compared to 45DAS and 30DAS. Harvest index of pro-tray seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 45 DAS ($d_2s_2m_2$) and 60 DAS ($d_3s_2m_2$) were on par. Compared to control plants it was observed that transplanted seedlings have higher HI. A better translocation of dry matter into rhizomes as reflected by high dry weight might have contributed to maximum HI. This result was also in conformity with findings of Maheswarappa *et al*., (1997) in galangal and Sajitha (2005) in garden bean.

5.3.3. Crop duration

With regard to the harvest maturity of rhizome, it was observed that seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($d_3s_2m_2$) matured earlier (180 DAP) followed by the seedlings of 2 node and 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) and M_1 (Cowdung + Coir pith + *Trichoderma*) media transplanted at 45 DAS (180-200 DAP) and 30 DAS (200 days). The control plants, on the other hand, took a maximum of 210-225 days to attain crop maturity. Thus the pro-tray seedlings have the advantage of saving about 30-40 days of duration in the open field. This result was also in conformity with the findings of Senapathy (2011) in turmeric. They observed that when turmeric seed rhizomes were sown directly in the field, they required 20-30 days to sprout and another 30 days to produce two to three leaves. Within 20 days such growth is attained in the rapid method and hence advantage of saving about 40 days of duration in the open field, thus avoiding one weeding.

5.3.3. Yield

The fresh yield and dry yield of rhizomes were found to be influenced by the age at transplanting and type of minisett seedlings (Fig.13 and 14). The age at transplanting differed significantly and the maximum fresh yield was associated with seedlings transplanted at 60 DAS (D_3) (13.92 t ha^{-1}). Among the type of seedlings, seedlings of 3 node bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media (S_2M_2) (15.98 t ha^{-1}) recorded the maximum fresh yield which was significantly superior to control plants (C) (15.33 t ha^{-1}) and seedlings of 3 node bits planted in M_2 (Cowdung + Coir pith + *Trichoderma*) media (S_2M_1) (13.345 t ha^{-1}). The lowest value was observed in seedlings of 2 node bits

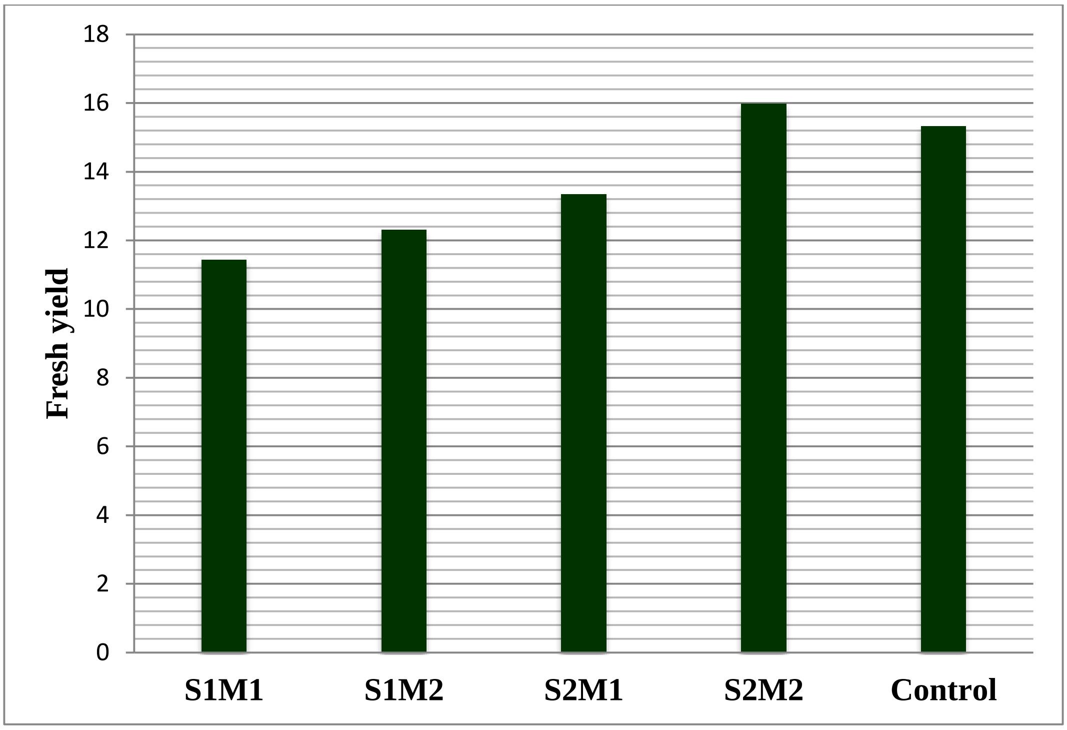


Fig.13. Effect of types of minisett seedlings on fresh yield (t ha^{-1}) in *Curcuma aromatica* Salisb.

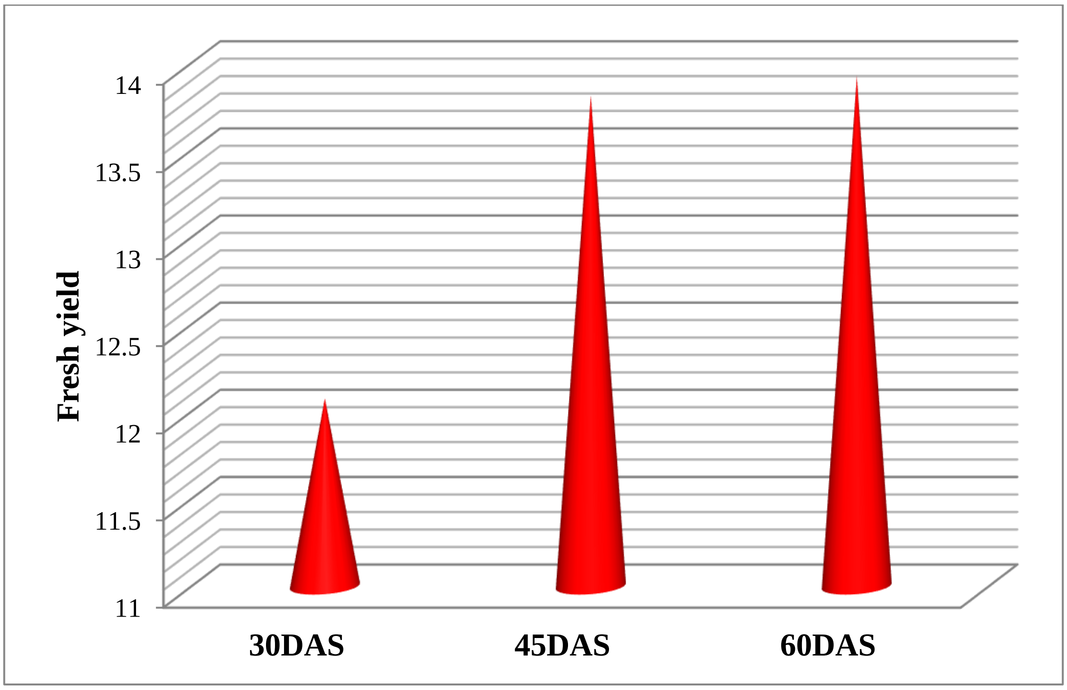


Fig.14. Effect of age at transplanting on fresh yield (t ha^{-1}) in *Curcuma aromatica* Salisb.

planted in M_1 (Cowdung + Coir pith + *Trichoderma*) (S_1M_1) (11.44 t ha^{-1}). Transplants with well-developed strong root system are probably much better prepared for a stress connected with planting in the field and such plants usually produce higher yield. The adequate transplanting age ensures continuous and uniform growth of plants after planting, which results in higher effectiveness and the yield and quality compared to control. The interaction effect of different media combination and seedlings from different rhizome size might be due to higher uptake of nutrients leading to more pronounced growth characters resulting in accumulation of more photosynthates and their further translocation to the rhizomes contributing yield.

5.3.4. Quality parameters

There seems to be not much difference in the quality parameters of rhizomes from the transplants and control plants. Volatile oil content was not influenced by different transplanting age and type of minisett seedlings, slight variation in non-volatile ether extract and oleoresin content was noticed but again it was on par with control plants. Similar findings have been reported in turmeric by Kumar and Gill (2010).

5.3.5. Economics of cultivation/ B: C ratio

Significant difference in the economics of cultivation of kasthuri turmeric using minisett seedlings and conventional planting was observed. Among the treatments, ($d_3s_2m_2$) recorded the highest gross income of Rs. 10, 50, 600 /- followed by ($d_2s_2m_2$) (Rs. 10, 33, 160/-) and control (Rs.9, 19, 800 /-). The same was observed with respect to net income. In the cost benefit analysis, treatment ($d_3s_2m_2$) recorded the highest B: C ratio of 3.29 followed by $d_2s_2m_2$ (3.23). The above result is in conformity with the findings of an on farm trial conducted by KVK, Dharmapuri, in which the use of protray seedlings reduced seed cost by an average of 15 percent and reduced the cost of cultivation. Here the yield and BCR was on par with that of seed rhizome planting.

Findings from the present study revealed that in an underexploited crop like kasthuri turmeric where there is shortage of good quality seed material, adoption of minisett technique can pave the way for successful crop production. The behaviour of the planting material like sprouting, vigour and viability hold a direct relationship with the size of planting material. So in order to get maximum number of viable rhizome bits, pre-treatment with growth regulators was essential. Pre-sprouting treatments with benzyl adenine 100 ppm enhances sprouting of two node and three node rhizome bits of kasthuri turmeric thereby reducing the quantity of the costly seed rhizome. Thus raising of pro-tray seedlings using three node bits in vermicompost and *Trichoderma* enriched coir pith mixture has good potential for obtaining sturdy, uniform and healthy seedlings. Maintaining such seedlings in the nursery for a period of not less than 30 days and transplanting such seedlings at 45-60 DAS in the main field ultimately leads to higher yield and 50% saving of seed material.

SUMMARY

6. SUMMARY

The study entitled, "Rapid multiplication of kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram during 2013-2015. The main objective of the study was to standardize minisett method of macro propagation and nursery techniques for rapid mass multiplication of kasthuri turmeric which is a medicinal and aromatic plant with multiple uses and has high cosmetic value.

The investigation was taken up as different experiments to find out the best pre-sprouting treatment for the minisetts, best media for the pro-tray seedlings, optimum age at transplanting of pro-tray seedlings and finally their field evaluation. The morphological characters, physiological parameters, yield attributes, biochemical characters and incidence of pests and diseases were noted during the crop period and B:C ratio was worked out.
The salient findings of the above studies are summarized in this chapter.

The first experiment ie, standardization of minisett size and pre-sprouting treatments showed that, rhizome bits with 3 node (S_2) showed better sprouting (72.5%) than 2 node bits (S_1) (64.13%). Also the pre-treatment with chemicals/growth regulators was significantly more influencing over the untreated control. Among the pre-treatments, soaking 3 node rhizome bits in benzyl adenine 100 ppm (T_3S_2) for 24 hrs recorded the highest sprouting (95.60 %) followed by 24 hr soaking of benzyl adenine 50 ppm (T_2S_2, 91.20 %). So the pre-sprouting treatments enhances sprouting of 2 node and 3 node rhizome bits thereby reducing the quantity of the costly seed rhizome.

In the second experiment ie, standardization of nursery media, it was observed that morphological characters like plant height, number, length and breadth of leaves, number, length and girth of roots were influenced by the different organic manure combination as well as the size of the rhizome bits. Seedlings from 3 node bits shows better performance compared to seedlings of 2 node bits. It was observed that seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coirpith + *Trichoderma*) media were vigorously growing and the growth parameters such as rooting percent, days to first leaf emergence, plant height, number of leaves, number of roots, and root length were significantly superior than 2 and 3 node bits in M_1 (Cowdung + Coirpith + *Trichoderma*) media.

For the standardization of optimum age at transplanting which was laid out in field, nursery seedlings of 30^{th}, 45^{th} and 60^{th} day old from different media combination were transplanted. Plants raised by conventional method i.e., planting of rhizomes with 15 g size were the control. Result of the experiment showed that the variation in transplanting age of minisett seedlings had significant effect on their morphological characters, physiological parameters and ultimately yield which was higher than that of conventional method of rhizome planting.

Comparing the morphological characters of the transplants with that of conventional rhizome planting (control) in the mainfield at 2, 4 and 6 MAP, it was observed that pro-tray seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($s_2m_2d_3$) established and grew well and their performance with regard to plant height, number of leaves, number and length of roots were significantly superior to seedlings of 2 node rhizome bits planted in M_1 (Cowdung + Coir pith + *Trichoderma*) media transplanted 30 DAS ($s_1m_1d_1$). In certain characters such as length and girth of primary and secondary rhizome, it was on par with 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 45 DAS ($s_2m_2d_2$) and control plants.

The fresh yield and dry yield of rhizomes were found to be influenced by the age at transplanting and type of minisett seedlings. Regarding fresh rhizome yield, 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($s_2m_2d_3$) recorded the highest value (15.98 t ha^{-1}) which was higher than control (15.33 t ha^{-1}).

With regard to physiological characters of transplants with that of conventional rhizome planting (control) in the mainfield at 2, 4 and 6 MAP, it was observed that pro-tray seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($s_2m_2d_3$) recorded maximum Leaf area index and Crop growth rate and was superior to control plants and seedlings of 2 node rhizome bits planted in M_1 (Cowdung + Coir pith + *Trichoderma*) media transplanted 30 DAS ($s_1m_1d_1$). Throughout the growth period, the effect of raising of seedlings using 3 node rhizome bits in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 45 DAS ($s_2m_2d_2$) and 60 DAS ($s_2m_2d_3$) were on par for Crop growth rate and Net assimilation rate.

Comparing the quality parameters of the transplants with that of conventional rhizome planting (control) in the mainfield after harvest, it was observed that compared to control there was no significant difference was found with respect to the quality parameters. Volatile oil content was not influenced by different transplanting age and type of minisett seedlings but influences Non-volatile ether extract and oleoresin content. The maximum value of both the content was associated with seedlings transplanted 60 DAS which was significantly superior to seedlings transplanted 45 and 30 DAS. Among the type of seedlings, seedlings of 3 node bits planted in M_2 media (Vermicompost + Coirpith + *Trichoderma*) recorded the maximum value which was on par with control plants.

In the cost benefit analysis, 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 ($d_3s_2m_2$) (3.29) and 45 ($d_2s_2m_2$) (3.23) DAS recorded higher B:C ratio compared to control (2.98). No serious pests and diseases were noted during the crop growth. But in certain pockets a mild attack by shoot borer (*Conogethes punctiferalis*) was noticed and plant protection measures were carried out by removing the affected shoots and spraying 0.05 per cent Dimethoate at fortnightly interval.

Findings from the present study revealed that in an under exploited crop like kasthuri turmeric where there is shortage of good quality seed material, adoption of minisett technique can pave the way for successful crop production. In kasthuri turmeric the sprouting, vigour and viability hold a direct relationship with size of planting material and pre-sprouting treatments with benzyl adenine 100 ppm enhances sprouting of both two node and three node rhizome bits thereby reducing the quantity of the costly seed rhizome. Thus raising of pro-tray seedlings using three node bits in vermicompost and *Trichoderma* enriched coir pith mixture has good potential for obtaining sturdy, uniform and healthy seedlings. Maintaining such seedlings in the nursery for a period of not less than 30 days and transplanting such seedlings at 45-60 DAS in the main field ultimately leads to higher yield and 50% saving of seed material.

Future line of study:

Continue the standardization of nursery technique by using different plug sizes for better seedling root proliferation and induced growth.

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RAPID MULTIPLICATION OF KASTHURI TURMERIC (*Curcuma aromatica* Salisb.) THROUGH MINISETT TECHNIQUE AND NURSERY MANAGEMENT

By

ASWATHY T. S

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ABSTRACT

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ABSTRACT

The study entitled "Rapid multiplication of kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management" was carried out with an objective to standardize minisett method of macro propagation and nursery techniques for rapid mass multiplication of kasthuri turmeric. The investigation was taken up as different experiments to find out the best pre-sprouting treatment for the minisetts, best media for the pro-tray seedlings and finally the optimum age at transplanting of these seedlings and their field evaluation.

In the 1st experiment, rhizome bits with two node (S_1 - approximate weight 5g) and three node (S_2- approximate weight 7g) was prepared and it was subjected to different pretreatments with chemicals/growth regulators such as Benzyl adenine (BA – 25 ppm, 50 ppm and 100 ppm for 24 hrs.), Ethrel (125 ppm for 30 mts and 250 ppm for 15 mts) , Potassium nitrate(KNO_3 - 0.2 % for 30 mts) and Urea (5g L^{-1} for 30 mts) with an absolute control (no pre-soaking treatment) to find out the best sprouting treatment. It was observed that better sprouting (72.50 %) was noticed in 3 node rhizome bits than in 2 node bits (64.13 %). Among the pre-treatments, soaking rhizome bits in benzyl adenine 100 ppm for 24 hrs. recorded the highest sprouting (95.60 %). The pre-treatment using 0.2% KNO_3 (45.80 %) gave the lowest sprouting which was on par with control (54.00 %)

In the 2nd experiment, the best media combinations for pro-tray seedlings as well as the optimum age at transplanting were assessed. The results revealed that out of the three nursery mixture combinations, growth parameters such as rooting percent, plant height, number of leaves, number of roots, and root length were significantly superior in M_2 (Vermicompost + Coirpith + *Trichoderma*) compared to M_1(Cowdung + Coirpith + *Trichoderma*) media. In M_3 (Coirpith + Neemcake + *Trichoderma*) decaying of the sprouted bits were noticed.

To find out the optimum age at transplanting ,the field experiment was laid out in split plot design with 3 different sowing dates (D_1 -30th, D_2 -45th and D_3 -60th DAS) of both 2 node (S_1) and three node (S_2) seedlings from M_1 and M_2 media combination (S_1M_1, S_1M_2, S_2M_1 and S_2M_2) with five replication. Plants raised by conventional method i.e., planting of rhizome with 15 g size was the control. The results revealed that minisett seedlings established better in the field and their morphological characters, physiological parameters and ultimately yield were higher than that of conventional method of rhizome planting.

The seedlings of 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($s_2m_2d_3$) recorded significantly superior performance with regard to plant height, number of leaves, number and length of roots, physiological parameters viz., Net assimilation rate, Crop growth rate, Leaf area index and biochemical characters such as oleoresin and non-volatile ether extract content than seedlings transplanted 30 DAS. Regarding fresh rhizome yield, 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 DAS ($s_2m_2d_3$) recorded the highest value (15.98 t ha $^{-1}$) which was higher than control (15.33 t ha $^{-1}$). In the cost benefit analysis, 3 node rhizome bits planted in M_2 (Vermicompost + Coir pith + *Trichoderma*) media transplanted 60 ($d_3s_2m_2$) (3.29) and 45 ($d_2s_2m_2$) (3.23) DAS recorded higher B:C ratio compared to control (2.98).

Findings from the present study reveal that pre-sprouting treatments with benzyl adenine 100 ppm enhances sprouting of two node and three node rhizome bits of kasthuri turmeric thereby reducing the quantity of the costly seed rhizome. Thus raising of pro-tray seedlings using three node bits in vermicompost and *Trichoderma* enriched coir pith mixture has good potential for obtaining sturdy, uniform and healthy seedlings. Maintaining such seedlings in the nursery for a period of not less than 30 days and transplanting such seedlings at 45-60 DAS in the main field ultimately leads to higher yield and 50% saving of seed material.

APPENDICES

APPENDIX - I

Month	Max. temp (◦C)	Min. temp (◦C)	Rainfall (mm)	RH (%)	Evaporation (mm)
May	31.94	24.73	21.56	90.03	3.60
June	30.91	23.19	3.14	92.47	3.20
July	29.99	24.30	5.83	84.74	3.80
August	29.55	23.74	31.55	86.00	5.40
September	30.21	24.19	16.88	84.88	4.20
October	30.52	23.82	12.11	84.67	4.00
November	30.18	23.38	6.87	85.35	1.60
December	30.19	23.38	11.12	83.52	2.00
January	30.60	21.56	4.00	79.43	3.05

Weather data during crop growth rate (Monthly average)

APPENDIX – II

Cost of cultivation (for 1 ha)

Cost of inputs (for 1 ha)

Inputs	Amount	Unit price
Seed material	500-1500 kg	60/ kg
FYM	50t	400/t
Fertilizers	-	9636
Plant protection	-	3000
BA	3g	3000/1g
Protrays	2000	38/ tray
Potting media		
1.Cow dung	500 Kg	5/kg
2.Vermicompost	500 Kg	10/kg
3.Coir pith	500 Kg	100/kg
4.Trichoderma	40 Kg	80/kg

Labour requirement

Activities	Number of labourers.
Land preparation	20
Ploughing	35
Bed preparations	60
Planting ,manuring and mulching	48
Weeding	18
Second weeding and mulching	26
Irrigation	10
Plant protection	5
Harvesting	32
Cleaning and removal of roots	20
Total	274

Appendix II (Continued.)

Particulars	S_1M_1	S_1M_2	S_2M_1	S_2M_2	Conventional method
Cost of planting material	(565 Kg) 33900	(565 Kg) 33900	(525 Kg) 31500	(525 Kg) 31500	(1500 Kg) 90000
Cost of pre-treatment chemical BA(100ppm)	15000	15000	15000	15000	-
Cost of Pro-trays	76000	76000	76000	76000	-
Cost of nursery mixtures	6100	8600	6100	8600	-
Cost of fertilizers and PP chemicals	32636	32636	32636	32636	62636
Cost of labour (@ Rs. 588/labour)	155232	155232	155232	155232	155232
Total cost	318868	321368	316468	318968	307868
Total return	(11.86t) 712000	(12.77t) 766440	(13.54t) 812840	(17.51t) 1050600	(15.33t) 919800