STANDARDISATION OF NURSERY TECHNIQUES THROUGH FIELD VALIDATION IN MINISETT CASSAVA (*Manihot esculenta* Crantz).

by

SRUTHY K.T.

(2016 - 11 - 007)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2018

DECLARATION

I, hereby declare that this thesis entitled **"STANDARDISATION OF NURSERY TECHNIQUES THROUGH FIELD VALIDATION IN MINISETT CASSAVA (*Manihot esculenta* Crantz)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,

Date: 06-07-2018

SRUTHY K.T.

(2016-11-007)

<u>**CERTIFICATE**</u>

Certified that this thesis, entitled **"STANDARDISATION OF NURSERY TECHNIQUES THROUGH FIELD VALIDATION IN MINISETT CASSAVA (*Manihot esculenta* Crantz)"** is a record of bonafide research work done independently by **Ms. SRUTHY K.T. (2016-11-007)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,

Date: 06/07/2018

Dr. RAJASREE G.

(Major Advisor, Advisory Committee)

Associate Professor

Department of Agronomy

College of Agriculture, Vellayani,

Thiruvananthapuram- 695 522

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Sruthy K.T. (2016-11-007)** a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy agree that this thesis entitled **"STANDARDISATION OF NURSERY TECHNIQUES THROUGH FIELD VALIDATION IN MINISETT CASSAVA (*Manihot esculenta* Crantz)"** may be submitted by **Ms. Sruthy K.T.** in partial fulfillment of the requirement for the degree.

6/7/2018

Dr. Rajasree G.
(Major Advisor, Advisory Committee)
Associate Professor
Department of Agronomy
College of Agriculture, Vellayani,
Thiruvananthapuram

Dr. Sansamma George
(Member, Advisory Committee)
Professor and Head
Department of Agronomy
College of Agriculture, Vellayani
Thiruvananthapuram

Dr. Vijayaraghava Kumar
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Statistics
College of Agriculture, Vellayani,
Thiruvananthapuram

Dr. Babu Mathew P.
(Member, Advisory Committee)
Professor
Department of Agronomy
College of Agriculture, Vellayani
Thiruvananthapuram

6.7.18

EXTERNAL EXAMINER
Dr. S. Sunitha
Principal Scientist
Division of crop production,
Central Tuber Crops Research Institute
Sreekaryam, Thiruvananthapuram

ACKNOWLEDGEMENT

First and foremost I bow my head before The Almighty for enlightening and making me confident and optimistic throughout my life and enabled me to successfully complete the thesis work in time.

It is with great respect and devotion, I express my deep sense of gratitude and indebtedness to my major advisor ***Dr. Rajasree. G****, Associate Professor, Department of Agronomyfor her expert advice, inspiring guidance, valuable suggestions, above all, the extreme patience, understanding and wholehearted co-operation rendered throughout my research work. I really consider it my greatest fortune in having the privilege of being guided by her.*

I am thankful to ***Dr. Sansamma George,*** *Professor and Head, Department of Agronomy and member of advisory committee for her valuable suggestions throughout the research programme and critical scrutiny of the manuscript.*

I am thankful to ***Dr. Vijayaraghava Kumar****, Professor and Head, Department of Agricultural Statistics for his invaluable help, guidance in preparation of the thesis.*

I am greatful to ***Dr. Babu Mathew P****, Professor, Department of Agronomyfor his expert advice and assistance throughout the conduct of experiment.*

I wish to record my profound sense of gratitude and indebtness to ***Dr.Sheela K. R,*** *Professor (Rtd.), Department of Agronomy for her unstinted support, valuable help, expert advice, constructive criticism, suggestions and keen interest shown at every stage of this research work.*

I take this opportunity to express my obligations to all teachers of the Department of Agronomy for their sincere co-operation and assistance during the course of investigation.

I express my deep sense of gratitude to non teaching staff of the ***Department of Agronomy*** *and labourers of Instructional farm for timely help rendered to me during the field and lab works.*

I am extremely thankful to my dear friends ***Priyatha, Shahiba, Suman, Ravi, Muhsi, Shamsi, Sree,Nasreen, Grichu, Gokul, Amru, Raeesa, Divya, Ajmal, Ajil, Ishrath itha****,* ***Maria****and all batchmates for their whole hearted support at one stage or any other stage of my research work.*

No words can truly express my indebtedness to my loving ***Achan****,* ***Amma*** *and* ***Kannettan*** *for their affection, constant encouragement, moral support, care and blessings that have enable me to do this work confidently, without which I could not have complete this research.*

Sruthy K. T

CONTENTS

LIST OF TABLES

8

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF PLATES

15

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
°C	Degree Celsius
%	Per cent
BC ratio	Benefit:cost ratio
CD(0.05)	Critical difference at 5 per cent level
cm	Centimetre
cm^3	Cubic Centimetre
CRD	Completely randomised design
dS m^{-1}	Deci Siemens per meter
EC	Electrical conductivity
et al.	Co- workers/ co-authors
Fig.	Figure
FYM	Farm yard manure
ha	Hectare
ha^{-1}	Per hectare
h	Hours
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
MAP	Months after planting
mm	Millimetre
No's	Numbers
$Plant^{-1}$	Per plant
RH	Relative humidity
$Seedling^{-1}$	Per seedling
SEm	Standard error of means
t ha^{-1}	Tonnes per hectare
var.	Variety
Vs.	Versus
Viz.,	Namely
WAP	Weeks after planting

INTRODUCTION

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) which is commonly called tapioca reigns as a major source of food to the hungry millions especially of the developing countries across the globe. Cassava was introduced to India in the Malabar region by the Portuguese in 17^{th} century and the crop has been in cultivation in the country for more than a century. The crop was popularized in Kerala by the King of erstwhile Travancore His Highness Visakhom Thirunal who introduced different cassava varieties from Malaya and other places and this new food crop saved the people of Travancore province from the clutches of famine during II World War.

Cassava is considered as a future food crop as regards to its biological efficiency coupled with ability to sustain biotic and abiotic stresses under changing climate especially during drought and to grow well in marginal soils. The cassava varieties generally take about 10 months for harvesting and thus occupy the land for a long period. The development of high yielding and short duration varieties of the crop has however enabled the farmers to adopt year round planting under high intensity cropping system especially under rainfed conditions. The aberrant weather conditions however makes the rainfed cultivation of cassava risky due to poor seedling establishment on account of drying of setts. Under such situation the crop can be raised in a nursery and transplanted to the main field when crop growing period is short. The Central Tuber Crops Research Institute (CTCRI) has developed a rapid multiplication technique for major tuber crops including cassava using minisetts (George and Nedunchezhiyan, 2008). However the root damage during transplanting from the raised beds and higher cost of production were found to be the major hurdles in popularising this method and hence there is a need to standardise cost effective nursery techniques for the rapid multiplication and production of cassava seedlings. Further more, there exists ample scope to explore the possibility of raising cassava minisetts in plastic cups or protrays as tried in case of hardening of tissue culture cassava seedlings, to reduce the root damage of seedlings, cost of production in nursery and for the easiness in transportation of seedlings.

Quality characteristics of potting media in providing the required conducive environment for sprouting of minisetts in the nursery differ considerably. Further more, it is also desirable to investigate whether the influence of potting media in the nursery is carried over to the main field through the seedling quality which can also reflect in the final crop productivity. Therefore there is a need to compare different types of growth substrates to find out the most suited one for minisett seedling production to make recommendations for economic multiplication of planting materials in the nursery.

In conventional planting method of cassava, 10 to 12 noded setts are used while in minisett propagation, one, two or three noded cuttings are used as planting material. In cassava, number of nodes per minisett is an important criteria in deciding the quantity of stored food materials in the setts and production of storage roots, and the initial dry matter content of nodes influence the growth and development of the crop through the production and subsequent partitioning of assimilates (Bridgemohan and Bridgemohan, 2014). Therefore it is desirable to compare the type of cuttings and to validate their performance in the main field in order to standardize the nursery techniques.

Age at which cassava seedlings are transplanted to the main field is another factor to be investigated as transplanting over aged seedlings can cause root damage, while transplanting the seedlings too early may result in poor establishment in the main field. The performance of crop transplanted in a staggered manner could also be reflected in the final yield and economics through variation in production of leaf canopy, storage roots and the dry matter accumulation in general.

The minisett technique is a good option for rapid multiplication of cassava planting materials for the production of rooted cuttings especially for the contingent planting in aberrant rainfall conditions and uncertainty in the rain fall pattern of the State has been reported by the India Meteorological Department (IMD, 2016).

However the scientific studies comparing the field performance of minisett cassava and normal sett planting are meager and hence there is a need to standardize the cassava minisett nursery techniques by validating its field performance in comparison with normal sett planting for developing rapid, cost effective and economic method of propagation in cassava.

With this background the present study was carried out with the following objectives;

- To standardise nursery techniques for minisett cassava and validate it's field performance
- To compare economics of cultivation of minisetts with normal sett planting

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cassava (*Manihot esculenta* Crantz.) is considered as the future food crop as regards to its biological efficiency coupled with ability to sustain under changing climate. Under rainfed conditions where the crop growing period is short, cassava can be cultivated by nursery planting and minisett technology is quite appropriate for producing rooted cuttings. Different types of potting media can be used in nursery for sprouting of minisetts and there is a need to standardise the potting medium for optimum germination and establishment of minisetts. The number of nodes of minisetts at planting is an important factor physiologically deciding the cassava tuber yield in main field. The optimum age at which minisett cassava seedlings are to be transplanted to the main field is another factor that needs to be investigated.

The minisett nursery techniques for rapid multiplication in tropical tuber crops and their effect on growth and yield in main field cultivation have been investigated by several researchers. In this chapter, a detailed review of research work done on minisett nursery techniques, type of minisett cutting, type of potting media, optimum age of transplanting and their effect on growth, yield and economics of cultivation of crops, especially tropical tuber crops and a comparison of minisett technology with conventional planting materials have been presented.

2.1 NURSERY TECHNIQUES AND CROP PERFORMANCE IN NURSERY

2.1.1 Effect of type of minisett cutting on sprouting, establishment and crop growth in nursery

Minisett technique is a good option for rapid multiplication of cassava planting materials for the production of rooted cuttings especially for the contingent planting in aberrant rainfall. According to IITA (2001), one or two node hardwood minisetts, four to six node semi mature minisetts and six to ten nodes tip shoot minisetts were successful in rapid multiplication of cassava which resulted about 60-

100 ministem cuttings from a cassava plant. In another study in cassava, George (2006) reported that the two node and three node cassava minisetts had higher establishment percentage of 86.94 and 88.68 respectively compared to single node minisett (76.79 per cent). In the rapid multiplication technique developed by the Central Tuber Crops Research Institute (CTCRI), cassava minisetts having two nodes were planted in the nursery in shade house (35 per cent shade), end to end horizontally, 5 cm deep leaving 5 cm between the rows and were transplanted to the main field 3 to 4 weeks after planting at a spacing of 45 x 45 cm (George and Nedunchezhiyan, 2008) and this method was found to result in better establishment of seedlings. However maximum root damage has been reported during uprooting the seedlings from minisett cassava nurseries (Nedunchezhiyan *et al.*, 2008). Planting rooted plantlets of tissue culture cassava having 4-5 cm length in plastic cups with perforations at bottom, filled with potting mixture and keeping them for one month period for hardening has been reported to be an effective method of acclimatisation by Shiji *et al.* (2014). According to Isaac *et al.* (2015), when three- noded cassava minisetts were planted in grow bags, days to 50 per cent sprouting was earlier (2.67 days) in cassava when compared with planting of eight-noded normal setts (4.33 days). The success of growing two-noded cassava minisetts in protrays is evident from the investigations carried out in Kerala Agricultural University by Vipitha (2016).

Minisetts techniques in other tuber crops such as yams and aroids have also been investigated by many researchers. Pre-sprouting of minisetts in nursery for the success of yam minisett technique was reported by Otoo *et al.* (2001). According to Akubuo (2002), minisetts from the head region of seed yam tubers of *Dioscorea* spp. sprouted earlier and achieved 50 per cent germination and maximum growth attributes before those from the middle and tail portions in nursery. Ayankanmi *et al.* (2005) reported that some varieties of *Dioscorea rotundata* showed higher sprouting potential with an increase in minisett size and the standard minisett size of 25 g resulted poor sprouting when compared to 50 to 125 g minisetts. Sprouting and non sprouting percentage of potato mini tubers were studied by Bolandi *et al.* (2011) and a positive correlation was observed between mini tubers diameter and their sprouting percentage. According to Aighewi *et al.* (2015), minisett tubers of 25–100 g size was used in yam (*Dioscorea rotundata* Poir.) by the farmers in West Africa due to the faster rate of multiplication, ease of operation and potential for production of better quality planting material. While investigating the performance of tuber minisetts in grow bags, Isaac *et al*. (2015) reported that days to 50 per cent sprouting and germination were delayed in minisett elephant foot yam and greater yam compared with conventional corms. Paul *et al.* (2016) reported that more reserve food was there in bigger mini tubers and hence larger tubers had better sprouting ability than the smaller ones in *Dioscorea rotundata* minisett nursery experiment.

2.1.2 Effect of potting media in nursery

2.1.2.1 Effect of potting media on sprouting, establishment and growth in nursery

The performance of seedlings in the nursery is often influenced by the potting medium used for multiplication of planting material. The sprouting and establishment of seed material and shoot and root growth of seedlings are the major factors influenced by the type of potting medium used in the nursery.

Coir pith is an organic waste composed of lignocellulosic fibrous material, which is separated from the husk of the coconut fruit. According to Savithri and Khan (1994), coir pith is having a spongy structure, increased bulk density, particle density, maximum water holding capacity and volume expansion as a growing medium. Positive effect of composted coir pith as potting media has been previously reported by Reghuvaran and Ravindranath (2010) and in their experiment on medicinal plants, pots containing higher percentage of coir pith than soil resulted in maximum shoot and root length. Jata *et al.* (2013) evaluated different nursery techniques in cassava and found that maximum shoot length was observed in plants grown in compost alone or in combination with sand and soil in dapog nursery method. Paramanandham *et al.* (2014) reported that coir pith is an ideal potting medium which facilitate the continuous and prolonged availability of water for the plants grown in soilless growing media. Based on germination and seedling growth characters (root length, shoot length, dry matter production and vigour index), the best nursery medium for tomato was found to be equal proportion of coir pith and vermi compost (Srinivasan and Srimathi, 2017).

Vermi compost could be considered as a commercial potting medium owing to its physical and chemical properties which support the better establishment and growth of seedlings. When potting medium was substituted with vermi compost, significantly higher shoot growth was recorded in tomato seedlings than those in the soil medium (Atiyeh *et al.*, 2000). According to Zaller (2007) vermi compost in potting media had no detrimental but rather a stimulatory effect on emergence and root growth of tomato seedlings and has thus considerable potential for substituting peat in horticultural potting substrates. In this study vermi compost as a potting medium was also found to favourably influence the emergence and root shoot ratio of seedlings. Manh and Wang (2014) reported that vermi compost as a potting substrate in combination with coconut husk and rice hull ash could significantly influence the seedling growth of muskmelon.

Normal top soil as a potting medium for nursery raising has been explored by several researchers. Abudulai and Quansah (2002) reported that normal top soil is an ideal medium for growing yam minisetts and 78-92 per cent sprouting of minisetts from *Diascoria alata* was observed when top soil was mixed with saw dust as a potting medium. In a study conducted in Kerala Agricultural University, Isaac *et al.* (2013) reported that soil component in the medium was important for stimulating sprouting of the minisetts and the sprouting percentage and speed of emergence of *Dioscorea* minisetts were significantly higher when soil alone was used as a potting medium compared to soil less media.

2.1.2.2 *Effect of potting media on nutrient status and quality of growing substrate*

Addition of different types of potting media can modify the available nutrient status, physical and chemical properties and quality of the growing medium in the nursery. Abbiramy and Ross (2012) reported that when vermi composted coir piths were amended with garden soil as a pot medium for the growth of okra, concentration of nitrogen in vermi composted coir pith increased with increase in cow dung (i.e. maximum in 1:1 ratio than others). In all ratios of vermi composted coir pith, a reduction of lignin and cellulose content was observed. In another nursery experiment on muskmelon (Manh and Wang, 2014) when vermi compost was added as a sole substrate, the pH and EC of the growing medium were higher compared to the media prepared by addition of vermi compost in different ratios with rice hull and coconut husk. The concentration of K, Mn, Fe, Zn and Cu in the substrate significantly increased with decreasing rate of mixed vermi compost in the medium while N, P, Ca and Mg were reduced when proportion of vermi compost was reduced in the media.

According to Prasath *et al.* (2014), addition of vermi compost in potting mixture increased the organic matter content, phosphorus, magnesium, iron, manganese and zinc availability when potting mixture was prepared by mixing coir pith compost and vermi compost in 3:1 ratio for raising pepper seedlings in protrays. Thenmozhi (2015) reported that when vermi composted coir pith was amended with garden soil as a potting medium for okra, the N, P and K content of the potting medium increased while the C:N ratio decreased in vermi compost with equal ratios of coir pith and cow dung.

2.2 NURSERY TECHNIQUES AND CROP PERFORMANCE IN MAIN FIELD

2.2.1 Effect of nursery techniques on growth and growth attributes in main field

2.2.1.1 Effect of type of minisett cutting on growth and growth attributes

Type of minisett cuttings or size of minisetts decide the quantity of stored food in the planting material and hence influence the performance of tuber crops in the main field. Several researchers have studied the influence of type of cutting on field performance of cassava. The length of the sett or number nodes per sett is an important factor affecting the field establishment and total dry matter production in cassava. In an early study on cassava planting material, Lozano *et al.* (1977) reported that quality of planting material or setts depend on stem age, thickness, number of nodes per cutting and size. According to Alves (2002), the shoot and root growth in cassava upto 30 days after planting depend on food reserves in the stem. Bridgemohan and Bridgemohan (2014) reported that three node-setts in cassava produced higher leaf dry weight compared to one, two or four-node setts throughout the growth period while the stem dry weight linearly increased with increasing node number. The Leaf Area Index (LAI) was however not influenced by sett size and a high LAI was observed during 90-180 days after establishment and declined afterwards. In another experiment on cassava stem cuttings, Remison *et al.* (2015) concluded that increase in size of cutting from 10 to 15cm resulted in increase in leaf dry weight by 14, 22, 30 and 130 per cent at 5, 7, 9 and 11 weeks respectively. The size of stem cuttings had no significant effect on dry matter partition to the stem except at 11weeks after planting.

The size of planting materials is also found to influence the growth performance of many other tuber crops such as yams and aroids. Early workers like Bourke and Perry (1976) reported that when longer seed setts are used for planting in colocasia, higher leaf area was produced. Nath *et al.* (2007) reported that shoot length, canopy width and shoots per hill increased with the increase in sett size of

Sree Padma variety of elephant foot yam. In another study, when corm was used in taro (*Colocasia esculenta* L.) as planting material, it resulted in high emergence percentage, mean height, leaf number, shoot number and leaf area compared to cormels as planting material (Tsedalu *et al.,* 2014). Maximum plant height, leaf number, shoot number, and leaf area index in taro (*Colocasia esculenta* L.) were resulted with increase in corm size (Gebre *et al.*, 2015). In a study on elephant foot yam, highest length, girth of pseudostem and canopy spread were observed in plants raised from bigger corm size of 500g (Salam *et al.*, 2016). Similar results are reported in taro by Singh *et al.* (2016) who observed that maximum petiole length, leaf polar and equatorial length and plant height were obtained with more than 75 g seed cormel weight.

2.2.1.2. Effect of potting media on growth and growth attributes

The initial vigour and root growth of seedlings in nursery are influenced by the potting media used in the nursery and hence it often decides the seedling establishment and growth when transplanted to the main field.

In an experiment on tomato Pill and Ridley (1998) reported that high shoot biomass was obtained in field when coir dust and vermiculite (1:1) was used as potting medium in nursery and suggested coir dust as an alternative for sphagnum peat. In another study on potting media, Dasbak *et al.* (2011) pointed out that the pre-sprouted minisetts of yam cultivars performed well in three sprouting media of sandy soil, rice straw and 1:1 sawdust and had a higher field establishment and growth. Lazcano *et al.* (2009) suggested that vermi compost when added in different proportions to the growth substrate in nursery it enhanced the number of leaves produced in tomato. In an experiment on *kasthuri* turmeric (*Curcuma aromatica* Salisb.) Aswathy (2015) reported that the morphological characters like plant height, number of leaves, number and length of roots were highest when 3 node rhizome bits were planted in vermicompost + coir pith + *Trichoderma* media transplanted 60 days after sowing.

2.2.2. Effect of nursery techniques on yield attributes and yield in main field

2.2.2.1 Effect of type of minisett cutting on yield attributes and yield

The type of minisett or number of nodes per minisett is likely to influence the yield attributes and yield of cassava through variation in quantity of stored food material. In an investigation conducted in Kerala Agricultural University, Isaac *et al.* (2011) reported that the per plant tuber yield obtained by planting two noded cassava minisetts was comparable to that obtained with normal sett planting. In another study, Bridgemohan and Bridgemohan (2014) concluded that 3-noded minisetts of cassava produced higher tuber yield at harvest compared to 1, 2 or 4 node setts and increasing number of nodes beyond 3 did not enhance tuber yield but decreased dry matter yield.

Many workers have reported influence of minisett size or type of minisett on the yield of other tuber crops. Sultana *et al.* (2001) reported that the yield of potato was increasing with the increase in seedling tuber size. Ayankanmi *et al.* (2005) found that some varieties of *Dioscorea rotundata* showed higher yield in main field with an increase in minisett size. According to Igwilo (2007), tuber yield of yam was influenced by sett size. In their study, minisett weighing 25g and peel sett weighing 6.25g were compared and the minisett was found to give better yield than peel sett in both rainy and dry seasons. According to Faisal *et al.* (2009), among primary corm (40 g), half cut corm (20 g), and secondary corm (10 g) as planting material in *Colocasia esculeta* L. Schott, highest corm yield of 3.71 t ha^{-1} was obtained when primary corm was used as planting material. Isaac, *et al.* (2012) obtained the highest corm yield of 83.19 t ha^{-1} in elephant foot yam when minisett weighing 100 g was planted at a spacing of 60 cm x 45 cm. But $plant^{-1}$yield was higher for conventional sett of 1 kg planted at a spacing of 90c m x 90 cm. In another study, Isaac *et al.*

(2015) has done the evaluation of minisetts as planting material for homestead cultivation of tuber crops and the cassava, tannia, taro, greater yam and elephant foot yam in grow bags produced satisfactory yields of 0.31 to 2.64 kg plant^{-1}. Higher yield attributes like number of cormel plant^{-1}, average cormel weight, and cormel yield plant^{-1} was observed in taro with seed corm weight of more than 75 g and least was in seed corm weighing less than 30g (Singh *et al.*, 2016).

2.2.2.2. Effect of potting media on yield attributes and yield

The nursery media used can influence the yield and yield attributes of the crop transplanted to the main field by virtue of its favourable effect on root growth and its proliferation.

According to Zaller (2007), marketable fruit yields in tomato were unaffected when vermicompost was included as a substrate in nursery medium though marketable quality parameters were influenced. Maximum root yield was obtained in cassava plants transplanted from dapog (hydro) nursery followed by compost alone medium and its combination with soil in dapog method of nursery and lower root yield was noticed with normal raised bed and soil alone treatments (Jata *et al.,* 2013). In another study, Aswathy (2015) reported that transplants of *kasthuri* turmeric grown in media containing vermi compost + coir pith + *Trichoderma* produced maximum yield in main field. Saha and Srivastava (2015) reported that growing media had influence on yield attributes in tomato and maximum fruit yield in main field was obtained from seedlings planted in compost containing media in nursery. While standardising the growth medium based on thermo chemical digest, Jayakrishna *et al.* (2016) reported that, highest fruit yield was obtained in chilli when thermo chemical digest, coir pith compost and soil were given in 1:2:1 proportion in potting medium.

2.2.3. Effect of nursery techniques on nutrient content of crop and its uptake

Type of planting material used in the nursery can influence the nutrient assimilation of the crop in the main field thereby changing its nutrient content and keeping quality. Adjei-Nsiah (2010) reported that cassava varieties with high root dry matter yield have the potential of exporting large quantities of nutrients from the soil. Nahar and Tan (2012) evaluated the performance of cassava mini-cuttings of 5 cm length wherein the mini-cuttings were pre sprouted for a month in polybags before being transplanted to the field. When the plants were harvested at 12 months, the mini cuttings and normal cuttings of 25 cm length gave comparable starch content.

The potting media used in the nursery can affect the root development, proliferation and establishment in the main field also thereby changing the nutrient assimilation through varied uptake which could modify the nutrient content and storage quality of the produce. Thankamani *et al.* (2007) reported that the total uptake of nitrogen in the black pepper plants were comparatively higher for the medium consisting of coir pith compost, granite powder, and farmyard manure in 2:1:1 proportion used in nursery compared to conventional potting mixture of soil: sand: farmyard manure in 2:1:1 proportion. According to Zaller (2007), an increased uptake of nutrients like C, N, P, K, Ca and Mg were observed in field planted tomato by vermi compost amendment in seedling substrate in nursery.

2.2.4. Effect of nursery techniques on economics of cultivation.

Nursery techniques particularly the size of planting material and potting media can influence the cost of production and economics of cultivation of the crop when cultivated on large scale.

Akubuo (2002) pointed out that the minisett technique in seed yams was developed to overcome the high cost of production and scarcity in supply of seed yams. According to Kambaska *et al.* (2009), yam minisett technology contributed to the reduction of the cost of planting materials, which is about 33 to 50 per cent of the total production cost. Economics of minisett seed yam production in Nigeria was found to be profitable when evaluated by Eyitayo *et al.* (2010) and 51.8 per cent of the cost of production was accounted by weeding and seed cost of yams for planting. Isaac *et al.* (2011) obtained highest benefit cost ratio (BCR) of 4.24 with two-noded minisetts planted at 45 cm x 45 cm spacing compared to conventional cassava planting. The percentage of adoption in case of raising cassava seedlings in beds in nursery has been found to be low, probably due to high cost of production and seedling damage on transplanting (Rani and Murugan, 2011). According to Nahar and Tan (2012), there was additional cost of labour and polybags for mini-cuttings which resulted in less profit compared to the normal cuttings and this finding emphasis on the need for a low cost nursery technique for minisett cassava. Yadav *et al.* (2014) also reported higher net income from cassava by using minisett as planting material but the benefit: cost ratio was slightly higher (2.71) for the conventional sett system which might be due to cost of nursery involved in minisett technique. When Greater yam sett weighing 200g planted at a spacing of 90 x 90 cm, it gave higher net returns and a higher benefit-cost ratio of 2.06 compared to the sett sizes of 100 g, 200 g and 300 g in coconut garden (Nedunchezhiyan *et al.*, 2015).

While comparing the economics of different potting media in a tomato hydroponic system, Joseph and Muthuchamy (2014) reported that highest benefit: cost ratio was obtained when cocopeat + gravel + silex stone was used as potting medium. In another study on cucumber, highest total and net income were obtained in green house production of cucumber when perlite was used as a potting medium compared to other treatments such as cocopeat alone, perlite-cocopeat in 1:1 ratio and perlite-cocopeat in 1:2 ratio (Mazahreh *et al.*, 2015).

2.3 TIME OF TRANSPLANTING IN CROP PERFORMANCE IN MAIN FIELD

2.3.1 Effect of time of transplanting on field establishment, growth and growth attributes

The transplanting age of the seedling is likely to have an influence on its establishment in the main field. According to Tetteh *et al.* (1997), the age of transplanting significantly influenced the establishment percentage and survival rate in seed propagated cassava which were found to be highest with transplanting at 41 DAS (Days After Sowing) compared to 27, 34 or 48 DAS. Marked variation in root length of cassava seedlings was reported in dapog nursery with different age of seedlings and increasing the age of seedlings in nursery led to lesser establishment in main field due to more transplanting shock (Jata *et al.*, 2013). According to Shukla *et al.* (2011), 100 per cent survival of the seedlings was obtained with 36 days old transplants in capsicum compared to 18 days old transplants. In a recent experiment on tomato, Jaiswal *et al.* (2017) reported that in too young or too old seedlings the plant growth was significantly reduced as compared to normal middle age seedlings. In their study, the plant height and spread were the highest for 24 days old seedlings compared to 16, 20, 28, 32, 36 and 40 days old seedlings. Number of branches plant^{-1} was found to be highest in 28 days old seedlings followed by 24 and 32 days old seedlings while it was minimum with 44 days old seedlings followed by 16 days old seedlings. Sarker *et al.* (2017) reported increase in plant height, number of leaves and branches with an increase in age of transplants in tomato.

2.3.2 Effect of time of transplanting on yield attributes and yield

Age of seedling decides the seedling quality which is one of the factors deciding the yield of the transplanted crop. According to Tetteh *et al.* (1997), the age of transplanting significantly influenced the tuber yield in seed propagated cassava and tuber yield ranged from 6525 kg ha^{-1} for the 27 days old seedlings to 17764 kg ha^{-1} for the 41 days old seedlings. It was concluded that the most appropriate age at which cassava seedlings to be transplanted to obtain highest yield was 41 days after sowing. Experiment conducted by Lommen (2015) revealed that seed crops from younger transplants of potato performed better than crops from older transplants in terms of ground cover and tuber yield.

Shukla *et al*. (2011) reported that highest number of fruits per plant (8.09) and fruit yield per plot (7.58 kg) were obtained with 36 days old transplants in capsicum and minimum values were recorded with 18 days old transplants. While comparing 40, 50 and 60 days seedlings and direct seed sowing, Jellani *et al.* (2016) reported that maximum yield per plant (1210.4 g) was obtained when 40 days old seedlings were transplanted to the main field and the plant $^{-1}$ yield was minimum (678.9 g) with direct sowing. In a study conducted in tomato, Jaiswal *et al*. (2017) reported that the number of fruits plant^{-1} (31.72), mean weight fruit^{-1} (41.55 g), fruit yield plant^{-1} (725 g) and fruit yield ha^{-1}(308.63 q) were highest with 24 days old seedlings compared to 6, 20, 28, 32, 36 and 40 days old seedlings. In this study, the 20 days old seedlings performed significantly at par with 24 days old seedlings in most of the crop characters including fruit yield per unit area and hence transplanting 20-24 days old seedlings was recommended to obtain optimum yield.

2.3.3 Effect of time of transplanting on qualitative aspects

Age of seedlings can influence the root architecture of the transplanted crop which consequently may affect the nutrient acquisition, uptake, partitioning and quality of produce. However, Shukla *et al.* (2011) reported that highest TSS content was recorded when capsicum seedlings were transplanted to the main field at 33 days after germination compared to 18 or 45 days old seedlings. Maximum value for quality parameters like content of volatile oil and oleoresin were reported in *kasthuri* turmeric transplanted at 60 DAS, which was on par with seedlings transplanted at 45 DAS and was significantly superior to seedlings transplanted at 30 DAS (Aswathy, 2015). Grabowska *et al.* (2007) pointed out that age of transplanting had no effect on percentage of hollow stems determining quality of heads in broccoli.

2.3.4 Effect of time of transplanting on economics of cultivation

Age of seedlings can affect the crop performance in the main field bringing variations in yield and thus modify the cost of cultivation and economics. While comparing the age of transplanting on economics of cultivation in cucumber, Jellani *et al.* (2015) reported that transplanting 45-60 days old seedlings produced higher gross returns and gross margin. The gross returns was 41.34- 44.33 per cent higher with 45-60 days old cucumber seedlings compared to 30 days old seedlings or direct sowing. In another study conducted in bitter gourd, Jellani *et al.* (2016) reported that maximum gross returns ha^{-1} (US $ 3600.4) was obtained when 40 days old seedlings were transplanted compared to 50 or 60 days old seedlings and direct sowing.

2.4 COMPARISON OF PLANTING MINISETTS WITH NORMAL SETTS

Limited studies have been conducted comparing the minisett planted crop with conventional planting. According to Otoo *et al.* (2001), an area of 3.77 ha of land can be planted using seed yams from yam raised in 1 ha area through minisett technique whereas under traditional practice, one ha may produce seed yams to plant only 1.3 ha. Experiment conducted in Central Tuber Crops Research Institute (CTCRI) by George (2006) revealed that transplanted minisett cassava showed higher establishment percentage (92.42 per cent) compared to normal sett planting (75.18 per cent) and an increased multiplication ratio of 1:60 compared to traditional method of planting (1:10). George and Nedunchezhiyan (2008) reported that stem yield ($no.ha^{-1}$) in cassava was 24,000 in normal sett planting, while in minisett technique it was 60,000. They also reported an increased yield of 80 t ha^{-1} for minisett cassava wherein the normal sett planting produced an yield of only 30 t ha^{-1}. Isaac *et al.* (2015) studied the initial growth habits and yield of different tropical tuber crops under minisett cultivation and compared it with conventional planting in grow bags under homestead situation. In cassava, germination was found to be earlier in minisetts than normal setts but further growth was slow and vegetative mass put forth was lower in minisetts. The vegetative growth in minisett taro, tannia and greater yam was rapid and appreciable compared to the planting of conventional planting material. In this experiment though the early growth of elephant foot yam was slow in minisetts, it progressed later. The tuber yields in all the tuber crops were generally higher with conventional planting material than the minisetts. However the authors concluded that from the perspective of commercial farming, minisett technology is advantageous as smaller planting materials require lesser spacing and this when coupled with higher plant density would lead to comparable yields as to that of normal planting materials.

The review of literature indicated the effects of different nursery techniques such as type of minisett cutting and potting media on the germination and establishment in the nursery as well as in the main field. Various studies also pointed out the influence of nursery techniques and age of transplanting on crop growth, yield, uptake pattern, quality and economics of cultivation and also a brief comparison of minisett cultivation with conventional planting.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment entitled "Standardisation of nursery techniques through field validation in minisett cassava (*Manihot esculenta* Crantz.)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram during April 2017 to January 2018 to standardise the cassava minisett nursery techniques by validating its field performance with normal sett planting and to work out the economics of cultivation. The details of materials used and the methods adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location

3.1.1.1 Experiment I (Nursery)

The nursery experiment was conducted in a hardening unit of the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala which provided rain sheltered condition and a partial shade of 50 per cent. It was situated at a latitude of N 08°25'46.85" and longitude of E 076°59'17.16" and at an altitude of 40 m above mean sea level (Fig.1).

3.1.1.2 Experiment II (Main field)

The main field experiment was conducted in the experimental plot in block D of the Instructional Farm, College of Agriculture, Vellayani. The field was located at a latitude of N 08°25'45.69" and longitude of E 076°59'23.67" and at an altitude of 19 m above mean sea level (Fig.1).

3.1.2 Soil

The soil of the experimental site was sandy clay loam belonging to the order Oxisol, Vellayani series. A composite soil sample was collected from the field before the experimentation and analysed to find out the mechanical

Fig. 1. Location map of nursery and main field experiment

composition and chemical properties. The mechanical composition and chemical properties of the soil are summarized in Table 1 and 2.

3.1.3 Climate and season

A warm humid climate was prevalent in the experimental location. The monthly average weather data on maximum and minimum temperature, relative humidity, evaporation and rainfall received during the cropping period were collected from the Agro meteorological observatory at College of Agriculture, Vellayani and are given in Appendix I and illustrated in Fig.2. The mean maximum temperature ranged between 30.5^{0}C to 31.8^{0}C and mean minimum temperature ranged between 22.1^{0}C to 24.9^{0}C during the crop season. The mean maximum relative humidity ranged between 90.6 per cent to 94.9 per cent, while the mean minimum relative humidity ranged between 72.4 per cent to 84.9 per cent. A total rainfall of 1539.7 mm and daily evaporation ranged between 3 mm to 4.1 mm were recorded during the crop period.

The nursery experiment was conducted during April to June 2017 and the field experiment was conducted during April 2017 to January 2018.

3.1.4. Previous cropping history of the field experimental plot

Banana and a ratoon was the previous crop of the experimental field.

3.2 MATERIALS

3.2.1. Crop and variety

Vellayani Hraswa was the cassava variety used for the experimentation. This variety, which is high yielding, early maturing with 6-7 months duration and excellent cooking quality was developed at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram by clonal selection in 2003 and released from Kerala Agricultural University.

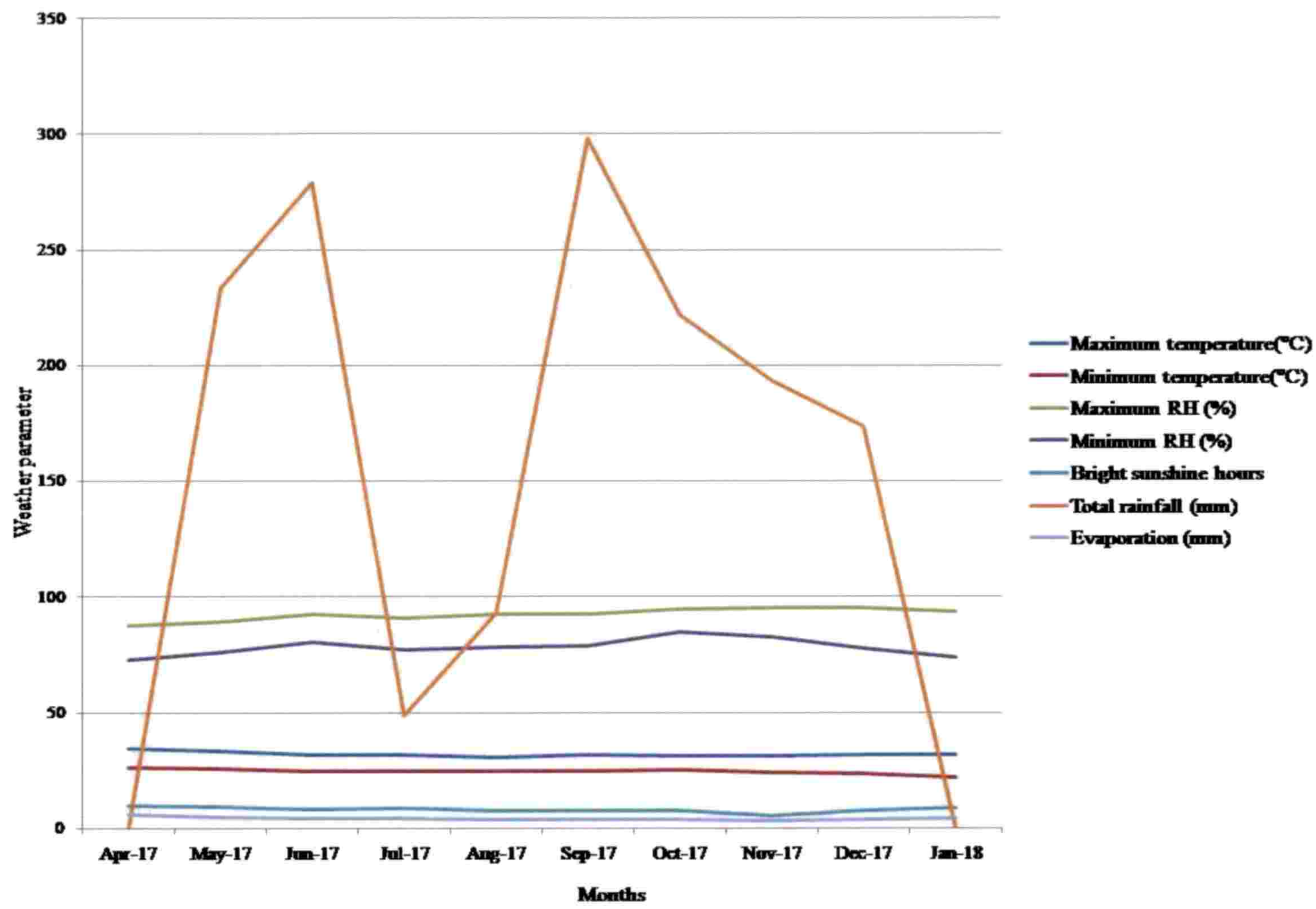


Fig.2. Weather parameters during cropping period

Table 1. Mechanical composition of the soil of the experimental site

Sl. No.	Fractions	Content (per cent)	Method used
1	Sand	47.44	Bouyoucos hydrometer method (Bouyoucos, 1962)
2	Silt	24.75	
3	Clay	27.81	

Table 2. Chemical properties of soil of the experimental site

Parameter	Content	Rating	Method used
Soil reaction (pH)	5.30	Strongly acidic	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dSm^{-1})	0.08	Safe	Digital conductivity meter (Jackson, 1973)
Organic carbon (per cent)	0.56	Medium	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	301.05	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	271.04	High	Bray colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	322.22	High	Ammonium acetate method (Jackson, 1973)

3.2.2 Planting material

Planting materials were obtained from the Instructional Farm, College of Agriculture, Vellayani. Healthy and disease free stakes were selected for preparing minisetts and normal setts as per the treatments.

3.2.2.1 Minisett cuttings for nursery planting

Stems of cassava plant free from pest and disease were selected and after discarding top one-third and bottom woody portion, two node minisetts (4 cm length) and three node minisetts (5 cm length) were prepared by cutting with circular wood saw attached to a power cutting machine.

3.2.2.2 Normal setts for planting in main field

Mature stems of healthy cassava plants were selected for preparing 15 cm long normal setts having 10 to 12 nodes. The top one-third and bottom woody portion of stems were discarded while preparing the cuttings and were directly planted in the main field.

3.2.3 Potting media

Three types of potting media were used in the nursery experiment. These were normal top soil, top soil and coir pith compost in 1:1 ratio and coir pith compost and vermi compost in 3:1 ratio. The soil used in the potting mixture was laterite red loam belonging to order oxisol of Vellayani series. Coir pith compost containing 0.45 per cent nitrogen, 0.46 per cent phosphorus and 0.18 per cent potassium and vermi compost containing 1.01 per cent nitrogen, 1.36 per cent phosphorus and 0.77 per cent potassium were used for preparing the potting media. Important chemical properties of the potting media used in the nursery are summarized in Table 3.

3.2.4 Protrays

The 50 cavity protrays were used for planting minisett cassava in the nursery.

Table 3. Chemical properties of the potting media used in the nursery experiment.

Parameter	Content			Method used
Potting medium	Normal top soil	Top soil and coir pith compost in 1:1 proportion	Coir pith compost and vermi compost in 3:1 proportion	
Soil reaction (pH)	5.12	6.56	6.23	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (dSm^{-1})	0.081	0.766	1.26	Digital conductivity meter (Jackson, 1973)
Organic carbon (per cent)	0.69	2.95	4.37	Walkley and Black rapid titration method (Jackson, 1973)
Available N (per cent)	0.008	0.013	0.039	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (per cent)	0.007	0.011	0.025	Bray colorimetric method (Jackson, 1973)
Available K (per cent)	0.019	0.029	0.047	Ammonium acetate method (Jackson, 1973)

3.2.5 Manures and fertilizers

Farm yard manure containing 0.68 per cent nitrogen, 0.52 per cent P_2O_5 and 0.85 per cent K_2O was used as a source of organic manure in the main field. Urea (46 per cent nitrogen), Rajphos (20 per cent P_2O_5) and Muriate of potash (60 per cent K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

3.3 METHODS

3.3.1 Design, Treatments and Layout

3.3.1.1 Experiment I (Nursery)

Cassava minisetts were raised in the nursery as per the treatments and evaluated for the variation in sprouting and root formation.

Design : Completely Randomised Design

Treatments : 2 x 3 = 6

Replications : 8

Variety : Vellayani Hraswa

Season : April to June 2017

Treatments

1. Type of minisett cutting (m) – 2

   m_1 - Two node cutting

   m_2 - Three node cutting

2. Potting media for the minisetts (p) - 3

   p_1- Normal top soil

   p_2- Top soil and coir pith compost (1:1 ratio)

   p_3- Coir pith compost and vermi compost (3:1 ratio)

3.3.1.2. Experiment II (Main field)

The minisetts produced by different nursery methods were transplanted to the main field as per the time of transplanting according to the treatments. These were compared with the normal sett planting in the main field.

Design : Randomised Complete Block Design

Treatments : 18 + 1(control)

Replications : 3

Gross plot size : 5.4 m x 4.5 m

Net plot size : 3.6 m x 2.7 m

Plants per plot : 30

Spacing : 90 cm x 90 cm

Season : April 2017 to January 2018

Variety : Vellayani Hraswa

Treatments

1. Type of minisett cutting (M)

m_1 - Two node cutting

m_2 - Three node cutting

2. Potting media for the minisetts (P)

p_1 - Normal top soil

p_2 - Top soil and coir pith compost (1:1 ratio)

p_3 - Coir pith compost and vermi compost (3:1 ratio)

3. Time of transplanting minisetts to main field (T)

t_1 - 3 weeks after planting

t_2 - 4 weeks after planting

t_3 - 5 weeks after planting

Control (C) – Normal sett planting in main field

The layout of the field experiment is given in Fig. 3.

3.3.2 Crop management

3.3.2.1. Nursery preparation and planting

Three different types of potting media were prepared and used for filling 50 cavity protrays. Each cavity had a lower radius of 1.5 cm, upper radius of 2.5 cm, height of 4 cm and volume of 51.31 cm^3. A quantity of 56.45 g of normal top soil (p_1), 28.42 g of potting mixture containing top soil and coir pith compost in 1:1 ratio (p_2) by volume and 18.35 g of potting mixture containing coir pith compost and vermi compost in 3:1 ratio (p_3) by volume were used for filling each cavity as per the treatments. Two node and three node minisett cuttings prepared were planted during last week of May 2017 as per the treatments in these portrays at a depth of 2 cm vertically and the protrays were kept in the hardening unit. Fifty minisetts were planted in one protray and maintained as a replication. The protrays were watered daily and minisetts were transplanted to the main field at 3 WAP, 4 WAP and 5 WAP as per the treatments.

3.3.2.2 Main field preparation and planting

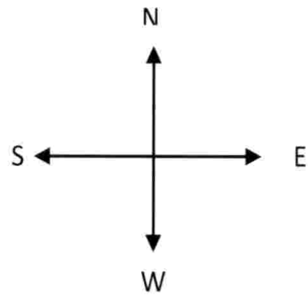
The experimental area was levelled and digged using mini excavator, Tata Hitachi 20. Mounds were taken at a spacing of 90 cm x 90 cm for planting of minisetts and normal setts. The protrays from the nursery were transported to the main field at 3 WAP, 4 WAP and 5 WAP. The minisetts from the protrays were removed by tapping the bottom of protray cavity with fingers and were planted on mounds immediately.

3.3.2.3 Application of manures and fertilizers

Farm yard manure was applied @ 12.5 t ha^{-1} at the time of land preparation. Calculated quantities of Urea, Rajphos and Muriate of potash were

Plate 1. Cassava minisett nursery.

Plate 2. Sprouted cassava minisett seedlings in protrays (4 WAP).



Replication 1		Replication 2		Replication 3	
$m_2p_3t_3$	$m_1p_2t_1$	$m_1p_1t_3$	$m_2p_3t_2$	$m_1p_1t_1$	$m_2p_2t_3$
$m_2p_1t_2$	$m_1p_1t_1$	$m_2p_2t_3$	$m_1p_3t_1$	$m_1p_3t_3$	$m_1p_1t_2$
$m_1p_1t_2$	$m_1p_2t_2$	$m_2p_3t_1$	$m_1p_2t_2$	$m_1p_3t_1$	$m_2p_2t_2$
$m_1p_3t_2$	$m_2p_1t_3$	$m_1p_2t_3$	$m_2p_2t_1$	$m_1p_2t_1$	$m_2p_3t_2$
$m_2p_2t_3$	$m_1p_3t_1$	$m_1p_3t_3$	$m_2p_1t_2$	$m_2p_1t_2$	$m_2p_1t_3$
$m_2p_3t_1$	$m_1p_1t_3$	$m_1p_1t_2$	$m_1p_3t_2$	$m_1p_2t_3$	$m_1p_1t_3$
$m_1p_3t_3$	$m_2p_3t_2$	$m_2p_1t_3$	$m_1p_1t_1$	$m_2p_2t_1$	$m_2p_3t_3$
$m_2p_2t_1$	$m_1p_2t_3$	$m_1p_2t_1$	$m_2p_1t_1$	$m_2p_1t_1$	$m_1p_3t_2$
$m_2p_2t_2$	$m_2p_1t_1$	$m_2p_2t_2$	$m_2p_3t_1$	$m_1p_2t_2$	$m_2p_3t_1$
Control (c)		Control (c)		Control (c)	

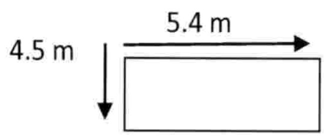


Fig 3. Lay out of the experiment

Plate 3. General view of the experimental plot.

applied in order to supply the dose of 50:50:100 kg NPK ha^{-1}as standardised by Sekar (2004) for cassava variety Vellayani Hraswa under upland conditions. The full dose of phosphorus and $1/3^{rd}$ dose each of nitrogen and potassium were applied as basal dose (one week after transplanting). The $1/3^{rd}$ dose each of nitrogen and potassium were again applied at 30 days after planting also and the balance $1/3^{rd}$ dose was applied at 60 days after planting.

3.3.2.4. Weeding and earthing up

Weeding and earthing up were done along with fertilizer application at 30 days and 60 days after planting.

3.3.2.5 Irrigation

The crop was raised as a rainfed crop. However due to insufficient rainfall, irrigation was given during July 2017 and August 2017 at fortnightly interval to bring the moisture content of soil to field capacity.

3.3.2.6 Plant protection

Spraying of Thiamethoxam 0.005 per cent was given twice at weekly interval at 2 MAP in the main field to control whitefly and mealy bug infestation.

3.3.2.7 Harvest

Harvesting was done 6 MAP onwards based on visual symptoms (yellowing and drying of lower leaves), by digging out the tubers and pulling out the stem.

3.4 OBSERVATIONS

3.4.1. Observations in the nursery

Five minisetts were randomly selected as observational plants from each treatment per replication for recording observations from the nursery.

3.4.1.1. Sprouting of minisetts

The total number of minisetts sprouted was counted at three weeks after planting and expressed as percentage.

3.4.1.2 Days to shoot initiation

Days taken for shoot initiation was recorded by counting days from planting to appearance of sprout in the minisett observational plants.

3.4.1.3 Shoot length

Shoot length of observational plants at the time of transplanting was recorded in cm from base to the growing tip in vertical position and the average was calculated.

3.4.1.4 Number of roots

Number of roots produced by the minisett observational plants was recorded at the time of transplanting at 3 WAP, 4 WAP and 5 WAP and the average was worked out.

3.4.1.5 Root length

The length of the longest root of minisett observational plants at the time of transplanting (3 WAP, 4 WAP and 5 WAP) was recorded in cm from base to the tip and the average was worked out.

3.4.1.6 Shoot biomass

Shoot biomass was taken by from the observational plants at the time of transplanting at 3 WAP, 4 WAP and 5 WAP by destructive sampling. After shade drying the samples were kept in an oven at 70 $\pm$5°C, dried to a constant weight and average shoot biomass was worked out on dry weight basis and expressed in g seedling^{-1}.

3.4.1.7 Root biomass

Root biomass was taken from the minisett observational plants at the time of transplanting at 3 WAP, 4 WAP and 5 WAP by destructive sampling. Samples were kept in an oven at 70 ±5°C, dried to a constant weight and average root biomass was worked out on dry weight basis and expressed in g seedling^{-1}.

3.4.1.8 Incidence of Cassava Mosaic Disease (CMD)

Incidence of Cassava Mosaic Disease (CMD) was recorded at weekly intervals in nursery and percentage of incidence was noted. The infected plants were removed from the nursery and destroyed.

3.4.2 Observations in the main field

Five observational plants were selected at random from net plot for recording of observations from the main field.

3.4.2.1 Growth and growth attributes

3.4.2.1.1 Establishment of minisetts and normal setts

The number of minisetts and normal setts established in the main field was counted two weeks after transplanting or planting and expressed in percentage.

3.4.2.1.2 Number of roots

The number of roots produced by the normal setts (control) planted in the main field was counted by uprooting the setts at 3 WAP, 4 WAP and 5 WAP.

3.4.2.1.3 Root length

The length of longest root of the normal setts (control) planted in the main field was noted by destructive sampling at 3 WAP, 4 WAP and 5 WAP. The average was worked out and expressed in cm.

3.4.2.1.4 Root biomass

The root biomass of the normal setts planted in the main field were taken on dry weight basis at 3 WAP, 4 WAP and 5 WAP by destructive sampling. Root samples were kept in an oven at 70 ±5°C, dried to a constant weight and average root biomass was worked out on dry weight basis and expressed in g seedling^{-1}.

3.4.2.1.5 Plant height

Plant height was measured from the base of the sprout to the terminal bud vertically at monthly intervals from the observational plants and expressed in cm.

3.4.2.1.6 Stem girth

The stem girth of the observational plants was taken from 10 cm above the soil surface and expressed in cm.

3.4.2.1.7 Functional leaves

Functional leaves plant^{-1}were taken by counting number of fully opened leaves retained in each observational plant at monthly interval.

3.4.2.1.8 Leaf area index (LAI)

The LAI (3 MAP) was calculated by using linear measurement method (Ramanujam and Indira, 1981). The leaf area of the plant was recorded by measuring the length of middle lob, breadth of middle lob, number of lobs and number of leaves. The leaf area was estimated using the formula,

$$\text{Leaf area} = \text{length of middle lob} \times \text{breadth of middle lob} \times \text{number of lobes} \times \text{number of leaves} \times 0.44$$

LAI was worked out using the formula putforth by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

3.4.2.1.9 Number of primary branches and secondary branches

Number of primary branches and secondary branches was counted from the observational plants three month after planting and mean value was computed to express it as number of primary branches and secondary branches $plant^{-1}$.

3.4.2.2 Yield attributes and yield

3.4.2.2.1 Number of tubers

Number of fully developed tubers was counted from observational plants at harvest and average was worked out to express it as number of tubers $plant^{-1}$.

3.4.2.2.2 Percentage of productive roots

Average number of tubers (productive roots) and roots (unproductive) were counted from the observational plants and percentage of productive roots $plant^{-1}$ was worked out at harvest.

3.4.2.2.3 Length of tuber

Length of medium sized tuber was recorded in cm at random from observational plants and average was worked out and expressed in cm.

3.4.2.2.4 Girth of tuber

Girth measurement was taken from the same tubers that were used for length measurements. Girth value was taken from centre and halfway between the centre and both ends of tubers. Average was worked out and expressed in cm.

3.4.2.2.5 Mean weight of tuber

The mean weight of tuber was taken from observational plants and expressed in g.

3.4.2.2.6 Tuber yield plant^{-1}

At the time of harvest, tubers were separated from observational plants and cleaned to remove adhering soil particles. Fresh tuber weight was taken and expressed in kg $plant^{-1}$.

3.4.2.2.7 Tuber yield ha^{-1}

The total weight of fresh tubers from net plot was taken and converted it to tuber yield ha^{-1}.

3.4.2.2.8 Top yield

The total weight of stem and leaves were taken from net plot at the time of harvest and was converted to t ha^{-}.^{1}

3.4.2.2.9 Total dry matter production

Sample plants were pulled out carefully and separated into leaves, stem and tubers. Fresh weight of each plant part was recorded and samples were taken to estimate the dry weight. After shade drying samples were kept in an oven at 70 ±5°C and dried to a constant weight. Dry weight of each plant part was recorded and added to get the total dry matter production and expressed as t ha^{-1}.

3.4.2.2.10 Days to harvest

Days taken for maturity was recorded by counting days from planting in nursery to harvest.

3.4.2.2.11 Harvest index (HI)

Harvest index was worked out from total tuber weight (economic yield) and total biological yield values using the equation put forth by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.2.2.12 Pest and disease incidence

Plants were regularly monitored to detect the pest and disease incidence if any. Mild incidence of white fly and mealy bug were noticed on few plants at 2 MAP and timely control measures (spraying of Thiamethoxam 0.005 per cent) were taken. Scoring of pest incidence was not done since infestation was below the economic threshold level.

The plants were observed for the incidence of cassava mosaic disease in the main field and the incidence was calculated as percentage of plants with symptoms at three months after planting. Severity of symptoms was assessed using the 1 to 5 severity scale of International Institute of Tropical Agriculture (IITA) as given below;

Table 4. Severity scale of cassava mosaic virus

Score	Symptoms
1	Unaffected shoots, no symptoms in leaves
2	Mild chlorosis, mild distortions at bases of most leaves, while the remaining parts of the leaves and leaflets appear green and healthy
3	Pronounced mosaic pattern on most leaves, narrowing and distortion of the lower one-third of the leaflets
4	Severe mosaic distortion of two thirds of most leaves and general reduction of leaf size and stunting of shoots
5	Very severe mosaic symptoms on all leaves, distortion, twisting, mis-shapen and severe leaf reductions of most leaves accompanied by severe stunting of plants.

IITA (1990)

3.4.3 Shelf life of tuber

The tubers from sample plants were stored in three different conditions viz., open air, in polythene cover and paper cover. Shelf life of tuber was determined by counting days taken for blackening of flesh from harvest. Moisture loss from the tuber was also recorded on the day of blackening of flesh and expressed in per cent.

3.4.4 Plant analysis

Plant samples were taken from the observational plants in each plot at harvest and separated into leaves, stem and tubers. Each part was separately sun dried and oven dried (70 ± 5° C) to a constant weight. Samples were ground well and required quantity of samples were digested and used for nutrient analysis. Nutrient analysis was separately done for the top portion (stem and leaves) and tubers.

3.4.4.1 Total nitrogen content

Total nitrogen content in plant sample was estimated by modified microkjeldhal method (Jackson, 1973).

3.4.4.2 Total phosphorus content

Total P content in plant sample was estimated by Vandadomolybdate phosphoric yellow colour method (Piper, 1966).

3.4.4.3 Total potassium content

Total K content in plant sample was determined by flame photometer method (Piper, 1966)

3.4.4.4 Uptake of nitrogen, phosphorus and potassium

Nutrient uptake by the crop was calculated by using the formula suggested by Jackson (1973) and expressed in kg ha^{-1}.

$$\text{N or P or K uptake} = \frac{\text{N or P or K (per cent)} \times \text{dry matter (kg ha}^{-1}\text{)}}{100}$$

Uptake was estimated separately for top portion (stem and leaves) and tuber portion of cassava and added for calculating the total uptake ha^{-1}.

3.4.4.5 Starch content of tuber

Starch content of tuber was estimated by using potassium ferricyanide method (Pigman, 1970). The values were expressed as percentage on fresh weight basis.

3.4.5 Soil properties after the experiment

Soil samples were analyzed for pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and available potassium before (Table 2) and after the experiment. Soil samples were collected from the experimental plots following standard procedures. The samples were air dried, powdered and passed through 0.5 mm sieve for analyzing organic carbon and 2 mm sieve for analyzing available nutrient status of the soil. Soil reaction (pH), electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium were estimated using the standard procedures as given in Table 2.

3.5 ECONOMICS OF CULTIVATION

Economics of cultivation of minisett and normal sett cassava was worked out by taking into account the cost of cultivation and prevailing market price of cassava.

Net income and benefit: cost ratio were calculated as follows:

$$\text{Net income } (₹\text{ ha}^{-1}) = \text{Gross income} (₹\text{ ha}^{-1}) - \text{Total expenditure } (₹\text{ ha}^{-1})$$

$$\text{Benefit: cost ratio } = \frac{\text{Gross income } (₹\text{ ha}^{-1})}{\text{Total expenditure } (₹\text{ ha}^{-1})}$$

3.6 STATISTICAL ANALYSIS

The data generated from the experiment were subjected to statistical analysis using Analysis of Variance technique (ANOVA) as applied to Completely Randomised Design for experiment I in nursery and Randomised Complete Block Design for Experiment II in main field (Panse and Sukhatme, 1985) and the significance was tested using F test (Snedecor and Cohran, 1967). Wherever F values were significant, critical differences were worked out at five per cent probability levels. The treatment effect was noted as 'NS' when not significant.

RESULTS

4. RESULTS

The research project entitled "Standardisation of nursery techniques through field validation in minisett cassava (*Manihot esculenta* Crantz.)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram. The investigation which consisted of a nursery experiment (April 2017 to June 2017) and a field experiment (April 2017 to January 2018) was conducted to standardise the cassava minisett nursery technique by validating its field performance comparing with normal sett planting and to work out the economics of cultivation. The results of the experiments are presented in this chapter.

4.1. EXPERIMENT - I (NURSERY)

4.1.1. Sprouting of cassava minisetts

Data presented in Table 5. represents the effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on minisett sprouting in per cent at 3 WAP in the nursery.

The main effects were found to be significantly influencing the sprouting of minisetts in nursery. While comparing the type of cassava minisett cutting, the m_2 (three node cutting) was found to have higher sprouting (92.26 per cent) than m_1 (two node cutting) producing a sprouting per cent of 87.08. Among different potting media used in the nursery experiment, the p_3 (coir pith compost and vermi compost in 3:1 ratio) resulted in higher sprouting (90.44 per cent) and was on par with p_2 (normal top soil and coir pith compost in 1:1 ratio) resulting in 90.35 per cent sprouting. Cassava minisett sprouting percentage was significantly lower (88.22 per cent) in case of p_1 (normal top soil). The interaction effects however did not significantly influence the minisett sprouting.

4.1.2. Days to shoot initiation

The effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on days to shoot initiation in nursery are indicated in Table 5.

Table 5. Effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on sprouting (per cent) and days to shoot initiation in nursery.

Treatments	Sprouting (3 WAP)	Days to shoot initiation
Type of minisett cutting (M)		
m_1	87.08	4.89
m_2	92.26	4.66
SEm (±)	0.285	0.095
CD (0.05)	0.816	NS
Potting media for the minisetts(P)		
p_1	88.22	4.89
p_2	90.35	4.68
p_3	90.44	4.75
SEm (±)	0.349	0.116
CD (0.05)	1.000	NS
M×P interaction		
m_1p_1	85.39	4.87
m_1p_2	87.80	4.73
m_1p_3	88.06	5.07
m_2p_1	91.06	4.91
m_2p_2	92.90	4.63
m_2p_3	92.91	4.42
SEm (±)	0.494	0.164
CD (0.05)	NS	NS

The result showed that type of cassava minisett cutting, potting media for the cassava minisetts and their interactions had no significant influence on days to shoot initiation.

4.1.3 Shoot length

The effects of type of cassava minisett cutting, potting media for the cassava minisetts and their interactions on cassava minisett shoot length at the time of transplanting from the nursery are given in Table 6.

Shoot length significantly varied with the type of cassava minisett cutting and potting media used for growing minisetts in nursery. Comparison of type of cassava minisetts indicated that m_2 (three node cutting) resulted in significantly higher shoot length at 3 WAP (7.26 cm), 4 WAP (9.62 cm) and 5 WAP (11.10 cm) when compared to m_1 (two node cutting) which produced a shoot length of 5.73, 8.91 and 9.57 cm at 3 WAP, 4 WAP and 5 WAP respectively.

Among the potting media used for raising minisetts, the p_3 (coir pith compost and vermi composst in 3:1 ratio) resulted in significantly higher shoot length in plants at all stages of observation (7.15 cm at 3 WAP, 10.45 cm at 4 WAP and 11.15 cm at 5 WAP). However the potting media p_2 (normal top soil and coir pith compost in 1:1 ratio) was on par with p_1 (normal top soil) with respect to its effect on cassava minisett shoot length at transplanting from nursery.

Interaction effects were significant at 3 WAP only in the nursery and among the interaction effects, the m_2p_3 resulted in significantly higher shoot length (8.38 cm) compared to other interactions, followed by m_2p_2 (6.83 cm) which was on par with m_2p_1 (6.56 cm). Cassava minisett shoot length at 3 WAP was lowest with m_1p_1 interaction (5.36 cm) which statistically did not vary from m_1p_2 (5.72 cm) or m_1p_3 (5.92 cm).

4.1.4 Shoot biomass

Data shown in Table 6. represent the effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on shoot biomass seedling^{-1} in nursery.

Shoot biomass seedling^{-1} significantly differed with type of cassava minisett cutting and potting media used. When types of cassava minisetts were compared, the m_2 (three node cutting) was found to be producing the highest shoot biomass seedling^{-1} at 3 WAP, 4 WAP and 5 WAP (4.08, 4.63 and 5.06 g seedling^{-1} respectively).

Among different potting media used in the nursery, p_3 (coir pith compost and vermi compost in 3:1 ratio) resulted in significantly higher shoot biomass seedling^{-1} (4.21, 4.57 and 5.13 g at 3 WAP, 4 WAP and 5 WAP respectively) irrespective of age when compared to p_2 (normal top soil and coir pith compost in 1:1 ratio) or p_1 (normal top soil). However the p_2 and p_1 were on par each other in their effects on shoot biomass production.

Interaction effects were significant only in case of 3 weeks old seedlings and among interaction effects the m_2p_3 resulted in higher shoot biomass seedling^{-1} (4.69 g) which was significantly higher than all other treatment combinations which were in turn on par in their effects.

4.1.5 Root length

The effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on root length of minisetts at transplanting from nursery are presented in Table 7.

Root length of cassava minisett was significantly influenced by the main effects at all stages of observation. Among different types of cassava minisetts used, the m_2 (three node cutting) resulted in significantly higher root length (8.09, 12.40 and 16.04 cm at 3 WAP, 4 WAP and 5 WAP respectively) when compared

Table 6. Effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on shoot length and shoot biomass seedling^{-1} at transplanting from nursery.

Treatments	Shoot length (cm)			Shoot biomass (g)		
	3 WAP	4WAP	5WAP	3WAP	4WAP	5WAP
Type of minisett cutting (M)						
m_1	5.73	8.91	9.57	3.70	3.98	4.71
m_2	7.26	9.62	11.10	4.08	4.63	5.06
SEm (±)	0.133	0.177	0.172	0.108	0.064	0.039
CD (0.05)	0.382	0.506	0.493	0.310	0.184	0.113
Potting media for the minisetts(P)						
p_1	5.96	8.49	9.93	3.53	4.07	4.73
p_2	6.38	8.86	9.92	3.79	4.29	4.78
p_3	7.15	10.45	11.15	4.21	4.57	5.13
SEm (±)	0.163	0.217	0.211	0.132	0.079	0.048
CD (0.05)	0.468	0.620	0.604	0.379	0.226	0.138
M×P interaction						
m_1p_1	5.36	7.80	9.06	3.44	3.67	4.57
m_1p_2	5.72	8.57	9.04	3.72	4.03	4.61
m_1p_3	5.92	10.36	10.60	3.92	4.25	4.94
m_2p_1	6.56	9.19	10.79	3.62	4.45	4.89
m_2p_2	6.83	9.15	10.80	3.92	4.56	4.95
m_2p_3	8.38	10.53	11.70	4.69	4.90	5.32
SEm (±)	0.231	0.306	0.298	0.187	0.112	0.068
CD (0.05)	0.662	NS	NS	0.536	NS	NS

to m_1 (two node cutting) which produced a root length of 7.42, 11.45 and 14.86 cm at 3 WAP, 4 WAP and 5 WAP respectively.

Significantly higher root length was recorded with potting medium p_3 (coir pith compost and vermi compost in 3:1 ratio) at the time of transplanting (8.60, 13.01 and 16.06 cm for transplanting at 3 WAP, 4 WAP and 5 WAP respectively) when compared to p_1 (normal top soil) which resulted in a root length of 7.06, 11.32 and 14.92 cm with transplanting at 3 WAP, 4 WAP and 5 WAP respectively and p_2 (normal top soil and coir pith compost in 1:1 ratio) which produced a root length of 7.60, 11.45 and 15.37 cm with transplanting at 3 WAP, 4 WAP and 5 WAP respectively in the cassava minisett nursery. However p_2 was on par with p_1 at 3 and 4 WAP in its effect on root length of minisetts.

Interaction effects were significant in case of 3 and 4 weeks old minisetts only in nursery. Among the interaction effects, m_2p_3 resulted in the highest value for root length at 3 WAP (9.36 cm) and 4 WAP (14.25 cm). All the other interaction effects produced significantly lower root length in 3 and 4 weeks old plants from minisetts which were also on par with each other.

4.1.6 Root biomass

Data presented in Table 7. indicate the effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on root biomass seedling^{-1}.

Root biomass seedling^{-1} was significantly influenced by the main effects at 3 WAP, 4 WAP and 5 WAP. Among different types of cassava minisetts used, the m_2 (three node cutting) recorded significantly greater root biomass (0.457, 0.731 and 0.850 g seedling^{-1} at 3 WAP, 4 WAP and 5 WAP respectively) compared to m_1 (two node cutting) which produced the root biomass value of 0.375, 0.617 and 0.751 g seedling^{-1} in 3, 4 and 5 weeks old seedlings respectively.

Higher root biomass seedling^{-1} was resulted with p_3 (coir pith compost and vermi compost in 3:1 ratio) potting media (0.516, 0.793 and 0.903 g seedling^{-1} at

Table 7. Effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on root length and root biomass seedling^{-1} at transplanting from nursery.

Treatments	Root length (cm)			Root biomass (g)		
	3 WAP	4 WAP	5 WAP	3 WAP	4 WAP	5 WAP
Type of minisett cutting (M)						
m_1	7.42	11.45	14.86	0.375	0.617	0.751
m_2	8.09	12.40	16.04	0.457	0.731	0.850
SEm (±)	0.158	0.173	0.317	0.019	0.025	0.033
CD (0.05)	0.453	0.497	0.907	0.039	0.073	0.094
Potting media for the minisetts (P)						
p_1	7.06	11.32	14.92	0.346	0.566	0.721
p_2	7.60	11.45	15.37	0.386	0.664	0.778
p_3	8.60	13.01	16.06	0.516	0.793	0.903
SEm (±)	0.194	0.212	0.388	0.023	0.031	0.040
CD (0.05)	0.555	0.608	NS	0.047	0.089	0.115
M×P interaction						
m_1p_1	7.07	11.51	14.03	0.297	0.511	0.670
m_1p_2	7.34	11.07	14.99	0.313	0.606	0.685
m_1p_3	7.85	11.78	15.56	0.513	0.735	0.899
m_2p_1	7.07	11.13	15.81	0.395	0.621	0.771
m_2p_2	7.85	11.83	15.75	0.450	0.723	0.871
m_2p_3	9.36	14.25	16.56	0.520	0.850	0.908
SEm (±)	0.274	0.300	0.548	0.023	0.044	0.057
CD (0.05)	0.785	0.861	NS	0.067	NS	NS

3, 4 and 5 WAP respectively) when compared to p_2 (normal top soil and coir pith compost in 1:1 ratio) recording a root biomass value of 0.386, 0.664 and 0.778 g seedling^{-1} at 3, 4 and 5 WAP respectively and p_1 (normal top soil) recording a root biomass value of 0.346, 0.566 and 0.721 g seedling^{-1} at 3, 4 and 5 WAP respectively. However the p_2 did not significantly differ from p_1 at 3 and 4 WAP in its effect on root biomass seedling^{-1}.

The treatment interaction effects with respect to root biomass production were significant in case of 3 weeks old seedlings only and the m_2p_3 recorded the highest root biomass seedling^{-1} (0.520 g) which was significantly superior to all other treatment combinations except m_1p_3 (0.513 g). The m_2p_3 treatment was however found to be on par with m_1p_3 which in turn did not vary from m_2p_2 (0.450 g). Root biomass was lower with m_1p_1 (0.297 g) and m_1p_2 (0.313 g) which were on par.

4.1.7 Incidence of pest and disease

The plants from cassava minisetts were regularly observed for monitoring pest and disease incidences. No pest incidence was noticed in the nursery. However cassava mosaic disease (CMD) incidence was observed on few plants and percentage of incidence was recorded. The effects of type of cassava minisett cutting, potting media for the cassava minisetts and their interactions on percentage incidence of CMD in cassava minisett nursery are presented in Table 8.

The percentage of incidence ranged from 9.50 to 13.50 under different treatments. However the main treatments or their interactions did not have any significant influence on CMD incidence in nursery.

4.1.8. Comparison of root initiation of cassava minisetts *Vs.* normal setts

A comparison of root initiation of cassava minisetts in nursery with normal setts planted at the same time in the main field is given in Table 9. The

Table 8. Effects of type of cassava minisett cutting, potting media for the minisetts and their interactions on incidence of Cassava Mosaic Disease(CMD) in minisett nursery, per cent

Treatments	Incidence of CMD
Type of minisett cutting (M)	
m_1	12.83
m_2	11.25
SEm (±)	0.840
CD (0.05)	NS
Potting media for the minisetts(P)	
p_1	11.50
p_2	12.62
p_3	12.00
SEm (±)	1.029
CD (0.05)	NS
M×P interaction	
m_1p_1	13.50
m_1p_2	13.00
m_1p_3	12.00
m_2p_1	9.50
m_2p_2	12.25
m_2p_3	12.00
SEm (±)	1.455
CD (0.05)	NS

mean values of the treatment combinations and control (normal sett planting) are presented.

At 3 WAP, more number of roots was initiated in cassava minisetts in the nursery compared to normal setts planted in main field. Among different treatments in nursery, the m_2p_3 (three node cutting raised in potting medium having coir pith compost and vermi compost in 3:1 ratio) produced the highest number of roots (33.50) followed by m_2p_2 (three node cutting in potting medium having normal soil and coir pith compost in 1:1 ratio – 31.62), m_2p_1 (three node cutting in normal soil as potting medium – 31.12), m_1p_3 (two node cutting raised in potting medium having coir pith compost and vermi compost in 3:1 ratio – 30.50), m_1p_2 (two node cutting in potting medium having normal soil and coir pith compost in 1:1 ratio – 29.62) and m_1p_1 (two node cutting in normal soil as potting medium – 28.62). In case of normal sett planting, the number of roots initiated was the lowest (11.20) compared to minisetts. Cassava minisetts in nursery produced higher number of roots at 4 WAP and 5 WAP also when compared to normal setts. At 4 WAP, highest number of roots were produced by m_2p_3 (35.25) which was followed by m_2p_2 (32.50), m_2p_1 (31.25), m_1p_3 (30.12), m_1p_2 (29.87) and m_1p_1 (29.50). At 5 WAP, m_2p_3 resulted higher number of roots (36.00) which was followed by m_2p_2 (35.00), m_1p_3 (33.00), m_2p_1(31.25), m_1p_2 (29.87) and m_1p_1 (29.75).

At 3 and 4 WAP, cassava minisetts grown in nursery had higher root length than normal setts (control). At 3 WAP, root length was the highest with m_2p_3 (9.36cm) followed by m_2p_2 or m_1p_3(7.85 cm), m_1p_2 (7.34 cm), m_2p_1 (7.07 cm) and m_1p_1 (7.06 cm), when compared to the control (5.23 cm). At 4 WAP, longer roots were produced by m_2p_3(14.25 cm) which was followed by m_2p_2 (11.83 cm), m_1p_3(11.78 cm), m_1p_1(11.51 cm), m_2p_1 (11.13 cm) and m_1p_2(11.07 cm) when compared to control (10.34 cm). However at 5 WAP, length of roots was higher with normal setts (16.46 cm) when compared to the minisetts except those which produced with nursery treatment m_2p_3. Highest root length of 16.56 cm was observed in case of m_2p_3 which was followed by the control (16.46 cm),

Table 9. Comparison of root initiation of cassava minisetts in nursery with normal setts in main field.

Treatments	***Number of roots**			***Root length (cm)**			***Root biomass (g seedling^{-1})**		
	3WAP	4WAP	5WAP	3WAP	4WAP	5WAP	3WAP	4WAP	5WAP
m_1p_1	28.62	29.50	29.75	7.06	11.51	14.03	0.297	0.511	0.670
m_1p_2	29.62	29.87	29.87	7.34	11.07	14.99	0.313	0.606	0.680
m_1p_3	30.50	30.12	33.00	7.85	11.78	15.56	0.513	0.735	0.891
m_2p_1	31.12	31.25	31.25	7.07	11.13	15.81	0.395	0.621	0.772
m_2p_2	31.62	32.50	35.00	7.85	11.83	15.75	0.450	0.723	0.871
m_2p_3	33.50	35.25	36.00	9.36	14.25	16.56	0.520	0.850	0.908
Control (normal sett planting)	11.20	22.80	26.00	5.23	10.34	16.46	0.235	0.777	1.050

*Not statistically analysed as replications were unequal in nursery (8 replications) and main field (3 replications)

m_2p_1 (15.81 cm), m_2p_2 (15.75cm), m_1p_3 (15.56 cm), m_1p_2 (14.99 cm) and m_1p_1 (14.03cm).

In case of root biomass production seedling^{-1} at 3 WAP, cassava minisetts performed better than control. Highest root biomass was produced by m_2p_3 (0.520 g) which was followed by m_1p_3 (0.513 g), m_2p_2 (0.450 g), m_2p_1(0.395 g), m_1p_2 (0.313 g) and m_1p_1 (0.297 g). The root biomass production in normal setts was only 0.235 g seedling^{-1}. However the root biomass production was found to increase beyond 3 WAP in case of normal setts. At 4 WAP, highest root biomass was produced by cassava minisetts under m_2p_3 treatment (0.850 g) which was followed by control (0.777 g), m_1p_3 (0.735 g), m_2p_2 (0.723 g), m_2p_1 (0.621 g), m_1p_2 (0.606 g) and m_1p_1 (0.511 g). At 5 WAP, the normal sett planting excelled in root biomass production (1.050 g) compared to cassava minisetts. Among different minisetts treatments, the m_2p_3 had the highest root biomass production (0.908 g).

4.2 EXPERIMENT - II (MAIN FIELD)

4.2.1 GROWTH AND GROWTH ATTRIBUTES

4.2.1.1 Establishment of minisetts and normal setts

The results of the establishment of minisetts and normal setts in per cent at three weeks after transplanting to the main field are presented in Table 10a, 10b and 10c.

The data indicated that type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field had significant influence on establishment. Establishment was significantly higher (85.47 per cent) for m_2 (three node cutting) which was superior to establishment of minisetts obtained with m_1 or two node cutting (83.39 per cent).

Among different potting media, the minisetts produced with p_3 (coir pith compost and vermi compost in 3:1 ratio) was found to have significantly higher (85.94 per cent) establishment than the minisetts raised in potting media p_1

Table 10a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on establishment of minisetts and normal setts, per cent

Treatments	Establishment
Type of minisett cutting (M)	
m_1	83.39
m_2	85.47
SEm (±)	0.659
CD (0.05)	1.895
Potting media for the minisetts(P)	
p_1	81.78
p_2	85.57
p_3	85.94
SEm (±)	0.807
CD (0.05)	2.320
Time of transplanting minisetts to main field (T)	
t_1	94.28
t_2	89.39
t_3	69.63
SEm (±)	0.807
CD (0.05)	2.320

Table 10b. Effects of M×P, M×T and P×T interactions on establishment of minisetts and normal setts in main field, per cent

Treatments	Establishment
M×P interaction	
m_1p_1	81.08
m_1p_2	83.83
m_1p_3	85.25
m_2p_1	82.47
m_2p_2	87.31
m_2p_3	86.64
SEm (±)	1.142
CD (0.05)	NS
M×T interaction	
m_1t_1	92.89
m_1t_2	88.69
m_1t_3	68.58
m_2t_1	95.66
m_2t_2	90.08
m_2t_3	70.66
SEm (±)	1.142
CD (0.05)	NS
P×T interaction	
p_1t_1	93.58
p_1t_2	91.50
p_1t_3	72.75
p_2t_1	93.58
p_2t_2	85.25
p_2t_3	69.63
p_3t_1	95.67
p_3t_2	91.42
p_3t_3	66.50
SEm (±)	1.398
CD (0.05)	NS

Table 10c. Effects of M×P×T interactions and treatment *Vs.* control effect on establishment of minisetts and normal setts in main field, per cent

Treatments	Establishment
M×P ×T interaction	
$m_1p_1t_1$	91.50
$m_1p_1t_2$	91.50
$m_1p_1t_3$	72.75
$m_1p_2t_1$	95.67
$m_1p_2t_2$	89.33
$m_1p_2t_3$	66.50
$m_1p_3t_1$	91.50
$m_1p_3t_2$	85.25
$m_1p_3t_3$	66.50
$m_2p_1t_1$	95.67
$m_2p_1t_2$	91.50
$m_2p_1t_3$	72.75
$m_2p_2t_1$	95.67
$m_2p_2t_2$	93.50
$m_2p_2t_3$	72.75
$m_2p_3t_1$	95.67
$m_2p_3t_2$	85.25
$m_2p_3t_3$	66.50
SEm (±)	1.977
CD (0.05)	NS
Treatment mean	84.43
Control	79.10
Treatments *Vs* control	S

(normal top soil – 81.78 per cent). The p_3 was however found to be on par with p_2 (top soil and coir pith compost in 1:1 ratio - 85.57 per cent).

On comparing different transplanting time, it was found that transplanting minisetts at 3 WAP (t_1) had highest establishment (94.28 per cent) in the main field which was followed by transplanting at 4 WAP (t_2 – 89.39 per cent) and 5 WAP (t_3 – 69.63 per cent).

Interaction effects had no significant influence on establishment of minisetts in the main field.

While comparing the treatments with control (normal sett planting in main field), it was observed that there was significant difference between treatments and control on establishment of minisetts. The normal setts planted directly in the main field was found to have lower establishment (79.10 per cent) when compared to the minisetts transplanted from nursery (treatment mean value - 84.43 per cent).

4.2.1.2 Plant height

The results of the plant height in cm at monthly interval are presented in Table 11a, 11b and 11c. As indicated by the data, type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field had significant effects on plant height of cassava.

Significantly higher plant height was obtained with planting m_2 (three node minsett cutting) at all the stages of observation (15.21, 35.71, 78.13, 128.41, 158.03, 182.42 and 182.80 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively) when compared to the m_1 (two node cassava minisett cutting) recording a plant height of 14.54, 33.84, 75.75, 119.50, 149.61, 177.96 and 178.35 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively.

Taller plants were produced with minisetts raised in p_3 (coir pith compost and vermi compost in 3:1 ratio) which recorded a plant height of 15.15, 36.14, 78.39, 156.21, 181.27 and 182.26 at 1 MAP, 2 MAP , 3 MAP, 5 MAP, 6 MAP and at harvest respectively. During 1 MAP, 5 MAP, 6 MAP and at harvest the p_3 was however on par with p_2 (normal top soil and coir pith compost in 1:1 ratio) with respect to plant height (15.05, 154.00, 181.18 and 181.87 cm). During 3 MAP and 5 MAP, there was no treatment difference between p_2 and p_1 (normal top soil) which resulted in a plant height of 76.10 and 76.33 cm at 3 MAP and 154.00 and 151.25 cm at 5 MAP respectively.

Time of transplanting of cassava minisetts from nursery to main field significantly influenced the plant height at all the stages of observation. Transplanting the minisetts at 3 WAP (t_1) resulted in significantly higher plant height at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest (15.74, 38.84, 83.23, 135.04, 162.17, 186.66 and 187.05 cm respectively) compared to transplanting at 4 WAP (t_2) and 5 WAP (t_3). The t_2 was significantly superior to the t_3 treatment which recorded a plant height of 15.40, 37.05, 81.53, 131.12, 157.72, 183.10 and 183.49 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively.

The M×P interaction significantly influenced the plant height only at 3 MAP, 5 MAP, 6 MAP and at harvest. At 3 MAP, the m_2p_3 resulted in significantly higher plant height (78.65 cm) compared to other interactions which was also on par with m_2p_2 (78.34 cm) and m_2p_1(78.14 cm). At 5 MAP also similar trend was noticed wherein the m_2p_3 produced a plant height of 158.80 cm which did not significantly differ from m_2p_2 (158.10 cm), m_2p_1 (157.18 cm) and m_1p_3 (155.22 cm). At 6 MAP and at harvest also the m_2p_3 interaction resulted in significantly higher plant height (186.47 cm and 186.86 cm respectively) than all other interactions. The m_1p_1 interaction produced lower plant height during 6 MAP and at harvest (174.64 cm and 175.03 cm respectively)

The M×T interaction could significantly influence the plant height in cassava only at 4 MAP wherein the m_2t_1 interaction produced a mean plant height

Table 11a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on plant height (at monthly interval), cm

Treatments	Plant height (cm)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
Type of minisett cutting (M)							
m_1	14.54	33.84	75.75	119.50	149.61	177.96	178.35
m_2	15.21	35.71	78.13	128.41	158.03	182.42	182.80
SEm (±)	0.089	0.180	0.329	0.824	1.105	0.653	0.652
CD (0.05)	0.255	0.517	0.947	2.370	3.178	1.875	1.875
Potting media for the minisetts(P)							
p_1	14.45	33.27	76.33	122.72	151.25	177.21	177.60
p_2	15.05	34.91	76.10	123.62	154.00	181.18	181.87
p_3	15.15	36.14	78.39	124.45	156.21	181.27	182.26
SEm (±)	0.109	0.220	0.403	1.010	1.354	0.799	0.799
CD (0.05)	0.313	0.633	1.160	NS	3.892	2.297	2.297
Time of transplanting minisetts to main field (T)							
t_1	15.74	38.84	83.23	135.04	162.17	186.66	187.05
t_2	15.40	37.05	81.53	131.12	157.72	183.10	183.49
t_3	13.43	28.43	66.07	105.72	141.56	170.81	171.19
SEm (±)	0.109	0.220	0.403	1.010	1.354	0.799	0.799
CD (0.05)	0.313	0.633	1.160	2.902	3.892	2.297	2.297

Table 11b. Effects of M×P, M×T and P×T interactions on plant height of cassava (at monthly interval), cm

Treatments	Plant height (cm)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
M×P interaction							
m_1p_1	14.11	32.18	74.32	121.11	144.40	174.64	175.03
m_1p_2	14.82	34.26	74.80	118.41	149.20	181.97	182.36
m_1p_3	14.71	35.07	77.39	118.99	155.22	177.27	177.66
m_2p_1	14.78	34.37	78.14	126.32	157.18	179.78	180.17
m_2p_2	15.27	35.56	78.34	128.02	158.10	180.99	181.39
m_2p_3	15.58	37.21	78.65	129.90	158.80	186.47	186.86
SEm (±)	0.154	0.312	0.571	1.428	1.915	1.130	1.130
CD (0.05)	NS	NS	1.640	NS	5.504	3.249	3.248
M×T interaction							
m_1t_1	15.27	37.81	81.79	130.31	158.84	183.73	184.11
m_1t_2	15.20	35.92	79.84	123.10	154.30	180.72	181.11
m_1t_3	13.16	27.78	65..62	105.37	135.68	169.43	169.82
m_2t_1	16.21	39.87	84.65	140.05	165.51	183.59	189.97
m_2t_2	15.73	38.18	83.21	138.13	161.15	185.48	185.86
m_2t_3	13.69	29.09	6.51	106.05	147.44	172.18	172.58
SEm (±)	0.154	0.312	0.571	1.428	1.915	1.130	1.130
CD (0.05)	NS	NS	NS	4.104	NS	NS	NS
P×T interaction							
p_1t_1	15.12	37.67	82.89	134.47	159.19	183.93	184.32
p_1t_2	14.92	35.65	81.19	129.51	155.59	180.09	180.48
p_1t_3	13.30	26.50	64.90	105.15	138.96	167.62	168.00
p_2t_1	15.89	38.74	82.35	133.09	160.30	187.17	187.56
p_2t_2	15.66	37.26	80.33	132.37	158.47	183.25	183.64
p_2t_3	13.58	28.72	65.63	105.69	143.23	174.05	174.41
p_3t_1	16.21	40.11	84.43	135.55	167.02	188.87	189.26
p_3t_2	15.83	38.23	83.08	131.48	159.11	185.96	186.35
p_3t_3	13.40	30.07	67.67	106.30	142.49	170.79	171.18
SEm (±)	0.188	0.382	0.699	1.749	2.345	1.384	1.384
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 11c. Effects of M×P×T interactions and treatment *Vs.* control effect on plant height of cassava (at monthly interval), cm

Treatments	Plant height (cm)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
m× p× t interaction							
$m_1p_1t_1$	14.60	36.33	81.32	134.03	154.38	179.91	180.30
$m_1p_1t_2$	14.53	34.65	78.95	124.41	146.98	177.21	177.60
$m_1p_1t_3$	13.19	25.56	62.67	104.88	131.83	166.79	167.18
$m_1p_2t_1$	15.58	38.72	80.72	127.88	157.05	186.71	187.10
$m_1p_2t_2$	15.64	36.05	78.72	122.04	156.13	183.48	183.86
$m_1p_2t_3$	13.23	27.99	64.98	105.31	134.41	175.71	176.10
$m_1p_3t_1$	15.62	38.36	83.34	128.17	165.09	184.55	184.94
$m_1p_3t_2$	15.44	37.04	81.85	124.86	159.78	181.48	181.86
$m_1p_3t_3$	13.07	29.78	69.21	105.93	140.79	165.78	166.17
$m_2p_1t_1$	15.63	39.00	84.47	138.91	164.01	187.94	188.33
$m_2p_1t_2$	15.30	36.65	83.42	134.61	164.20	182.97	183.35
$m_2p_1t_3$	13.42	27.44	67.12	105.43	146.10	168.43	168.82
$m_2p_2t_1$	16.21	38.74	83.98	138.303	163.55	187.63	188.01
$m_2p_2t_2$	15.69	38.47	81.93	139.70	160.81	183.03	183.41
$m_2p_2t_3$	13.93	29.45	66.27	106.07	152.05	172.33	172.72
$m_2p_3t_1$	16.79	41.86	85.51	142.93	168.95	193.19	193.58
$m_2p_3t_2$	16.21	39.42	84.29	140.100	158.43	190.44	190.82
$m_2p_3t_3$	13.74	30.36	66.12	106..67	144.18	175.79	176.18
SEm (±)	0.266	0.540	0.988	2.473	3.316	1.958	1.957
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
Treatment mean	14.88	34.77	76.99	123.96	153.82	180.19	180.57
Control	12.03	24.55	73.72	117.66	148.00	174.42	174.68
Treatments *Vs* control	S	S	S	S	S	S	S

of 140.05 cm which was significantly superior to other interactions and on par with m_2t_2 (138.13 cm).

The P×T or M×P×T interaction could not significantly influence the plant height at any stage of observation.

While comparing the minisetts with normal setts, it was observed that at all stages of observation the treatment *Vs.* control interaction was significant and the treatments (minisetts) produced taller plants than the control (normal setts). The control means were 12.03 cm, 24.55 cm,73.72 cm, 117.66 cm, 148 cm, 174.42 cm and 174.68 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively. The higher values of treatment means with respect to plant height were 14.88 cm, 34.77 cm, 76.99 cm, 123.96 cm, 153.82 cm, 180.19 cm and 180.57 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively.

4.2.1.3 Stem girth

The results of the main effects and interaction effects of treatments on stem girth at monthly interval are presented in Table 12a, 12b and 12c.

The data indicated that the type of cassava minisett cutting had significant influence on stem girth of cassava plants in main field at 2 MAP, 4 MAP, 6 MAP and at harvest. During 2 MAP, the three node cutting (m_2) resulted in significantly higher stem girth (3.88 cm) than two node cutting (m_1 – 3.51 cm). At 4 MAP, 6 MAP and at harvest the trend was repeated and the m_2 produced a stem girth of 5.77 cm, 7.97 cm and 7.98 cm respectively when compared to m_1 which produced a stem girth of 5.58 cm, 7.51 cm and 7.52 cm respectively.

Type of potting media used for minisetts in nursery could significantly influence the stem girth of cassava only at 1st month of observation. At 1 MAP the p_3 recorded significantly higher stem girth (1.73 cm) compared to p_1 (1.46 cm) and the p_3 was however on par with p_2 (1.60 cm) and there is no treatment difference between p_2 and p_1.

Table 12a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on stem girth, cm

Treatments	Stem girth (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
Type of minisett cutting (M)							
m_1	1.55	3.51	4.81	5.58	6.71	7.51	7.52
m_2	1.65	3.88	4.90	5.77	6.74	7.97	7.98
SEm (±)	0.044	0.083	0070	0.051	0.057	0.08	0.075
CD (0.05)	NS	0.238	NS	0.147	NS	0.23	0.214
Potting media for the minisetts(P)							
p_1	1.46	3.72	4.79	5.66	6.76	7.66	7.67
p_2	1.60	3.70	4.95	5.68	6.74	7.73	7.74
p_3	1.73	3.67	4.83	5.68	6.67	7.82	7.83
SEm (±)	0.054	0.101	0.086	0.063	0.069	0.09	0.091
CD (0.05)	0.157	NS	NS	NS	NS	NS	NS
Time of transplanting minisetts to main field (T)							
t_1	2.15	4.27	5.22	6.51	7.31	8.26	8.33
t_2	1.77	4.08	5.21	5.73	7.10	8.06	8.10
t_3	0.87	2.74	4.14	4.79	5.76	6.80	6.81
SEm (±)	0.054	0.101	0.086	0.063	0.069	0.09	0.091
CD (0.05)	0.157	0.291	0.247	0.180	0.199	0.27	0.262

Table 12b. Effects of M×P, M×T and P×T interactions on cassava stem girth, cm

Treatments	Stem girth (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
M×P interaction							
m_1p_1	1.41	3.45	4.70	5.60	6.66	7.37	7.38
m_1p_2	1.57	3.62	4.85	5.48	6.66	7.58	7.58
m_1p_3	1.67	3.46	4.89	5.65	6.80	7.59	7.61
m_2p_1	1.51	3.88	4.87	5.72	6.85	7.96	7.97
m_2p_2	1.63	3.77	4.77	5.88	6.82	7.87	7.87
m_2p_3	1.79	4.00	5.06	5.72	6.54	8.07	8.078
SEm (±)	0.077	0.143	0.122	0.089	0.098	0.13	0.129
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
M×T interaction							
m_1t_1	1.96	3.88	5.08	6.43	7.27	8.01	8.12
m_1t_2	1.80	3.96	5.25	5.70	7.13	7.89	7.91
m_1t_3	0.89	2.70	4.11	4.61	5.73	6.52	6.53
m_2t_1	2.34	4.58	5.34	6.59	7.36	8.50	8.55
m_2t_2	1.74	4.29	5.19	5.76	7.07	8.32	8.38
m_2t_3	0.85	2.78	4.16	4.97	5.78	7.09	7.10
SEm (±)	0.077	0.143	0.122	0.089	0.098	0.13	0.129
CD (0.05)	0.221	NS	NS	NS	NS	NS	NS
P×T interaction							
p_1t_1	1.86	4.01	5.38	6.37	7.33	8.12	8.28
p_1t_2	1.70	4.33	4.97	5.76	7.20	8.27	8.33
p_1t_3	0.83	2.84	4.01	4.85	5.74	6.59	6.60
p_2t_1	2.19	4.17	5.06	6.42	7.21	8.19	8.26
p_2t_2	1.72	4.21	5.38	5.72	7.03	8.11	8.15
p_2t_3	0.88	2.71	4.05	4.91	5.99	6.91	6.92
p_3t_1	2.39	4.07	5.31	6.73	7.40	8.46	8.47
p_3t_2	1.90	4.27	5.20	5.70	7.07	8.11	8.12
p_3t_3	0.91	2.67	4.35	4.62	5.53	6.92	6.93
SEm (±)	0.094	0.175	0.149	0.109	0.120	0.16	0.158
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 12c. Effects of $M \times P \times T$ interactions and treatment *Vs.* control effect on cassava stem girth, cm

Treatments	Stem girth (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
$M \times P \times T$ interaction							
$m_1p_1t_1$	1.67	3.91	5.27	6.45	7.33	7.79	7.80
$m_1p_1t_2$	1.73	3.64	4.92	5.59	7.10	8.09	8.10
$m_1p_1t_3$	0.84	2.80	3.91	4.78	5.56	6.22	6.23
$m_1p_2t_1$	2.10	4.10	5.08	6.21	7.18	8.16	8.17
$m_1p_2t_2$	1.80	4.13	5.29	5.74	7.02	8.02	8.02
$m_1p_2t_3$	0.92	2.65	4.18	4.50	5.80	6.56	6.58
$m_1p_3t_1$	2.11	3.61	4.89	6.63	7.30	8.09	8.10
$m_1p_3t_2$	1.99	4.11	5.53	5.76	7.26	7.89	7.90
$m_1p_3t_3$	0.92	2.65	4.25	4.56	5.83	6.79	6.81
$m_2p_1t_1$	2.05	4.10	5.48	6.30	7.33	8.46	8.47
$m_2p_1t_2$	1.67	5.02	5.02	5.93	7.30	8.46	8.47
$m_2p_1t_3$	0.82	2.89	4.12	4.92	5.93	6.96	6.97
$m_2p_2t_1$	2.29	4.24	5.32	6.63	7.25	8.22	8.27
$m_2p_2t_2$	1.76	4.30	5.34	5.70	7.04	8.19	8.19
$m_2p_2t_3$	0.83	2.78	4.52	5.32	6.19	7.26	7.27
$m_2p_3t_1$	2.67	4.53	5.24	6.83	7.50	8.82	8.82
$m_2p_3t_2$	1.81	4.43	5.23	5.65	6.89	8.32	8.33
$m_2p_3t_3$	0.90	2.68	3.85	4.68	5.24	7.06	7.07
SEm (±)	0.133	0.248	0.210	0.154	0.170	0.23	0.224
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
Treatment mean	1.60	3.70	4.86	5.68	6.73	7.74	7.75
Control	1.42	3.55	4.82	6.00	7.10	8.03	8.17
Treatments *Vs* control	NS	NS	NS	NS	NS	NS	NS

Different time of transplanting did influence the stem girth of cassava plants at all the stages of observation. Transplanting the minisetts 3 WAP (t_1) resulted in significantly higher stem girth (2.15 cm, 4.27 cm, 5.22 cm, 6.51 cm, 7.31 cm, 8.26 cm and 8.33 cm at 1 MAP, 2 MAP, 3 MAP, 4 MAP, 5 MAP, 6 MAP and at harvest respectively) compared to t_3 (at all stages of observation) and t_2 (at 1 MAP, 4 MAP, and 5 MAP only). At 2 MAP, 3 MAP, 6 MAP and at harvest the t_1 was however on par with t_2 with respect to its effect on stem girth.

The M×P interaction or P×T interaction could not significantly influence the stem girth of cassava plants at any stages of observation. The M×T interaction however was significant at 1 MAP wherein the m_2t_1 interaction produced significantly higher stem girth of 2.34 cm than other interactions which was followed by m_1t_1 (1.96 cm), m_1t_2 (1.80 cm) and m_2t_2 (1.74 cm) which were on par with each other. Lowest value for stem girth was recorded by m_2t_3 (0.85 cm) which in turn was on par with m_1t_3 producing a stem girth of 0.89 cm.

The M×P×T interactions did not influence the cassava stem girth at any stages of observation. The treatment *Vs.* control effect was also not significant with respect to stem girth at all the stages of observation.

4.2.1.4 Functional leaves plant^{-1}

The results of the main effects and interaction effects of treatments on functional leaves plant^{-1} at monthly interval are presented in the Table 13a, 13b and 13c.

Different types of minisett cuttings could influence the number of functional leaves plant^{-1} only at 3 MAP, 4 MAP, 5 MAP and at harvest. The three node minisett cuttings in nursery (m_2) produced significantly higher number of functional leaves in the main field (58.24, 92.79, 125.27 and 146.41 no's at 3 MAP, 4 MAP, 5 MAP and at harvest respectively) compared to two node cutting (m_1) which produced 56.60, 89.73, 120.79 and 143.99 leaves respectively.

Table 13a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on functional leaves plant^{-1}, no's.

Treatments	Functional leaves plant^{-1} (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
Type of minisett cutting (M)							
m_1	8.46	20.49	56.60	89.73	120.79	147.54	143.99
m_2	8.68	20.93	58.24	92.79	125.27	146.52	146.41
SEm (±)	0.098	0.310	0.403	0.534	0.768	0.728	0.564
CD (0.05)	NS	NS	1.158	1.536	2.207	NS	1.621
Potting media for the minisetts(P)							
p_1	8.64	20.63	56.49	89.20	121.71	146.50	145.39
p_2	8.35	20.09	57.14	92.11	122.65	146.34	144.72
p_3	8.72	21.41	58.72	92.31	124.73	147.09	145.49
SEm (±)	0.120	0.379	0.493	0.654	0.940	0.891	0.691
CD (0.05)	NS	NS	1.418	1.881	NS	NS	NS
Time of transplanting minisetts to main field (T)							
t_1	9.76	25.75	65.42	96.80	137.08	151.09	155.81
t_2	9.09	23.32	62.81	93.04	126.69	149.17	153.27
t_3	6.86	13.06	44.12	83.92	105.32	139.74	126.52
SEm (±)	0.120	0.379	0.493	0.654	0.940	0.891	0.691
CD (0.05)	0.344	1.090	1.418	1.881	2.703	2.562	1.986

Table 13b. Effects of M×P, M×T and P×T interactions on functional leaves plant^{-1} in cassava, no's

Treatments	Functional leaves plant^{-1} (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
M×P interaction							
m_1p_1	8.69	20.88	56.41	92.02	120.16	147.12	145.34
m_1p_2	8.31	20.44	56.61	87.53	122.39	145.66	142.89
m_1p_3	8.38	20.16	56.97	89.63	119.82	147.54	146.75
m_2p_1	8.58	20.39	57.86	92.59	123.27	145.89	145.44
m_2p_2	8.39	19.75	56.37	90.87	122.91	147.02	146.57
m_2p_3	9.06	22.65	60.47	94.83	129.63	146.66	147.21
SEm (±)	0.169	0.536	0.698	0.925	1.330	1.260	0.977
CD (0.05)	NS	1.541	2.006	NS	3.82	NS	NS
M×T interaction							
m_1t_1	9.65	25.19	63.83	93.95	134.87	151.07	155.29
m_1t_2	9.04	23.42	62.10	92.04	123.09	149.04	152.49
m_1t_3	6.69	12.86	44.07	83.20	104.42	140.21	124.21
m_2t_1	9.86	26.31	67.01	99.66	139.28	151.12	156.34
m_2t_2	9.14	23.21	63.52	94.05	130.29	149.17	154.06
m_2t_3	7.03	13.26	44.11	84.64	106.23	139.28	128.84
SEm (±)	0.169	0.536	0.698	0.925	1.330	1.260	0.977
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
P×T interaction							
p_1t_1	9.71	26.02	65.27	97.46	135.73	151.45	155.11
p_1t_2	9.26	23.14	62.98	95.11	124.41	148.72	152.72
p_1t_3	6.94	12.74	43.16	84.35	104.99	139.34	128.34
p_2t_1	9.58	24.72	63.61	93.25	136.07	150.88	155.37
p_2t_2	8.89	22.88	62.32	90.77	125.86	149.04	152.38
p_2t_3	6.59	12.68	43.56	83.58	106.02	139.11	126.45
p_3t_1	9.98	26.51	67.39	99.69	139.42	150.96	156.96
p_3t_2	9.13	23.94	63.13	93.26	129.81	149.55	154.72
p_3t_3	6.86	13.77	45.63	83.83	104.95	140.78	124.78
SEm (±)	0.207	0.657	0.855	1.133	1.628	1.544	1.196
CD (0.05)	NS	NS	NS	NS	NS	NS	NS

Table 13c. Effects of M×P×T interactions and treatment *Vs.* control effect on functional leaves plant^{-1} in cassava, no's.

Treatments	Functional leaves plant^{-1} (at monthly interval)						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	At harvest
M×P ×T interaction							
$m_1p_1t_1$	9.80	26.04	63.83	96.44	134.65	152.30	155.63
$m_1p_1t_2$	9.47	23.80	61.70	94.66	120.49	149.36	153.36
$m_1p_1t_3$	6.76	12.77	43.70	84.96	105.33	139.68	127.02
$m_1p_2t_1$	9.82	25.19	63.19	91.80	137.11	148.54	153.54
$m_1p_2t_2$	8.59	23.50	61.84	88.80	125.50	147.19	149.86
$m_1p_2t_3$	6.51	12.63	44.81	82.00	104.58	141.26	125.26
$m_1p_3t_1$	9.31	24.36	64.47	93.60	132.84	152.35	156.68
$m_1p_3t_2$	9.04	22.97	62.75	92.66	123.29	150.58	154.24
$m_1p_3t_3$	6.78	13.16	43.68	82.63	103.33	139.68	120.34
$m_2p_1t_1$	9.59	26.00	66.70	98.49	136.81	150.59	154.59
$m_2p_1t_2$	9.03	22.49	64.27	95.56	128.33	148.08	152.08
$m_2p_1t_3$	7.10	12.68	42.61	83.73	104.65	138.99	129.66
$m_2p_2t_1$	9.33	24.26	64.03	94.70	135.04	153.19	157.19
$m_2p_2t_2$	9.17	22.26	62.79	92.74	126.22	150.89	154.89
$m_2p_2t_3$	6.67	12.72	42.30	85.17	107.46	136.96	127.63
$m_2p_3t_1$	10.65	28.66	70.31	105.78	146.00	149.56	157.23
$m_2p_3t_2$	9.21	24.90	63.51	93.85	136.33	148.53	155.19
$m_2p_3t_3$	7.30	14.39	47.57	85.02	106.56	141.88	129.22
SEm (±)	0.293	0.929	1.209	1.603	2.303	2.183	1.692
CD (0.05)	NS	NS	NS	NS	NS	NS	NS
Treatment mean	8.57	20.71	57.45	91.26	123.03	146.65	146.31
Control	8.66	20.50	55.77	91.56	123.03	147.82	148.00
Treatments *Vs* control	NS	NS	NS	NS	NS	NS	NS

Type of potting media used for minisetts in nursery could significantly influence the number of functional leaves plant^{-1} only at 3 MAP and 4 MAP. At 3 MAP, the p_3 recorded significantly higher number of functional leaves (58.72) compared to p_2 (57.14) and p_1 (56.49) which were on par each other. At 4 MAP also the p_3 produced significantly higher number of functional leaves (92.31) than p_1 (89.20) and the p_3 was however on par with p_2 (92.11) in its effect on functional leaf production.

The time of transplanting of minisetts could influence the functional leaf production at all stages of observation. Transplanting cassava minisetts 3 WAP (t_1) to the main field produced significantly higher number of functional leaves (9.76, 25.75, 65.42, 96.80, 137.08, 151.09 and 155.81 at 1 MAP to 6 MAP and at harvest respectively) compared to t_2 (transplanting at 4 WAP) and t_3 (transplanting at 5 WAP). At 6 MAP, the t_1 (151.09) was however on par with t_2 (149.17) in its effect on production of functional leaves plant $^{-1}$.

The M×P interaction could significantly influence the production of functional leaves of cassava in main field only at 2 MAP, 3 MAP and 5 MAP wherein the m_2p_3 produced significantly higher number of functional leaves (22.65 at 2 MAP, 60.47 at 3 MAP and 129.63 at 5 MAP) than all other interactions. At 2 MAP, functional leaf production which was highest with m_2p_3 interaction (22.65) was followed by m_1p_1 (20.88), m_1p_2 (20.44), m_2p_1 (20.39), m_1p_3 (20.16) and m_2p_2 (19.75) which were on par with each other. At 3 MAP the m_2p_3 was followed by m_2p_1 (57.86), m_1p_3 (56.97), m_1p_2 (56.61), m_1p_1 (56.41) and m_2p_2 (56.37) with respect to functional leaf production and the m_2p_1 was on par with all other interactions except the one which recorded the highest value (m_2p_3). Like wise at 5 MAP, the m_1p_1 (120.16), m_1p_2 (122.39), m_1p_3 (119.82), m_2p_1 (123.27) and m_2p_2 (122.91) were on par with each other with respect to production of functional leaves.

The M×T or P×T interactions could not significantly influence the functional leaf production at any stage of observation. As indicated by Table 13c, the M×P×T interactions or treatment *Vs.* control effect did not significantly influence the functional leaves plant^{-1} during any stage of observation.

4.2.1.5 Leaf Area Index (at 3 MAP)

The main effects and interaction effects of type of cassva minisett cutting, potting media for minisetts and time of transplanting from the nursery on Leaf Area Index (LAI) at 3 MAP are presented in the Table 14a, 14b and 14c.

The LAI was significantly influenced by the type of minisett cuttings. Three node minisetts (m_2) had significantly higher LAI (2.40) compared to two node minisetts or m_1 (2.18).

Potting media used for raising minisetts in nursery also influenced the LAI at 3 MAP in the main field. Significantly higher LAI was recorded (2.56) when p_3 (coir pith compost and vermi compost in 3:1 ratio) was used for growing minisetts in nursery which was superior to p_2 (normal top soil and coir pith compost in 1:1 ratio) and p_1 (normal top soil) which recorded a LAI of 2.23 and 2.07 respectively.

The LAI of cassava plants was influenced by the age of minisetts or the time of transplanting to the main field. The LAI was significantly higher (3.15) with t_1 (transplanting at 3 WAP) when compared to t_2 (transplanting at 4 WAP) or t_3 (transplanting at 5 WAP) which produced a LAI of 2.33 and 1.38 respectively.

The M×P interaction could significantly influence the LAI of the crop. The LAI was the highest (2.85) with m_2p_3 interaction which was significantly superior to all other interactions and was followed by m_2p_2 interaction (2.36) which was on par with m_1p_3 (2.26).

The M×T interaction also significantly influenced the LAI of the crop. The LAI was significantly higher (3.28) with m_2t_1 interaction when compared to others and it was followed by m_1t_1 interaction (3.02) and m_2t_2 interaction (2.51).

The P×T interaction could also influence the LAI of cassava. The p_3t_1 interaction produced the highest LAI (3.51) which was superior to other interactions and was followed by p_1t_1, p_2t_1 and p_1t_2 interactions which recorded a LAI of 3.17, 2.77 and 2.20 respectively.

The LAI was however not influenced by the M×P×T interactions. Comparing treatments with control, it was observed that there was significant difference between treatments and control with respect to the LAI and the treatments recorded a higher value of LAI (2.29) than the control (2.16).

4.2.1.6 Number of primary and secondary branches

The effect of main factors and their interactions on the number of primary and secondary branches plant^{-1} are presented in the Table 14a, 14b and 14c. The number of primary branches was noted at 3 MAP. Since the secondary branches were initiated only in the 4th month of planting, its number was noted as zero at 3 MAP and count was again taken at 4 MAP.

The main effects such as type of minisett cuttings or potting media for minisetts did not significantly influence the number of primary and secondary branches plant^{-1}. However the time of transplanting of minisetts from nursery to main field influenced the production of branches. Highest number of primary branches was recorded with minisetts transplanted at 3 WAP (t_1- 2.83) which was significantly higher than the number of branches produced with transplanting at 5 WAP (t_3- 1.65). The t_1 was however on par in effect with t_2 or transplanting at 4 WAP (2.76). Similar trend was noticed in case of secondary branches also wherein the t_1 (transplanting at 3 WAP) recorded higher number of branches (8.59) which was on par with t_2 (8.53) and significantly superior to t_3 (transplanting at 5 WAP) recording 7.64 secondary branches.

The M×P, M×T, P×T or M×P×T interactions could not influence the production of branches in cassava. Comparing treatments with control, it was observed that there was no significant difference between treatments and control with respect to the number of primary and secondary branches plant^{-1}.

Table 14a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on Leaf Area Index and number of primary and secondary branches plant^{-1}.

Treatments	Leaf Area Index (at 3 MAP)	Number of branches plant^{-1}	
		Number of primary branches plant^{-1} (at 3 MAP)	Number of secondary branches plant^{-1} (at 4 MAP)*
Type of minisett cutting (M)			
m_1	2.18	2.36	8.20
m_2	2.40	2.47	8.30
SEm (±)	0.022	0.046	0.07
CD (0.05)	0.063	NS	NS
Potting media for the minisetts(P)			
p_1	2.07	2.39	8.16
p_2	2.23	2.34	8.25
p_3	2.56	2.51	8.35
SEm (±)	0.027	0.056	0.09
CD (0.05)	0.077	NS	NS
Time of transplanting minisetts to main field (T)			
t_1	3.15	2.83	8.59
t_2	2.33	2.76	8.53
t_3	1.38	1.65	7.64
SEm (±)	0.027	0.056	0.093
CD (0.05)	0.077	0.161	0.268

*At 3 MAP the number of secondary branches was zero

Table 14b. Effects of M×P, M×T and P×T interactions on Leaf Area Index and number of primary and secondary branches plant^{-1}.

Treatments	Leaf Area Index (at 3 MAP)	Number of branches plant^{-1}	
		Number of primary branches plant^{-1}(at 3MAP)	Number of secondary branches plant^{-1}(at 4 MAP)*
M×P interaction			
m_1p_1	2.10	2.33	8.11
m_1p_2	2.17	2.29	8.22
m_1p_3	2.26	2.46	8.25
m_2p_1	1.98	2.44	8.14
m_2p_2	2.36	2.38	8.36
m_2p_3	2.85	2.57	8.44
SEm (±)	0.038	0.079	0.132
CD (0.05)	0.109	NS	NS
M×T interaction			
m_1t_1	3.02	2.81	8.55
m_1t_2	2.15	2.78	8.55
m_1t_3	1.36	1.50	7.51
m_2t_1	3.28	2.85	8.62
m_2t_2	2.51	2.74	8.51
m_2t_3	1.40	1.81	7.77
SEm (±)	0.038	0.079	0.132
CD (0.05)	0.109	NS	NS
P×T interaction			
p_1t_1	3.17	2.89	8.44
p_1t_2	2.20	2.78	8.49
p_1t_3	1.32	1.50	7.55
p_2t_1	2.77	2.72	8.55
p_2t_2	2.15	2.72	8.55
p_2t_3	1.30	1.58	7.62
p_3t_1	3.51	2.89	8.77
p_3t_2	2.64	2.78	8.55
p_3t_3	1.52	1.88	7.72
SEm (±)	0.046	0.097	0.162
CD (0.05)	0.133	NS	NS

*At 3 MAP the number of secondary branches was zero

Table 14c. Effects of M×P×T interactions and treatment *Vs.* control effect on Leaf Area Index (at 3 MAP) and number of primary and secondary branches plant^{-1}.

Treatments	Leaf Area Index (at 3 MAP)	Number of branches plant^{-1}	
		Number of primary branches plant^{-1} (at 3MAP)	Number of secondary branches plant^{-1}(at 4 MAP)*
M×P ×T interaction			
$m_1p_1t_1$	2.96	2.89	8.44
$m_1p_1t_2$	2.01	2.78	8.55
$m_1p_1t_3$	1.33	1.33	7.44
$m_1p_2t_1$	2.92	2.78	8.44
$m_1p_2t_2$	2.19	2.78	8.56
$m_1p_2t_3$	1.40	1.33	7.45
$m_1p_3t_1$	3.18	2.78	8.77
$m_1p_3t_2$	2.25	2.78	8.57
$m_1p_3t_3$	1.36	1.83	7.67
$m_2p_1t_1$	3.37	2.89	8.44
$m_2p_1t_2$	2.39	2.78	8.45
$m_2p_1t_3$	1.32	1.66	7.44
$m_2p_2t_1$	2.62	2.67	8.66
$m_2p_2t_2$	2.11	2.66	8.56
$m_2p_2t_3$	1.20	1.83	7.87
$m_2p_3t_1$	3.84	3.00	8.78
$m_2p_3t_2$	3.03	2.78	8.56
$m_2p_3t_3$	1.69	1.94	8.00
SEm (±)	0.066	0.137	0.229
CD (0.05)	NS	NS	NS
Treatment mean	2.29	2.42	7.82
Control	2.16	2.67	8.66
Treatments *Vs* control	S	NS	NS

*At 3 MAP the number of secondary branches was zero

4.2.2. YIELD ATTRIBUTES AND YIELD

4.2.2.1 Number of tubers

The effect of treatments on the number of tubers plant^{-1}are presented in the Table 15a, 15b and 15c.

The perusal of the data revealed that the type of minisett cutting or potting media used for raising minisetts in nursery could not influence the number of tubers plant^{-1}. However the time of transplanting minisetts to the main field significantly influenced the number of tubers plant^{-1}. The minisetts which were transplanted at 3 WAP (t_1) recorded significantly higher number (5.44) of tubers plant^{-1} compared to t_2 (transplanting at 4 WAP) and t_3 (transplanting at 5 WAP) which produced 4.73 and 4.13 tubers respectively.

None of the interaction effects could significantly influence the number of tubers plant^{-1}. Comparison of treatments with control indicated that there was no significant difference between treatments and control with respect to the production of number of tubers plant^{-1}.

4.2.2.2 Percentage of productive roots

The effect of treatments and their interactions on the percentage of productive roots in cassava are presented in the Table 15a, 15b and 15c.

The main effects of type of minisett cutting and potting media in nursery could not affect the percentage of productive roots. However the time of transplanting minisetts to the main field significantly influenced the productive root formation. Highest percentage of productive roots was resulted with t_1 (transplanting at 3WAP–56.88) which was significantly superior to t_2 (transplanting at 4 WAP-53.48 per cent). The productive root formation was greatly reduced with delayed transplanting in t_3 (transplanting at 5 WAP- 42.49 per cent)

Interaction effects were not significant to influence the percentage of productive roots. Comparison of treatments with control (normal setts) indicated that there was significant difference between treatments and control in case of percentage of productive roots and treatments produced higher percentage of productive roots (50.95) than the control (46.30).

4.2.2.3 Length of tuber

The effect of treatments and their interactions on the length of tuber are presented in the Table 15a, 15b and 15c.

The length of tuber was significantly influenced by the type of minisett cutting and longer tubers were produced with three node cutting (m_2- 45.99 cm) compared to two node cutting (m_1- 43.85 cm).

The potting media used for raising minisetts in the nursery could not influence the length of tuber in main field crop.

The time of transplanting the cassava minisetts could however significantly influence the tuber length and longest tubers (46.97 cm) were produced with t_1 (transplanting at 3 WAP) which was significantly superior to t_2 (transplanting at 4 WAP) with respect to tuber length (45.46 cm). Delaying the transplanting to 5 WAP significantly reduced the tuber length to 42.33 cm in t_3.

None of the two factor or three factor interactions could significantly influence the length of the tuber. On comparing treatments with control (normal setts), it was observed that there was significant difference between treatments and control in case of length of tuber wherein the minisetts produced longer tubers (44.92 cm) than the normal setts (32.56 cm).

4.2.2.4 Girth of tuber

The effects of treatments and their interactions on the girth of tuber are presented in the Table 15a, 15b and 15c.

The perusal of the data revealed that the type of minisett cutting had significant influence on girth of tuber and the three node minisetts (m_2) produced more tuber girth (23.92 cm) which was significantly superior to two node minisetts (m_1- 22.89 cm).

Different potting media used in nursery could not however influence the tuber girth in cassava.

The girth of tuber was significantly influenced by the time of transplanting minisetts to main field and early transplanting (3 WAP-t_1) produced significantly higher tuber girth (25.44 cm) than delayed transplanting in 4 WAP (t_2- 23.95 cm) and 5 WAP (t_3- 20.83 cm).

The two factor interactions or the three factor interaction had no influence on the girth of tuber in cassava. The treatment *Vs.* control effect was also not significant in case of tuber girth.

4.2.2.5 Mean weight of tubers

Effect of cassava minisett cuttings, potting media for minisetts and time of transplanting and their interactions on mean weight of tubers is expressed in Table 15a, 15b and 15c.

Significantly higher value for mean weight of tubers was obtained with m_2 (three node cutting – 668.18 g) when compared to m_1 (two node cuttings – 624.14 g).

The type of potting media for minisett setts production in nursery did not influence the mean weight of tubers in the main field.

Significantly higher mean weight of tubers (747.65 g) was recorded with early transplanting in t_1 (3 WAP) when compared to t_2 (transplanting at 4 WAP- 659.24 g) and t_3 (transplanting at 5 WAP- 531.58 g).

Among the two factor interactions, only M×P interactions did influence the mean weight of tubers. The m_2p_3 interaction produced significantly higher

Table 15a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting of minisetts on number of tubers plant^{-1}, percentage of productive roots, length of tuber, girth of tuber and mean weight of tubers.

Treatments	Number of tubers plant^{-1}	Percentage of productive roots	Length of tuber (cm)	Girth of tuber (cm)	Mean weight of tubers (g)
Type of minisett cutting (M)					
m_1	4.67	50.73	43.85	22.89	624.14
m_2	4.87	51.18	45.99	23.92	668.18
SEm (±)	0.098	0.411	0.327	0.237	6.603
CD (0.05)	NS	NS	0.939	0.682	18.984
Potting media for the minisetts(P)					
p_1	4.85	50.99	44.62	22.93	644.29
p_2	4.62	50.87	45.25	23.51	641.82
p_3	4.82	51.00	44.89	23.77	652.36
SEm (±)	0.120	0.503	0.400	0.291	8.088
CD (0.05)	NS	NS	NS	NS	NS
Time of transplanting minisetts to main field (T)					
t_1	5.44	56.88	46.97	25.44	747.65
t_2	4.73	53.48	45.46	23.95	659.24
t_3	4.13	42.49	42.33	20.83	531.58
SEm (±)	0.120	0.503	0.400	0.291	8.088
CD (0.05)	0.345	1.445	1.15	0.836	23.250

Table 15b.Effects of M×P, M×T and P×T interactions on number of tubers plant^{-1}, percentage of productive roots, length of tuber, girth of tuber and mean weight of tubers.

Treatments	Number of tubers plant^{-1}	Percentage of productive roots	Length of tuber (cm)	Girth of tuber (cm)	Mean weight of tubers (g)
M×P interaction					
m_1p_1	4.64	50.37	43.36	22.81	641.35
m_1p_2	4.55	50.91	44.52	22.79	640.22
m_1p_3	4.81	50.91	43.67	23.07	590.84
m_2p_1	5.07	51.61	45.88	23.06	647.24
m_2p_2	4.69	50.83	45.98	24.22	643.41
m_2p_3	4.83	51.08	46.11	24.48	713.88
SEm (±)	0.170	0.711	0.566	0.411	11.438
CD (0.05)	NS	NS	NS	NS	32.881
M×T interaction					
m_1t_1	5.31	56.41	45.64	24.90	720.27
m_1t_2	4.63	52.78	43.96	23.53	634.28
m_1t_3	4.06	42.99	41.96	20.24	517.85
m_2t_1	5.57	57.35	48.30	25.97	775.03
m_2t_2	4.83	54.18	46.97	24.36	684.19
m_2t_3	4.19	42.00	42.71	21.42	545.31
SEm (±)	0.170	0.711	0.566	0.411	11.438
CD (0.05)	NS	NS	NS	NS	NS
P×T interaction					
p_1t_1	5.23	56.99	46.37	25.40	737.54
p_1t_2	5.17	53.17	45.11	23.00	672.87
p_1t_3	4.17	42.81	42.38	20.40	522.47
p_2t_1	5.38	56.21	47.39	25.22	731.59
p_2t_2	4.45	54.06	45.83	24.13	659.77
p_2t_3	4.04	42.35	42.54	21.17	534.08
p_3t_1	5.71	57.45	4.14	25.69	773.82
p_3t_2	4.58	53.21	45.46	24.72	645.07
p_3t_3	4.17	42.33	42.08	20.92	538.19
SEm (±)	0.208	0.871	0.693	0.504	14.008
CD (0.05)	NS	NS	NS	NS	NS

Table 15c. Effects of M×P×T interaction and treatment *Vs.* control effect on number of tubers plant^{-1}, percentage of productive roots, length of tuber, girth of tuber and mean weight of tubers.

Treatments	Number of tubers plant^{-1}	Percentage of productive roots	Length of tuber (cm)	Girth of tuber (cm)	Mean weight of tubers (g)
M×P ×T interaction					
$m_1p_1t_1$	5.08	55.44	45.29	25.32	745.97
$m_1p_1t_2$	4.83	52.04	43.59	23.00	677.42
$m_1p_1t_3$	4.00	43.63	41.20	20.10	500.67
$m_1p_2t_1$	5.25	56.62	46.70	24.78	734.35
$m_1p_2t_2$	4.40	53.41	44.33	22.99	672.34
$m_1p_2t_3$	4.00	42.69	42.52	20.61	513.97
$m_1p_3t_1$	5.58	57.16	44.92	24.61	680.50
$m_1p_3t_2$	4.67	52.89	43.95	24.60	553.10
$m_1p_3t_3$	4.17	42.67	42.14	20.00	538.91
$m_2p_1t_1$	5.37	58.53	47.44	25.48	729.10
$m_2p_1t_2$	5.50	54.28	46.63	22.99	668.32
$m_2p_1t_3$	4.33	42.00	43.57	20.00	544.29
$m_2p_2t_1$	5.50	52.79	48.08	25.67	728.84
$m_2p_2t_2$	4.50	54.72	47.32	25.27	647.21
$m_2p_2t_3$	4.08	42.00	42.55	21.73	554.19
$m_2p_3t_1$	5.83	57.73	49.37	26.77	867.15
$m_2p_3t_2$	4.50	53.53	46.96	24.83	737.04
$m_2p_3t_3$	4.12	42.00	42.01	21.84	537.46
SEm (±)	0.291	1.232	0.980	0.712	19.810
CD (0.05)	NS	NS	NS	NS	56.951
Treatment mean	4.77	50.95	44.92	23.40	646.16
Control	4.33	46.30	32.56	23.76	569.76
Treatments *Vs* control	NS	S	S	NS	S

mean weight of tubers (713.88 g) which was superior to all other interactions and was followed by m_2p_1(647.24 g) which was on par with m_2p_2 (643.41 g) and was followed by m_1p_1 (641.35 g) which again did not differ from m_1p_2 (640.22 g).

The three factor interaction also significantly influenced the mean weight of tubers in cassava. The $m_2p_3t_1$ recorded the highest mean weight of tubers (867.15 g) which was superior to all other interactions and was followed by $m_1p_1t_1$ (745.97 g), $m_2p_3t_2$ (737.04 g), $m_1p_2t_1$ (734.35 g), $m_2p_1t_1$ (729.10 g) and $m_2p_2t_1$ (728.84 g) which were on par with each other.

Significant difference was observed between the treatments (minisetts) and the control (normal setts) wherein the treatments recorded a higher mean weight of tubers (646.16 g) than the control (569.76 g).

4.2.2.6 Tuber yield plant^{-1}

The results of the tuber yield plant^{-1} are presented in the Table 16a, 16b and 16c.

The tuber yield plant^{-1} was affected by the type of minisett cuttings. The three node cassava minisett cutting (m_2) recorded significantly higher tuber yield of 3.90 kg plant $^{-1}$ compared to the two node minisett cutting(m_1- 3.48 kg).

Among different types of potting media used in nursery, the p_3 (coir pith compost and vermi compost in 3:1 ratio) recorded significantly higher tuber yield plant^{-1} (3.91 kg) than P_2 (top soil and coir pith compost in 1:1 ratio-3.62 kg) and p_1 (normal top soil- 3.51 kg). The potting medium p_1 however did not statistically differ from p_2 with respect to tuber yield plant^{-1}.

Time of transplanting of cassava minisetts to the main field also significantly influenced the tuber yield plant^{-1}. Transplanting of minisetts 3 WAP recorded the highest tuber yield of 4.09 kg plant^{-1} which was significantly higher than the other treatments and was followed by t_2 (transplanting at 4 WAP) and t_3 (transplanting at 5 WAP) which recorded a tuber yield of 3.81 kg and 3.13 kg respectively.

The M×P, M×T, P×T and M×P×T interactions did not have any influence on tuber yield plant^{-1}.

The treatment *Vs.* control effect was however significant and treatment plants (minisetts) produced higher yield (3.70 kg plant^{-1}) than the control plants (normal setts-3.23 kg plant^{-1}).

4.2.2.7 Tuber yield ha^{-1}

The results of the tuber yield ha^{-1} are presented in the Table 16a, 16b and 16c.

The data indicated that the type of minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field had significant effect on tuber yield ha^{-1} of cassava.

Between two types of minisett cuttings, highest value of tuber yield ha^{-1} was recorded by m_2 (three node minsett cutting- 39.25 t ha^{-1}) which was significantly higher than the yield recorded by m_1 (two node minisett cutting- 35.82 t ha^{-1}).

Among different types of potting media tried in the nursery for minisett production, the p_3 (coir pith compost and vermi compost in 3:1 ratio) recorded significantly higher tuber yield (37.92 t ha^{-1}) compared to p_1 (normal top soil- 36.92 t ha^{-1}) and the p_3 was however on par with p_2 (37.77 t ha^{-1}) in its effect on tuber yield ha^{-1}.

While comparing the age of minisetts at the time of transplanting to the main field, it was observed that minisetts transplanted at 3 WAP (t_1) produced significantly higher tuber yield (40.57 t ha^{-1}) which was significantly superior to the seedlings transplanted at 4 WAP (t_2- 38.89 t ha^{-1}) and 5 WAP (t_3- 33.15 t ha^{-1}).

The M×P interactions significantly influenced the tuber yield t ha^{-1} of cassava. Tuber yield was found to be highest with m_2p_3 (40.08 t ha^{-1}) which was significantly superior to all other M×P interactions and the m_2p_3 was followed by

m_2p_1 (39.57 t ha^{-1}) and m_2p_2 (38.09 t ha^{-1}). The m_2p_2 however did not vary from m_1p_2 (37.44 t ha^{-1}) in its effect on tuber yield production ha^{-1}.

Among the M×T interactions, the m_2t_1 recorded significantly higher tuber yield (42.62 t ha^{-1}) than other interactions which was followed by m_2t_2 (40.08 t ha^{-1}), then m_1t_1 (38.52 t ha^{-1}) which was on par with m_1t_2 (37.70 t ha^{-1}) followed by m_2t_3 (35.05 t ha^{-1}) and m_1t_3 (31.24 t ha^{-1}).

The P×T interaction also significantly influenced the cassava tuber yield t ha^{-1}. The p_3t_1 produced significantly higher tuber yield (41.55 t ha^{-1}) which was on par with p_2t_1 (40.66 t ha^{-1}). The p_2t_1 was however on par with p_3t_2 (39.68 t ha^{-1}) which in turn on par with p_1t_1 (39.49 t ha^{-1}) and p_2t_2(39.40 t ha^{-1}).

The M×P×T interaction also significantly influenced the tuber yield ha^{-1} and the highest yield was recorded with $m_2p_3t_1$ (44.83 t ha^{-1}) which was significantly superior to all other three factor interactions. The $m_2p_3t_1$ was followed by $m_2p_1t_1$ recording a tuber yield of 42.63 t ha^{-1} which was on par with $m_2p_3t_2$ (41.59 t ha^{-1}) and followed by $m_1p_2t_1$ (40.93 t ha^{-1}), $m_1p_2t_2$ (40.59 t ha^{-1}), $m_2p_1t_2$ (40.45 t ha^{-1}) and $m_2p_2t_1$ (40.38 t ha^{-1}) which did not statistically differ each other.

Comparing the treatments with control, it was observed that there was significant difference between treatments and control with respect to tuber yield ha^{-1} and the minisetts (treatments) produced higher tuber yield (37.54 t ha^{-1}) than the normal setts or control (34.95 t ha^{-1}). Among the minisett treatments, the $m_2p_3t_1$ was found to have an yield advantage of 22.03 per cent over the control or normal setts.

4.2.2.8 Top yield

The effect of treatments on cassava top yield ha^{-1} are presented in the Table 16a, 16b and 16c.

The main effects of type of minisett cutting, potting media for the minisetts and time of transplanting to main field significantly influenced the top

Table 16a. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on tuber yield plant^{-1}, tuber yield ha^{-1} and top yield ha^{-1}.

Treatments	Tuber yield plant^{-1} (kg)	Tuber yield ha^{-1} (t)	Top yield ha^{-1} (t)
Type of minisett cutting (M)			
m_1	3.48	35.82	12.20
m_2	3.90	39.25	13.86
SEm (±)	0.072	0.189	0.001
CD (0.05)	0.206	0.543	0.003
Potting media for the minisetts(P)			
p_1	3.51	36.92	13.00
p_2	3.62	37.77	12.84
p_3	3.91	37.92	13.24
SEm (±)	0.088	0.231	0.001
CD (0.05)	0.252	0.665	0.004
Time of transplanting minisetts to main field (T)			
t_1	4.09	40.57	14.12
t_2	3.81	38.89	13.33
t_3	3.13	33.15	11.63
SEm (±)	0.088	0.231	0.001
CD (0.05)	0.252	0.665	0.004

Table 16b. Effects of M×P, M×T and P×T interactions on tuber yield plant^{-1}, tuber yield ha^{-1} and top yield ha^{-1}.

Treatments	Tuber yield plant^{-1} (kg)	Tuber yield ha^{-1} (t)	Top yield ha^{-1} (t)
M×P interaction			
m_1p_1	3.39	34.26	12.03
m_1p_2	3.51	37.44	12.24
m_1p_3	3.54	35.75	12.34
m_2p_1	3.62	39.57	13.98
m_2p_2	3.80	38.09	13.45
m_2p_3	4.28	40.08	14.15
SEm (±)	0.124	0.327	0.002
CD (0.05)	NS	0.941	0.006
M×T interaction			
m_1t_1	3.81	38.52	13.25
m_1t_2	3.70	37.70	12.44
m_1t_3	2.94	31.24	10.92
m_2t_1	4.38	42.62	14.99
m_2t_2	4.01	40.08	14.23
m_2t_3	3.32	35.05	12.35
SEm (±)	0.124	0.327	0.002
CD (0.05)	NS	0.941	0.006
P×T interaction			
p_1t_1	3.90	39.49	13.78
p_1t_2	3.69	37.61	13.22
p_1t_3	2.94	33.67	12.01
p_2t_1	4.07	40.66	14.00
p_2t_2	3.73	39.40	13.00
p_2t_3	3.17	33.25	11.52
p_3t_1	4.32	41.55	14.58
p_3t_2	4.15	39.68	13.78
p_3t_3	3.28	32.51	11.37
SEm (±)	0.152	0.401	0.002
CD (0.05)	NS	1.152	0.007

Table 16c. Effects of M×P×T interaction on tuber yield plant^{-1}, tuber yield ha^{-1} and top yield ha^{-1}.

Treatments	Tuber yield plant^{-1} (kg)	Tuber yield ha^{-1} (t)	Top yield ha^{-1} (t)
M×P ×T interaction			
$m_1p_1t_1$	3.77	36.35	12.85
$m_1p_1t_2$	3.67	34.73	11.93
$m_1p_1t_3$	2.73	31.69	11.31
$m_1p_2t_1$	3.86	40.93	13.48
$m_1p_2t_2$	3.60	40.59	12.23
$m_1p_2t_3$	3.08	30.80	11.00
$m_1p_3t_1$	3.80	38.28	13.41
$m_1p_3t_2$	3.83	37.77	13.16
$m_1p_3t_3$	3.01	31.22	10.44
$m_2p_1t_1$	4.02	42.63	14.70
$m_2p_1t_2$	3.70	40.45	14.52
$m_2p_1t_3$	3.14	35.65	12.72
$m_2p_2t_1$	4.28	40.38	14.52
$m_2p_2t_2$	3.86	38.22	13.78
$m_2p_2t_3$	3.26	35.70	12.05
$m_2p_3t_1$	4.83	44.83	15.75
$m_2p_3t_2$	4.47	41.59	14.39
$m_2p_3t_3$	3.55	33.81	12.30
SEm (±)	0.215	0.567	0.004
CD (0.05)	NS	1.630	0.010
Treatment mean	3.70	37.54	13.03
Control	3.23	34.95	12.04
Treatments *Vs* control	S	S	S

yield of cassava. Minisetts raised from three node cuttings (m_2) produced significantly higher top yield of 13.86 t ha^{-1}compared to the minisetts produced from two node cutting (m_1) which recorded a top yield of 12.20 t ha^{-1}only.

The minisetts raised in potting media p_3 (coir pith compost and vermi compost in 3:1 proportion) in nursery produced significantly higher top yield in the main field (13.24 t ha^{-1}) compared to p_1-normal top soil (13.00 t ha^{-1}) and p_2 – normal top soil and coir pith compost in 1:1 ratio (12.84 t ha^{-1}).

Transplanting the minisett seedlings at an early age in t_1 (3 WAP) recorded significantly higher quantity of top yield (14.12 t ha^{-1}) compared to transplanting at 4 WAP (13.33 t ha^{-1}) and 5 WAP (11.63 t ha^{-1}) in t_2 and t_3.

The M×P interaction could significantly influence the top yield wherein it was highest with m_2p_3 interaction (14.15 t ha^{-1}) which was significantly superior to other interactions. The m_2p_3 was followed by m_2p_1 (13.98 t ha^{-1}) and m_2p_2 (13.45 t ha^{-1}) with respect to production of top yield in cassava.

The M×T interaction also did affect the top yield of cassava significantly. The m_2t_1 interaction produced significantly higher top yield (14.99 t ha^{-1}) which was followed by m_2t_2 (14.23 t ha^{-1}) and m_1t_1 (13.25 t ha^{-1}).

The P×T interaction also found to have influenced the top yield of cassava. The p_3t_1 interaction resulted in significantly higher top yield (14.58 t ha^{-1}) which was followed by p_2t_1 (14.00 t ha^{-1}) and p_1t_1 or p_3t_2 (13.78 t ha^{-1}).

The M×P×T interaction was found to have significant influence on the top yield of cassava. Highest top yield was recorded with $m_2p_3t_1$ (15.75 t ha^{-1}) which was significantly superior to all other interactions. The $m_2p_3t_1$ was followed by $m_2p_1t_1$ (14.70 t ha^{-1}) and $m_2p_1t_2$ or $m_2p_2t_1$ (14.52 t ha^{-1}) with respect to top yield production.

Comparing the treatments with control, it was observed that there was significant difference between treatments and control with respect to top yield ha^1.

The minisetts produced higher top yield (13.03 t ha^{1}) when compared to the normal setts or control (12.04 t ha^{1}).

4.2.2.9 Total dry matter production

The effects of treatments on the total dry matter production are presented in the Table 17a, 17b and 17c.

The main factor ie. the type of cassava minisett cutting significantly influenced the total dry matter production and significantly higher value (13.76 t ha^{-1}) was recorded with m_2 (three node cutting) when compared to m_1 (two node cutting – 12.44 t ha^{-1}).

Among different potting media used in nursery, the p_3 (coir pith compost and vermi compost in 3:1 ratio) produced significantly higher total dry matter content (13.82 t ha^{-1}) than p_2(top soil and coir pith compost in 1:1 ratio - 12.74 t ha^{-1}) and p_1 (normal top soil - 12.53 t ha^{-1}). The treatment p_2 was however on par with p_1.

Variation in transplanting time significantly influenced the total dry matter production of cassava and the early transplanting (t_1- transplanting at 3 WAP) produced significantly higher dry matter yield (14.90 t ha^{-1}) than late transplanting [13.49 and 10.91 t ha^{-1} for t_2 (transplanting at 4 WAP) and t_3 (transplanting at 5 WAP) respectively].

Among the two factor interactions only the M×T and P×T interactions influenced the total dry matter production. The m_2t_1 recorded significantly higher total dry matter production (15.78 t ha^{-1}) among M×T interactions and was followed by m_2t_2 (14.46 t ha^{-1}) which was on par with m_1t_1 (14.02 t ha^{-1}). Among P×T interactions, the p_3t_1 recorded significantly higher (15.79 t ha^{-1}) total dry matter production compared to other interactions and was followed by p_2t_1 (14.83 t ha^{-1}), p_3t_2 (14.67 t ha^{-1}) and p_1t_1 (14.12 t ha^{-1}) which were on par each other. Among the P×T interactions, the p_2t_2 (13.21 t ha^{-1}) did not statistically vary from p_1t_2 (12.58 t ha^{-1}) and p_3t_3 (11.05 t ha^{-1}) did not differ from p_1t_3 (10.88 t ha^{-1}).

The three factor interaction was non significant with respect to total dry matter production.

While comparing treatments with control, it was observed that there was significant difference between treatments (minisetts) and control (normal setts) and the treatments recorded higher total dry matter production (13.11 t ha^{-1}) than the control (12.09 t ha^{-1}).

4.2.2.10 Days to harvest

The results of the days to harvest under the influence of main effects and interaction effects of the treatment are presented in the Table 17a, 17b and 17c.

The main effects like type of minisett cutting or potting media for minisetts in the nursery did not have effect on the days to harvest. Time of transplanting could however significantly influence the days to harvest. The minisetts transplanted at 3 WAP (t_1) took shortest days to harvest (212.41 days) than minisetts transplanted at 4 WAP (t_2- 219.42 days) and 5 WAP (t_3- 229.42 days).

The M×P interaction could not influence the days to harvest in cassava. However, both M×T and P×T interactions had significant effect on days taken for harvesting. Among M×T interactions, significantly less number of days were taken to harvest with m_1t_1 (212.27) followed by m_2t_1 (212.57), m_1t_2 (219.26), m_2t_2 (219.57), m_1t_3 (229.27) which was on par with m_2t_3(229.42). Among P×T interactions, less number of days were taken for the harvesting of tuber in p_1t_1 (212.32) followed by p_2t_1 (212.42) which was on par with p_3t_1 (212.50), again followed by p_1t_2 (219.32) and p_2t_2 (219.43) which statistically did not differ from p_3t_2 (219.52).

The days to harvest was not affected by the three factor interaction (M×P ×T).

There was significant difference between treatments and control for days to harvest and the normal setts took less days (197.00) for harvesting than the minisetts (220.42).

4.2.2.11 Harvest index

The results of main effect and interaction effects of treatments on the harvest index are presented in the Table 17a, 17b and 17c.

The main effects, two factor interactions and three factor interactions could not significantly influence the harvest index of cassava. The treatment *Vs.* control effect was also non significant with respect to harvest index.

4.3. PEST AND DISEASE INCIDENCE

4.3.1 Pest Incidence

While observing the plants for pest attack, mild incidence of white fly and mealy bug were noticed on few plants and timely control measures were taken. Scoring was not done for the pest population since infestation was below the economic threshold level.

4.3.2. Disease incidence

While monitoring plants for diseases, only the incidence of Cassava Mosaic Disease (CMD) was noticed in the main field.

4.3.2.1 Incidence of Cassava Mosaic Disease (CMD)

The incidence of CMD was calculated as the percentage of plants showing symptoms at three months after planting. The influence of main effect and interaction effect of treatments on percentage incidence of CMD is shown in Table 18a, 18b and 18c. The CMD incidence ranged between 14.58 to 31.25 per cent in different treatments.

The main effects of the treatments could not influence the percentage of incidence of CMD. The M×P, M×T, P×T or M×P×T interactions did not affect

Table 17a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on total dry matter production, days to harvest and harvest index of cassava.

Treatments	Total dry matter production (t ha^{-1})	Days to harvest	Harvest index
Type of minisett cutting (M)			
m_1	12.44	220.27	0.688
m_2	13.76	220.56	0.695
SEm (±)	0.154	0.043	0.008
CD (0.05)	0.443	NS	NS
Potting media for the minisetts(P)			
p_1	12.53	220.31	0.703
p_2	12.74	220.42	0.689
p_3	13.82	220.52	0.682
SEm (±)	0.189	0.053	0.010
CD (0.05)	0.542	NS	NS
Time of transplanting minisetts to main field (T)			
t_1	14.90	212.41	0.686
t_2	13.49	219.42	0.695
t_3	10.91	229.42	0.693
SEm (±)	0.189	0.053	0.010
CD (0.05)	0.542	0.152	NS

Table 17b. Effects of M×P, M×T and P×T interactions on total dry matter production, days to harvest and harvest index of cassava.

Treatments	Total dry matter production (t ha^{-1})	Days to harvest	Harvest index
M×P interaction			
m_1p_1	12.01	220.17	0.695
m_1p_2	12.15	220.27	0.699
m_1p_3	13.16	220.45	0.668
m_2p_1	13.47	220.47	0.710
m_2p_2	13.52	220.51	0.679
m_2p_3	14.49	220.70	0.695
SEm (±)	0.267	0.075	0.014
CD (0.05)	NS	NS	NS
M×T interaction			
m_1t_1	14.02	212.27	0.688
m_1t_2	12.51	219.26	0.695
m_1t_3	10.77	229.27	0.680
m_2t_1	15.78	212.57	0.885
m_2t_2	14.46	219.57	0.694
m_2t_3	11.05	229.42	0.705
SEm (±)	0.267	0.075	0.014
CD (0.05)	0.766	0.216	NS
P×T interaction			
p_1t_1	14.12	212.32	0.706
p_1t_2	12.58	219.32	0.712
p_1t_3	10.88	229.32	0.689
p_2t_1	14.83	212.42	0.687
p_2t_2	13.21	219.43	0.677
p_2t_3	10.99	229.40	0.703
p_3t_1	15.79	212.50	0.665
p_3t_2	14.67	219.52	0.695
p_3t_3	11.05	229.52	0.685
SEm (±)	0.327	0.264	0.018
CD (0.05)	0.939	0.092	NS

Table 17c. Effects of M×P×T interactions and treatment *Vs.* control effect on total dry matter production, days to harvest and harvest index of cassava.

Treatments	Total dry matter production (t ha^{-1})	Days to harvest	Harvest index
M×P ×T interaction			
$m_1p_1t_1$	13.27	212.17	0.685
$m_1p_1t_2$	11.68	219.16	0.707
$m_1p_1t_3$	10.43	229.16	0.693
$m_1p_2t_1$	14.25	212.26	0.719
$m_1p_2t_2$	12.29	219.27	0.681
$m_1p_2t_3$	10.52	229.26	0.698
$m_1p_3t_1$	14.54	212.36	0.659
$m_1p_3t_2$	13.57	219.36	0.697
$m_1p_3t_3$	11.37	229.36	0.650
$m_2p_1t_1$	14.97	212.46	0.727
$m_2p_1t_2$	13.49	219.47	0.717
$m_2p_1t_3$	11.33	229.46	0.686
$m_2p_2t_1$	15.40	212.56	0.655
$m_2p_2t_2$	14.13	219.57	0.673
$m_2p_2t_3$	11.07	229.57	0.708
$m_2p_3t_1$	16.96	212.66	0.672
$m_2p_3t_2$	15.7	219.67	0.693
$m_2p_3t_3$	10.74	229.67	0.721
SEm (±)	0.462	0.130	0.025
CD (0.05)	NS	NS	NS
Treatment mean	13.11	220.42	0.691
Control	12.09	197.00	0.69
Treatments *Vs* control	S	S	NS

Table 18a. Effects of type of minisett cutting, potting media for minisetts and time of transplanting minisetts to main field on Cassava Mosaic Disease (CMD) incidence, per cent

Treatments	CMD
Type of minisett cutting (M)	
m_1	25.23
m_2	21.99
SEm (±)	1.167
CD (0.05)	NS
Potting media for the minisetts(P)	
p_1	26.38
p_2	22.56
p_3	21.87
SEm (±)	1.429
CD (0.05)	NS
Time of transplanting cassava minisetts to main field (T)	
t_1	23.95
t_2	25.69
t_3	21.99
SEm (±)	1.429
CD (0.05)	NS

Table 18b. Effects of M×P, M×T and P×T interactions on Cassava Mosaic Disease (CMD) incidence, per cent

Treatments	CMD
M×P interaction	
m_1p_1	28.47
m_1p_2	22.92
m_1p_3	24.31
m_2p_1	24.31
m_2p_2	22.22
m_2p_3	19.45
SEm (±)	2.021
CD (0.05)	NS
M×T interaction	
m_1t_1	25.00
m_1t_2	26.38
m_1t_3	24.31
m_2t_1	22.91
m_2t_2	25.00
m_2t_3	18.06
SEm (±)	2.021
CD (0.05)	NS
P×T interaction	
p_1t_1	27.08
p_1t_2	30.21
p_1t_3	21.88
p_2t_1	20.83
p_2t_2	25.00
p_2t_3	21.88
p_3t_1	23..96
p_3t_2	21.88
p_3t_3	19.79
SEm (±)	2.475
CD (0.05)	NS

Table 18c. Effects of M×P×T interactions and treatment *Vs.* control effect on Cassava Mosaic Disease (CMD) incidence, per cent

Treatments	CMD
M×P ×T interaction	
$m_1p_1t_1$	27.08
$m_1p_1t_2$	29.17
$m_1p_1t_3$	29.16
$m_1p_2t_1$	22.92
$m_1p_2t_2$	25.00
$m_1p_2t_3$	20.83
$m_1p_3t_1$	25.00
$m_1p_3t_2$	25.00
$m_1p_3t_3$	22.91
$m_2p_1t_1$	27.08
$m_2p_1t_2$	31.25
$m_2p_1t_3$	14.58
$m_2p_2t_1$	18.75
$m_2p_2t_2$	25.00
$m_2p_2t_3$	22.92
$m_2p_3t_1$	22.92
$m_2p_3t_2$	18.75
$m_2p_3t_3$	16.67
SEm (±)	3.501
CD (0.05)	NS
Treatment mean	23.61
Control	27.08
Treatments *Vs* control	NS

the incidence of CMD. The treatment *Vs.* control effect was also non significant in this respect.

4.3.2.2 Scoring of Cassava Mosaic Disease (CMD)

The severity of the symptoms was assessed by the scoring of mosaic symptoms treatment wise at 3 MAP and is indicated in Table 19.

The mean score of CMD ranged from 2.08 in $m_2p_1t_1$, $m_1p_2t_3$ and $m_2p_3t_2$ to 2.50 in $m_1p_3t_1$, $m_1p_3t_3$ and $m_2p_3t_1$ which indicated that the symptoms were falling under mild to moderate incidence based on 1-5 severity scale. The treatment *Vs.* control effect was not significant with respect to scoring of CMD.

4.4. PLANT ANALYSIS

4.4.1. Total nitrogen

4.4.1.1 Total nitrogen (top portion)

The effects of type of minisett cutting, potting media in nursery and time of transplanting on the total nitrogen content in top portion of cassava are presented in the Table 20a, 20b and 20c.

The type of cassava minisett cuttings significantly influenced the total nitrogen content in top portion. Significantly higher value of 1.33 per cent was recorded by three node cutting or m_2 when compared to m_1 or two node cutting (1.14 per cent).

Among the main effects, time of transplanting minisetts to main field was also found to be significant to influence the total nitrogen content in the top portion of cassava. The early transplanting in t_1 (3 WAP) resulted in significantly higher total nitrogen content of 1.36 per cent in the top portion compared to t_2 (transplanting at 4 WAP- 1.29 per cent) and t_3 (transplanting at 5 WAP- 1.05 per cent).

Table 19. Treatment wise mean score of the Cassava Mosaic Disease

Treatments *	Mean Score
$m_1p_1t_1$	2.33
$m_1p_1t_2$	2.41
$m_1p_1t_3$	2.16
$m_1p_2t_1$	2.16
$m_1p_2t_2$	2.41
$m_1p_2t_3$	2.08
$m_1p_3t_1$	2.50
$m_1p_3t_2$	2.25
$m_1p_3t_3$	2.50
$m_2p_1t_1$	2.08
$m_2p_1t_2$	2.25
$m_2p_1t_3$	2.25
$m_2p_2t_1$	2.33
$m_2p_2t_2$	2.41
$m_2p_2t_3$	2.16
$m_2p_3t_1$	2.50
$m_2p_3t_2$	2.08
$m_2p_3t_3$	2.41
Treatment mean	2.28
Control	2.58
Treatments *Vs* control	NS

*Only treatment *Vs.* control effect was statistically analysed

None of the two factor interactions or three factor interactions could significantly affect the total nitrogen content in top portion. Like wise, there was no significant difference between the total nitrogen content in top portion of treatment plants and control plants.

4.4.1.2 Total nitrogen (tuber)

The effects of main factors and their interactions on total nitrogen content of tuber is shown in Table 21a, 21b and 21c.

The type of minisett cuttings, potting media for minisetts in nursery or time of transplanting of minisetts to the main field could not influence the total nitrogen content in the tuber portion of cassava.

The M×P , M×T, P×T or M×P×T interactions did not affect the total nitrogen content in cassava tuber. There was no significant difference between treatment and control plants with respect to total nitrogen content in tuber.

4.4.2. Total phosphorus

4.4.2.1 Total phosphorus (top portion)

The results of the influence of main effects and their interactions on total phosphorus content in top portion are presented in the Table 20a, 20b and 20c.

The type of minisett cuttings or potting media for nursery raising could not influence the total phosphorus content in the top portion of cassava. However the time of transplanting of minisetts to the main field was found to affect the total phosphorus content in top portion. It was highest (0.37 per cent) with t_1 (transplanting at 3 WAP) which was on par with the content produced with t_2 (transplanting at 4 WAP- 0.36 per cent) and significantly superior to the content obtained with t_3 (transplanting at 5WAP- 0.35 per cent). The treatment t_3 was however on par with t_2.

The two factor interactions or three factor interactions could not affect the total phosphorus content in the top portion of the plant. There was no significant difference between the treatment plants and control plants with respect to total phosphorus content in top portion.

4.4.2.2 Total phosphorus (tuber)

The results of the influence of main effects and their interactions on total phosphorus content in cassava tuber are presented in the Table 21a, 21b and 21c.

The type of minisett cutting had an influence on total phosphorus content in cassava tuber. The three node cutting (m_2) resulted in significantly higher total phosphorus content of 0.18 per cent compared to two node cutting (m_1- 0.15 per cent).

Different types of potting media could not affect the total phosphorus content in tuber portion of cassava.

The time of transplanting was however found to have an effect on total phosphorus content of cassava tuber. The early transplanting (t_1) produced the highest total phosphorus content (0.19 per cent) which was significantly superior to t_3-transplanting at 5 WAP (0.13 per cent) but on par with t_2- transplanting at 4 WAP (0.18 per cent).

None of the interactions or control *Vs.* treatment effects were significant to influence the total phosphorus content in tuber portion of cassava.

4.4.3. Total potassium

4.4.3.1 Total potassium (top portion)

The results of the influence of main effects and their interaction effects on total potassium content in top portion of cassava are presented in the Table 20a, 20b and 20c.

All the main factors and their interactions were found to be non significant in case of total potassium content in top portion of cassava. No significant

Table 20a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts on total nitrogen, phosphorus and potassium content in top portion of cassava, per cent

Treatments	Top portion		
	Total nitrogen	Total phosphorus	Total potassium
Type of minisett cutting (M)			
m_1	1.14	0.36	0.82
m_2	1.33	0.37	0.83
SEm (±)	0.014	0.006	0.022
CD (0.05)	0.039	NS	NS
Potting media for the minisetts(P)			
p_1	1.22	0.35	0.80
p_2	1.24	0.36	0.83
p_3	1.25	0.37	0.86
SEm (±)	0.017	0.007	0.027
CD (0.05)	NS	NS	NS
Time of transplanting minisetts to main field (T)			
t_1	1.36	0.37	0.85
t_2	1.29	0.36	0.82
t_3	1.05	0.35	0.82
SEm (±)	0.017	0.007	0.027
CD (0.05)	0.048	0.021	NS

Table 20b. Effects of M×P, M×T and P×T interactions on total nitrogen, phosphorus and potassium content in top portion of cassava, per cent

Treatments	Top portion		
	Total nitrogen	Total phosphorus	Total potassium
M×P interaction			
m_1p_1	1.11	0.36	0.82
m_1p_2	1.14	0.36	0.82
m_1p_3	1.16	0.37	0.84
m_2p_1	1.31	0.36	0.80
m_2p_2	1.34	0.36	0.84
m_2p_3	1.35	0.37	0.88
SEm (±)	0.023	0.010	0.038
CD (0.05)	NS	NS	NS
M×T interaction			
m_1t_1	1.27	0.36	0.84
m_1t_2	1.21	0.36	0.81
m_1t_3	0.93	0.35	0.80
m_2t_1	1.44	038	0.86
m_2t_2	1.37	0.38	0.83
m_2t_3	1.18	0.34	0.82
SEm (±)	0.023	0.010	0.038
CD (0.05)	NS	NS	NS
P×T interaction			
p_1t_1	1.33	0.36	0.80
p_1t_2	1.28	0.35	0.78
p_1t_3	1.02	0.35	0.72
p_2t_1	1.34	0.37	0.83
p_2t_2	1.30	0.37	0.82
p_2t_3	1.05	0.34	0.74
p_3t_1	1.39	0.39	0.91
p_3t_2	1.30	0.38	0.88
p_3t_3	1.08	0.35	0.85
SEm (±)	0.029	0.012	0.047
CD (0.05)	NS	NS	NS

Table 20c. Effects of M×P×T interactions and treatment *Vs.* control effect on total nitrogen, phosphorus and potassium content in top portion of cassava, per cent

Treatments	Top portion		
	Total nitrogen	Total phosphorus	Total potassium
M×P ×T interaction			
$m_1p_1t_1$	1.23	0.357	0.85
$m_1p_1t_2$	1.20	0.31	0.77
$m_1p_1t_3$	0.91	0.35	0.67
$m_1p_2t_1$	1.33	0.37	0.86
$m_1p_2t_2$	1.23	0.36	0.81
$m_1p_2t_3$	0.92	0.34	0.84
$m_1p_3t_1$	1.24	0.39	0.81
$m_1p_3t_2$	1.21	0.38	0.85
$m_1p_3t_3$	0.97	0.36	0.81
$m_2p_1t_1$	1.43	0.38	0.76
$m_2p_1t_2$	1.37	0.36	0.79
$m_2p_1t_3$	1.14	0.33	0.81
$m_2p_2t_1$	1.44	0.38	0.79
$m_2p_2t_2$	1.36	0.38	0.89
$m_2p_2t_3$	1.19	0.36	0.83
$m_2p_3t_1$	1.44	0.40	1.03
$m_2p_3t_2$	1.38	0.38	0.93
$m_2p_3t_3$	1.20	0.34	0.82
SEm (±)	0.041	0.018	0.066
CD (0.05)	NS	NS	NS
Treatment mean	1.24	0.36	0.83
Control	1.23	0.35	0.77
Treatments *Vs* control	NS	NS	NS

difference between treatments and control was observed with respect to total potassium content.

4.4.3.2 Total potassium (tuber)

The results of the influence of main effects and their interactions on total potassium content in cassava tuber are presented in the Table 21a, 21b and 21c.

The type of minisett cuttings or potting media for nursery raising did not influence the total potassium content of tuber. However the time of transplanting affected the total potassium content in tuber and the highest content (0.93 per cent) was obtained with t_1 (transplanting at 3 WAP) which was significantly superior to t_3 (transplanting at 5 WAP) producing a content of 0.84 per cent. The t_1 was however on par with t_2 (transplanting at 4 WAP- 0.90 per cent) while the t_2 was on par with t_3.

All the main factors and their interactions were found to be non significant in case of total potassium content in cassava tuber. No significant difference between treatments and control was also observed.

4.4.4. Nitrogen uptake

The effect of type of minisett cutting, potting media for nursery raising and time of transplanting and their interactions on the nitrogen uptake at harvest are presented in the Table 22a, 22b and 22c.

The type of minisett cutting used in nursery had an influence on nitrogen uptake at the time of harvest. Significantly higher uptake (204.82 kg ha^{-1}) was observed in case of m_2 (three node cutting) compared to m_1 (two node cutting- 164.72 kg ha^{-1}).

Different types of potting media did not influence the nitrogen uptake by the crop. However transplanting time or age of minisetts significantly influenced the nitrogen uptake at harvest. Uptake was significantly higher with t_1-

Table 21a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on total nitrogen, phosphorus and potassium content in tuber portion of cassava, per cent

Treatments	Tuber		
	Total nitrogen	Total phosphorus	Total potassium
Type of minisett cutting (M)			
m_1	0.26	0.15	0.88
m_2	0.27	0.18	0.91
SEm (±)	0.008	0.004	0.021
CD (0.05)	NS	0.012	NS
Potting media for the minisetts(P)			
p_1	0.26	0.16	0.86
p_2	0.27	0.17	0.89
p_3	0.28	0.17	0.92
SEm (±)	0.010	0.005	0.025
CD (0.05)	NS	NS	NS
Time of transplanting minisetts to main field (t)			
t_1	0.29	0.19	0.93
t_2	0.26	0.18	0.90
t_3	0.25	0.13	0.84
SEm (±)	0.010	0.005	0.025
CD (0.05)	NS	0.015	0.070

Table 21b. Effects of M×P, M×T and P×T interactions on total nitrogen, phosphorus and potassium content in tuber portion of cassava, per cent

Treatments	Tuber		
	Total nitrogen	Total phosphorus	Total potassium
M×P interaction			
m_1p_1	0.25	0.15	0.87
m_1p_2	0.26	0.16	0.90
m_1p_3	0.28	0.16	0.90
m_2p_1	0.26	0.18	0.91
m_2p_2	0.27	0.18	0.82
m_2p_3	0.29	0.18	0.95
SEm (±)	0.014	0.008	0.036
CD (0.05)	NS	NS	NS
P×T interaction			
m_1t_1	0.29	0.17	0.89
m_1t_2	0.26	0.16	0.91
m_1t_3	0.24	0.13	0.79
m_2t_1	0.29	0.20	0.94
m_2t_2	0.27	0.20	0.91
m_2t_3	0.26	0.14	0.90
SEm (±)	0.014	0.008	0.036
CD (0.05)	NS	NS	NS
P×T interaction			
p_1t_1	0.26	0.18	0.91
p_1t_2	0.25	0.18	0.89
p_1t_3	0.24	0.14	0.83
p_2t_1	0.28	0.19	0.92
p_2t_2	0.28	0.18	0.85
p_2t_3	0.27	0.12	0.82
p_3t_1	0.32	0.19	0.97
p_3t_2	0.26	0.18	0.92
p_3t_3	0.25	0.13	0.87
SEm (±)	0.017	0.009	0.044
CD (0.05)	NS	NS	NS

Table 21c. Effects of M×P×T interactions and treatment *Vs.* control effect on total nitrogen, phosphorus and potassium content in tuber portion of cassava, per cent

Treatments	Tuber		
	Total nitrogen	Total phosphorus	Total potassium
M×P ×T interaction			
$m_1p_1t_1$	0.26	0.18	0.87
$m_1p_1t_2$	0.25	0.16	0.85
$m_1p_1t_3$	0.24	0.13	0.83
$m_1p_2t_1$	0.28	0.18	0.94
$m_1p_2t_2$	0.28	0.15	0.90
$m_1p_2t_3$	0.27	0.13	0.86
$m_1p_3t_1$	0.29	0.16	0.97
$m_1p_3t_2$	0.26	0.17	0.96
$m_1p_3t_3$	0.21	0.13	0.89
$m_2p_1t_1$	0.26	0.18	0.94
$m_2p_1t_2$	0.25	0.21	0.94
$m_2p_1t_3$	0.29	0.14	0.86
$m_2p_2t_1$	0.28	0.20	0.90
$m_2p_2t_2$	0.28	0.21	0.88
$m_2p_2t_3$	0.21	0.13	0.84
$m_2p_3t_1$	0.32	0.22	0.97
$m_2p_3t_2$	0.29	0.19	0.95
$m_2p_3t_3$	0.29	0.13	0.77
SEm (±)	0.024	0.013	0.062
CD (0.05)	NS	NS	NS
Treatment mean	0.27	0.17	0.90
Control	0.27	0.16	0.83
Treatments *Vs* control	NS	NS	NS

transplanting at 3 WAP (224.29 kg ha^{-1}) which was followed by t_2- transplanting at 4 WAP (195.99 kg ha^{-1}) and t_3- transplanting at 5 WAP (134.03 kg ha^{-1}).

The two factor interactions M×P, M×T or P×T and the three factor interaction M×P×T did not influence the nitrogen uptake by crop. The treatment *Vs.* control effect was also not significant to influence the nitrogen uptake.

4.4.5. Phosphorus uptake

The effect of type of minisett cutting, potting media for nursery raising and time of transplanting and their interactions on the phosphorus uptake of crop at harvest are presented in the Table 22a, 22b and 22c.

The phosphorus uptake was varying with the type of minisett cutting and significantly higher phosphorus uptake was recorded (114.67 kg ha^{-1}) with m_2 (three node cutting) when compared to m_1 (two node cutting- 94.66 kg ha^{-1}).

The potting medium p_3 (coir pith compost and vermi compost in 3:1 ratio) recorded significantly higher phosphorus uptake (112.07 kg ha^{-1}) than p_1 (normal top soil- 99.52 kg ha^{-1}) and p_2 (top soil and coir pith compost in 1:1 ratio -102.41 kg ha^{-1}). The p_1 was however found to be on par with p_2.

The time of transplanting also was found to influence the phosphorus uptake by crop and the uptake was significantly higher (124.89 kg ha^{-1}) with t_1 (transplanting at 3 WAP) when compared to t_2 (transplanting at 4 WAP- 116.09 kg ha^{-1}) and t_3 (transplanting at 5 WAP- 73.02 kg ha^{-1}). In t_3 the phosphorus uptake was found to be drastically reduced.

None of the interactions could significantly influence the phosphorus uptake by the crop at harvest. The difference between phosphorus uptake of normal setts (control) and minisetts (treatment) was not significant.

4.4.6. Potassium uptake

The main effects of the treatments and their interactions on the potassium uptake by the crop at harvest are presented in the Table 22a, 22b and 22c.

Table 22a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting of minisetts on uptake of nitrogen, phosphorus and potassium, kg ha^{-1}

Treatments	Nitrogen uptake	Phosphorus uptake	Potassium uptake
Type of minisett cutting (M)			
m_1	164.72	94.66	207.89
m_2	204.82	114.67	218.99
SEm (±)	3.171	1.844	4.779
CD (0.05)	9.110	5.302	NS
Potting media for the minisetts(P)			
p_1	178.91	99.52	207.52
p_2	183.62	102.41	213.52
p_3	191.77	112.07	219.27
SEm (±)	3.884	2.259	5.853
CD (0.05)	NS	6.49	NS
Time of transplanting minisetts to main field (T)			
t_1	224.29	124.89	240.43
t_2	195.99	116.09	222.32
t_3	134.03	73.02	177.55
SEm (±)	3.884	2.259	5.853
CD (0.05)	11.16	6.49	16.82

Table 22b. Effects of M×P, M×T P×T interactions on uptake of nitrogen, phosphorus and potassium, kg ha^{-1}

Treatments	Nitrogen uptake	Phosphorus uptake	Potassium uptake
M×P interaction			
m_1p_1	157.69	89.91	190.32
m_1p_2	163.09	95.74	211.89
m_1p_3	173.39	98.30	221.44
m_2p_1	200.15	109.13	224.72
m_2p_2	204.16	110.09	225.14
m_2p_3	210.16	125.80	227.10
SEm (±)	5.492	3.194	8.278
CD (0.05)	NS	NS	NS
M×T interaction			
m_1t_1	200.57	112.23	231.26
m_1t_2	173.85	104.55	210.12
m_1t_3	119.74	67.19	182.27
m_2t_1	248.02	137.55	249.61
m_2t_2	218.12	127.62	234.52
m_2t_3	148.32	78.85	192.83
SEm (±)	5.492	3.194	8.278
CD (0.05)	NS	NS	NS
P×T interaction			
p_1t_1	212.07	115.87	230.36
p_1t_2	189.25	110.09	207.97
p_1t_3	135.42	67.83	180.31
p_2t_1	227.61	124.70	232.81
p_2t_2	193.04	114.72	225.87
p_2t_3	130.22	67.82	181.80
p_3t_1	233.21	134.11	258.14
p_3t_2	205.67	123.46	229.12
p_3t_3	136.44	78.63	180.55
SEm (±)	6.727	3.912	10.138
CD (0.05)	NS	NS	NS

Table 22c. Effects of M×P×T interactions and treatment *Vs.* control effect on uptake of nitrogen, phosphorus and potassium, kg ha^{-1}

Treatments	Nitrogen uptake	Phosphorus uptake	Potassium uptake
M×P ×T interaction			
$m_1p_1t_1$	182.87	107.35	215.71
$m_1p_1t_2$	166.80	94.50	177.96
$m_1p_1t_3$	123.39	67.87	167.31
$m_1p_2t_1$	206.80	114.70	231.05
$m_1p_2t_2$	169.82	110.14	225.39
$m_1p_2t_3$	112.64	62.37	179.22
$m_1p_3t_1$	212.04	114.64	247.01
$m_1p_3t_2$	184.94	109.02	227.03
$m_1p_3t_3$	123.18	71.34	190.29
$m_2p_1t_1$	241.27	125.68	249.90
$m_2p_1t_2$	211.70	124.38	237.97
$m_2p_1t_3$	147.46	77.34	190.29
$m_2p_2t_1$	248.41	134.71	229.66
$m_2p_2t_2$	216.26	129.30	234.35
$m_2p_2t_3$	147.81	79.28	191.40
$m_2p_3t_1$	254.37	153.58	269.26
$m_2p_3t_2$	226.41	137.90	231.22
$m_2p_3t_3$	149.70	85.93	200.81
SEm (±)	9.513	5.533	14.338
CD (0.05)	NS	NS	NS
Treatment mean	184.77	104.67	211.84
Control	182.34	99.62	182.3
Treatments *Vs* control	NS	NS	NS

In case of potassium uptake, only the time of transplanting was significant enough to influence the uptake. The early transplanting (t_1-transplanting at 3WAP) resulted in significantly higher potassium uptake of 240.43 kg ha^{-1} than t_2 (transplanting at 4 WAP-222.32 kg ha^{-1}) and t_3 (transplanting at 5 WAP- 177.55 kg ha^{-1}).

Different interaction effects were not significant to influence the potassium uptake by crop. The treatment *Vs.* control effect was also not significant with respect to potassium uptake.

4.4.7. Starch content of tubers

The results of the starch content of tubers at harvest as influenced by the main effects of the treatments and their interactions are presented in the Table 23a, 23b and 23c.

Data indicated that that type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions did not significantly influence the starch content of tubers at harvest. The treatment *Vs.* control effect was also not significant in case of starch content of tubers.

4.5. SOIL PROPERTIES AFTER THE EXPERIMENT

4.5.1. pH

The results of the pH of soil after the experiment as influenced by the main effects and interaction effects of the treatments are presented in the Table 24a, 24b and 24c.

Data showed that type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions were not significant to influence the pH of soil after the experiment. There was no significant difference between the pH of treatment and control plots after the experiment. A slight decline in the pH was observed in the experimental plots when compared to the initial pH.

Table 23a. Effects of type of minisett cutting, potting media for the minisetts, and time of transplanting minisetts on starch content of tuber at harvest, per cent

Treatments	Starch content of tuber
Type of minisett cutting (M)	
m_1	24.85
m_2	25.09
SEm (±)	0.235
CD (0.05)	NS
Potting media for the minisetts(P)	
p_1	24.87
p_2	24.95
p_3	24.75
SEm (±)	0.288
CD (0.05)	NS
Time of transplanting minisetts to main field (T)	
t_1	24.60
t_2	25.01
t_3	25.23
SEm (±)	0.288
CD (0.05)	NS

Table 23b. Effects of M×P, M×T and P×T interactions on starch content of tuber at harvest, per cent

Treatments	Starch content of tuber
M×P interaction	
m_1p_1	24.67
m_1p_2	24.48
m_1p_3	25.39
m_2p_1	25.08
m_2p_2	25.42
m_2p_3	24.75
SEm (±)	0.408
CD (0.05)	NS
M×T interaction	
m_1t_1	24.82
m_1t_2	24.46
m_1t_3	25.26
m_2t_1	24.50
m_2t_2	25.57
m_2t_3	25.19
SEm (±)	0.408
CD (0.05)	NS
P×T interaction	
p_1t_1	24.81
p_1t_2	24.75
p_1t_3	25.06
p_2t_1	24.76
p_2t_2	25.23
p_2t_3	24.85
p_3t_1	24.40
p_3t_2	25.05
p_3t_3	25.76
SEm (±)	0.499
CD (0.05)	NS

Table 23c. Effects of M×P×T interactions and treatment *Vs.* control effect on starch content of tuber at harvest, per cent

Treatments	Starch content of tuber
M×P ×T interaction	
$m_1p_1t_1$	25.28
$m_1p_1t_2$	24.47
$m_1p_1t_3$	24.25
$m_1p_2t_1$	24.58
$m_1p_2t_2$	23.81
$m_1p_2t_3$	25.05
$m_1p_3t_1$	24.60
$m_1p_3t_2$	25.09
$m_1p_3t_3$	26.48
$m_2p_1t_1$	24.35
$m_2p_1t_2$	25.02
$m_2p_1t_3$	25.87
$m_2p_2t_1$	24.95
$m_2p_2t_2$	26.67
$m_2p_2t_3$	24.66
$m_2p_3t_1$	24.20
$m_2p_3t_2$	25.03
$m_2p_3t_3$	25.01
SEm (±)	0.706
CD (0.05)	NS
Treatment mean	24.96
Control	24.68
Treatments *Vs* control	NS

4.5.2. Electrical conductivity

The influence of main effects and interaction effects of the treatment on electrical conductivity of soil after the experimentation is presented in the Table 24a, 24b and 24c.

Data showed that type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions could not significantly influence electrical conductivity of soil after the experiment. No significant variation between the treatment plots and control plots (normal setts) was observed in case of electrical conductivity of soil after the experiment. There was a slight increase in the electrical conductivity of the experimental plot after the experimentation in comparison to the initial value.

4.5.3. Organic carbon

The results of the organic carbon status of soil after the experiment as influenced by the main effects and interaction effects are presented in the Table 24a, 24b and 24c.

The type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions did not significantly influence the organic carbon status of soil after the experiment. The treatment *Vs.* control effect was also not significant in this respect. After the experimentation the organic carbon content in soil was reduced when compared to the initial status.

4.5.4. Available nitrogen

The available nitrogen status of the soil after the experiment under the influence of main effects and interaction effects of the treatments are presented in the Table 25a, 25b and 25c.

The results indicated that the type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions were not significant to influence the available nitrogen status of soil after the

Table 24a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts on pH, electrical conductivity and organic carbon status of soil after the experiment.

Treatments	pH	Electrical conductivity (dSm^{-1})	Organic carbon (per cent)
Type of minisett cutting (M)			
m_1	5.12	0.101	0.475
m_2	5.09	0.106	0.470
SEm (±)	0.083	0.004	0.010
CD (0.05)	NS	NS	NS
Potting media for the minisetts(P)			
p_1	5.22	0.096	0.477
p_2	5.04	0.106	0.488
p_3	5.06	0.101	0.451
SEm (±)	0.102	0.005	0.012
CD (0.05)	NS	NS	NS
Time of transplanting minisetts to main field (T)			
t_1	5.08	0.101	0.464
t_2	5.11	0.105	0.490
t_3	5.13	0.105	0.463
SEm (±)	0.102	0.005	0.012
CD (0.05)	NS	NS	NS
Initial status	5.30	0.08	0.560

Table 24b. Effects of M×P, M×P and P×T interaction on pH, electrical conductivity and organic carbon status of soil after the experiment.

Treatments	pH	Electrical conductivity (dSm^{-1})	Organic carbon (per cent)
M×P interaction			
m_1p_1	5.25	0.096	0.491
m_1p_2	5.06	0.106	0.483
m_1p_3	5.05	0.101	0.451
m_2p_1	5.19	0.097	0.463
m_2p_2	5.02	0.113	0.494
m_2p_3	5.07	0.108	0.452
SEm (±)	0.144	0.007	0.018
CD (0.05)	NS	NS	NS
M×T interaction			
m_1t_1	5.21	0.094	0.469
m_1t_2	5.02	0.107	0.485
m_1t_3	5.15	0.103	0.471
m_2t_1	4.96	0.107	0459
m_2t_2	5.21	0.104	0.495
m_2t_3	5.11	0.107	0.455
Sem (±)	0.144	0.007	0.018
CD (0.05)	NS	NS	NS
P×T interaction			
p_1t_1	5.29	0.099	0.450
p_1t_2	5.11	0.102	0.513
p_1t_3	5.25	0.089	0.469
p_2t_1	4.93	0.104	0.473
p_2t_2	5.05	0.109	0.417
p_2t_3	5.15	0.116	0.475
p_3t_1	5.03	0.100	0.469
p_3t_2	5.17	0.104	0.440
p_3t_3	4.98	0.111	0.445
Sem (±)	0.176	0.009	0.022
CD (0.05)	NS	NS	NS

Table 24c. Effects of M×P×T interaction and treatment *Vs.* control effect on pH, electrical conductivity and organic carbon status of soil after the experiment.

Treatments	pH	Electrical conductivity (dSm^{-1})	Organic carbon (per cent)
M×P ×T interaction			
$m_1p_1t_1$	5.36	0.102	0.478
$m_1p_1t_2$	5.00	0.105	0.513
$m_1p_1t_3$	5.39	0.081	0.482
$m_1p_2t_1$	5.11	0.099	0.452
$m_1p_2t_2$	5.03	0.106	0.489
$m_1p_2t_3$	5.06	0.115	0.508
$m_1p_3t_1$	5.15	0.081	0.477
$m_1p_3t_2$	5.02	0.110	0.454
$m_1p_3t_3$	4.99	0.114	0.423
$m_2p_1t_1$	5.22	0.095	0.421
$m_2p_1t_2$	5.23	0.099	0.513
$m_2p_1t_3$	5.12	0.097	0.455
$m_2p_2t_1$	4.76	0.108	0.495
$m_2p_2t_2$	5.08	0.113	0.454
$m_2p_2t_3$	5.24	0.117	0.441
$m_2p_3t_1$	4.91	0.119	0.461
$m_2p_3t_2$	5.32	0.099	0.426
$m_2p_3t_3$	4.98	0.107	0.468
Sem (±)	0.249	0.013	0.030
CD (0.05)	NS	NS	NS
Treatment mean	4.96	0.104	0.472
Control	4.99	0.106	0.475
Treatments *Vs* control	NS	NS	NS

experiment. Similarly no significant difference between the treatment and control plots also was found in this respect. The available nitrogen status of the soil after the experiment was declined when compared to its initial status.

4.5.5. Available phosphorus

The results of the available phosphorus content of soil after the experiment under the influence of main effects and their interactions are presented in Table 25a, 25b and 25c.

Data showed that type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions did not significantly influence the available phosphorus status of soil after the experiment. While comparing control (196.37) with treatment means (214.56), it was observed that there was no significant difference between them with respect to available phosphorus content of soil after the experiment. The available phosphorus status of the soil after the experiment was declined when compared to its initial status.

4.5.6. Available potassium

The available potassium status of soil after the experiment as influenced by the main effects and interaction effect of the treatments are presented in the Table 25a, 25b and 25c.

Results indicated that the type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions had no significant influence on the available potassium content of soil after the experiment. The treatment *Vs.* control effect was also not significant and hence no variation was found between treatments and control in case of available potassium status of soil after the experiment. The available potassium status of the soil after the experiment was declined when compared to its initial status.

Table 25a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts on available nitrogen, phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	Available nitrogen	Available phosphorus	Available potassium
Type of minisett cutting (M)			
m_1	271.78	225.32	291.91
m_2	279.68	223.79	294.18
Sem (±)	3.316	7.825	6.327
CD (0.05)	NS	NS	NS
Potting media for the minisetts(P)			
p_1	271.09	221.63	287.92
p_2	274.57	229.10	300.60
p_3	281.54	222.94	290.62
Sem (±)	4.062	9.583	7.749
CD (0.05)	NS	NS	NS
Time of transplanting minisetts to main field (T)			
t_1	279.45	219.02	296.43
t_2	275.96	213.17	292.60
t_3	271.78	241.48	290.11
Sem (±)	4.062	9.583	7.749
CD (0.05)	NS	NS	NS
Initial status	301.05	271.04	322.22

Table 25b. Effects of M×P, M×T and P×T interactions on available nitrogen, phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	Available nitrogen	Available phosphorus	Available potassium
M×P interaction			
m_1p_1	274.57	224.74	284.10
m_1p_2	277.36	222.25	294.92
m_1p_3	287.11	228.97	296.72
m_2p_1	274.57	218.52	291.73
m_2p_2	264.81	235.94	306.28
m_2p_3	275.96	216.90	284.53
SEm (±)	5.744	13.553	10.958
CD (0.05)	NS	NS	NS
M×T interaction			
m_1t_1	281.54	220.01	292.55
m_1t_2	278.75	206.57	291.11
m_1t_3	276.75	249.38	292.08
m_2t_1	277.36	218.02	300.30
m_2t_2	264.81	219.76	294.10
m_2t_3	273.18	233.58	288.13
SEm (±)	5.744	13.553	10.958
CD (0.05)	NS	NS	NS
P×T interaction			
p_1t_1	284.33	204.58	297.49
p_1t_2	271.78	207.20	292.76
p_1t_3	267.60	230.12	273.50
p_2t_1	275.96	226.61	302.99
p_2t_2	257.15	214.29	289.52
p_2t_3	286.15	246.40	309.28
p_3t_1	267.60	225.86	288.811
p_3t_2	280.14	218.02	295.53
p_3t_3	278.19	224.93	287.54
SEm (±)	7.035	16.598	13.421
CD (0.05)	NS	NS	NS

Table 25c. Effects of M×P×T interactions and treatment *Vs.* control effect on available nitrogen, phosphorus and potassium status of soil after the experiment, kg ha^{-1}

Treatments	Available nitrogen	Available phosphorus	Available potassium
M×P ×T interaction			
$m_1p_1t_1$	284.33	232.21	283.58
$m_1p_1t_2$	275.96	193.38	306.61
$m_1p_1t_3$	263.42	248.64	262.11
$m_1p_2t_1$	275.96	206.08	292.80
$m_1p_2t_2$	263.42	205.33	281.04
$m_1p_2t_3$	292.69	255.36	310.91
$m_1p_3t_1$	284.33	221.76	301.28
$m_1p_3t_2$	296.87	221.01	285.667
$m_1p_3t_3$	280.15	244.16	303.22
$m_2p_1t_1$	284.33	176.96	311.39
$m_2p_1t_2$	267.60	221.01	278.91
$m_2p_1t_3$	271.78	257.60	284.89
$m_2p_2t_1$	275.96	247.14	313.18
$m_2p_2t_2$	250.88	223.25	297.99
$m_2p_2t_3$	267.60	237.44	307.66
$m_2p_3t_1$	271.78	229.97	276.34
$m_2p_3t_2$	275.96	215.04	305.38
$m_2p_3t_3$	280.15	205.70	271.86
SEm (±)	9.949	23.474	18.980
CD (0.05)	NS	NS	NS
Treatment mean	275.74	224.56	293.05
Control	271.67	196.37	284.70
Treatments *Vs* control	NS	NS	NS

4.6. SHELF LIFE OF TUBER

As indicated by the data Table 26a, 26b and 26c the type of minisett cutting, potting media for the minisetts, time of transplanting minisetts to main field and their interactions could not significantly influence the shelf life of tuber. There was no significant variation between treatments and control with respect to shelf life of tuber.

4.7. ECONOMICS OF CULTIVATION

4.7.1 Net income

The effects of treatments on the net income of cultivation are presented in the Table 27.

The highest net income (₹ 6,92,267 ha^{-1}) was obtained from $m_2p_3t_1$ (three node cutting when raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio and transplanted 3 WAP) treatment which was followed by $m_2p_1t_1$ (three node cutting in normal top soil and transplanted at 3 WAP) treatment and $m_2p_3t_2$ (three node cutting in potting medium containing coir pith compost and vermi compost in 3:1 ratio and transplanted at 4 WAP) which recorded a net income of ₹ 6,52,967 ha^{-1} and ₹ 6,27,550 ha^{-1} respectively. When compared to the normal sett planting (control) which recorded a net income of ₹ 5,06,446 ha^{-1}, the minisett planting (treatments) produced a higher net income ₹ 5,48,910 ha^{-1} and was more economic.

4.7.2 Benefit : cost ratio

The benefit : cost ratio of the experiment as influenced by different treatments are presented in the Table 27.

Highest benefit : cost ratio (4.39) was obtained from $m_2p_3t_1$ (three node cutting in the potting media containing coir pith compost and vermi compost in 3:1 ratio and transplanted 3 WAP) followed by $m_2p_1t_1$ (three node cutting in normal top soil and transplanted 3 WAP) and $m_2p_3t_2$ (three node cutting in the potting medium containing coir pith compost and vermi compost in 3:1 ratio and transplanted 4 WAP) which recorded a benefit : cost ratio of 4.27 and 4.07 respectively. On comparing the normal sett planting (control) with treatments (minisetts), it was found that the minisetts (treatments) produced a higher benefit : cost ratio of 3.72 than the control or normal setts (3.62).

Results of the study indicated the effect of type of cassava minisett cuttings and potting media for the minisetts on the sprouting, establishment and early growth of minisetts in the nursery. The data also revealed the influence of nursery techniques and time of transplanting of minisetts on growth, yield, harvest index, dry matter production, pest and disease incidence, tuber quality and shelf life, nutrient uptake, available nutrient status after the experimentation and economics of cultivation of cassava in the main field.

Table 26a. Effects of type of minisett cutting, potting media for the minisetts and time of transplanting minisetts on shelf life and physiological loss in weight (PLW) of cassava tubers.

Treatments	Shelf life of tubers (days)			Physiological loss in weight (per cent)		
	Open air	Paper cover	Polythene cover	Open air	Paper cover	Polythene cover
Type of minisett cutting (M)						
m_1	5.66	9.33	10.63	12.53	11.59	11.25
m_2	5.37	8.70	10.48	11.63	11.45	10.34
SEm (±)	0.172	0.345	0.260	0.329	0.358	0.357
CD (0.05)	NS	NS	NS	NS	NS	NS
Potting media for the minisetts(P)						
p_1	5.16	8.33	10.61	11.51	10.82	10.23
p_2	5.77	9.56	10.38	12.82	12.02	11.54
p_3	5.61	9.17	10.67	11.90	11.72	10.62
SEm (±)	0.211	0.423	0.318	0.403	0.438	0.437
CD (0.05)	NS	NS	NS	NS	NS	NS
Time of transplanting minisetts to main field (T)						
t_1	5.38	8.78	10.50	11.77	11.31	11.15
t_2	5.77	9.56	10.83	12.23	11.01	10.84
t_3	5.39	8.72	10.33	12.25	12.24	12.08
SEm (±)	0.211	0.423	0.318	0.403	0.438	0.437
CD (0.05)	NS	NS	NS	NS	NS	NS

Table 26b. Effects of M×P, M×T and P×T interactions on shelf life and physiological loss in weight (PLW) of cassava tubers.

Treatments	Shelf life of tubers (days)			Physiological loss in weight (per cent)		
	Open air	Paper cover	Polythene cover	Open air	Paper cover	Polythene cover
M×P interaction						
m_1p_1	5.55	9.11	10.67	11.66	10.43	10.30
m_1p_2	5.88	9.78	10.66	13.72	12.27	12.16
m_1p_3	5.56	9.11	10.56	12.22	12.08	11.94
m_2p_1	4.78	7.56	10.55	11.37	11.22	11.03
m_2p_2	5.67	9.33	10.11	11.93	11.76	11.56
m_2p_3	5.66	9.22	10.78	11.58	11.36	11.17
SEm (±)	0.299	0.598	0.450	0.570	0.620	0.618
CD (0.05)	NS	NS	NS	NS	NS	NS
M×T interaction						
m_1t_1	5.44	8.89	10.44	12.35	11.35	11.22
m_1t_2	6.00	10.00	10.67	12.56	11.33	11.20
m_1t_3	5.56	9.11	10.77	12.69	12.10	11.97
m_2t_1	5.33	8.67	10.56	11.19	11.27	11.08
m_2t_2	5.55	9.11	11.00	11.89	10.69	10.49
m_2t_3	5.22	8.33	9.89	11.80	12.38	12.19
SEm (±)	0.299	0.598	0.450	0.570	0.620	0.618
CD (0.05)	NS	NS	NS	NS	NS	NS
P×T interaction						
p_1t_1	5.00	8.00	10.83	11.42	11.34	11.20
p_1t_2	5.33	8.67	10.50	11.39	10.09	9.92
p_1t_3	5.16	8.33	10.50	11.74	11.04	10.87
p_2t_1	5.83	9.67	10.33	12.62	10.90	10.73
p_2t_2	6.00	10.00	10.67	12.53	11.46	11.31
p_2t_3	5.50	9.00	10.17	13.33	13.70	13.54
p_3t_1	5.33	8.66	10.33	11.28	11.70	11.54
p_3t_2	6.00	10.00	11.33	12.76	11.48	11.30
p_3t_3	5.50	8.83	10.33	11.67	11.99	11.83
SEm (±)	0.366	0.732	0.551	0.699	0.759	0.757
CD (0.05)	NS	NS	NS	NS	NS	NS

Table 26c. Effects of M×P×T interactions and treatment *Vs.* control effect on shelf life and physiological loss in weight (PLW) of cassava tubers.

Treatments	Shelf life of tubers (days)			Physiological loss in weight (per cent)		
	Open air	Paper cover	Polythene cover	Open air	Paper cover	Polythene cover
M×P ×T interaction						
$m_1p_1t_1$	5.33	8.67	10.66	11.26	10.73	10.60
$m_1p_1t_2$	5.67	9.33	10.00	11.30	9.96	9.83
$m_1p_1t_3$	5.66	9.33	11.33	12.43	10.60	10.46
$m_1p_2t_1$	6.00	10.00	10.66	14.23	11.70	11.56
$m_1p_2t_2$	6.00	10.00	10.67	13.13	11.83	11.72
$m_1p_2t_3$	5.67	9.33	10.67	13.80	13.30	13.18
$m_1p_3t_1$	5.00	8.00	10.00	11.56	11.63	11.52
$m_1p_3t_2$	6.33	10.66	11.33	13.26	12.20	12.05
$m_1p_3t_3$	5.33	8.67	10.33	11.85	12.41	12.27
$m_2p_1t_1$	4.67	7.33	11.00	11.58	11.95	10.30
$m_2p_1t_2$	5.00	8.00	11.00	11.48	10.21	10.20
$m_2p_1t_3$	4.67	7.33	9.67	11.05	11.48	9.76
$m_2p_2t_1$	5.67	9.33	10.00	11.00	10.10	9.71
$m_2p_2t_2$	6.00	10.00	10.67	11.93	11.10	10.65
$m_2p_2t_3$	5.33	8.67	9.67	12.86	14.10	11.58
$m_2p_3t_1$	5.66	9.33	10.67	11.00	11.76	9.71
$m_2p_3t_2$	5.67	9.33	11.33	12.26	10.76	10.98
$m_2p_3t_3$	5.66	9.00	10.33	11.50	11.56	10.21
SEm (±)	0.517	1.035	0.779	0.988	1.073	1.070
CD (0.05)	NS	NS	NS	NS	NS	NS
Treatment mean	5.52	9.01	10.56	12.08	12.00	11.36
Control	5.00	8.33	11.33	10.67	11.52	11.53
Treatments *Vs* control	NS	NS	NS	NS	NS	NS

Table 27. Effects of type of minisett cutting, potting media for minisetts and time of transplanting of minisetts on net income and benefit : cost ratio of cassava cultivation*.

Treatments	Net income (₹ ha^{-1})	Benefit : cost ratio
$m_1p_1t_1$	527921	3.65
$m_1p_1t_2$	496234	3.49
$m_1p_1t_3$	434871	3.18
$m_1p_2t_1$	616891	4.05
$m_1p_2t_2$	609895	4.02
$m_1p_2t_3$	414216	3.05
$m_1p_3t_1$	561804	3.75
$m_1p_3t_2$	551516	3.70
$m_1p_3t_3$	420507	3.06
$m_2p_1t_1$	652967	4.27
$m_2p_1t_2$	609510	4.05
$m_2p_1t_3$	513502	3.57
$m_2p_2t_1$	605270	3.99
$m_2p_2t_2$	562019	3.77
$m_2p_2t_3$	511648	3.52
$m_2p_3t_1$	692267	4.39
$m_2p_3t_2$	627550	4.07
$m_2p_3t_3$	471788	3.30
Treatment mean	548910	3.72
Control	506446	3.62

*Statistically not analysed

DISCUSSION

5. DISCUSSION

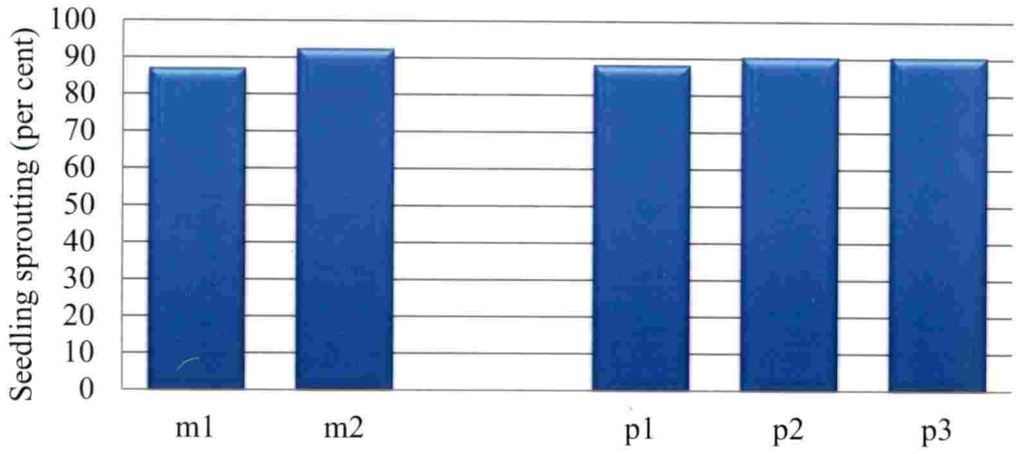
The investigation entitled "Standardisation of nursery techniques through field validation in minisett cassava (*Manihot esculenta* Crantz.)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram to standardise the cassava minisett nursery technique by validating its field performance, comparing with normal sett planting and to work out the economics of cultivation. The results of the experiment are discussed in this chapter.

5.1 EXPERIMENT – I (NURSERY)

5.1.1 Early growth attributes of minisetts

The main effects were found to be significantly influencing the early growth attributes of minisetts in nursery. The three node cutting (m_2) was found to have higher seedling sprouting (Fig. 4) and shoot length (Fig. 5), shoot biomass (Fig. 6), root length (Fig. 7) and root biomass (Fig. 8) than two node cutting (m_1). The size of the cutting decides the quantity of stored food in the planting material and the initial dry matter content in the nodes influence the growth and development of the cassava crop as observed by Bridgemohan and Bridgemohan (2014). The three node cuttings expressed a direct advantage over the two node cuttings due to higher initial dry matter content or stored food materials which might have reflected in the early growth attributes. An increase in size of minisetts enhancing the sprouting potential was reported by Ayankanmi *et al.* (2005) in yam. The three node minisetts producing higher rooting percentage, number of roots and root length than the two node minisetts was reported previously by Aswathy (2015) in *kasthuri* turmeric (*Curcuma aromatica* Salisb).

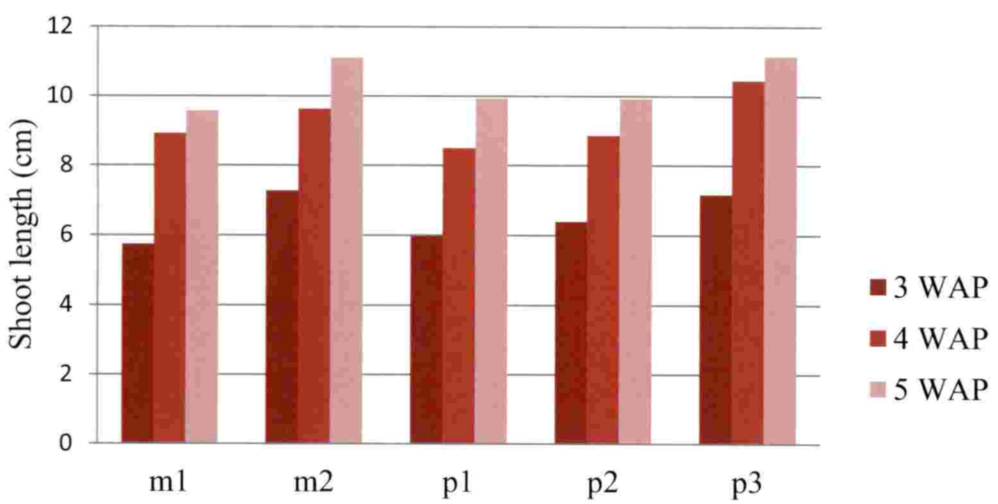
Among different potting media used in the experiment, p_3 (coir pith compost and vermi compost in 3:1 ratio) or p_2 (normal top soil and coir pith compost in 1:1



Type of minisett cutting
m_1 - Two node cutting
m_2 - Three node cutting

Potting media for the minisetts
P_1- Normal top soil
P_2 - Top soil+coir pith compost (1:1)
P_3- Coir pith compost+vermi compost (3:1)

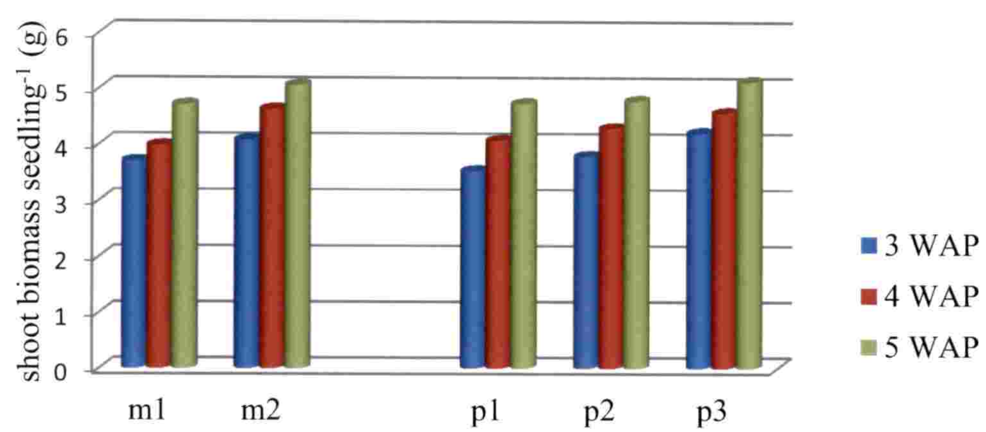
Fig. 4. Effects of type of cassava minisett cutting and potting media for the minisetts on seedling sprouting in nursery, per cent



Type of minisett cutting
m_1 – Two node cutting
m_2 - Three node cutting

Potting media for the minisetts
P_1- Normal top soil
P_2 - Top soil+coir pith compost (1:1)
P_3- Coir pith compost+vermi compost (3:1)

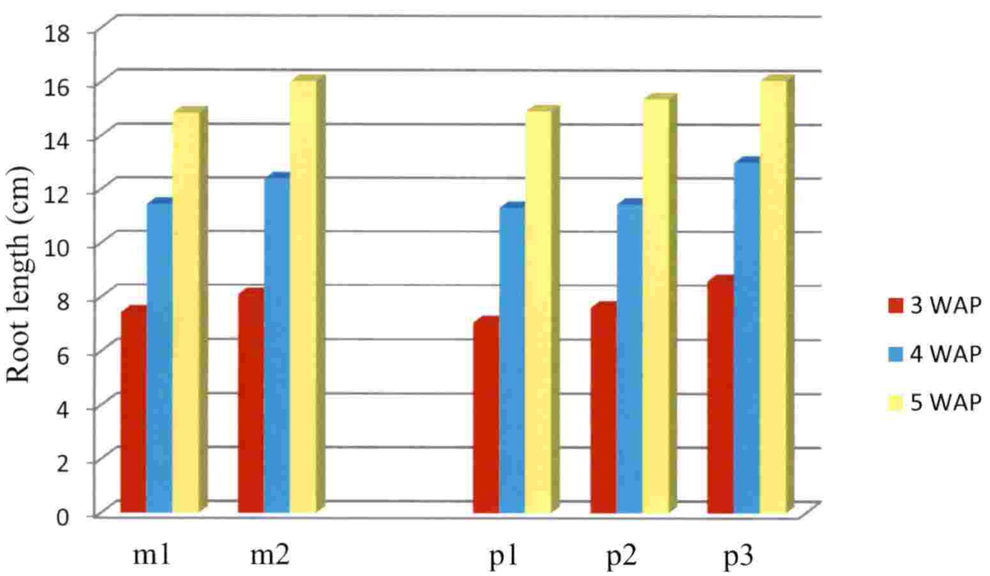
Fig. 5. Effects of type of cassava minisett cutting and potting media for the minisetts on shoot length of minisetts in nursery, cm



Type of minisett cutting
m_1 – Two node cutting
m_2 - Three node cutting

Potting media for the minisetts
P_1- Normal top soil
P_2 - Top soil+coir pith compost in (1:1)
P_3- Coir pith compost + vermi compost (3:1)

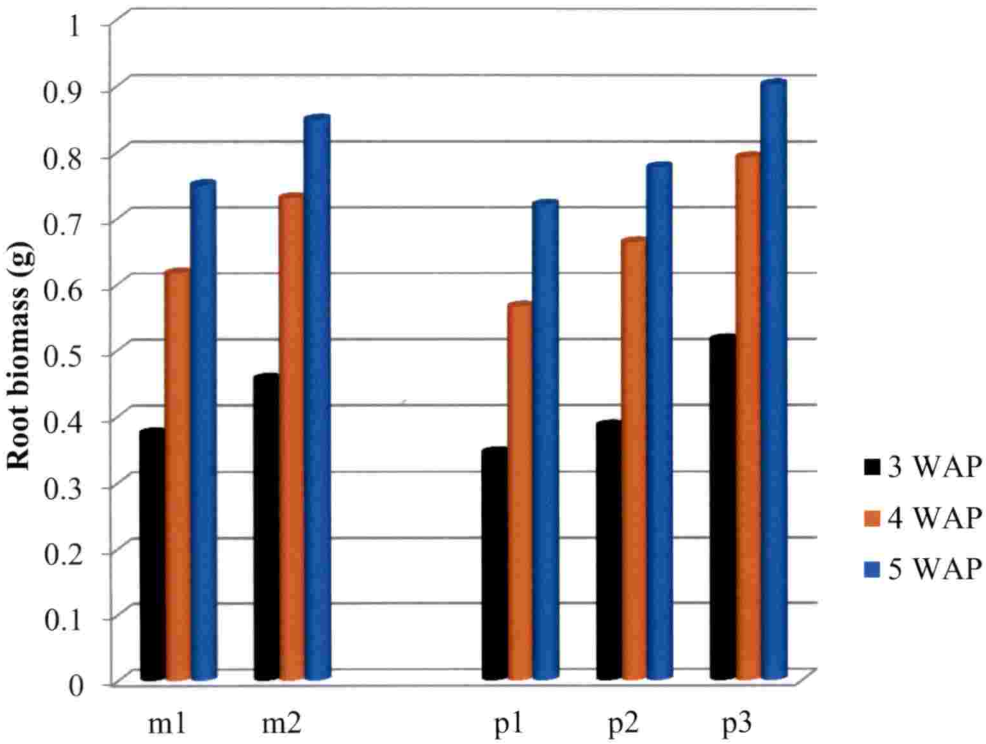
Fig. 6. Effects of type of cassava minisett cutting and potting media for the minisetts on shoot biomass of minisetts in nursery, g seedling^{-1}



Type of minisett cutting
m_1 – Two node cutting
m_2 - Three node cutting

Potting media for the minisetts
P_1- Normal top soil
P_2 - Top soil+coir pith compost (1:1)
P_3- Coir pith compost+vermi compost (3:1)

Fig. 7. Effects of type of cassava minisett cutting and potting media for the minisetts on root length of minisetts in nursery, cm



Type of minisett cutting
m_1 – Two node cutting
m_2 - Three node cutting

Potting media for the minisetts
P_1- Normal top soil
P_2 - Top soil+coir pith compost (1:1)
P_3- Coir pith compost+vermi compost (3:1)

Fig. 8. Effects of type of cassava minisett cutting and potting media for the minisetts on root biomass of minisetts in nursery, g seedling^{-1}

ratio) resulted in higher seedling sprouting compared to normal top soil as potting medium. However p_3 was found to be performing better than other potting media with respect to shoot length (Fig. 5), shoot biomass (Fig. 6), root length (Fig. 7) and root biomass (Fig. 8) of minisett seedlings. According to Reghuvaran and Ravidranath (2010), raising the seedlings in potting medium containing higher percentage of bio-degraded coir pith produced higher shoot and root length in medicinal plants. The degraded or composted coir pith has the ability to store and release nutrients to plants for extended periods of time and also has great oxygenation properties which is important for healthy root development (Prasath *et al.,* 2014). Similarly Abiram *et al.* (2010) indicated that vermi compost, when added to coir dust, improved the physical property and nutrient content of the medium. Further more, the addition of vermi compost in the potting medium was found to have a stimulatory effect on emergence and root growth of seedlings as reported by Zaller (2007) in tomato. The combination of coir pith compost and vermi compost as potting medium therefore might have combined the positive effect of both the media which would have reflected in the early growth attributes of cassava minisetts. Similar findings are reported by Aswathy (2015) in *kasthuri* turmeric and Srinivasan and Srimathi (2017) in tomato.

Among the interaction effects, growing three node cuttings in potting medium containing coir pith compost and vermi compost in 3:1 ratio (m_2p_3) resulted in higher shoot length, shoot bio mass, root length and root biomass seedling^{-1} in cassava minisetts. The favourable influence of the main effects was manifested in their interactions also.

5.1.2 Root initiation of minisetts *Vs.* normal setts

Comparison of the mean values of number of roots produced per minisett seedling and normal setts indicated that when three node minisett cuttings were raised in the potting medium containing coir pith compost and vermi compost in 3:1 ratio

(m_2p_3), highest number of roots, root length and root biomass were observed in three and four weeks old seedlings. However when the seedling age was increased to 5 weeks, the normal setts (control) were found to produce higher root biomass than the minisetts. In case of minisetts, the sprouting and emergence of sprouts occurred within 5 days of planting (Table 5) whereas in normal sett planting it was delayed by 12-15 days. The late emergence of adventitious roots and sprouting of normal setts in cassava was previously reported by Alves (2002). The early emergence of sprouts would have favoured the fibrous root production in case of minisetts due to early availability of photosynthates for root initiation. The early rooting characteristics of minisetts would have been further accentuated by the potting medium containing coir pith compost and vermi compost in 3:1 ratio. The higher moisture retention capacity, porosity and nutrient status of coir pith has been reported by Nagarajan *et al.* (1985). The favourable influence of coir pith compost when coupled with the root promoting effect of vermi compost (Lazcano *et al.*, 2009) would have resulted in higher root growth in comparison with normal setts planted directly to the field. However at 5 WAP, the emergence of sprouts was completed and subsequent shoot growth was improved in normal setts and emergence of more sprouts would have led to higher photosynthetic assimilation compared to minisetts which would have given a boost to the root growth.

5.2 EXPERIMENT - II (MAIN FIELD)

5.2.1 Growth and growth attributes

The growth and growth attributes of cassava such as seedling establishment, plant height, stem girth, functional leaves plant^{-1}, Leaf Area Index (LAI) and number of primary and secondary branches were found to be influenced by different treatments and their interactions.

The three node cutting (m_2) was found to have higher seedling establishment (Fig. 9), plant height at different crop stages (Fig. 10), stem girth, functional leaves

Plate 4. Comparison of root initiation in cassava minisetts *Vs*. Normal setts (control) at 3 WAP.

Plate 5. Comparison of root initiation in cassava minisetts *Vs*. Normal setts (control) at 4 WAP.

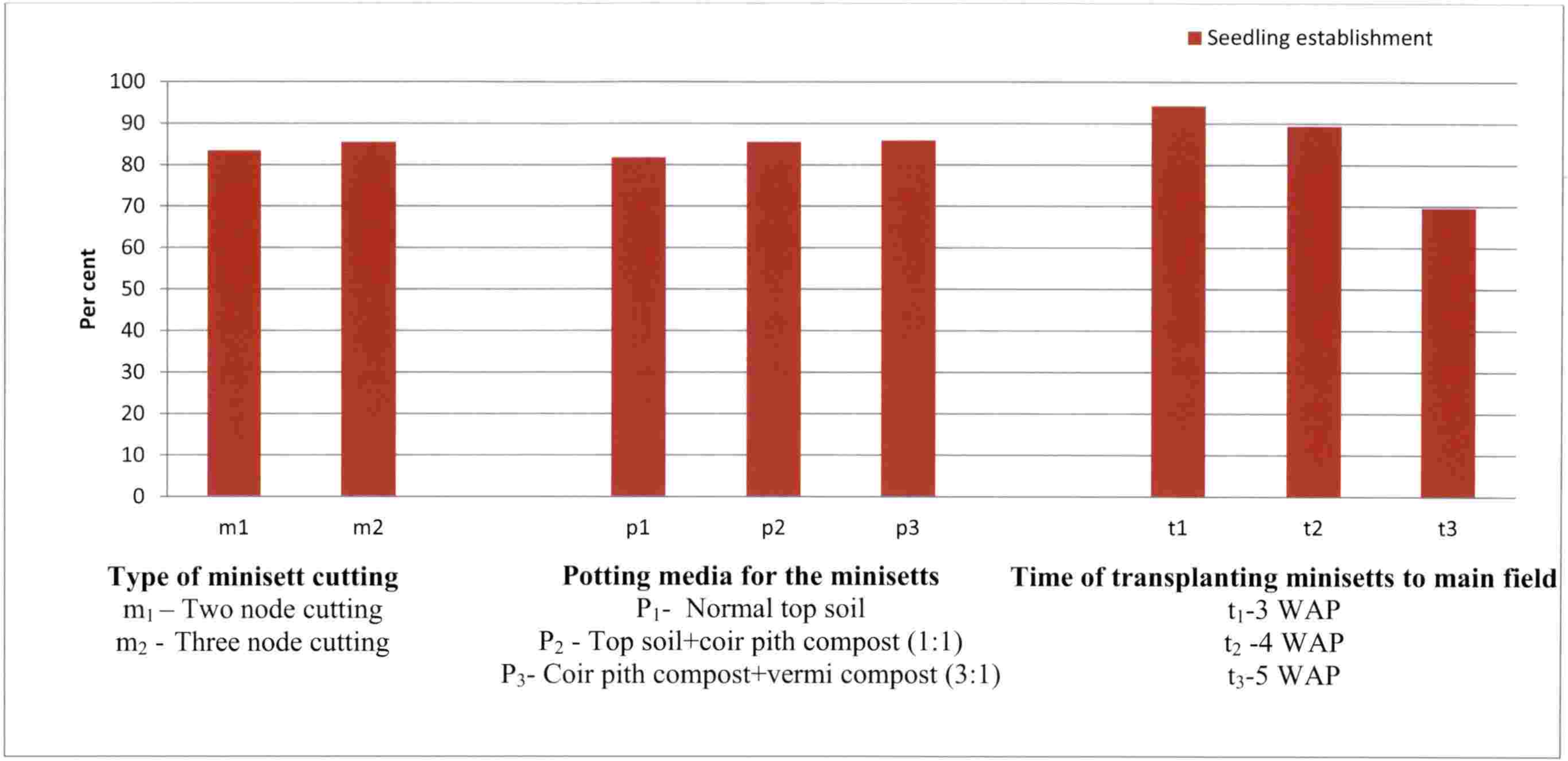


Fig. 9. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on seedling establishment in main field, per cent

plant^{-1} and LAI (Fig. 11) in the main field. These findings are in agreement with George (2006) who reported that the three node minisett cuttings of cassava had higher establishment per cent than single node or two node minisetts. According to Bridgemohan and Bridgemohan (2014), initial strength of minisett cutting due to higher accumulation of dry matter influence the final growth and development of the plant as observed in case of cassava crop raised from three node minisetts compared to the two node or single node minisetts. In the present investigation, the three node miniets had higher dry matter content compared to two node minisetts in the nursery as indicated by the Table 6 and this would have favoured the growth and growth attributes of the crop in the main field. Increase in size of minisetts favourably reflecting on the growth attributes like plant height, leaf number, shoot number and LAI has been previously reported by Gebre *et al*. (2015) in taro. Further more, the three node minisett cuttings had better root growth than the two node minisett cuttings in the nursery (Table 7). The higher initial root growth and better ramification of root system in plants are often found to be followed by improved growth and growth attributes due to better uptake and translocation of nutrients as reported by Aswathy (2015) in *kasthuri* turmeric.

Minisett seedlings produced in potting media containing coir pith compost and vermi compost in 3:1 ratio was found to have higher seedling establishment, plant height, stem girth, number of functional leaves and LAI at different stages of observation than those raised in potting medium containing normal top soil and coir pith compost in 1:1 ratio or normal top soil alone. Prasath *et. al.* (2014) have reported the favourable influence of degraded or composted coir pith on growth parameters of pepper nursery plants due to its promotional effect on healthy root system and greater oxygenation property in the rhizosphere. The positive influence of vermi compost in the nursery substrate favourably influencing the seeding establishment and biomass allocation in the tomato plants in main field due to stimulatory effect was previously reported by Zaller (2007). Favourable effect of combined application of coir pith compost and vermi compost in the potting medium as indicated by the root development in nursery (Table 7) might have been reflected in growth and growth attributes in the main field also due to direct stimulatory effect and through the production of healthy root system. Similar results are reported by Vadiraj *et al.* (1996) in vanilla and Aswathy (2015) in *kasthuri* turmeric.

The early transplanting of minisett seedlings (3 WAP) resulted in higher seedling establishment (Fig. 9) and better growth attributes than late transplanting (4 WAP or 5 WAP). Though the number of roots, root length and root biomass were highest with minisetts of 5 weeks age, the coiling or upward curling of root system started after 3 weeks and became prominent in 5 weeks as illustrated in Plate 7 and consequently the minisett seedling establishment in main field was found to be higher with those transplanted at 3 WAP (Table 9a). According Jata *et al.* (2013) though increasing the nursery age increased the length of roots at the time of transplanting, late transplanting resulted in poor establishment in the field due to transplanting shock and seedling damage in aged seedlings in cassava. The better establishment of seedlings in the main field coupled with a healthy root system would have promoted growth and growth attributes of cassava minisetts transplanted at an early age of 3 WAP. Similar results are reported by Singh *et al.* (2013) in transplanted cotton.

When three node minisett cuttings were raised in the nursery in a potting medium containing coir pith compost and vermi compost in 3:1 ratio, it produced taller plants with more number of functional leaves and LAI. As explained in case of main effects, the three node minisett cuttings and potting medium comprising coir pith compost and vermi compost were observed to have many favouable characteristics such as higher initial dry matter content and better root growth in case of former and stimulatory effect in case of the later (potting medium). Combination of these effects would have positively influenced the growth attributes of the crop as observed in the case of main effects.

Plate 6. Comparison of root initiation in cassava minisetts *Vs*. Normal setts (control) at 5 WAP.

Plate 7. Coiling and upward curling of roots of cassava minisett seedlings at 5 WAP.

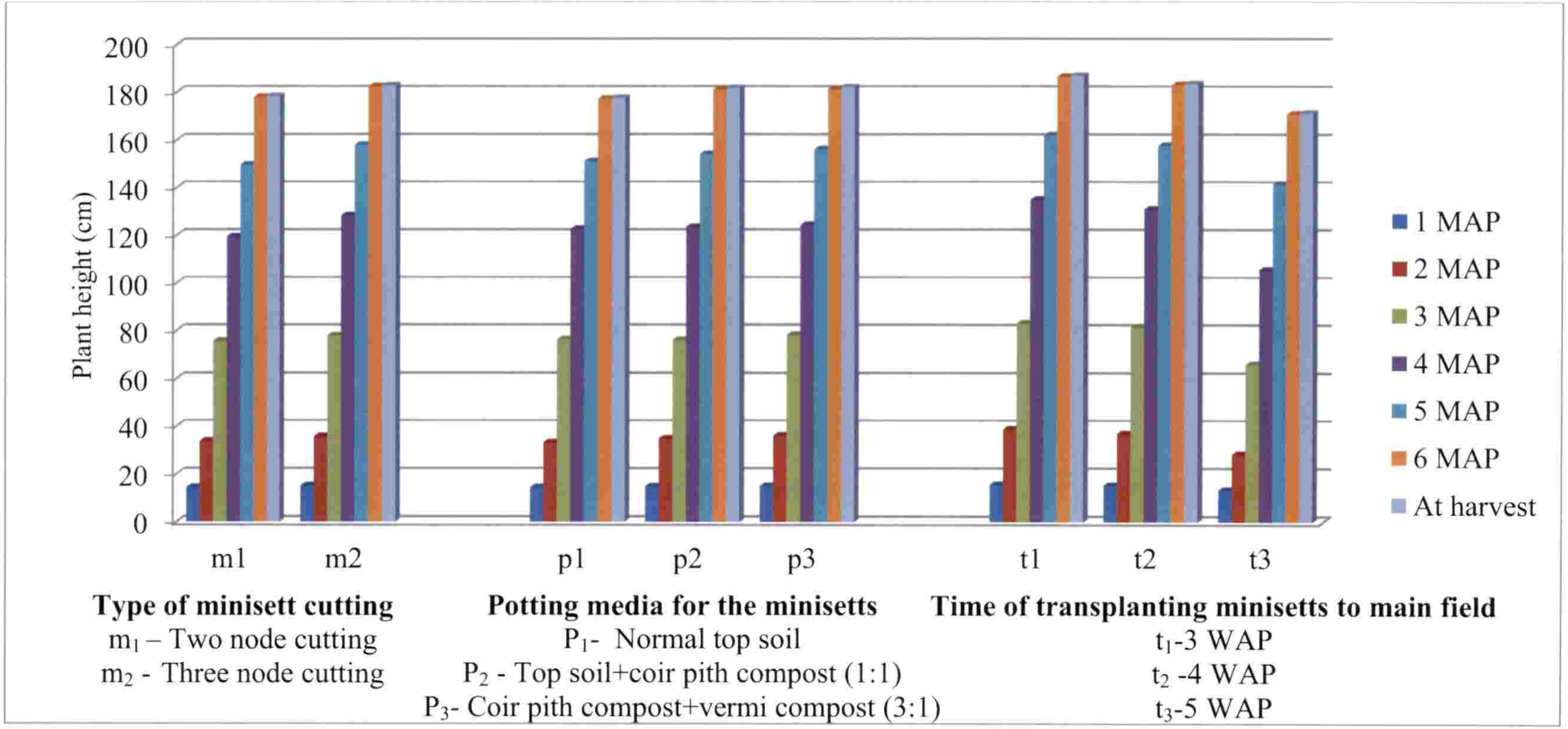


Fig. 10. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on plant height at monthly interval, cm

When three node minisett cuttings (m_2) were transplanted at 3 WAP (t_1), it produced more plant height, stem girth and LAI of cassava plants in the main field. The superiority of three node cuttings when combined with positive influence of early transplanting was found to have benefitted the growth attributes of the crop as observed in case of main effects.

Irrespective of the type of cuttings, when minisetts were raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio (p_3) and transplanted at 3 WAP (t_1) it produced higher LAI in the main field in p_3t_1 interaction which was also a manifestation of the main effects.

The minisetts planted in nursery and transplanted to the main field were found to be superior than the normal setts (control) planted directly in the main field with respect to seedling establishment, plant height and LAI of the crop. The comparison of the rooting pattern of minisetts and normal setts indicated that the number of roots and root length in minisetts at the time of transplanting were higher than the normal setts irrespective of potting medium and age of transplanting (Table 9) which also reflected in its field establishment. The root biomass of the minisett seedlings was also higher than the normal setts except in case of late transplanting. The root architecture of the cassava as studied by Izumi *et al.* (1999) indicated that the axial roots emerge as upper adventitious roots from the 1st and 2nd nodes above soil surface, middle roots from 3rd and 4th nodes and lower roots from below 5th node position or basal cut surface in case of normal cuttings wherein the root distribution is limited during the early period. The late emergence of adventitious roots of normal setts in cassava was previously reported by Alves (2002). However in case of minisetts, more number of fibrous roots were formed at the early stage and were found to have confined to the basal cut surface as shown in Plate 8. As observed by Rubio *et al.* (2001), the root architecture in cassava is determined in the early stages of growth and these root architectural characteristics persist throughout the vegetative phase of the crop. The highly ramified fibrous root system observed in case of

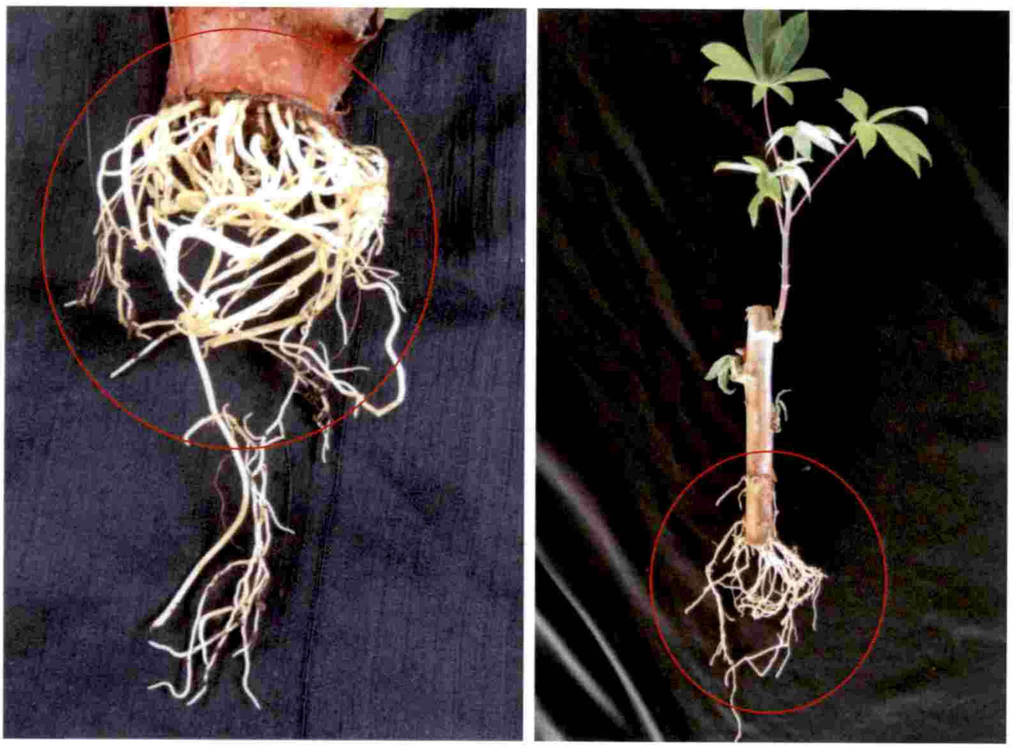


Plate 8.Comparison of root emergence in minisetts (from base) and normal setts (upper nodes).

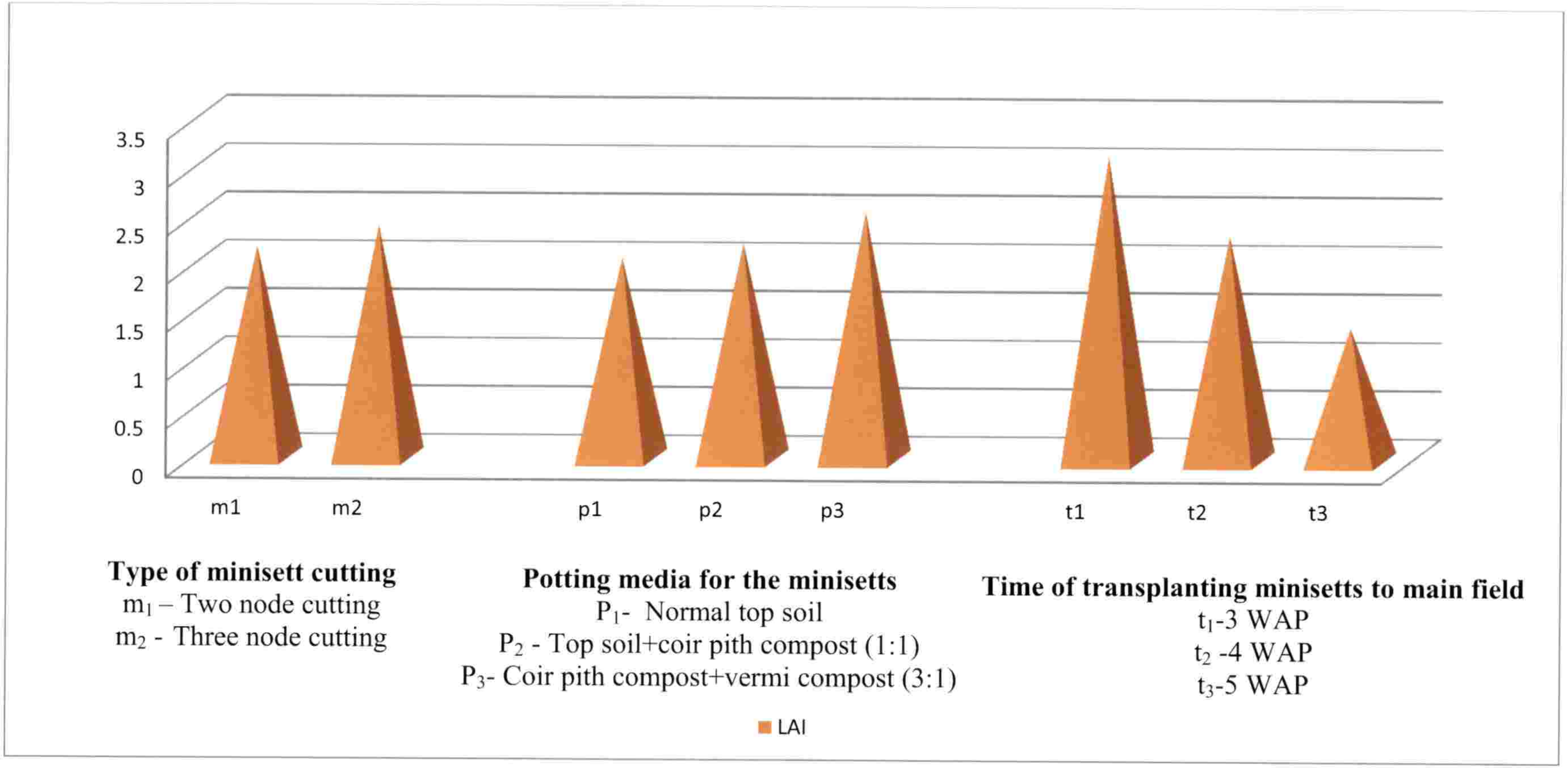


Fig. 11. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on Leaf Area Index (LAI) at 3 MAP.

minisetts would have therefore persisted throughout the vegetative stage of crop favouring the growth attributes through higher field establishment and better uptake of nutrients.

5.2.2 Yield attributes and yield

The three noded minisett cuttings produced more tuber length and girth (Fig. 12), mean weight of tuber (Fig. 13), tuber yield plant^{-1} (Fig. 14), yield ha^{-1}, top yield and total dry matter production (Fig. 15). The cassava growth model described by early investigators like Cock *et al.* (1979) indicated that the storage roots receive the assimilates that remained after meeting the growth needs of the canopy and hence it could be assumed that the higher dry matter production in cassava leads to better partitioning of assimilates to the storage roots improving the yield attributes and yield. In this respect, higher initial dry matter content of the nodes is an important factor influencing the growth and development of the crop as pointed out by Bridgemohan and Bridgemohan (2014) who reported that higher initial dry matter content of three node cuttings gave a head start over the one or two noded minisett cutting and thus was more efficient in allocating the dry matter produced for storage. The higher LAI (Table 14a) and dry matter production obtained with three node minisetts (Table 17 a) in the present study further substantiates this explanation. .

Among different types of potting media used for raising cassava minisetts in nursery, the coir pith compost and vermi compost in 3:1 ratio (p_3) produced the highest tuber yield plant^{-1} , tuber yield ha^{-1}, top yield ha^{-1} and total dry matter production. As indicated by Table 6 and 7, combined application of coir pith compost and vermi compost in the potting medium improved the shoot and root development in the minisett cassava which also favourably reflected on the growth and growth attributes in the main field. According to Vivek and Duraisamy (2017), decomposed coir pith was a good growth medium with acceptable pH, electrical conductivity and other chemical attributes and it has the virtuous oxygen diffusion and provides

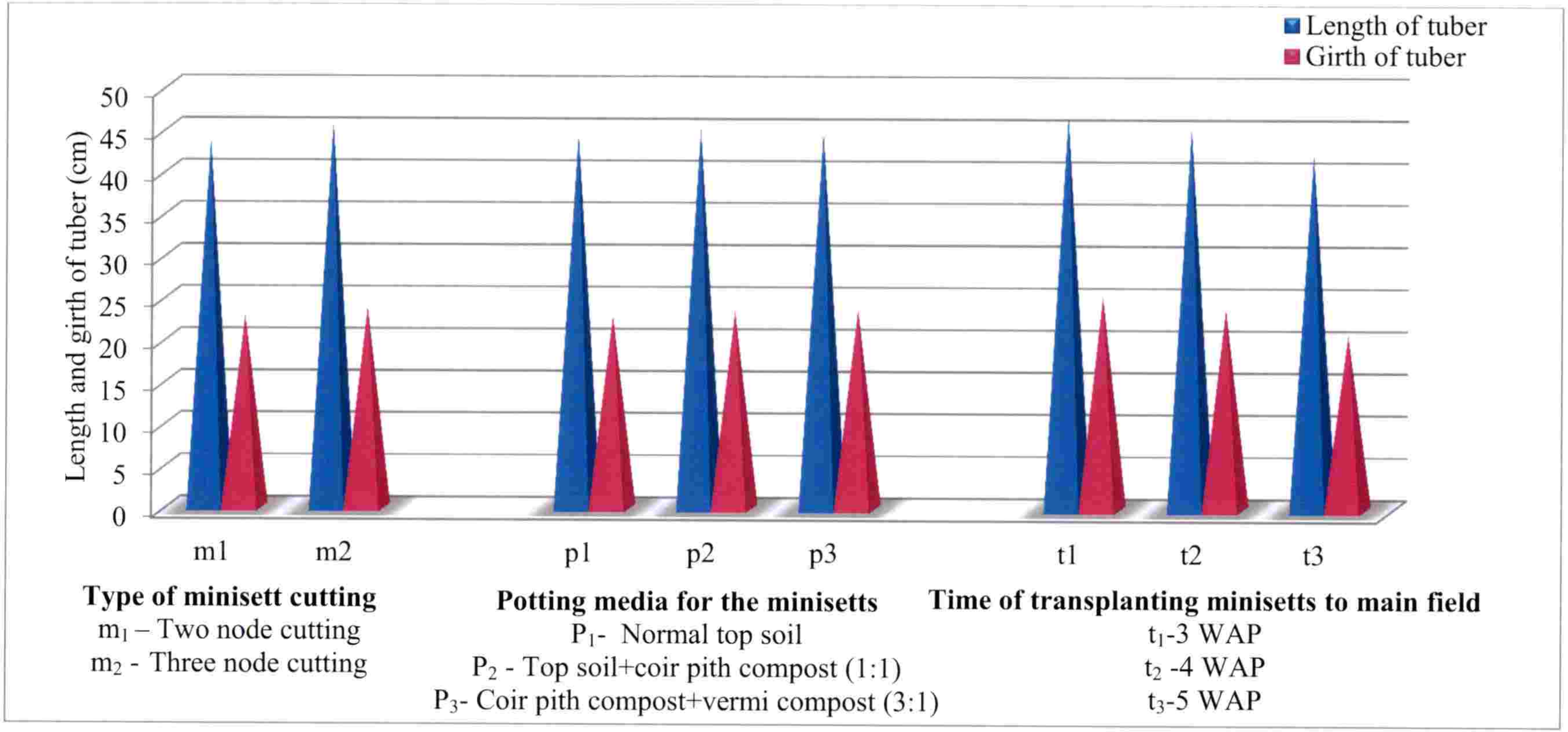


Fig. 12. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on length and girth of tuber, cm

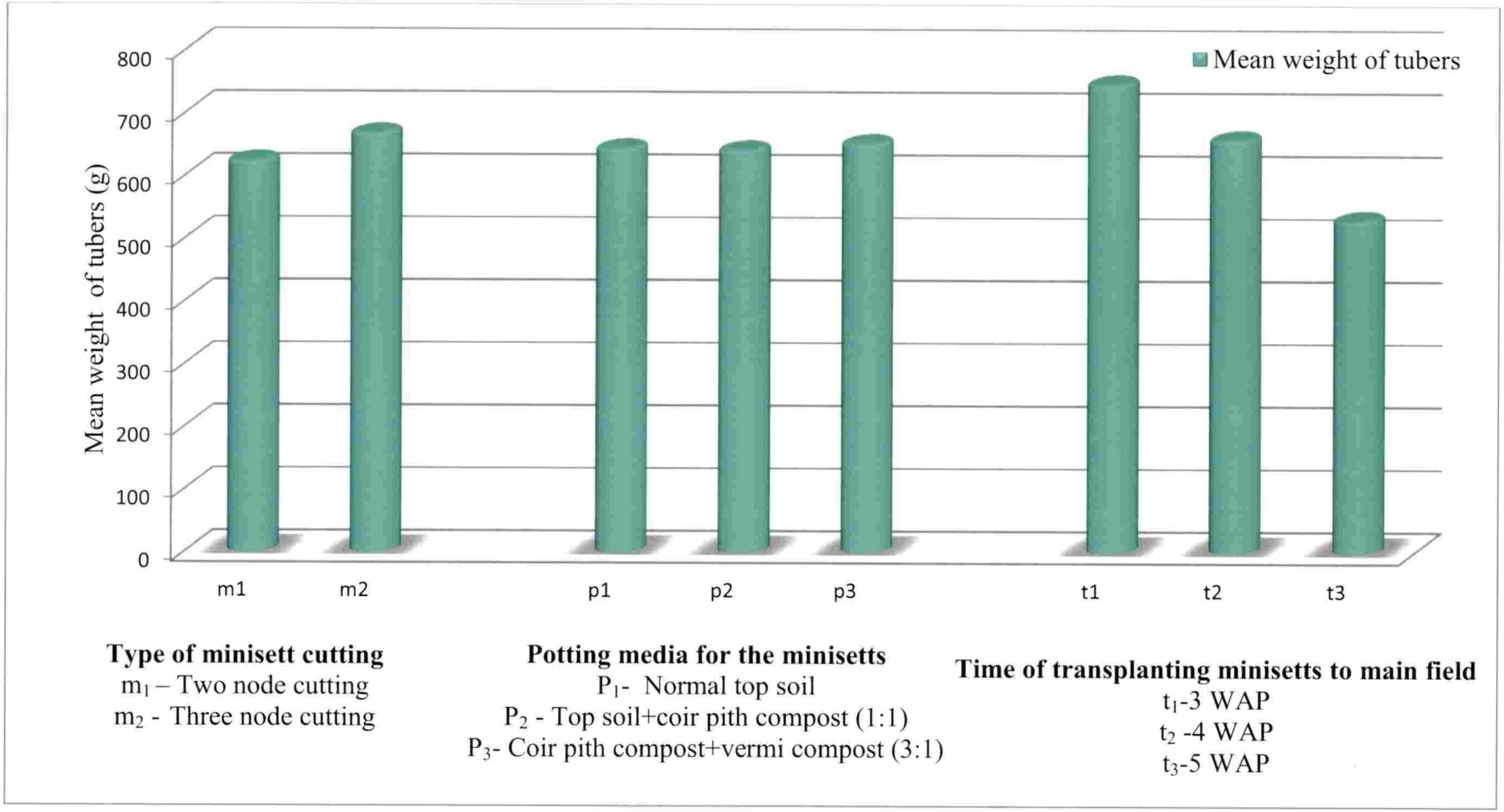


Fig. 13 . Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on mean weight of tubers, g

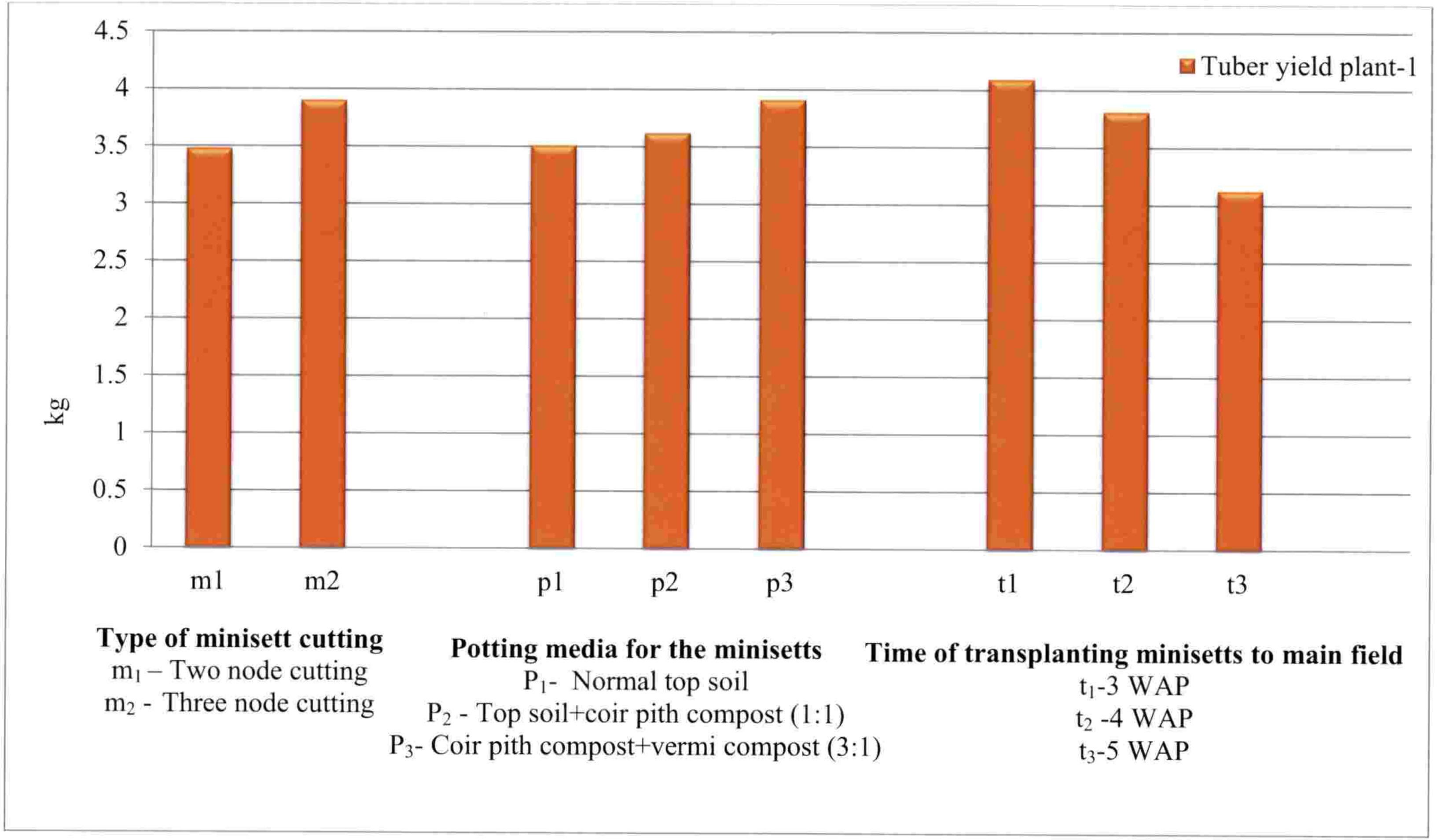


Fig. 14 . Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on tuber yield plant^{-1}, kg

support to fast growth of the seedlings due to better availability of nutrients in root zone of seedlings. Combined application of coir pith compost and vermi compost showed significant effect on seedlings growth parameters due to the synergistic combination of both factors in improving the physical conditions of the media and nutritional factors. The improved shoot and root characteristics in the minisett seedlings consequent to the use of potting medium would have resulted in higher vegetative growth and leaf area (Table 49) leading to higher photosynthetic efficiency, dry matter production and yield. Supporting this explanation, Nedunchezhiyan *et al.* (2012) pointed out the positive correlation between photosynthetic rate and tuber bulking rate resulting in higher yield attributes and yield in cassava.

The minisett seedlings transplanted at 3 WAP (t_1) produced higher number of tubers, percentage of productive roots, tuber length, girth of tuber, mean weight of tuber, tuber yield plant^{-1}, tuber yield ha^{-1}, top yield and dry matter production and required less number of days for harvesting compared to late transplanting at 4 weeks and 5 weeks after planting. As discussed in case of growth and growth attributes, the early transplanting of minisett seedlings (3 WAP) resulted in production of more healthy root system than late transplanting (4 WAP or 5 WAP) and consequently resulted in higher seedling establishment, better growth attributes and photosynthetic efficiency leading to higher accumulation of dry matter and its effective partitioning to the storage roots. Beyond 3 weeks age the roots of the seedlings started coiling leading to transplanting shock and resulted in low yield attributes and yield. This is in agreement with the findings of Lommen (2015) who reported that early transplanted potato seedlings produced higher dry matter content which was allocated to the tuber portion producing higher yield. The variation in the days to harvest can be directly related to the difference in the time of transplanting to the main field.

The MxP interaction influenced yield attributes and yield in the main field and the highest mean weight of tuber, tuber yield ha^{-1} and top yield were obtained when three noded minisetts (m_2) were raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio (p_3). The superiority of three noded minisetts and potting medium (p_3) was also manifested in their interaction effect producing higher yield attributes and yield with cassava minisetts in the main field.

Among MxT interactions, raising three node minsett cuttings in nursery and transplanting them 3 WAP (m_2t_1) produced higher tuber yield ha^{-1}, top yield ha^{-1} and total dry matter yield which also could be considered as a combined effect of superiority of main effects.

Among the PxT interaction, raising the minisetts irrespective of the node number in potting medium containing coir pith compost and vermi compost in 2:1 ratio and transplanting them to the main field at 3 WAP (p_3t_1) produced higher tuber yield in t ha^{-1} and top yield besides having greater dry matter production which is a repetition of trends expressed by the respective main effects.

Among the three factor interactions, raising three node minisett cuttings in the nursery in potting medium having coir pith compost and vermi compost in 3:1 ratio and transplanting the minisetts at 3 WAP produced highest mean weight of tubers, tuber yield ha^{-1} and top yield. The trends expressed by the single factor and two factor interactions also reflected in the third order interactions with respect to yield attributes and yield.

The minisetts were found to be superior than the normal setts with respect to formation of productive roots, length of tuber, mean weight of tubers, tuber yield $plant^{-1}$, tuber yield ha^{-1}, top yield and total dry matter production. However the normal setts were found to take less number of days for harvesting than the minisetts. Observations in the nursery indicated that roots emerged within 5 days from the basal cut surface of the minisett which were more in number while in case of normal setts, the root emergence was very slow and the axial roots few in number emerged as adventitious roots from different nodal positions. The slow initial emergence of the

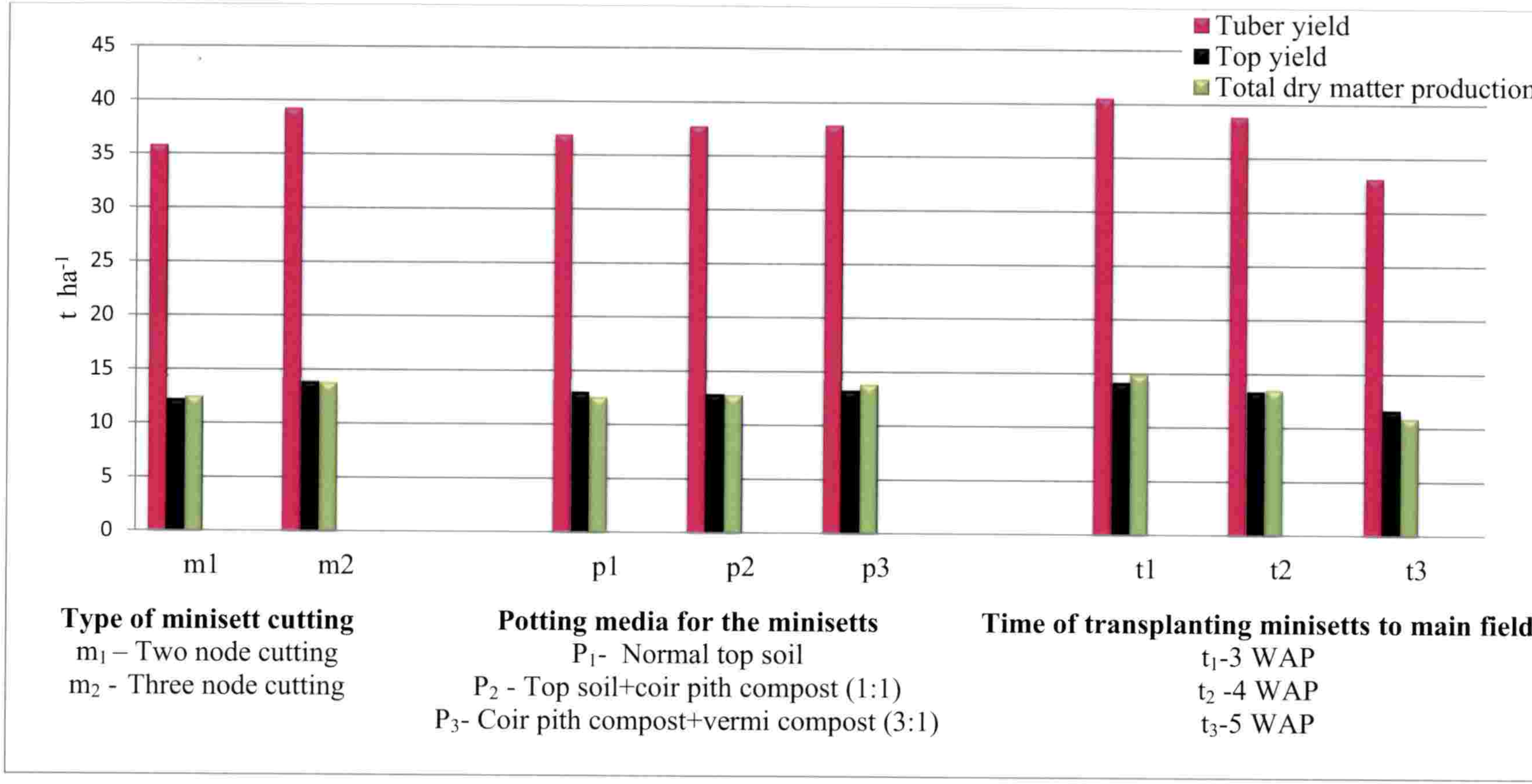


Fig. 15. Effects of type of cassava minisett cutting, potting media for the minisetts and time of transplanting minisetts to main field on tuber yield, top yield and total dry matter production, t ha^{-1}.

Plate 9. Tuber yield in the treatment $m_2p_3t_1$ (highest yield)

Plate 10. Tuber yield in the treatment $m_1p_2t_3$ (lowest yield)

Plate 11. Tuber yield in control (normal sett)

roots could be considered as the reason for lower seedling establishment associated with normal sett planting in the main field which necessitated the gap filling especially under rainfed conditions. The vigorous and healthy root system present during the early crop growth period in cassava minisetts were also found to favour the growth and development of the crop. This was further highlighted by improved growth parameters such as plant height (Table 11c) and LAI (Table 14c) which are also the indicators of higher photosynthetic efficiency. The rate of photosynthesis determines the rate of dry matter accumulation to different plant parts and in cassava more than 60 per cent of dry matter is accumulated in the shoot portion upto 2 months age and in the later stage more dry matter is partitioned to the storage roots (Nedunchezhiyan *et al.*, 2012). Therefore the improved growth and growth attributes such as higher plant height and leaf area observed during the early periods of growth would have promoted the accumulation of more dry matter in the storage roots through increased photosynthetic efficiency, thus improving the yield attributes and yield in minisetts in comparison to normal setts.

5.2.3. Nutrient content and uptake

The three node minisett cuttings recorded higher total nitrogen content in top portion and total phosphorus content in cassava tuber. The nitrogen and phosphorus uptake were also higher in case of three node minisetts compared to two node minisetts. The three node minisett cuttings were found to be superior over the two node cuttings with respect to production of better root system with more number of roots and root biomass. The plant roots act as an absorptive surface for nutrients and relationship between root morphology and nitrogen uptake from soil was pointed out by Robinson and Rorison (1983). The increased rooting intensity increasing the phosphorus uptake and plant phosphorus status was also previously reported by Fuleky and Nooman (1991). The more active root system produced by the three node cuttings would have therefore resulted in better uptake and accumulation of nutrients as observed in the study.

The minisetts raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio had higher P uptake than other potting media. According to Sahni *et al.* (2008), the combined application of coir pith and vermi compost in the potting medium had significant effect on seedlings growth parameters due to the synergistic combination of both factors in improving the physical conditions of the media and nutritional factors. The improvement in the vegetative growth and root characteristics consequent to the use of coir pith compost and vermi compost as potting medium would have thus promoted the uptake of phosphorus from the phosphorus rich soil in the experimental plot. The positive correlation between vegetative growth characters such as number of leaves per plant with phosphorus uptake was previously reported by Akinjoba (2014) in sweet potato. Further more, an increased total dry matter production was observed in case of minisetts raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio and the total dry matter yield is one of the factors taken into account for estimating the nutrient uptake (Jackson, 1973).

Early transplanting (3WAP) resulted in higher nitrogen in top portion and phosphorus content in both top portion and tubers and potassium content in tuber portion of cassava. The early transplanting also resulted in higher nitrogen, phosphorus and potassium uptake by the crop compared to late transplanting. The root characters and vegetative characters of cassava plants were found to be superior in minisetts transplanted at early age (3 WAP). As pointed out by Wang *et al.* (2016), vigorous root growth was a better indicator of early nutrient acquisition and found to favour high macro nutrient concentration in shoots which is assumed to be important for later crop growth.

5.2.4 Economics of cultivation

The highest net income and benefit : cost ratio was obtained from $m_2p_3t_1$ (three node cutting in potting medium containing coir pith compost and vermi compost in 3:1 ratio (p_3) and transplanted at 3 WAP) as shown in Fig. 16 and 17. The minisetts raised under $m_2p_3t_1$ recorded highest tuber yield ha^{-1} (Table. 16c) and this combination produced the highest net returns and benefit : cost ratio due to yield advantage.

Raising minisetts in the nursery and transplanting them to the main field produced higher net income and benefit : cost ratio than planting normal setts directly in the field. The quantity of planting material required was lower in the case of minisett cultivation when compared to the normal sett cultivation. The higher yield advantage observed with minisetts compensated the additional cost for nursery raising, leading to higher economics of cultivation. Similar results are reported by Akubuo (2002) and Kambaska *et al.* (2009) in yams and Aswathy (2015) in *kasthuri* turmeric.

The results obtained from this investigation indicated the superiority of raising three noded minisett cuttings of cassava in potting medium containing coir pith compost and vermi compost in 3:1 ratio in the nursery and transplanting these at 3 WAP to the main field. This was found to be the most technically and economically viable nursery technique for getting higher yield and income from the cassava cultivation compared to the conventional planting of normal setts directly in the field.

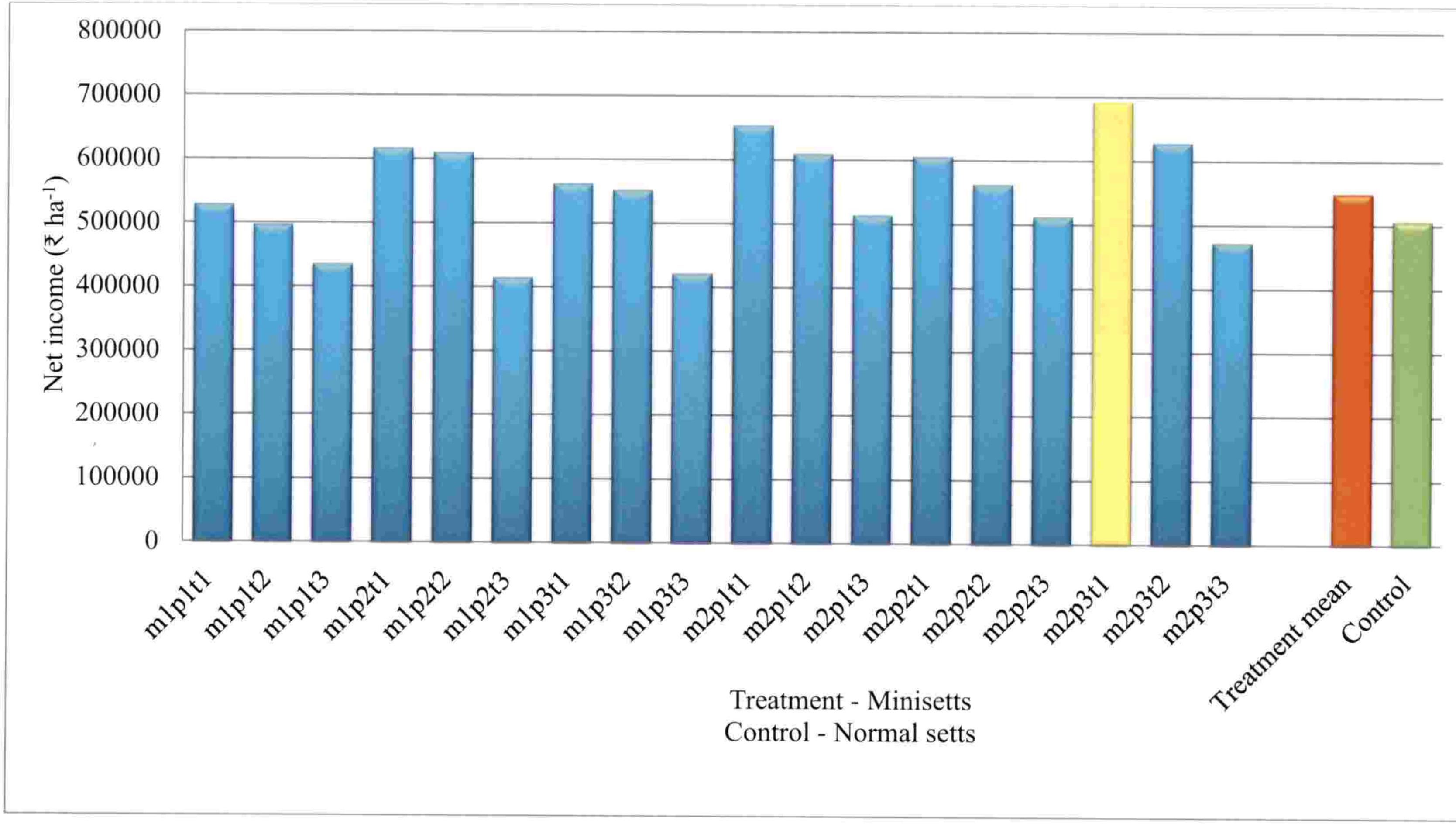


Fig. 16 . Effects of M×P×T interactions and treatment *Vs.* control effect on net income of cassava cultivation, ₹ ha^{-1}

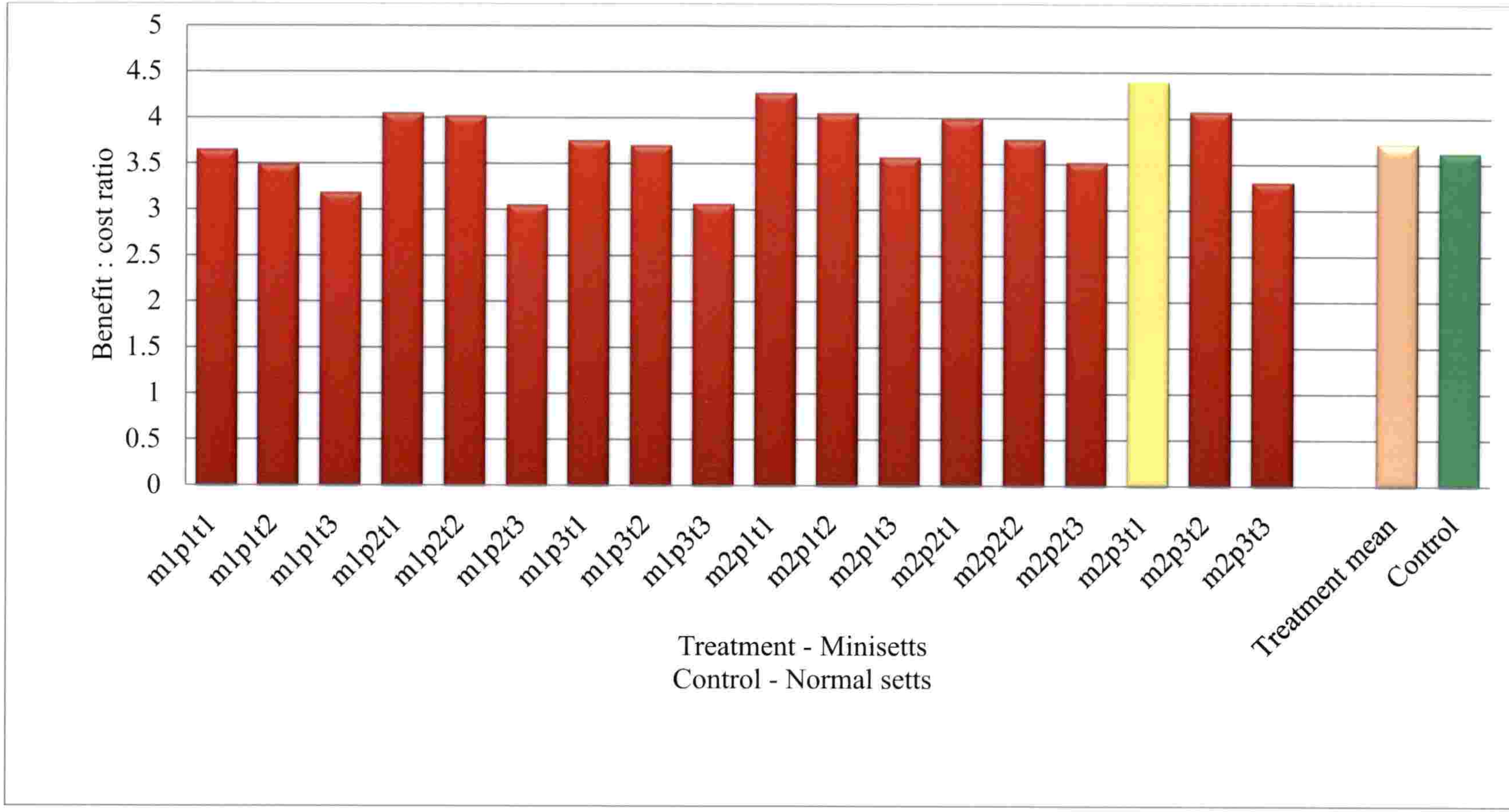


Fig. 17. Effects of M×P×T interactions and treatment *Vs.* control effect on benefit:cost ratio of cassava cultivation.

SUMMARY

6. SUMMARY

The study entitled "Standardisation of nursery techniques through field validation in minisett cassava (*Manihot esculenta* Crantz.)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram. The investigation which consisted of a nursery experiment (April 2017 to June 2017) and a field experiment (April 2017 to January 2018) was conducted to standardise the cassava minisett nursery technique by validating its field performance comparing with normal sett planting and to work out the economics of cultivation.

The nursery experiment was done in the Instructional Farm, Vellayani by raising minisetts of cassava var. Vellayani Hraswa in 50 cavity protrays of uniform size with 6 treatment combinations involving two types of minisett cuttings (m_1 - two node cutting and m_2 - three node cutting) and three types of potting media (p_1 - normal top soil, p_2 - normal top soil and coir pith compost in 1:1 ratio and p_3 - coir pith compost and vermi compost in 3:1 ratio). The nursery experiment was laid out in Completely Randomised Design with eight replications. The field experiment was conducted in D block of the Instructional Farm, College of Agriculture, Vellayani. The experiment was laid out in Randomised Complete Block Design with three replications and 18 treatment combinations involving two type of minisett cuttings and three type of potting media tried in the nursery, and three different time of transplanting of minisetts to main field ie. t_1 - 3 WAP (weeks after planting), t_2 - 4 WAP and t_3 - 5 WAP and one control (normal sett planting).

The result revealed that the main effects and interaction effects of nursery treatments such as type of minisett cuttings, type of potting media and time of transplanting minisetts to main field significantly influenced the growth and growth attributes, yield attributes, yield and economics of cassava cultivation. Significant variation between the treatments (minisetts) and control (normal setts) with respect to growth, yield and economics of cultivation was also observed in the study. The salient results of the study are summarised in this chapter.

Major findings of nursery experiment are as follows:

The three node minisett cutting (m_2) was found to have significantly higher seedling sprouting (92.26 percent), shoot length, shoot biomass, root length and root biomass at 3 WAP, 4 WAP and 5 WAP.

Among different potting media used in the experiment, p_3 (coir pith compost and vermi compost in 3:1 ratio) resulted in higher seedling sprouting (90.44 per cent), shoot length, shoot biomass seedling^{-1}, root length and root biomass seedling^{-1} in plants of all ages. The potting medium p_3 was however on par with p_2 (normal top soil and coir pith compost in 1:1 ratio - 90.35 per cent) in case of sprouting while the p_2 in turn did not vary from p_1 (normal top soil) with respect to its effect on minisett shoot length and shoot biomass seedling^{-1} at all stages. This on par relation was however observed in case of root length and root biomass only in case of seedlings transplanted at 3 and 4 WAP.

Among the interaction effects, the m_2p_3 resulted in significantly higher shoot length (8.38 cm) and shoot biomass (4.69 g seedling^{-1}) at 3 WAP, root length at 3 WAP (9.36 cm) and 4 WAP (14.25 cm). The m_2p_3 also recorded highest root biomass (0.520 g seedling^{-1}) at 3 WAP which was on par with m_1p_3 (0.513 g seedling^{-1}).

The main factors and interaction effects were not significant with respect to days to shoot initiation and incidence of pest and diseases in the nursery.

A comparison of root initiation of cassava minisetts in nursery with normal setts planted at the same time in the main field was done. It was found that the three node minisetts raised in the potting medium containing coir pith compost and vermi compost in 3:1 ratio (m_2p_3) was superior in production of root number (33.50, 35.25 and 36.00 at 3 WAP, 4 WAP and 5 WAP respectively), root length (9.36, 14.25 and 16.56 cm at 3 WAP, 4 WAP and 5 WAP respectively) and root biomass (0.52, 0.85 g seedling^{-1} at 3 WAP and 4 WAP respectively) than the control (normal sett). However at 5 WAP root biomass was found to be higher

(1.05 g seedling^{-1}) for the normal setts than the minisett treatment m_2p_3 (0.908 g seedling^{-1}).

Major findings of the field experiment are as follows:

Seedling establishment in the main field was significantly higher (85.47 per cent) for m_2 (three node cutting) which was superior to m_1 or two node cutting (83.39 per cent seedling establishment). Among different potting media, the seedlings produced with p_3 (coir pith compost and vermi compost in 3:1 ratio) was found to have significantly higher (85.94 per cent) seedling establishment and the p_3 was however found to be on par with p_2 (top soil and coir pith compost in 1:1 ratio - 85.57 per cent). On comparing different time of transplanting, it was found that seedlings transplanted at 3 WAP (t_1) to the main field had highest seedling establishment (94.28 per cent).

Growth attributes *viz.,* plant height at all stages of observations, stem girth at 2 MAP, 4 MAP, 6 MAP and at harvest, functional leaves plant^{-1} at 3 MAP, 4 MAP, 5 MAP and at harvest and LAI (Leaf Area Index) at 3 MAP were significantly higher with the three noded minisetts than the two noded minisetts.

The minisetts raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio or p_3 recorded significantly higher plant height (15.15, 36.14, 78.39, 156.21, 181.27 and 182.26 at 1 MAP, 2 MAP, 3 MAP, 5 MAP, 6 MAP and at harvest respectively). During 1 MAP, 5 MAP, 6 MAP and at harvest the p_3 was however on par with p_2 (normal top soil and coir pith compost in 1:1 ratio) with respect to plant height. The other growth attributes *viz.,* stem girth at 1 MAP, functional leaves plant^{-1} at 3 MAP and 4 MAP and LAI at 3 MAP were also significantly higher for p_3. The p_3 was however on par with p_2 (92.11) in its effect on functional leaf production at 4 MAP.

Transplanting the minisetts at 3 WAP (t_1) registered significantly higher plant height, stem girth, functional leaves plant^{-1}, LAI and primary and secondary branches plant^{-1} at all stages of observation. However an on par relation was observed between t_1 and t_2 (transplanting at 4 WAP) in case of stem girth at 2

MAP, 3 MAP, 6 MAP and at harvest, functional leaves plant^{-1} at 6 MAP and also in case of number of primary and secondary branches.

The two factor treatment combination, m_2p_3 (three noded minisetts raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio) was significantly superior over other M×P interactions in its effect on plant height at 3 MAP, 5 MAP, 6 MAP and at harvest, production of functional leaves of cassava in main field at 2 MAP, 3 MAP and 5 MAP and LAI at 3 MAP. Among the combined effect of type of potting media with time of transplanting minisetts to the main field, the m_2t_1 interaction produced significantly higher value for plant height in cassava at 4 MAP (140.05 cm), stem girth at 1 MAP (2.34 cm) and LAI at 3 MAP (3.28). The LAI was only influenced by the P×T interaction and the treatment combination, p_3t_1 produced the highest value (3.51).

While comparing the treatments with control (normal sett planting in main field), it was observed that there was significant difference between treatments and control with respect to seedling establishment, plant height and LAI and the minisetts were superior than the normal setts with regard to these parameters.

Three node cutting or m_2 recorded significantly higher yield attributes *viz.*, length of tuber (45.99 cm), girth of tuber (23.92 cm), mean weight of tubers (668.18 g), tuber yield plant $^{-1}$ (3.90 kg), tuber yield ha^{-1} (39.25 t), top yield (13.86 t ha^{-1}) and total dry matter production (13.76 t ha^{-1}) compared to two node cutting (m_1).

The minisetts raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio (p_3) produced a tuber yield of 3.91 kg plant^{-1} and 37.92 t ha^{-1}, top yield of 13.24 t ha^{-1} and total dry matter production of 13.82 t ha^{-1} which were significantly higher than the minisetts raised in potting medium p_2 (top soil and coir pith compost in 1:1 ratio) and p_1 (normal top soil). However the p_3 was on par with p_2 (37.77 t ha^{-1}) in its effect on tuber yield ha^{-1}.

The early transplanted minisetts (t_1- transplanting at 3 WAP) produced significantly superior yield attributes and yield *viz.*, number of tubers plant^{-1}

(5.44), percentage of productive roots (56.88 per cent), tuber length (46.97 cm), tuber girth (25.44 cm), mean weight of tubers (747.65 g), tuber yield plant^{-1} (4.09 kg), tuber yield ha^{-1} (40.57 t), top yield ha^{-1} (14.12 t) and total dry matter production (14.90 t ha^{-1}) and lesser days to harvest (212.41 days).

M×P interactions did influence the yield attributes and yield wherein the treatment combination m_2p_3 recorded significantly higher mean weight of tubers (713.88 g), tuber yield ha^{-1} (40.08 t) and top yield (14.15 t ha^{-1}). The m_2t_1 recorded significantly higher tuber yield (42.62 t ha^{-1}), top yield (14.99 t ha^{-1}) and total dry matter production (15.78 t ha^{-1}) than all other M×T interactions. The combined effect of potting medium containing coir pith compost and vermi compost in 3:1 ratio with transplanting at 3 WAP (p_3t_1) produced significantly higher tuber yield (41.55 t ha^{-1}), top yield (14.58 t ha^{-1}) and total dry matter production (15.79 t ha^{-1}). However p_3t_1 was on par with p_2t_1 (minisetts raised in potting medium containing normal top soil and coir pith compost in 1:1 ratio-40.66 t ha^{-1}) in its effect on tuber yield ha^{-1}. Significantly less number of days were taken to harvest with the two factor treatment combinations m_1t_1 (two noded minisetts transplanted at 3 WAP - 212.27 days) and p_1t_1 (minisetts raised in potting medium containing normal top soil transplanting at 3 WAP-212.32 days) .

The M×P×T interaction also significantly influenced the mean weight of tuber, tuber yield ha^{-1} and top yield. Highest yield was recorded with $m_2p_3t_1$ which produced tuber with mean weight of 867.15 g, tuber yield of 44.83 t ha^{-1} and top yield of 15.75 t ha^{-1}.

The minisetts had significantly higher percentage of productive roots (50.95), tuber length (44.92 cm), mean weight of tubers (646.16 g), tuber yield plant^{-1} (3.70 kg), tuber yield ha^{-1} (37.54 t), top yield (13.03 t ha^{1}) and total dry matter production (13.11 t ha^{-1}) than the normal setts (control). The yield advantage of the minisett treatment $m_2p_3t_1$ over the control was to the tune of 22.03 per cent. While comparing treatment *Vs.* control effect on days to harvest, normal setts took less days (197.00 days) for harvest than the minisetts (220.42 days).

The plant analysis data showed that the main effect of m_2 was significantly superior than that of m_1 in its effect on total nitrogen content in top portion, total phosphorus content in cassava tuber, nitrogen and phosphorus uptake. The potting medium p_3 was superior only in case of phosphorus uptake compared to other potting media. The results of plant analysis revealed that among the different time of transplanting minisetts to the main field, t_1 was significantly superior over t_2 and t_3 in its effect on total nitrogen content in the top portion, total phosphorus content in the top and tuber portion, total potassium content in tuber, nitrogen uptake, phosphorus uptake and potassium uptake.

The main effects, interaction effects and treatment *Vs.* control effects had no significant influence on starch content and shelf life tubers. The post experimental status of pH, electrical conductivity, organic carbon, available nitrogen, available phosphorus and available potassium in soil were also unaffected by the treatments.

Among different treatment combinations, the highest net returns (₹6,92,267 ha^{-1}) and benefit :cost ratio (4.39) were registered by $m_2p_3t_1$ (three node cutting in the potting medium containing coir pith compost and vermi compost in 3:1 ratio and transplanted 3WAP). While comparing different treatment combinations with control for economics of cultivation, treatments (minisetts) were found to have higher net returns (₹5,48,910 ha^{-1}) and benefit :cost ratio (3.72) when compared to the control (normal setts) which produced a net returns of (₹5,06,446 ha^{-1}) and benefit :cost ratio of 3.62.

The results of the study indicated that raising three noded minisett cassava cuttings in potting medium containing coir pith compost and vermi compost in 3:1 ratio in the nursery and transplanting these at 3 WAP was found to be the most appropriate, technically and economically viable nursery technique for getting higher yield and income from cassava cultivation compared to the conventional practice of planting normal setts directly in the main field.

FUTURE LINE OF WORK

- Popularisation of the minisett nursery technique standardised in the present investigation is a priority area under future line of work.

- Variation in the rooting pattern of minisetts and normal setts points out the need for standardizing the agro techniques such as planting methods and nutrient management for minisett cassava cultivation and more agronomic research may be taken up in this respect.

- Field studies on establishment and growth of minisetts under the influence of plant growth hormones for commercial cultivation of cassava is another future area of research to be exploited.

REFERENCES

7. REFERENCES

Abbiramy, K. S. and Ross, R. P. 2012. Efficacy of vermicomposted coir pith on growth physiology of *Abelmoschus esculentus*. *Int. J Envir. Biol.* 2(3):153-155.

Abiram, K., J., Rema, P.A., Mathew, V., Srinivasan., and Hamza, S. 2010. Effect of different propagation media on seed germination, seedling growth and vigour of nutmeg (*Myristica fragrans* Houtt.). *J. Med. Plants Res.*4: 2054-2058.

Abudulai, M. and Quansah, C. 2002. Alternative media to sawdust for minisett propagation of seed yam (*Dioscoria* spp.). *Trop. Sci.* 42:47-51.

Adjei-Nsiah, S. 2010.Yield and nitrogen accumulation in five cassava varieties and their subsequent effects on soil chemical properties in the forest/savanna transitional agro- ecological zone of Ghana. *J. Soil Sci. Environ. Manag.* 1(1): 15-20.

Aighewi, B. A., Asiedul, R., Maroyal, N ., and Balogun, M. 2015. Improved propagation methods to raise the productivity of yam (*Dioscorea rotundata* Poir.). *Food Sec.* 7: 823–834.

Akinjoba, U. 2014. phosphorus fertilizer on tuber yields vegetative growth and phosphorus uptake of sweet potato (*Ipomoea batatas*). *Int. J. Manures Fertilizers*. 3 (7): 558-560.

Akubuo, C.O. 2002. Determination of a basis for design of a yam (*Dioscorea* spp.) minisett sorter. *Nigerian J. Technol.* 21(1): 1-8.

Alves, A. A. C. 2002. Cassava botany and physiology. In: Hillocks, R. J., Thresh, J. M. and Bellotty, A. C. (eds.), *Cassava- Biology, Production and Utilization.* CABI Publishing, U.K, pp.67-89.

Aswathy, T.S. 2015. Rapid multiplication of *kasthuri* turmeric (*Curcuma aromatic* salisb.) through minisett technique and nursery management. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 160p.

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D., and Shuster, W. 2000. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedo biol.* 44: 579-590.

Ayankanmi, T., Shiwachi, H., and Asiedu, R. 2005.Sprouting and yield of yam (*Dioscorea* spp.) minisetts in relation to sett size, soil moisture and agro-ecology. *Trop. Sci.* 45: 23-27.

Bolandi, A. R., Hamidi, H., and Ghavidel, R.A. 2011. The effects of size and microtuberdormancy on production of potato minitubers. *American-Eurasian J. Agric. & Environ. Sci.* 10(2): 169-173.

Bourke, R.M. and Perry, C.H. 1976. Influence of sett size on growth and yield of taro (*Colocasia esculenta*). *Papua New Guinea Agric. J.* 27: 115-120.

Bouyoucos, C. J. 1962. Hydrometer method improved for making particle size analysis of soil. *J. Agron.* 54: 464-465.

Bridgemohan, P. and Bridgemohan, R. S. H. B. 2014.Effect of initial stem nodal cutting strength on dry matter production and accumulation in cassava (*Manihot esculenta* Crantz). *J Plant Breed. Crop Sci.* 6(6): 64-72.

Cock, J. H., Franklin, D., Sandoval, G., and Juri, P. 1979. The ideal cassava plant for maximum yield. *Crop Sci.* 19: 271-279.

Dasbak, M.A., Manggoel, W., and Dawang, C.N. 2011.Evaluation of nursery sprouting media for the minisetts of some *Dioscorea rotundata* yam cultivars and the field establishment of sprouted minisetts in Garkawa, Plateau State, Nigeria.*Int. Res. J. Agric. Sci. Soil Sci.* 1(11): 81-484.

Donald, C. M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.* 28: 361-405.

Eyitayo, O. A.,Anthony, T.O., and Theresas, I. 2010. Economics of seed yam production using minisett technique in Oyo state, Nigeria[on-line]. Available: http://factsreports.revues.org/659[21 Jan. 2017].

Faisal, S.M., Salam, M.A., Islam, M.S., and Hossain, M.I. 2009. Effects of planting material and earthing-up on yield and yield contributing attributes of *mukhikachu*. *Bangladesh J. Agric. Res*. 34(2): 263-267.

Fuleky, G. and Nooman, J. 1991. Effects of soil volume on root growth and nutrient uptake. *Dev. Agric. Manag. For. Ecol.* 24: 446-448.

Gebre, A., Tesfaye, B., and Kassahun, B. M. 2015. Effect of corm size and plant population density on corm yield of Taro (*Colocasia esculenta* L.). *Int. J. Adv. Biol. Biomedical Res*. 3(4): 405-412.

George, J. 2006. Quality planting material production in tuber crops. In: *Proceedings of the 14th Triennial Symposium of ISRTC*, 20-26, November 2006, Trivandrum, 315p.

George, J. and Nedunchezhiyan, M. 2008. Rapid production techniques in tuber crops. In: Nedunchezhiyan, M.(ed.), *Advance Techniques in Quality Planting Material Production and Commercial Cultivation of Tropical Tuber Crops,* Regional Centre, Central Tuber Crops Research Institute, Bhubaneswar, Orissa, pp. 70-78.

Grabowska, A., Kunicki, E., and Libik, A. 2007. Effects of age and cold storage of transplants on the growth and quality of Broccoli heads. *Veg. Crops Res. Bull.*. 66: 31-38.

Igwilo, N. 2007.Seed yam production in Nigeria using minisett and peelsett technique. *J. Root Crops*. 33(2): 104- 108.

IITA [International Institute of Tropical Agriculture]. 1990. *Cassava in Tropical Africa: A reference manual*. Ibadan, Nigeria. pp. 61-63.

IITA[International Institute of Tropical Agriculture]. 2001. Rapid Multiplication of Cassava. International Institute of Tropical Agriculture, Nigeria. 63p.

IMD [India Meteorological Department]. 2016. Available:http://www.imdtvm.gov.in [20, Dec 2016]

Isaac, S. R., Dickson, V. J., and Varghese J. 2015. Evaluation of minisetts as planting material for homestead cultivation of tuber crops.*Indian J. Agric. Allied Sci.* 1(4): 7-10.

Isaac, S. R., Podikunju, B., and Pillai, S. P. 2011. Evaluation of minisetts as planting materials in cassava [abstract]. In: *Abstracts, National Seminar on Climate Change and Food Security: Challenges and Opportunities for Tuber Crops*; 20-22, January, 2011, Thiruvananthapuram. Indian Society for Root Crops, Thiruvananthapuram, Kerala, p.137. Abstract No. PWNM/P7.

Issac, S. R., Podikunju, B., and Pillai, S. 2012. Minisett technology for tuber crops-performance evaluation in coconut based farming systems. In: Muralidharan, K., Jayasekhar, S., and Rakesh, M.K. (eds.), Proceedings of Twenty Second Swadeshi Science Congress, 6-8 November 2012, Kochi. Central Plantation Crops Research Institute, Kasargod, Kerala. pp. 142-145.

Isaac, S. R., Varghese, J., Remya, N., and Krishnan, A. 2013. Influence of nursery media and mulching on sprouting and growth of Greater Yam (*Dioscorea alata*) minisetts. *J. Root Crops.* 39(2): 247-249.

Izumi, Y., Yuliandi, E., Sunyooto, S., and Iijima, M. 1999. Root system development including root branching in cutting of cassava with reference to shoot growth and tuber bulking. *Plant Prod. Sci.* 2(4): 267-272.

Jackson, M. L. 1973. *Soil Chemical Analysis (2nd Ed.).* Prentice Hall of India, New Delhi, 498p.

Jaiswal, A. K., Singh, J. P., Tomar, S., Abhishek and Thakur, N. 2017. Effect of seedlings age on growth, yield attributes and yield of Tomato (*Lycopersicon esculentum* Mill.).*Int. J. Curr. Microbiol.Appl .Sci.* 6(9): 1521-1524.

Jata, S. K., Lenka, A., and Nedunchezhiyan, M. 2013. Evaluation of different nursery techniques in cassava (*Manihot esculenta* Crantz). *J. Root Crops.* 30(2): 238-241.

Jayakrishna, J., Thampatti, M. K. C., and Leno, N. 2016. Standardisation of growth medium based on thermo chemical digest produced from degradable solid waste by rapid conversion technology. *Int. J. Appl. Pure Sci. Agri.* 2(10): 76-80.

Jellani, G., Atif, M. J., Ullah, H., Ali, H. and Musa, M. 2015. Influence of seedling age on cucumber (*cucumis sativus*) production. *SAARC J. Agri.* 13(2): 214-221.

Jellani, G., Atif, M. J., Ullah, H., Khan, T. N., and Saleem, N. 2016. Seedling age impact on growth and yield of bitter gourd. *Sci. Techol. Dev.* 35 (2): 94-97.

Joseph, A and Muthuchamy, I. 2014.Productivity, quality and economics of tomato (*Lycopersicon esculentum* mill.) cultivation in aggregate hydroponics - a case study from Coimbatore region of Tamil Nadu. *Indian J.Sci.Technol.* 7(8):1078-1086.

Kambaska, K. B., Santilata, S., Trinanth, M and Debashrita, P. 2009. Response of vine cuttings to rooting in different months in three Dioscorea species. *J. Nature Sci.* 7: 48–51.

Lazcano, C., Arnold, J., Tato,J., Zaller, J. G., and Domíngue, J. 2009. Compost and vermi compost as nursery pot components: effects on tomato plant growth and morphology. *Spanish J. Agric. Res.* 7(4): 944-951.

Lommen, W. J. M. 2015. How age of transplants from in vitro derived potato plantlets affects crop growth and seed tuber yield after field transplanting. *Potato Res.* 58: 343–360.

Lozano, J. C., Toro, J. C., Castro, A., and Belloti, A. C. 1977.*Production of cassava planting material.* Cassava information centre series, GE-17, CIAT, Columbia.

Manh, V. H. and Wang, C. H. 2014. Vermi compost as an important component in substrate: effects on seedling quality and growth of muskmelon (*Cucumis melo* L.). *APCBEE Procedia 8* : 32- 40.

Mazahreh, N., Nejatian, A., and Mousa, M. 2015. Effect of different growing media on cucumber production and water productivity in soilless culture under UAE Conditions. *J. Agric. Sci. Soil Sci.* 3(9): 131-138.

Nagarajan, R., Manickam, T. S., and Kothandaraman, G. V. 1985. Manurial value of coir pith. *Madras Agric. J.* 72: 533–535.

Nahar, N.E., and Tan, S.L.2012. Cassava mini-cuttings as a source of planting material. *J. Trop. Agric. and Food Sci.* 40(1): 145–151.

Nath, R., Kundu, C.K., Majumder, A., Gunri, S., Biswas, T., Islam, S.J., Chottopadhyay, A., and Sen, H. 2007. Seed corm production of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst, Nicholson) through mini corm setts in rainfedlaterite ecosystem of Eastern India. *J.Root Crops*. 33(1): 30-37.

Nedunchezhiyan, M., Byju, G., and Ravi, V. 2012. Photosynthesis, dry matter production and partitioning in cassava (*Manihot esculenta* Crantz) under partial shade of a coconut plantation. *J. Root Crops*. 38(2): 116-125.

Nedunchezhiyan, M., Byju, G., and Kumar, D. 2015. Effect of sett size and spacing on growth, yield and economics of greater yam intercropped in coconut garden. *Indian J. Hort*. 65(2): 248-251.

Nedunchezhiyan, M., George, J., and Byju, G. 2008. Nursery techniques in tuber crops. In: Nedunchezhiyan, M(ed.), *Advance Techniques in Quality Planting Material Production and Commercial Cultivation of Tropical Tuber Crops*, Regional Centre, Central Tuber Crops Research Institute, Bhubaneswar, India, pp. 66-78.

Otoo, J. A., Okoli, O., and Ilona, P. 2001. Improved production of seed yam.*IITA Research Guide No. 63*. International Institute for Tropical Agriculture, Ibadan, Nigeria, pp.1 - 4.

Panse, V. G. And Sukhatme, P. V. 1985. *Statistical Method for Agricultural Workers (4th Ed.).*Indian Council of Agricultural Research, New Delhi, 347p.

Paramanandham, J., Ross, R. P., Abbiramy, K.S., and Muthulingam, M. 2014. Studies on the moisture retention capacity of coir pith, as a function of time. *Int. J. Chem.Tech. Res*. 6(12): 5049-5052.

Paul, O.O., Claire, K., Jacques, D. 2016. Effects of planting methods and tuber weights on growth and yield of yam cultivars (*Dioscorea rotundata* Poir.) in Gabon. *Int. Res. J. Agric. Sci. Soil Sci.* 6(3): 32-42.

Pill, W. G. and Ridley, K.T. 1998.Growth of tomato and coreopsis in response to coirdust in soilless media. *Hort. Technol*. 8(3): 401-404.

Piper, C. S. 1966.*Soil and Plant Analysis*. Hans Publication, Bombay, 368 p.

Prasath, D., Vinitha, K. B., Srinivasan, V., Kandiannan, K., and M. Anantharaj. 2014. Standardisation of soil-less nursery mixture for black pepper (*Piper nigrum* L.) multiplication using plug trays. *J. Spices Arom. Crops.* 23(1): 1-9.

Ramanujam, T. and Indira, P. 1981. Linear measurement and weight methods for estimation of leaf area in cassava and sweet potato. *J Root Crops*. 4: 47-50.

Rani, J. A. and Murugan, P. P. 2011. Yield maximisation of cassava through the adoption of recommended technologies in Tamil Nadu [abstract]. In: *Abstracts, National Seminar on Climate Change and Food Security: Challenges and Opportunities for Tuber Crops*; 20-22, January, 2011, Thiruvananthapuram. Indian Society for Root Crops, Thiruvananthapuram, Kerala, p.137. Abstract No. PTD/01.

Reghuvaran, A. and Ravindranath, A. D. 2010. Efficacy of biodegraded coir pith for cultivation of medicinal plants. *J. Sci. Ind. Res.* 69: 554-559.

Remison, S.U., Omorodion, E., andEifedyi, E.K. 2015. A re- examination of the effects of length of stem cuttings on the growth and yield of cassava (*Manihot esculenta* Crantz). *Nigerian Annals Natural Sci*. 15 (1): 9-13.

Robinson, D. and Rorison, I. H. 1983. Relationships between root morphology and nitrogen availability in a recent theoretical model describing nitrogen uptake from soil. *Plant, Cell Environ*. 6(8): 641-647.

Rubio, G., Walk, T., Ge, Z., Yan, X., Liao, H., and Lynch, P. J. 2001. Root gravitropism and below ground competition among neighbouring plants: A modelling approach. *Ann. Bot*. 88: 929-940.

Saha, S. and Srivastava, B. K. 2015.Performance of tomato seedlings on different growing media [on-line]. Available: http:// www. biotecharticles. com./ agriculture-article/3313.html [23 Jan 2017].

Sahni, S. B. K., Sharma, D. P., Singh, H. P., and Singh, K.P. 2008.Vermicompost enhances performance of plant growth promoting rhizobacteria in *Cicer arietinum* rhizosphere against *Sclerotium rolfsii*. *Crop Prot*. 27: 369-376.

Salam, P.K., Singh, B., Ram, D.S., and Patel, R.K. 2016. Effect of spacing and size of planting material on Elephant Foot Yam grown as intercrop in coconut Garden. *J. Root Crops.* 42(2): 62-65.

Sarker, R., Ray, S. P., Paul, J., Nusrat, A and Tithi, M. J. 2017. Effect of seedling age on growth and yield of tomato. *Int. J. Agric.Papers*. 2 (2): 13-17.

Savithri, P. and Khan, H. H. 1994. Characteristics of coconut coir pith and its utilization in agriculture. *J. Plant. Crops.* 22(1): 1-18.

Sekar, J. 2004. Fertilizer scheduling for the short duration cassava variety "vellayani hraswa". M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 118p.

Shiji, R., George, J., Sunitha, S., and Muthuraj, R. 2014. Micropropagation for rapid multiplication of planting materials in cassava (*Manihot esculenta* Crantz). *J. Root Crops* 40(1): 23-30.

Shukla, Y. R., Chhopal, T., andsharma, R. 2011. Effect of age of transplants on growth and yield of capsicum. *Int. J. Farm Sci.* 1(2): 56-62.

Singh, H., Khurana, D.S., Nedunchezhiyan, M., and Mukherjee, A. 2016. Effect of seed cormelweight on growth and yield of Taro (*Colocasia esculenta* (L.) Schott.) in Punjab condition. *J. Root Crops.* 42(1): 95-97.

Singh, K., Singh, H., Singh, K., and Rathore, P. 2013. Effect of transplanting and seedling age on growth, yield attributes and seed cotton yield of Bt cotton (*Gossypium hirsutum*). *Indian J. Agric. Sci.* 83 (5): 508–513.

Snedecor, G. W. And Cochran, W. G. 1967.*Statistical Methods* (16th Ed.).Oxford and IBH publishing Co., Culcutta. pp. 349-351.

Srinivasan, J. and Srimathi, P. 2017. Standardization of seed treatment and potting mixture for production of tomato seedlings in protray nursery. *Int. J. Sci. Nat.* 8(1):138-142.

Subbiah, D. V. and Asija, G. L. 1956.Rapid procedure for estimation of available nitrogen in soil. *Curr. Sci.* 25: 259-260.

Sultana, N., Bari, M. S., and Rabbani, M. G. 2001.Effect of seedling tuber size and depth of planting on the growth and yield of potato. *Pakistan J. Biol. Sci.* 4(10): 1205-1208.

Tetteh, J. P., Omenyo, E. L., and Dankwa, A. 1997.Tuberisation and effect of age of seedlings at transplant on yield of seed propagated cassava. *Ghana J. Agric. Sci.* 30(1): 9-14.

Thankamani, C. K., Srinivasan, V., Hamza, S., Kandiannan, K and Mathew, P. A. 2007. Evaluation of nursery mixture for planting material production in black pepper (*Piper nigrum* L.). *J. Spices Arom. Crops*. 16(2): 111-114.

Thenmozhi, P. 2015. Performance evaluation of vermicomposted coir pith by *Eudrilus eugeniae* kinberg on the growth of *Abelmoschus esculentus*. *Int. J. Mod. Res.* 3(11): 1049-1053.

Tsedalu, M., Tesfaye, B., and Goa, Y. 2014. Effect of type of planting material and population density on corm yield and yield components of taro (*Colocasia esculenta* L.). *J. Biol. Agric. Healthcare*. 4(7): 124-137.

Vadiraj, S. B. A., sudharshan, M. R., and Krishnakumar, V. 1996.Standardisation of rooting media for propagation of vanilla (*Vanilla planifolia* Andr.). *J. Spices Aromat. Crops*. 5 (2): 131-133.

Vipitha, V. P. 2016. Agronomic interventions for a sustainable rice based cropping system in paddy fields. Ph.D thesis, Kerala Agricultural University, Thrissur, 228p.

Vivek, P. and Duraisamy, V.M. 2017. Study of growth parameters and germination on tomato seedlings with different growth media. *Int. J.Agric. Sci. Res*. 7(3): 461-470.

Wang, Y., Thorup-Kristensen, K., Jensen, L. S., and Magid, J. 2016. Vigorous root growth is a better indicator of early nutrient uptake than root hair traits in spring wheat grown under low fertility. *Frontiers Plant Sci.* 7: 1-9.

Pigman,W. W. 1970. *Analytical methods for carbohydrates- The Carbohydrates Vol.,IIB.* Academic press, New York and London. 763p.

Watson, T. J. 1947. The physiological basis of variation in yield.Academic press. INC, New York. *Adv. Agron.* 4: 101-145.

Yadav, P., Abraham, N., and Vinitha, V. 2014. Frontline demonstration on minisett technique for rapid propagation of cassava in Kollam district. In: Proceedings of Twenty Fourth Swadeshi Science Congress. 6-8 November 2014, Malappuram, Swadeshi Science Movement, Thiruvananthapuram, pp 38 - 41.

Zaller, J. G. 2007. Vermi compost in seedling potting media can effect germination, biomass allocation, yield and fruit quality of three tomato varieties. *European J. Soil. Biol.* 43(1): 332-336.

STANDARDISATION OF NURSERY TECHNIQUES THROUGH FIELD VALIDATION IN MINISETT CASSAVA (*Manihot esculenta* Crantz).

by

SRUTHY K.T.

(2016 - 11 - 007)

Abstract of the thesis

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2018

ABSTRACT

The investigation entitled "Standardisation of nursery techniques through field validation in minisett cassava (*Manihot esculenta* Crantz.)" which consisted of a nursery experiment (April 2017 to June 2017) and a field experiment (April 2017 to January 2018) was conducted at College of Agriculture, Vellayani, Thiruvananthapuram. The objectives were to standardise the cassava minisett nursery technique by validating its field performance in comparison with normal sett planting and to work out the economics of cultivation.

The nursery experiment was conducted in the Instructional Farm, College of Agriculture, Vellayani. Minisetts of cassava, var. *Vellayani Hraswa* were raised in protrays (50 cavity) with six treatment combinations in eight replications as Completely Randomised Design. The treatments comprised two types of minisett cuttings (m_1- two node cutting and m_2 - three node cutting) and three types of potting media (p_1 - normal top soil, p_2 - normal top soil and coir pith compost in 1:1 ratio and p_3 - coir pith compost and vermi compost in 3:1 ratio). The field experiment was laid out in the Instructional Farm, Vellayani with 18 treatment combinations replicated thrice in Randomised Complete Block Design with the two types of minisett cuttings (m_1 and m_2) and three types of potting media (p_1, p_2 and p_3) tried in the nursery and three different time of transplanting of minisetts to the main field ie. t_1 - 3 WAP (weeks after planting), t_2 - 4 WAP and t_3 - 5 WAP as treatments and normal sett planting as control. The minisetts and normal setts were planted at a spacing of 90 cm x 90 cm.

The results of the nursery experiment revealed that the three node cutting (m_2) recorded significantly higher seedling sprouting (92.26 per cent), shoot length (7.26, 9.62 and 11.10 cm), shoot biomass (4.08, 4.63 and 5.06 g seedling^{-1}), root length (8.09, 12.40 and 16.04 cm) and root biomass (0.46, 0.73 and 0.85 g seedling^{-1}) at 3 WAP, 4 WAP and 5 WAP respectively when compared to the two node cutting (m_1). The potting medium p_3 recorded significantly higher shoot length, shoot biomass seedling^{-1}and root biomass seedling^{-1} at 3 WAP, 4 WAP

and 5 WAP and had significantly higher root length at 3 WAP and 4 WAP than other potting media. The results on M x P interaction indicated that when three node cuttings were raised in potting medium p_3 (m_2p_3), the highest shoot length, shoot biomass seedling^{-1} and root biomass seedling^{-1} were recorded at 3 WAP while it recorded the highest root length at 3 WAP and 4 WAP .

Growth and growth attributes *viz.*, seedling establishment, plant height, stem girth and number of functional leaves plant^{-1} at monthly interval and the leaf area index at 3 MAP (months after planting) were significantly higher for the three node minisett cuttings transplanted at an age of three weeks from nursery than two noded minisetts transplanted at an age of four or five weeks. The seedlings raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio (p_3) produced significantly taller plants at all stages of observation except 4 MAP besides significantly higher stem girth at 1MAP (1.73 cm), number of functional leaves plant^{-1} at all stages of observation and leaf area index at 3 MAP (2.56).

The study revealed that the three node cutting (m_2) was significantly superior in terms of yield attributes and yield *viz.*, length of tuber (45.99 cm), girth of tuber (23.92 cm), mean weight of tuber (668.18 g), tuber yield plant^{-1} (3.90 kg), tuber yield (39.25 t ha^{-1}), top yield (13.86 t ha^{-1}) and total dry matter production (13.76 t ha^{-1}). The potting media p_3 produced significantly higher tuber yield plant^{-1} (3.91 kg), tuber yield ha^{-1} (37.92 t), top yield (13.24 t ha^{-1}) and total dry matter production (13.82 t ha^{-1}). Cassava minisetts transplanted at 3 WAP was significantly superior with respect to yield attributes and yield. Three node cuttings raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio, transplanted at 3 WAP ($m_2p_3t_1$) recorded significantly higher mean weight of tuber (867.15 g), tuber yield ha^{-1}(44.83 t), top yield (15.75 t ha^{-1}), net income (₹ 6,92,267 ha^{-1}) and benefit cost ratio (4.39). The uptake of nitrogen and phosphorus were higher with m_2 (three node cutting) ,while the uptake of phosphorus alone was higher with p_3 and uptake of nitrogen, phosphorus and potassium was found to be higher with t_1 (transplanted at 3

WAP). Comparing minisetts with normal sett planting (control), the former was found to be superior in seedling establishment, plant height at all stages of observation, leaf area index at 3 MAP, percentage of productive roots, length and mean weight of tuber, tuber yield plant^{-1}, tuber yield ha^{-1}, top yield ha^{-1}, total dry matter production ha^{-1} and economics of cultivation.

The results of the study indicated that raising three noded minisett cassava cuttings in potting medium containing coir pith compost and vermi compost in 3:1 ratio in the nursery followed by transplanting at 3 WAP was found to be economically and technically viable nursery technique for getting higher yield and income from cassava cultivation compared to the conventional practice of planting normal setts directly in the main field.

സംഗ്രഹം

"മരച്ചീനിയുടെ മിനിസെറ്റ് നഴ്സറി സമ്പ്രദായത്തിന്റെ ക്രമീകരണം തുറസ്സായ കൃഷിസ്ഥല സ്ഥിതീകരണത്തിലൂടെ" എന്ന വിഷയത്തെ സംബന്ധിച്ചു ഒരു പഠനം 2017-2018 കാലയളവിൽ വെള്ളയാണി കാർഷിക കോളേജിൽ വച്ച് നടത്തുകയുണ്ടായി. മരച്ചീനിയിലെ മിനിസെറ്റ് നഴ്സറി സമ്പ്രദായം സാധാരണ തണ്ട് ഉപയോഗിച്ചുള്ള നടീൽ രീതിയുമായി താരതമ്യം ചെയ്യുക, കൃഷി ചിലവ് കണക്കാക്കുക എന്നിവ ആയിരുന്നു പഠന ലക്ഷ്യങ്ങൾ.

പഠനത്തിനായി രണ്ടു രീതിയിലുള്ള മിനിസെറ്റുകളും (രണ്ടു മുളകൾ ഉള്ള മിനിസെറ്റ് , മൂന്ന് മുളകൾ ഉള്ള മിനിസെറ്റ്) മൂന്ന് രീതിയിലുള്ള പ്രോട്രേയ് മിശ്രിതങ്ങളും (മേൽമണ്ണ് , മേൽമണ്ണും ചകിരിച്ചോർ കമ്പോസ്റ്റും 1:1 അനുപാതം ,ചകിരിച്ചോർ കമ്പോസ്റ്റും മണ്ണിര കമ്പോസ്റ്റും 3:1 അനുപാതം) തയ്യാറാക്കി. തുടർന്നു മിനി സെറ്റുകൾ മേല്പറഞ്ഞ മിശ്രിതങ്ങൾ നിറച്ച 50 കുഴികളുള്ള പ്രോട്രേയിൽ നട്ടതിനു ശേഷം തണലിൽ സൂക്ഷിക്കുകയുണ്ടായി.

ചകിരിച്ചോർ കമ്പോസ്റ്റും മണ്ണിര കമ്പോസ്റ്റും 3:1 അനുപാതത്തിൽ ഉള്ള മിശ്രിതത്തിൽ വളർത്തിയ മൂന്ന് മുളകൾ ഉള്ള മിനിസെറ്റ് തൈകൾ, തണ്ടുകളുടെയും വേരുകളുടെയും നീളത്തിലും ഭാരത്തിലും സാധാരണ തണ്ടുകളിൽ നിന്നും വളർത്തിയ മരച്ചീനി തൈകളെക്കാളും മുന്നിട്ട് നിന്നു

നഴ്സറിയിൽ വളർത്തിയ മിനിസെറ്റ് തൈകൾ മൂന്ന് വ്യത്യസ്ത സമയങ്ങളിൽ (നട്ടു മൂന്ന് ആഴ്ചക്ക് ശേഷം, നട്ടു നാല് ആഴ്ചക്കു ശേഷം, നട്ടു അഞ്ചു ആഴ്ചക്കു ശേഷം) തുറന്ന കൃഷി സ്ഥലത്തേക്ക് മാറ്റി നട്ടു. മാറ്റി നട്ട മിനിസെറ്റ് തൈകളിൽ ,മൂന്നാഴ്ചക്കു ശേഷം നട്ട മൂന്ന് മുകുളങ്ങളുള്ള ചകിരിച്ചോർ കമ്പോസ്റ്റും മണ്ണിര കമ്പോസ്റ്റും 3:1 അനുപാതത്തിൽ ചേർത്ത മിശ്രിതത്തിൽ വളർത്തിയ തൈകൾക്കായിരുന്നു വളർച്ച കൂടുതൽ.

കിഴങ്ങിന്റെ വലുപ്പത്തിലും വിളവിലും മേല്പറഞ്ഞ മിനിസെറ്റ് തൈകൾ മുന്നിട്ട് നിൽക്കുന്നതായി കണ്ടെത്തി.

ചകിരിച്ചോർ കമ്പോസ്റ്റും മണ്ണിര കമ്പോസ്റ്റും 3:1 അനുപാതത്തിൽ തയ്യാറാക്കിയ പ്രോട്രേയ് മിശ്രിതത്തിൽ വളർത്തിയ മൂന്ന് മുളകളുള്ള മരച്ചീനി മിനിസെറ്റ് തൈകൾ മൂന്നാഴ്ചക്കു ശേഷം തുറന്ന കൃഷി സ്ഥലത്തേക്ക് നടുന്ന കൃഷി രീതി സാധാരണ മരച്ചീനി തണ്ടുകൾ ഉപയോഗിച്ചുള്ള കൃഷി രീതിയെക്കാൾ വിളവിലും അറ്റാദായത്തിലും വരവ് ചിലവ് അനുപാതത്തിലും മുന്നിട്ടു നിൽക്കുന്നതായി രേഖപ്പെടുത്തി.

APPENDICES

APPENDIX - I

Weather parameters during the cropping period (April-2017 to January 2018)

Month	Temperature (°C)		Relative Humidity (%)		Bright sunshine hours	Rainfall (mm)	Evaporation (mm)
	Max.	Min.	Max.	Min.			
April-2017	34.57	26.18	87.62	72.62	9.77	0.00	5.62
May-2017	33.66	25.54	89.25	76.12	9.02	233.00	4.51
June-2017	31.40	24.50	92.29	80.50	7.90	278.70	3.90
July-2017	31.60	24.70	90.61	77.00	8.50	48.70	4.00
August-2017	30.50	24.60	92.16	78.32	7.70	93.00	3.70
September-2017	31.50	24.50	92.50	78.93	7.70	297.80	3.60
October-2017	31.10	24.90	94.50	84.90	7.20	221.60	3.60
November-2017	30.80	24.20	94.90	82.50	5.20	193.20	3.00
December-2017	31.80	23.40	94.66	77.38	7.20	173.70	3.30
January-2018	31.70	21.79	93.54	73.73	8.51	0.00	3.98

APPENDIX – II

Cost of cultivation of cassava

Sl. No.	Particulars	Two nodedminisetts			Three nodedminisetts			Normal setts		
		Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})	Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})	Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})
1	Planting material (setts)	450 stems	3 m^{-1}	1350	620	3 m^{-1}	1860	2470	3 m^{-1}	7410
2	Protray	260	*6 $protray^{-1}$	1560	260	6	1560	-	-	-
3	Coir pith compost	350 kg	8 kg^{-1}	2800	350	8 kg^{-1}	2800	-	-	-
4	Vermi compost	100 kg	20 kg^{-1}	2000	100	20 kg^{-1}	2000	-	-	-
5	Labourers	192	741	142272	192	741	142272	180	741	133380
6	Fuel charge	16 hr	700 h^{-1}	11500	16 hr	700 h^{-1}	11500	16 hr	700 h^{-1}	11500
7	Stem cutting machine	1	2000	2000	1	2000	5000	-	-	-
8	Farm Yard Manure	12500 kg	2.5 kg^{-1}	31250	12500 kg	2.5 kg^{-1}	31250	12500 kg	2.5 kg^{-1}	31250
9	Urea	109 kg	7 kg^{-1}	763	109kg	7 kg^{-1}	763	109kg	7 kg^{-1}	763
10	Rajphos	250 kg	20 kg^{-1}	5000	250 kg	20 kg^{-1}	5000	250 kg	20 kg^{-1}	5000

Cost of cultivation of cassava (Continued)

Sl. No.	Particulars	Two nodedminisetts			Three nodedminisetts			Normal setts		
		Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})	Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})	Units (ha^{-1})	Unit cost (₹)	Total cost (₹ha^{-1})
11	Muriate of potash	167 kg	14 kg^{-1}	2338	167 kg	14 kg^{-1}	2338	167 kg	14 kg^{-1}	2338
12	Plant protection chemicals			1000			1000			1000
Two nodedminisett cutting raised in potting mediium containing normal top soil				199033	Three nodedminisett cutting raised in potting medium containing normal top soil		199543	Normal sett planting		192641
Two nodedminisett cutting raised in potting medium containing top soil and coir pith compost in 1:1 ratio				201833	Three nodedminisett cutting raised in potting medium containing top soil and coir pith compost in 1:1 ratio		202343			
Two nodedminisett cutting raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio				203833	Three nodedminisett cutting raised in potting medium containing coir pith compost and vermi compost in 3:1 ratio		204343			
Produce – Market price of cassava -₹ 20 kg^{-1}										

*Unit cost is for protray^{-1} season^{-1}