NUTRIPRIMING AND MAT THICKNESS ON TRAY NURSERY IN RICE

by

ANCY U. A.

(2014-11-125)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2016

DECLARATION

I, hereby declare that the thesis entitled **"Nutripriming and mat thickness on tray nursery in rice"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 07/10/2016

Ancy U. A.

(2014-11-125)

CERTIFICATE

Certified that thesis entitled **"Nutripriming and mat thickness on tray nursery in rice"** is a bonafide record of research work done independently by **Ms. Ancy U. A. (2014-11-125)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

Date : 07/10/2016

Dr. A. Latha

(Major advisor, Advisory Committee)

Professor (Agronomy)

Agriculture Research Station,

Kerala Agricultural University

Thrissur, Kerala

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Ancy U. A. (2014-11-125)**, a candidate for the degree of **Master of Science in Agriculture**, with major field in **Agronomy**, agree that the thesis entitled **"Nutripriming and mat thickness on tray nursery in rice"** may be submitted by **Ms. Ancy U. A.**, in partial fulfillment of the requirement for the degree.

Dr. A. Latha
(Chairperson, Advisory Committee)
Professor (Agronomy)
Agriculture Research Station
Mannuthy

Dr. C. George Thomas
(Member, Advisory committee)
Professor and Head
Department of Agronomy
College of Horticulture
Vellanikkara

Dr. U. Jaikumaran
(Member, Advisory committee)
Professor and Head
Agriculture Research Station
Mannuthy

Dr. P. Sureshkumar
(Member, Advisory committee)
Professor and Head
Radio Tracer Laboratory
College of Horticulture
Vellanikkara

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

Words are insufficient to express gratitude and indebtedness. Though, it is an attempt to remember the faces with a sense of gratitude. So many have been with me on the path traversed during the two year journey!

"To the end that my heart may sing praise to You, and not be silent. Lord my God, I will give thanks to you forever" (Psalms 30: 12)

First and foremost I bow my head before the ***Almighty God*** *for his blessings, providing me favourable conditions and making me confident throughout my life and enabled me to successfully complete the thesis work in time.*

It is with immense pleasure I avail this opportunity to express my deep sense of whole hearted gratitude and indebtedness to my major advisor ***Dr. A. Latha****, Professor, Agriculture Research Station, Mannuthy for her candid advice, ever present help, motherly guidance, valuable suggestions, constructive criticisms and above all, understanding and wholehearted co-operation rendered throughout the course of my study. I really consider it my greatest fortune in having her guidance for my research work and my obligation to her lasts forever. I owe her more than I could care to admit.*

No expression of thanks will be sufficient to recognize the patronage bestowed upon me by the members of my advisory committee. I consider it as my privilege to express my deep-felt gratitude to ***Dr. C. George Thomas****, Professor and Head, Dept. of Agronomy for his constant support, valuable suggestions, cooperation throughout the research programme and critical scrutiny of the manuscript. I thank him for all the help and cooperation he has extended to me. I am deeply obliged to* ***Dr. U. Jaikumaran****, Professor and Head, Agriculture Research Station, Mannuthy for his invaluable help, guidance and critical assessment throughout the period of work. I express my heartfelt thanks to* ***Dr. P. Sureshkumar****, Professor and Head, Radiotracer Laboratory for his constant encouragement, critical evaluation, expert advice and support throughout the conduct of experiment and preparation of the thesis.*

My heartfelt thanks to my beloved teachers ***Dr. P. S. John, Dr. C. T. Abraham, Dr. P. A. Joseph, Dr. K. E. Savithri, Dr. P. Sreedevi, Dr. E. K. Lalitha Bai, Dr. Meera V. Menon, Dr. P.***

Prameela, Dr. K. P. Pramila, Dr. K. E. Usha, Dr. P. V. Sindhu and **Dr. S. Anitha** for their encouragement, valuable help , constant inspiration and advice rendered during the course of my study which helped in successful completion of this work..

I express my gratitude to **Sri. S Krishnan**, Associate Professor and Head, Dept. of Agricultural Statistics, College of Horticulture, for his valuable assistance, immense help and guidance during the statistical analysis of the data. I am also thankful to **Dr. Jayasree Shankar**, Professor and Head, Dept. of Soil Science and Agricultural Chemistry for her expert advice and precious suggestions especially during physico-chemical analysis. I express my heartfelt gratitude to **Dr. P. K. Sushama** and **Dr. Beena V. I.** from the Department of Soil Science and Agricultural Chemistry for their sincere support during the course of study. I am deeply obliged to, **Dr. Surendragopal** for his generous valuable suggestions during my study. I am also thankful to **Dr. Nirmaladevi, Dr. Jessy** and **Dr. Dijee Bastian** for providing the necessary facilities to complete this study.

I express my heartful thanks to all the members of **ARS, Mannuthy**, especially **Dr. Shyla Joseph, Biju sir**, Food Security Army executives, labour chechees and chetas for their constant help and support.

I am grateful to **Mrs. Sreela and Mrs. Syamala**, Lab assistants, Dept. of Agonomy, **Mr. Arun, Mrs. Geetha and Mrs. Devi** Teaching assistants cum Lab Technicians Dept. of Soil Science and Agricultural Chemistry, College of Horticulture, for their immense help and cooperation during the laboratory work.

I owe my ecstatic thanks to my beloved senior **Ms. Greeshma V. Mathew** for her words of advice, encouragement and timely help whenever approached. I duly acknowledge the encouragement, moral support, precious suggestions and timely persuasions by my dear seniors **Mrs. Savitha, Mrs. Syama, Mrs. Kavitha, Mrs. Indulekha, Ms. Vandana, Mrs. Sreelakshmi, Mr. Rajanand, Ms. Sreedhu, Ms. Shahanila, Ms. Ammu, Ms. Ashly, Mr. Faras** and **Mr. Quwat Ali**. I am in dearth of words to express my sincere thanks towards my classmates **Archana, Atheena, Rameesa, Reshma** and **Yansing** for their affection and kind help offered during not only in my research work but also throughout my PG programme. I have infinite pleasure to express whole hearted thanks to **Aristaeus'10** and **Fortuners'14** friends for their moral support and encouragement. Immense thanks to **Ashly, Priyanka S. Chandran,**

Jyolsna, Rajasree, Sameer and **Mrs.Sindhu** for their unconditional support, help, timely valuable suggestions and encouragement which gave me enough mental strength and perseverance to get through all odds and tedious circumstances. I thank all my dear juniors **Ayishamol, Dhanalakshmi, Shamla, Aparna, Lakshmi, Anjana, Akhil,** and **Abid** for their innumerable help and support. I am thankful to all my seniors and juniors of College of Horticulture for their kind co-operation, care support and continuous encouragement.

I owe special thanks to **library of College of Horticulture, Kerala Agricultural University central library, Dr. A. T. Francis** and all other staff members of Library, who guided me in several ways, which immensely helped for collection of literature for writing my thesis. Very many thanks are also due to **Students'computer** club and **Office of College of Horticulture.**

The financial and technical support provided by **Kerala Agricultural University** is also highly acknowledged.

All the words in lexicon will be futile and meaningless if I fail to reveal my extreme sense of regards to **my amma, appa, family** and **relatives** for their sacrifices, moral support, eternal love, deep concern, prayers and blessings has been giving at every moment of my life.

A word of apology to those I forgot to mention here. Once again I express my sincere thanks to all those who supported my humble attempt in one way or another and tried to make it success.

Ancy U. A.

Dedicated to "all the farming families who work hard from dawn to set for feeding the world"

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List of abbreviations

@	:	at the rate of
CD	:	Critical Difference
CPC	:	Coir pith compost
CRD	:	Completely Randomised Design
DAS	:	Days after sowing
DAT	:	Days after transplanting
DMRT	:	Duncan's Multiple Range Test
et al.	:	and co-workers
etc.	:	etcetera
FYM	:	Farm Yard Manure
ha	:	Hectares
i.e.	:	that is
KAU	:	Kerala Agricultural University
NS	:	Not significant
RBD	:	Randomised Block Design
RHC	:	Rice husk charcoal
S	:	Significant
VC	:	Vermicompost
viz.	:	Namely
%	:	per cent

INTRODUCTION

I. INTRODUCTION

Rice has an exalted position among other cereals as it feeds major share of population. In Asia, more than two billion people depend on rice and its products for 60-70 per cent of their calorie requirement (FAOSTAT, 2014). India stands first in area under paddy (43.95 million ha) and second in terms of production (106 million tonnes) (GOI, 2015). Being the staple food for more than 62 per cent of population, it has a pivotal role in our national food security. The country has to achieve production of about 140 million tonnes of rice by 2025 to meet the food requirement of exploring population (Chandrasekaran *et al.*, 2008). Increase in rice productivity with development of sustainable low cost technologies can pave way for achieving food security in the present scenario of shrinking agricultural land.

Depending upon the availability of water, rice can be cultivated either by transplanting seedling in flooded field conditions or by direct sowing (Ganapathy and Kumar, 2015). Johnkutty *et al.* (2002) reported better crop establishment of rice under transplanting. Paddy cultivation is labour intensive. Transplanting requires about 250-300 working hours/ ha which is roughly 25 percent of the total labour requirement of its cultivation (Singh *et al.*, 1985). Farm labour has become scarce and costly during last few years. In the context of labour shortage and growing commercialization of agriculture, mechanization is very important for ensuring timeliness and precision of operations. Even though there is a perceptible improvement in agricultural mechanization in India it is still evolving. Mechanized rice cultivation can play a crucial role in transforming rice production in the country.

In Kerala paddy is being cultivated in almost all districts during the three unique seasons of *Virippu, Mundakan* and *Puncha*. It occupies 1.98 lakh ha with the production of 5.62 lakh tonnes with an average productivity of 2733 kg ha^{-1} (GOK, 2016). Kerala is facing severe paddy crisis due to labour shortage. Rice cultivation needs as much as 1000-1200 man hours per ha of labour input in Kerala compared to 800 working hours per ha in other states in India (Veeramani, 2010).

Mechanized paddy cultivation is an accessible solution to overcome shortage of labour. Mechanization saves time, money and labour.

Paddy cultivation needs appropriate mechanization to cope up with the increased cost of cultivation due to high wages and shortage of labourers. Mechanical transplanting of rice seedling is the key link to the entire mechanization of paddy cultivation. Transplanting of rice seedlings using machines has been explored since late 90's in our country. However, mechanized transplanting is not widely adopted. Nursery raising with specific technique is inevitable for mechanical transplanting. Lack of proper standardization of tray nursery production technologies appears to be a hurdle against the appropriate exploitation of transplanting machineries. Early germination, better seedling development, uniform crop establishment and good strength of mat are major determinants of good quality tray nursery for proper mechanical transplanting. Poor nursery quality reduces efficiency of mechanical transplanting and field performance of crop.

The experiments conducted at the Agricultural Research Station, Mannuthy to standardize the media for tray nursery revealed several constraints in mechanical transplanting, *viz.* low mat thickness, non-binding of the media and deficiency of nutrients in the seedlings (Rajesh, 2003; Mathew, 2015). Soil media used for mat nursery is costly and heavy to carry. Substitution of soil media with locally available low cost materials like rice husk charcoal, vermicompost and coir pith compost is possible (Islam, 2008; Lazcano *et al.*, 2009). Reduction of media thickness without hindering quality of seedlings is a way to produce light weight seedling mats. Use of light weight materials as growing media can reduce labour requirement because of less effort in handling of seedling trays (Ko *et al.*, 2005). Economic viability without compromising seedling quality must also be considered. Thus, production of low cost nursery with easily available light weight materials will lead to wider acceptance of the technology and cost reduction of rice cultivation. Standardization of media and mat characteristics for easy transport of nursery and smooth transplanting will help to revive the paddy cultivation of Kerala.

Both micro and macro nutrients are inevitable for crop production and pertinent for higher yield. Imbalance or lack of any essential element causes suppression or complete inhibition of plant growth (Mengel *et al.*, 2001). A survey conducted as a part of the project entitled 'Soil based plant nutrient management plan for agro-ecosystems of Kerala' by Kerala State Planning Board reported widespread deficiency of Zn and B in soils of Kerala.

Nutrient supplement through seed is a method of nutrient supplementation for crops. Seed priming may be effective technique to tackle nutrient deficiency problems. It is a simple and low cost technique for improved germination, seedling growth and increased yield (Yilmaz *et al.*, 1998) and also be practiced to overcome micro and macro nutrient deficiencies of soil (Harris *et al.*, 1999). Nutripriming is a novel seed invigoration technique which includes restricted hydration of seeds in nutrient solution and drying process (Farooq *et al.*, 2011). Rice continues to be an avenue to sustain food security of the country and hence there is need to increase the nutritional status of the grain also. Sufficient nutrient supply can improve nutrient status of plants as well as grains and thereby helps to meet the nutritional requirement of human beings.

Production of paddy tray nursery with reduced cost, easiness in transport, healthy seedlings and quality nursery for easy planting will streamline the commercial production of paddy mat nursery for the supply of ready to transplant mat nursery trays. Agricultural Research Station, Mannuthy is set to begin the commercial production of paddy mat nursery using 'Automatic Paddy Mat Nursery Sowing Machine'. Commercialization of mat nursery can become a driving force for increased area of rice cultivation in Kerala.

So far various techniques have been studied for the production of tray nursery in rice with different media and nutrient supplements. However, knowledge on the specific influence of thickness of media on growth and nutritional status of rice seedlings in nursery and nutripriming as a nutritional supplementation technique are limited. The present study is focused on standardization of growing media, thickness and nutripriming techniques for best performing, low cost and light weight tray nursery for rice. The investigation is proposed with the following objectives:

1. To standardize growing media composition and thickness for tray nursery technique in rice
2. Selection of suitable nutripriming technique for production of best performing seedlings
3. To evaluate the efficiency of nursery media and nutripriming technique under field condition

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

"Rice for life"- the slogan is very much relevant with regard to Kerala as rice is the staple food for people of the state. However, presently we are witnessing a steady decline in paddy area over the year from 8.76 lakh ha in 1975-76 to 1.98 lakh ha in 2015-16 (GOK, 2016). High average daily minimum wages for agricultural workers in Kerala compared to all other states of India is one of the key factors for the situation. Agricultural mechanisation is still at its infant stage in the state. The possibilities with respect to the use of machineries for cultivation of paddy in Kerala should be exploited. Mechanised rice cultivation is a step with the goal of production enhancement keeping labour scarcity, timeliness in operation and cost reduction in mind.

2.1 MECHANISED TRANSPLANTING OF RICE

Transplanting of rice seedlings is the most widely practicing rice planting system. Manual transplanting is a labour intensive operation consisting of nursery raising, uprooting of the seedlings, transportation and transplanting of seedlings in the main field, with a total labour requirement of about 280-350 man h/ha. Transplanting was found to be a tedious operation for the majority of farm labourers. High demand of labour during peak transplanting period adversely influences the timeliness of transplanting and thereby leads to reduction in crop yield (Sharma and Singh, 2008). A delay in transplanting alone causes about 15 per cent reduction in total rice production (Ponnuswamy *et al.,* 1999). However, Islam *et al.* (2008) reported 9 per cent yield reduction due to the delay in transplanting from normal date. To overcome these problems, mechanical transplanting can be considered as a promising option. Large area can be covered within a short duration of time by the adoption of mechanized transplanting. Experiments on efficiency of farm mechanization reported that appropriate exploitation of mechanization helps to save time of 20-30 per cent, seeds of 15-20 per cent, fertilizer of 20-30 per cent, labourers of 5-20 per cent and increase in cropping intensity of 10-15 per cent and hence higher productivity of 15 - 20 per cent (Singh, 2008). Mechanical transplanting of rice was initiated by 1970s and

1980s in Japan and Korea, respectively (Haytham *et al.*, 2010). They also developed new technologies for raising seedling for rice transplanter (Tasaka *et al.*, 1996).

There are ample opportunities for the use of machineries which leads to a considerable reduction in the cost of cultivation of rice in Kerala as the wage rates of this state are the highest in India (James *et al.,* 1996). In the present scenario, mechanized rice farming is regarded as the most important ingredient for sustaining cultivation of rice in the state. However, a survey conducted by Balachandran (2004) at Palakkad district and *Kole* area of Kerala found that mechanical transplanters were quite new to the farmers of the region. There is low usage of this device, even though it was labour saving and efficient. Paddy transplanter was less popular in the *Kole* than in Palakkad region due to the unavailability of the implements suitable to the *Kole* land condition and lack of awareness of the farmers about these machines. According to Sharma and Singh (2008) the major constraint in the adoption of mechanical transplanters is the complex and labour intensive technique of raising mat type nursery in frames on perforated plastic sheets.

A study to assess the performance of self-propelled rice transplanter and its effect on yield showed that the number of productive tillers per hill, panicle length and number of grains per panicle were higher under mechanized transplanting than manual transplanting due to transplanting of younger seedlings with uniform spacing (Manjunatha *et al.,* 2009). Higher number of productive tillers per hill (14.2) and number of filled grains per panicle (115) was also recorded which ultimately increased yield by 10 per cent under mechanized transplanting. Increased number of panicles per hill and fertile grains per panicle under mechanical planting was also reported by Sheeja *et al.* (2012). Mechanically transplanted rice stabilizes the yield and maintains high efficiency (Yajie *et al.*, 2013).

Pasha *et al.* (2014) while studying the different crop establishment techniques *viz.* machine transplanting, drum seeding, broadcasting and conventional transplanting in puddle condition noticed that the machine transplanting led to the maximum panicle length, number of grains per panicle and the grain yield.

2.2 MAT NURSERY OF RICE

Paddy mat nursery is a necessary requirement for mechanised paddy transplanting where paddy seedlings form a dense mat of root. It can be rolled into a cylindrical shape for transportation and later it can be easily fed directly into the transplanter. Requirement of size of tray nursery varies according to the dimensions of seedling platform of transplanter. Rice seedlings have been raised using seedling trays for machanized transplanting since 1970s in Korea. Mat nursery is especially suitable for rainfed lowland rice areas where it can be started when the main field is flooded and ready for land preparation. Modified mat nursery saves costs on seed (85-90 per cent), fertilizer (90 per cent), labour (34 per cent) and water (55 per cent) compared to the traditional rice wet nursery. The young seedlings of modified rice mat nursery out yielded the aged traditional nursery seedlings and achieved the maximum benefit: cost ratio. It is therefore highly economical and affordable to farmers (Rajendran *et al.*, 2005).

Rajesh (2003), while conducting a field experiment at Agricultural Research Station, Mannuthy to standardize production technology of rice mat nursery observed that the mechanical or manual transplanting with mat nursery derived better economic return compared to manual transplanting using conventional nursery. Based on this standardization experiment production technology of mat nursery has been included in the Package of Practices Recommendations Crops of Kerala Agricultural University (KAU, 2007).

Pasuquin *et al.* (2008) found that the timing of tiller emergence and grain yield was not significantly influenced by nursery types such as seedling tray, dapog, mat nursery, and traditional wet-bed seeding in a series of experiments conducted at IRRI. However, plant dry weight, specific leaf area and N content was higher in the case of dapog and wet bed nursery and maximum tillering was higher in the case of the seedling tray.

However, in field experiment carried out at Tamil Nadu Agricultural University to evaluate the performance of mat and conventional nursery methods reported that the growth and yield of rice were not influenced by nursery methods (Baskar *et al.*, 2012).

2.2.1 Mat nursery raising machine

Manual preparation of paddy mat nursery often creates problem of uneven seed distribution. Non uniform plant population in the mat adversely affects the efficiency of mechanical transplanters and also the performance of crop. With a view to reduce the drudgery in mat nursery preparation several attempts has been taken to design a device to fill the nursery box automatically. A prototype of mat nursery raising machine was developed at Indonesian Center for Agricultural Engineering Research and Development, Serpong, Indonesia for filling of soil and distribution of seeds in the nursery box. There are cylindrical type soil and seed metering devices which along with speed of belt conveyor determines filling and seed distribution mechanism. This machine has ability to fill base soil of 2 cm depth and then distribute 150 g seeds uniformly above the base soil and finally cover with thin soil layer at 0.5 cm thickness. Machine has capacity to fill 100 boxes per hour (Harjono and Handaka, 2007).

In India, a mat type nursery raising device was designed at G.B. Pant University of Agriculture and Technology for the easiness of nursery preparation and even plant population. Sharma and Singh (2008) evaluated the performance of the device. The device performed well and gave the density of 80-100 g seed per mat with three passes of the device at 1.03 mm sprout length. Throughout the length of the mat the thickness of the soil layer was maintained to 20 mm, as required in a single pass. Labour and time was reduced by 33.33 and 72 per cent, respectively, over the manual method. The cost of raising mat type nursery was Rs.299 for one hectare (400 mats) compared to Rs. 1,608 with manual method.

Commercially, a model of mat nursery sowing machine has been introduced by Redlands Company named as 'Redlands automatic rice mat nursery sowing machine RNM 600'for large scale production of paddy mat nursery. Machine consists of three hoppers: one for media delivery, second for seed distribution and third one for covering of surface layer of media over the seeds. Trays were filled by passing through the conveyor belts of this electric motor powered machine. Quantity of media and seed were adjusted according to the treatment requirements. Water was sprinkled over the surface soil layer from the pipe system. Efficiency of the machine is about 600-800 trays/hour. This machine was tested and introduced first in Kerala by Agricultural Research Station, Mannuthy, Thrissur (Anon., 2012).

2.3 NURSERY GROWING MEDIA

According to Bilderback *et al.* (2005) growing media have three main functions *viz.* provide aeration and water, allow for maximum root growth and physically support the plant. Large particles with adequate pore spaces between the particles are ideal for growing media. Appropriate combination is critical for a light and well-aerated medium that promotes quick germination of seed, strong root growth and adequate water drainage (Olle *et al.*, 2012). Successful production of container grown plants is influenced by the physical and chemical properties of the growing media. Availability of many nutrients depends on media pH. Optimum pH of a growing medium varies with plant species, but in general it ranges from 5.0 to 6.5 (Fitzpatrick, 2001). A number of critical chemical and physical properties have to be evaluated before making a final media composition.

2.3.1 Characteristics of soilless growing media and its influence on growth of seedlings

The soilless growing media is getting wider acceptance and becoming an inevitable part of present agriculture. It is an artificial means of providing plants with adequate water, nutrients and support from a reservoir other than soil. Compared to conventional soil culture there are several advantages of soilless culture due to poor structure, poor drainage, and salinity problems of soil. Apart from that soil borne pathogens are also creates a great problem. Substrate plays a crucial role in emergence of seedlings, because seed has characteristic requirements for oxygen and moisture for germination (Justice, 1972). Nowadays, raising plants in soilless media is increasing considerably as a result of the non-suitable conditions of soil. Several characteristics have to be considered while selecting materials for soilless growing media. The best substrate can provide maximum productivity at less expense. Very limited information is available in India on selection of appropriate soilless growing media (Murumkar *et al.*, 2012). Growing media or substrates include all materials that can be used to grow plants either under greenhouse cultivation or urban agriculture (Cao *et al.*, 2014).

Substrate needs to be non- toxic, free of pathogens or moulds with adequate moisture and aeration for germination of seeds. Justice (1972) concluded that higher germination in FYM is due to the non-toxicity of compost, rich NPK and has adequate aeration and moisture for germination of seeds. These properties can be balanced by manipulating the percentage composition of components in the growing medium. Marschner (1995) reported that the shoot dry weight of plant mainly depends on the nutrient concentration in the growing media, and other chemical, physical and microbiological conditions which influences root activity and formation of new roots. In natural vegetation the shoot dry weight decreases with decrease in soil fertility. According to Cantliffe *et al.* (2003) characteristics to be taken care while selecting materials for soilless growing media are high water holding capacity, good drainage, high ionic exchange capacity and absence of weeds, pathogens and pests. Dewayne *et al.* (2003) opined that among the physical properties, total porosity and water holding capacity are probably the most crucial factors whereas, chemical characteristics such as pH, EC and nutritional status of the media mixture play a pertinent role in the plant development. Along with the above mentioned properties the components used in the media should be accessible, less expensive, preferably organic (Shaw *et al.*, 2004) and rich in organic matter (Kukal *et al.*, 2012). Local experience on its use is also important as it directly influence the development and maintenance of the functional rooting system of plant (Murumkar *et al.*, 2012). The greater advantage of the organic matter based media over the soil alone is the slow release of macro and micro-nutrients during the period of growth (Mamun *et al.*, 2013). According to Basmanj *et al.* (2016) an ideal growing media also need to be sufficiently light weight material in order to handle easily and the transportation should be economically reasonable.

Shaw *et al.* (2004) found that cucumber raised in medium-grade perlite yielded more marketable fruit than those raised in coarse-grade perlite, pine bark, and peat moss as soilless media.

A pot culture experiment was conducted under greenhouse conditions to evaluate the bioefficacy of coir pith on anthurium cultivars Agnihotri and Lima White. The combination of coarse sand, coconut husk and coir pith in a 1:1:1 ratio and that of coarse sand, coconut husk, cow dung and coir pith in a 1:1:1:1 ratio were the best substrates for anthurium cultivation under greenhouse conditions, improving the vegetative (plant height, number of leaves per plant and total leaf area) and floral characters (peduncle length, spathe length and breadth, candle length and number of spadices per plant) of both cultivars (Suharban *et al.*, 2004).

Expanded rice hull is cheaper and light weight material. A reduction in the labour requirement is possible by using expanded rice husk as a media for growing rice seedlings, because of less effort in handling due to light weight of seedling trays. Expanded rice hull based rice seedling media may differ from soil based media in buffering ability for chemicals in the media. (Ko *et al.*, 2005). Oselebe *et al.* (2008) found that soilless media was the fastest means of plantlet generation for *Musa* spp. at the farm level.

Saw dust based media 1:4:3 and 1:2:3 (saw dust: poultry manure: river sand) exhibited superior performance in terms of growth parameters such as height, seedling girth, number of compound leaves, length of compound leaf, number of branches and length of longest root compared to rice hull based media 1:2:3 and 2:3:1 (rice hull: poultry manure: river sand) in a study conducted in tamarind (Ugese, 2010).

Wira *et al.* (2011) determined the best medium to be used as an additive in coconut coir dust culture for growing rock melon var. Waka Natsu 1 as The experiment proved that a mixture of coconut coir dust and empty fruit bunches compost in a ratio of 7:3 was found to be the best medium for growing rock melon var. Waka Natsu 1 using fertigation system. The plants grown in this medium produced largest fruit diameter (14.15 cm) with highest fruit fresh weight (1482.9 g) and total soluble solids (15.33 per cent).

Experiments conducted in benjamin tree (*Ficus benjamina*) to study the effect of different soilless growing media *viz.* composted tree bark, composted tea wastes peat, perlite and rice husks on biometric characters revealed that the influence of different soilless growing media on the growth characteristics was significant and the growing medium containing composted tea wastes + rice husks in the proportions of 50 and 50 per cent (v/v) was the promising medium for all the growth characteristics (Abouzari *et al.,* 2012).

Soilless substrates made of peat moss, perlite, coconut coir, rockwool or bark was found to be suitable in strawberry production in Europe in containers. Soilless media ensures raising of disease free crops (Martinez *et al.,* 2013). Addition of zeolite and perlite to rice hull or saw dust in most cases, significantly increased the bell pepper yield compared with their pure treatments in a soilless pot experiment carried out by Aghdak *et al.* (2016) to examine the influence of different growing media on vegetative and reproductive growth of bell pepper. In all measured vegetative traits the highest and the lowest amount was observed with the plants grown in the perlite+ zeolite and pure rice hull or saw dust, respectively. Media containing perlite+ zeolite produced the highest fruit number and yield, whereas plant grown in the saw dust+ zeolite yielded the lowest fruit number.

2.3.2 Characteristics of soil containing growing media and its influence on growth of seedlings

Soil is a natural entity having properties to support plant growth. The texture or particle size distribution of potting medium is an important soil physical property affecting growth of shoot and root (Dickson *et al.* 1960). Physico-chemical properties of soil that affect the growth of potted plants include air conditioning, C: N ratio, cation exchange capacity and water holding capacity (Conover and Poole, 1990). Isaac *et al.* (2003) identified the positive influence of soil in stimulation of germination and nutrient supply for the growth of seedlings from the organic component.

Sujatha and Maria (2010) observed that a combination of coir pith compost, mixed weed compost, sand and soil was the most ideal as this combination would alter the properties of coir pith which creates more conducive environment for producing healthy seedlings.

The garden soil mixed with farm yard manure and leaf manure is found to the most common media for raising potted ornamental plants by Kukal *et al.* (2012). They also observed that field soil is generally inadequate for the growth of plants in containers, because they do not contribute the required aeration and water retention status that are inevitable to maintain equilibrium between moisture content and gaseous exchange in a limited volume of container.

Higher yield of bell pepper was recorded in sandy loam soil (88.6 t ha^{-1}) followed by coco peat (62 t ha^{-1}) in a study conducted to determine the effect of different growing media on quality, growth and yield of bell pepper (*Capsicum annuum var. grossum*) under shade house condition (Nagaraj *et al.*, 2015). Best growth attributes for *Afzelia africana* were obtained when seedlings grown in 2:1:1 mixture of top forest soil+ saw dust+ poultry manure with mean seedling height of 22.4 cm., mean leaf area of 120.6 cm^2 and more number of leaves (Nzekwe *et al.*, 2016).

2.3.3 Growing media containing rice husk charcoal and its influence on growth of seedlings

Rice husk charcoal is found abundantly in rice processing mills as a by-product obtained after burning of rice hull in cyclonic husk furnaces for operating rice driers. The adjustment of temperature below 500^0 C and insufficient oxygen in the furnace generate carbonised rice husk and combustible gases (Sheng and Huang, n.d.). Rice husk charcoal often retains its husk shape and appears in gray or black in colour according to the ash content. It has high water holding capacity of 55.8 per cent (Chulaka *et al.*, 2003). According to Theeba *et al.* (2012) RHC is highly alkaline (pH value 8.9) having 16 per cent carbon content. It has ability to retain the moisture and adsorb the organic compounds. Thus, addition of RHC into the growing media helps to release nutrients slowly into the soil and thus leads to the efficient crop uptake and nutrient losses can be reduced. Njoku and Mbah (2012) reported increase in maize grain yield due to reduced bulk density and total porosity and increased pH, exchangeable potassium, available phosphorus and calcium in the soil by the addition of rice husk charcoal. According to Milla *et al.* (2013) rice husk contains a high content of silicon, potassium and other essential nutrients which have great potential for amending soil and the carbonization process improves the water holding capacity of the rice husks. A series of studies were conducted in a greenhouse to find out the effect of different types of biochar on phosphate, nitrate and potassium retention reported gasified rice hull biochar to provide more phosphate to the system than applied fertilizer which revealed nutrient retention ability (Altland and Locke, 2013). However, due to the lack of knowledge on effective utilization of the rice husk charcoal major portion of it is disposed off to the landfills. Requirement of labour can be reduced by the use of rice husk charcoal as a media component for raising mat nursery of rice because of ease of handling due to light weight of trays. Agricultural utilization of RHC has been explored through so many experiments and researches.

Annapurna *et al.* (2005) reported that overall growth of *Santalum album* L. seedlings in terms of height, shoot dry weight, collar diameter, root dry weight, root fibrosity, total dry weight and quality index was favoured by a potting medium containing burnt rice husk , sand, soil, charcoal and compost in the ratio of 50:25:15:5:5. Ko *et al.* (2005) observed that performance of rice seedlings in the growing media with 30 per cent and 60 per cent substitution of expanded rice hull were on par with that in the commercial seedling medium.

Higher per cent seedling emergence, earlier days to seedling emergence, longer stem and thicker stem girth at 24 week after planting were obtained in African breadfruit when grown in rice hull based media than in soil based media (Baiyeri and Mbah, 2006). Best results of plant growth parameters in tropical cauliflower nursery raised in growing media consists of rice husk charcoal, decomposed cow dung and press mud in 1:1:1 (v/v) ratio was reported by Dhatt and Kaler (2009).

Rapid growth immediately after transplanting was observed in lettuce plug seedlings when growing medium has covered with rice husk charcoal. RHC covering on the growing media increased growth, head fresh weight at harvest and nitrogen uptake. An increase in the seedling nitrogen content was observed with increase in rice husk volume (Sato and Kato, 2010). When 100 per cent RHC was used as polybag medium for chilli crop under fertigation system in green house experiments biomass yield and root distribution improved by 15 per cent and 10 per cent respectively (Theeba *et al.*, 2012). Utami *et al.* (2012) noticed increase in phosphorus uptake by *Brassica sp.* by the application of rice husk charcoal in the soil. Fifty per cent addition of biochar from green waste as substitute for peat growing media increased the biomass production in *Calathea rotundifolia* cv. *Fasciata* by 22 per cent in comparison to peat alone (Tian *et al.*, 2012).

2.3.4 Influence of vermicompost as a component of growing media on growth of seedlings

Vermicompost is finely divided peat-like material with high porosity, aeration, drainage and water-holding capacity (Edwards and Burrows, 1988). Their huge surface area provides great absorbability and retention of nutrients (Shi-wei and Fu-zhen, 1991). Vermicompost contains plant available form of nutrients such as nitrates, exchangeable phosphorus, soluble potassium, calcium, magnesium as well as enzymes, vitamins and plant growth hormones (Edwards and Burrows, 1988; Orozco *et al.*, 1996; KAU, 2011). Accordingly, vermicompost has a greater potential as media for plant growth. Use of vermicompost opens an avenue for sustainable agricultural practices in nursery preparation with environmental safety and economic benefits. The effects of vermicompost cannot be generalized because it might vary based on the characteristics of parent waste and production process (Lazcano *et al.*, 2009). Application of vermicompost is an effective way to improve physical characteristics of soil. Aksakal *et al.* (2016) reported that addition of vermicompost in sandy loam, loam and clay soil can improve its organic matter content. Increase in wet aggregate stability and total porosity and decrease in mean bulk density was noticed by the vermicompost application. As a result of this there was a significant increase in air permeability and decrease penetration resistance. Vermicompost has finer structure than ordinary compost and it has excellent chemical and biological properties with plant growth regulators which may lack in other composts. Significantly larger and diverse microbial populations are associated with vermicompost than the conventional thermophilic composts (Tomati and Galli, 1995).

Siddagangaiah *et al.* (1996) evaluated nine media for rooting of vanilla cuttings and found that sprout length, number of sprouts, leaf area/vine, numbers of leaves/vine, root length and number of roots were higher in vermicompost or decomposed coir pith. Sainz *et al.* (1998) found that the addition of vermicompost to soil increased mineral contents of the substrate and which resulted in higher concentrations phosphorus, calcium, magnesium, zinc, manganese, and copper in shoot tissues of cucumber and red clover plants in fields. The increase in the shoot and root dry weight of tomato and green gram seedling was noticed due to the inclusion of vermicompost to the potting media (Szczech, 1999).

Atiyeh *et al.* (2002) observed that addition of 10 or 20 per cent vermicomposted pig solids into a standard commercial horticultural potting medium (Metro-Mix 360) increased the growth of marigold and tomato seedlings significantly as compared to the Metro-Mix 360 alone, even when all required mineral nutrients were supplied. They also noticed that the greater proportions of vermicompost substituted in growth media have not increased plant growth as much as smaller proportions. According to Hidalgo and Harkess (2002) incorporation of vermicompost has influence on the physical properties of plant growth substrates.

Several pot and field trials carried out with tomato (*Solanum lycopersicum*) and marigold (*Tagetes patula*) seedlings had shown that vermicompost produced significant positive influences on plant growth and yield at relatively low proportions (up to 20 % of the growing media), even when plants are adequately supplied with mineral fertilizers, therefore mentioning the existence of non nutrient mediated mechanisms in promotion of plant growth (Edwards *et al.*, 2004).

Incorporation of vermicompost into growing media was found to be significantly improved plant growth, since it contained slow-release source of nutrients that also improved the physical properties of the potting substrates (Hidalgo *et al.*, 2006). For pepper, modification of the physical structure of the potting medium by vermicompost increased the populations of beneficial microorganisms and enhanced availability of plant growth influencing substances and increased fruit yields (Aracnon *et al.*, 2006).

Vermicompost is suitable substrates for tomato plant. Complete replacement of peat by vermicompost was found to be possible in a study conducted by Lazcano *et al.* (2009). Significant increases in above ground and root biomass of the tomato plants was noticed by the vermicompost application in higher doses. It also improved plant morphology significantly in terms of number of leaves, leaf area, branching and root volume.

The addition of vermicompost in the growing media at 10 per cent and 20 per cent showed positive effects on plant growth. Growth increase up to 40 per cent was observed in dry shoot tissue and leaf area of marigold, tomato, green pepper, and cornflower due to addition of vermicompost in the media (Bachman and Metzger, 2008). Replacement of peat by vermicompost in a commercial potting media showed a significant increase in seedling shoot height of pine with a significant change in plant morphology and increase in the shoot: root ratio (Lazcano *et al.*, 2010).

Murumkar *et al.* (2012) concluded that growing medium containing peat and vermicompost in 1:1 ratio could be highly profitable to grow beetroot under naturally ventilated polyhouse round the year. An experiment conducted by the above mentioned team superiority of media containing peat and vermicompost in 1:1 ratio with respect to plant height, dry matter production, root volume, root length, yield and quality of the beetroot grown in that media. However, combination of vermicompost and coir pith compost in 1:1 yielded lowest plant height.

Bejbaruah *et al.* (2013) noticed that the split application of vermicompost in rice resulted in higher number of panicles, filled grains per panicle, spikelets per panicle, increased grain yield and nutrient use efficiency. Split application of vermicompost promotes the sustainability of rice cropping system.

The medium of vermicompost + pond soil + sand (1:1:1) was observed to be the best substrate for the growth of papaya seedlings as it provided the best performance in terms of seedling height, number of leaves, leaf area, stem girth, production of total biomass, number of roots, root length and least root/ shoot ratio. Highest germination percentage, maximum speed of emergence, maximum germination index, highest seedling vigour, germination value and least time required for imbibitions and minimum germination period were also recorded by this media with 2 cm cocopeat on top of the container. Reduction in seedling mortality and production of healthy seedlings was found to be possible with this media composition (Bhardwaj, 2014).

The vermicompost (30 %) in combination with rice husk ash and coconut husk resulted in better plant growth of muskmelon seedlings in a study conducted in National Pingtung University of Science and Technology (Manh and Wang, 2014). The study on effect of different organic amendments *viz.* farm yard manure, vermicompost and biochar on germination and seedling growth of okra (*Abelmoschus esculentus* L.) showed highest homogeneity of seed germination in vermicompost (Sarma and Gogoi, 2015).

2.3.5 Influence of coir pith compost as component of growing media on growth of seedlings

Coir pith is a mass of heterogeneous particles available as a by-product during the process of coir fibre extraction from coconut husk in the coir industry which constitutes about 50-60 per cent of the total weight of the husk (Mathew *et al.*, 2000). It is not a conducive medium for the cultivation of crop plants in its natutal form. It is comparatively rich in potash, but low in nitrogen and phosphorus

(Abad *et al.*, 2002). Slow rate of decomposition of coir pith is due to the structural and chemical complexity of lignin cellulose complex and low pentosan: lignin ratio (< 0.5) (Ramalingam *et al.*, 2004). High content of lignin (28.25 %) and C: N ratio also leads to the slow degradation (Vinodhini *et al.*, 2005). Physical characteristics of coir pith vary with particle size (Jeyaseeli and Raj, 2010). An experiment carried out by Sureshkumar and Ganesh (2012) at Annamalai University, noticed that the composted coir pith had optimum physical, chemical and biological properties and rich in nutrients also. Coir pith can be bio-converted into compost and could use in organic farming in effective manner to bring fruitful along with quality of produce. According to Paramanandham *et al.* (2014) coir pith provides good aeration around the plant roots grown over it and has ability to retain water for longer period of time. This property may promote the prolonged and continuous availability of water for the plants grown at large and thus can be an ideal growing medium.

Thilagavathi and Mathan (1996) observed that the plots where coir pith compost was applied registered significantly higher available N than the control. Increase in yield of grain and straw of the rice was also noticed due to coir pith application. Increase in rice yield and K uptake due to composted coir pith application than the other organic fertilizers was reported in pot experiment by Bhagavathiammal (1997). Increase in potassium uptake is due to the conversion of the compost into soil humus substances (Velmurugan *et al.*, 2007).

To evaluate the efficacy of composted coir pith based potting mixture with garden soil, a pot culture experiment was carried out in Alappuzha district of Kerala using five different potting media with four different medicinal plants. The mixture of garden soil and composted coir pith in proportion of 1:3 increased shoot and root length over 1:1, 3:1 proportion of garden soil and composted coir pith and 100 per cent garden soil (Reghuvaran and Ravindranath, 2010).

However, coir pith media amended with vermicompost exhibited reduced seedling performance with respect to germination percentage of *Eucalyptus tereticornis* than control (sand) in 30 days (Murugesan *et al.*, 2016).

2.3.6 Effect of composition of growing media on seedling characters and field performance

A field experiment was carried out by Venkataraman (1999) for raising dapog nursery in rice with four media such as clay + cattle dung slurry, composted coir pith, raw coir pith and straw bit. Clay + cattle dung slurry or composted coir pith recorded higher yield and was found to be suitable media for raising dapog nursery.

Nursery media, sowing rate, changing imbibition greening temperature and harvest time were not influenced either seedling emergence rate or establishment rate of a giant-embryo rice cultivar 'Haiminori'. However, seedling height was higher in chaff mats than that in soil (Shiratsuchi *et al.*, 2002).

Soil + press mud mixture (1:1 w/w) produced highly vigorous seedlings in 15 days, registering the maximum seedling height (20.8 cm), leaves/ seedling (4.2 numbers), root length (9.9 cm) and seedling vigour index (8.2) in rice. Soil alone or 90 per cent soil + 10% rice husk mixture also raised robust seedlings (Rajendran *et al.*, 2005).

A study was carried out by Matsuyama *et al.* (2007) to examine the mineral content of rice seedlings (cultivar Tsugaruroman) when a molded rice-hull mat was used as a seedbed. The weight of seedlings varied between 2.8 and 21.2 mg as they grew. It was observed that there were no significant differences of nitrogen, potassium and phosphoric acid content or quality of seedlings in the rice-hull mat compared to seedlings in the ordinary seedbed soil. However, silic acid (0.55mg) content was observed to be higher in the seedlings grown in the rice-hull mat.

A study was conducted by Dhananchezhiyan *et al.* (2013) to develop technique for nursery raising for machine transplanting under 'system of rice intensification'. Nine media compositions studied were field soil + vermicompost (1:1, 2:1 and 3:1), field soil+ farm yard manure (1:1, 2:1 and 3:1), field soil+coirpith (1:1 and 2:1) and field soil alone. Among the nine media studied the maximum seedling height and root length of 17.06 and 10.75 cm were reported in field soil+ farm yard manure (1:1) and field soil+ vermicompost (1:1) respectively.

The same media compositions in the ratio 2:1 registered 16.26 and 10.14 cm respectively.

A study conducted at agricultural Research Station Manuuthy to standardise the media for tray nursery revealed that media containing 80 % rice husk charcoal+ 20 % vermicompost, 60% rice husk charcoal+20% soil+ 20 % vermicompost and 60 % rice husk charcoal+ 30 % soil+ 10 % vermicompost were produced seedlings which were superior in seedling height, biomass production, shoot dry weight, root length and dry matter production at transplanting (Mathew, 2015).

2.3.7 Effect of composition of growing media on mat characteristics and performance of transplanter

Ezaki *et al.* (1980) found that the deflection of rice seedling mats was affected by the factors like conditions of raising of seedlings, planting rate, kinds of bed soil, weight of roots, days for raising of seedling and water content of mat.

Ho *et al.* (1998) found that tension of the root mat was greater at the higher sowing rate. Whereas, seedling height, shoot dry weight and root dry weight per seedling during growth were slightly higher at the lower sowing rate in the seedling trays.

Beena and Jaikumaran (1999) were conducted an experiment to evaluate the performance of an 8-row power operated rice transplanter under different nursery rice mat densities. They observed that in order to get an optimum seedling rate of 3-4 plants per hill (66-79 per cent of hills had 1-5 seedlings, and 51-69 per cent had 2-5) and to reduce the number of missing hills to a minimum (<13 per cent) the density between 0.4 and 0.6 kg/m² was required. The distribution of seeds in the mat at the rate of 3 seeds cm^{-2} i.e. sowing density of 0.41 kg/m² was found to be appropriate because each picker on the transplanter picks up an area of 1.5 cm² of mat.

Tasaka (1999) had grown rice seedlings hydroponically in a long mat, with a mat size of 6 m x 28 cm to save labour during transplanting and tested its performance in the field. This type of seedling mat was weighed about 12 kg. It was about 20 per cent of the weight of a conventional mat containing young seedlings in a soil bed. Lower per cent of number of missing hills (3%) was recorded when the number of plants per hill ranged from 7 to 8.Working rate of the transplanter was approximately 0.5 ha/ h for a working speed of 1.13 m /s and a working width of 1.8 m.

The tensile strength of the seedling mats of a giant-embryo rice cultivar 'Haiminori' in the chaff mats was twice as strong as that in soil. Sowing rate of 270 g per nursery box was found to be sufficient to obtain appropriate number of seedlings (Shiratsuchi *et al.,* 2002). An optimum rate of 2-3 seedlings per hill was noticed with mat density of 2.65 seedling/ cm^2 (110 gm/ mat seed rate). Missing hill percentage ranged between 8.59 to 14.85, 6.25 to 9.79 and 3.13 to 9.38 percent with seed rate of 70, 90 and 110 g/mat (50 x 22 cm mat size) due to non-uniform seedling distribution in the mat (Behra *et al.*, 2007).

Laboratory investigations were conducted by Chaudhary and Varshney (2003) to optimize the parameters of seedlings as well as transplanter. The optimum density of seedling mat recorded to be in between 2.0 and 3.0, 1.25 and 2.00 and less than 1.25 seedlings per cm^2 corresponding to 7, 12 and 17 mm cutting finger length, respectively in order to obtain the recommended 2-3 seedlings per hill and minimum missing of hills. The number of mats (size 52 × 22 cm) required for one hectare area was 400, 700 and 1000 with densities of 3 to 2, 2 to 1.25 and less than 1.25 seedlings/cm^2 for cutting finger length of 7, 12 and 17 mm, respectively. The missing hills were noticed from 0 to 14.1 per cent which were mainly because of non uniformity of seedlings in the mat. When the density and cutting finger length was increased there was a decrease in the percentage of missing hills. The hill percentage with mechanically damaged seedlings ranged from 0.92 to 8.40 per cent which was greater at greater cutting finger length, lower age of seedling and operating speed. Rajesh (2003) reported the presence of chaff in the media resulted in stronger mats.

An increase in the plant height, root length and tensile strength was observed under the pool raising method of seedlings mat in another giant-embryo rice cultivar 'Koshiguruma'. Seed rate of 300 g per nursery box were required in soil media for proper establishment of seedling emergence and for sufficient tensile strength of the seedling mat, which was twice the standard sowing rate. The vacant hills after machine transplanting were 9.3 per cent. Such a high rate of vacant hills may be due to floating on water surface of non-germinating seeds coexisting with germinated seeds (Kobayashi *et al.,* 2009).

A study was conducted to elucidate the workability of 'no-box seedlings' using seed mats. Hardened rice seeds glued onto a molded rice-hull mat and covered with a glued soil layer to raise 'seed-mat'. No-box seedling mats were weighed about 2.8 kg and less than half of that of the conventional seedling boxes. Slightly less tensile strength of 160N/ 28cm was reported with the no-box seedling mats compared to conventional seedling mats. Rate of missing hills of the no-box seedlings was higher than that of the conventional seedlings on transplanting in the field, but it was less than 7 per cent (Shiratsuchi *et al.*, 2009).

An experiment was conducted by Dhananchezhiyan *et al.* (2013) to develop technique for nursery raising for machine transplanting under 'system of rice intensification'. They evaluated the stiffness of mat where either fibrous coirpith or decomposed sieved coirpith were mixed with field soil each in the ratio of 1:1 and 1:2 and tested with and without base layer. The maximum mat stiffness was recorded for a media containing coirpith and field soil at 1:1 and 1:2 ratios with a corrugated sheet base layer.

Mathew (2015) reported that media comprised of 80 per cent rice husk charcoal+ 20 per cent coir pith compost, 60 per cent rice husk charcoal+ 30 per cent soil + 10 per cent vermicompost and 60 per cent rice husk charcoal+ 30 per cent soil+ 10 per cent coir pith compost were superior with respect to the mat strength. 80 per cent rice husk charcoal+ 20 per cent coir pith compost was found to be the light weight media among the treatments.

An investigation conducted by Jiannong *et al.* (2003) revealed that the tensile strength of the rice seedlings increased when the age and the height of the seedlings increased. The strength of pulling seedlings from trays is much influenced by the humidity of the trays and little influenced by the age of the seedlings. The strength decreases with the increase in humidity of the trays and the pulling strength reached the least value when the relative humidity was between 40 percent and 60 percent. Under the normal situation, the tensile strength of the seedlings was much bigger than the strength of pulling seedlings from trays.

2.3.8 Influence of thickness of growing media on mat and seedling characteristics

Thickness of the growing media plays a crucial role in the root and shoots development. Increasing thickness beyond an optimum limit is not possible as it leads to a proportional increase in weight. Requirement of large amount of growing media associated with increase in thickness creates a situation of economically unfeasible. Hence, it is necessary to find out an optimum thickness for growing media. Je *et al.* (2002) used mixed substrate of rice hull and perlite in the ratio 1:1 with a thickness of 0.5 mm in plastic bags of varying volume to grow sweet pepper hydroponically. The vigorous root growth of sweet pepper was noticed in poly bag having the highest volume among treatments.

Thickness of paddy tray nursery mat influences not only the characters of seedling but also determines performance of mechanical transplanter in the field. It has influence on other mat characteristics such as shearing (tensile) strength, weight of mat, density of mat and slippage.

Oya and Kikuchi (1999) opined that paddy seedlings can be raised satisfactorily even if the thickness of growing medium is reduced from the normal thickness of 3 cm to 2 cm, if it is in combination with either paddy raising sheet or nursery box of 2 cm thick having grooves on the bottom which help to spread the roots. This helps to reduce the weight by 1.5 kg compared to conventional mat nursery. They also found that paddy seedlings can be grown well in the growing medium mixed with compost consist of crushed rice husks in the ratio 3:1 and fixed to a thickness of 2.5 cm with an automatic seeding machine. This led to the reduction of mat weight by half and material cost by 40 per cent compared with conventional method.

It was unpractical to use 0 or 7 mm depth of basin soil in nursery box for raising paddy rice seedlings according to Takahashi *et al.* (2004). The practical depth of the soil in a nursery box was found to be 18 mm, comprised of 11 mm depth of basing soil and 7 mm covering soil. Approximately 20 per cent reduction in the weight of the nursery box and 25 per cent reduction in the cost were reported with this method compared to the conventional method. According to Rajendran *et al.* (2005) growing medium with 4 cm thickness was found to be satisfactory to produce healthy robust rice seedlings in 15 days. Dixit *et al.* (2007) reported 2 cm thickness of mat as ideal thickness where soil was used as growing media.

Planting rice on the soil of 20-40 cm thick or on 10 cm thick soil plus peat soil formulation substrate with 30 cm thick could gain a rice yield of over 9000 kg/hm^2, equivalent to or slightly higher than that of a conventional rice field (Fen, 2013). Population of the paddy seedlings ranged from 0.94 to 2.21 number/ cm^2 on 15 mm mat and from 0.97 to 2.26 number/ cm^2 on 20 mm mat as the seed rate increased from 0.35 to 1.15 kg/m^2 (Kumar and Thomas, 2015).

2.4 COST OF MAT NURSERY PREPARATION AND MECHANISED TRANSPLANTING

There are reports showing that mechanical transplanting using paddy mat nursery is advantageous over manual transplanting with respect to the cost associated with transplanting operation and returns.

According to Rajendran *et al.* (2005) in addition to the benefits of limited water and land use, the modified rice mat nursery reduces the cost involved in the production of seedling by about Rs 1,600 (35 US $ to plant 1 ha) field. Ruiyin *et al.* (2008) reported 7.53 per cent increase in yield and 46.78 per cent increase in net profit for rice under mechanized transplanting compared to the manual transplanting. Labour hours reduced by 41.4 per cent on an average.

A survey conducted by collecting data from rice growers of Thrissur, Palakkad and Malappuram districts of Kerala showed that yield obtained in conventional method was 4.8t/ha and it was 5.7 t/ha in mechanically transplanted paddy. The average net returns were Rs. 27,462/ ha and Rs. 19,798/ ha in mechanical and conventional transplanting methods of paddy cultivation respectively. The benefit cost ratio was 1.87 in mechanical transplanting technology as compared to 1.65 in manual transplanting (Singh and Rao, 2012).

Economic analysis indicated that maximum net income of Rs.6427 ha^{-1} was obtained from transplanting with 20 cm spacing and higher B:C ratio of 1.21 when a study conducted for comparison of different planting methods for optimization of plant population of fine rice (*Oryza sativa* L.) in punjab ,Pakistan (Ehsanullah *et al.*, 2007). According to Manjunatha *et al.* (2009) cost of mechanical transplanting was Rs.789/ ha as compared to Rs.1625/ ha in case of manual transplanting if machines are used for their maximum usage of 90 ha in a year. Rani *et al.* (2010) reported that seedling throwing and machine transplanting registered higher benefit: cost ratios of 2.85 and 2.82 respectively. Line transplanting resulted in the lowest benefit: cost ratio.

The medium of vermicompost + sand+ pond soil (1:1:1) with 2 cm cocopeat in top of the polybag for papaya nursery gave the highest net profit (Rs. 3493/1000 seedling) and B: C ratio of 1.85 in the year 2008-09 (Bhardwaj, 2014). On farm trials carried out by Sreenivasalu and Reddy (2014) in seventeen locations of Chittoor district of Andhra Pradesh to evaluate the performance of mechanized transplanting using Yanji sakthi rice transplanter for yield, yield attributes and economics reported higher grain yield with a cost reduction of Rs. 2784 ha^{-1} under mechanized transplanting as manual tranaplanting involves more labour and drudgery. Hence it is obvious that mechanical transplanting could be a successful alternative option to manual transplanting.

Mathew (2015) reported 80 per cent rice husk charcoal+ 20 per cent vermicompost and 60 per cent rice husk charcoal+ 30 per cent soil+ 10 per cent vermicompost containing media as low cost media composition for raising tray nursery with cost of Rs. 4947 and Rs. 5034 respectively.

2.5 SEED PRIMING AND ITS INFLUENCE ON GROWTH AND YIELD

Seed priming refers to pre sowing treatments in water or in an osmotic solution that allows seed to hydrate partially to initiate first stage of germination, but prevents radicle to reach the irreversible point of protrusion through the seed coat. It is a strategy for improving seed germination and seedling development by modifying pre-germination metabolic activity (Bradford, 1986). Different kinds of priming techniques are reported by many authors which includes on-farm priming (Harris *et al.*, 1999), hydropriming (Basra *et al.*, 2003; Mahajan *et al.*, 2011), osmopriming (Ashraf and Rauf, 2001), hardening (Juraimi *et al.*, 2012), hormonal priming (Yarnia and Tabrizi, 2012), redox priming (Sahu and Singh, 1995), chemical priming (Jisha *et al.*, 2013), biopriming (Bennett and Whipps, 2008) and nutripriming (Farooq *et al.*, 2011). According to Ozdemir and Sade (2015), seed priming is mainly classified into hydro priming, osmopriming and matripriming. Nutrient, chemical, hormonal, and redox priming are various kinds of osmopriming in which low potential osmotic solutions are used for soaking of seed. It is a technique for the improvement of seed performance with regard to early and uniform germination (Taylor and Vananen, 1998). Effectiveness of various priming techniques differ under different climatic condition and with crop species. Several researches have shown that priming of seeds have superiority over non-primed seeds.

Osmotic adjustment (Bradford, 1986), metabolic repair during imbibition (Bray *et al.*, 1989), build up of germination supporting metabolites (Basra *et al.*, 2005) and dormancy break down (Farooq *et al.*, 2004) help for uniform germination of primed seeds. Activity of Ca^{+2}, co- factor in activation of certain enzyme like amylase was found to be increased by priming treatments (Taiz and Zeiger, 2002). Alpha- amylase activity was positively related with sugars and germination rate (Lee and Kim, 2000).

Mahajan *et al.* (2011) found that hydro-priming and water-hardening treatments improved germination percentage and seed vigour index, which is related to earlier and uniform emergence and subsequent seedling growth and ultimately led to more panicles/ m^2 and high grain yield of dry direct-seeded rice. Primed seeds help in improving seedling density per unit area and leaf area index under optimal and adverse soil conditions. Rehman *et al.* (2011) suggested seed priming as a doable technology for better performance of direct seeded rice. Seed priming had significant influence on germination, seedling emergence, days to heading, duration to plant maturity, number of tillers, number of fertile panicles and grain yield of dry seeded NERICA rice (Binang *et al.*, 2012). An investigation by Yari *et al.* (2012) also reported that seed priming with water and $CaCl_2$ could enhance germination percentage and rate of germination in rice. Seed priming duration of 24 h and temperature of 25°C improved germination percentage and mean growing time in rice cultivars. Kaur (2015) reported better performance of okra due to different seed priming.

Clark *et al.* (2001) reported that faster emergence and improvement in the competitive ability of maize against weed along with enhanced vigour due to seed priming. Robust seedlings stand observed with primed seeds enhanced competitiveness of wheat against weeds and tolerance to environmental stress (Ghiyasi *et al.*, 2008). According to Juraimi *et al.* (2012) weed dry matter was reduced due to priming where reduction was ranged from 22 to 27 per cent compared to control. Weed inflicted relative yield loss was reduced by 10 per cent as a consequence of seed priming. Seed priming by soaking in water for 8 h produced significantly higher grain yield over the use of non-pried seeds in chickpea (Bhowmick *et al.*, 2013).

The field experiment carried out at College of Agriculture, Trivandrum recorded increase in grain and straw yields due to seed priming in upland rice which in turn increased the net income and benefit: cost ratio. Hence, seed priming is a technique for increased returns on rainfed upland rice (Thomas *et al.*, 2000).

2.5.1 Nutripriming

Nutrient priming is a novel strategy with combined benefits of seed priming with an improved nutrient supply (Al-Mudaris and Jutzi, 1999; Farooq *et al.*, 2011). It is an osmopriming technique (Ozdemir and Sade, 2015) in which nutrients act as osmotica (Imran *et al.,* 2004). Priming the seeds with nutrients allow them to rapidly imbibe water and revive metabolism and germination. Priming with nutrients leads to higher germination rate, improved crop establishment (Farooq *et al.*, 2009), increased pest and drought tolerance, and ultimately higher yields (Harris *et al.*, 1999).

Recently, it is focused on macro or micronutrient enriched seeds as reported by Rehman *et al.* (2012) and Mirshekari *et al.* (2012a). It is a simple, low cost and effective technique for supply of nutrients to crops (Farooq *et al.*, 2012). The use of seeds primed with nutrients is a better option for resource poor farmers under inherent low soil fertility to overcome nutrient deficiencies from an economic perspective as less requirement of nutrient, easiness in application and improvement in seedling growth (Singh *et al.*, 2003). Nutripriming not only helps to solve the agronomic need of the crop but also improves human nutrition (Rakshit *et al.*, 2013).

Khalid and Malik (1982) found increase in growth, grain yield and Mn content of grain due to priming of wheat seeds with $MnSO_4$ solution. According to Asgedom and Becker (2001) seed priming with limiting plant nutrients around or within the seed can be an attractive solution to overcome poor establishment and P and Zn deficiencies. Deficiencies of Zn, B and Mo in soil limit crop production in India. Better nutrient status of plants increase yield and nutrient content of seeds which leads to better nutrition of progeny crop. Imran *et al.* (2013) also reported increased seed contents of micronutrients that were applied through nutrient seed priming.

Miraj *et al.* (2013) while experimenting with maize seeds primed with water, Phosphorus or P amended solutions found higher vigour than unprimed seeds as increased fresh and dry shoot weights, fresh shoot height and P content of shoot. Yield was also increased as a result of P priming with significant responses in cob yield, grain and straw yields. Phosphorus content of grain was also increased as compared to control. Additionally, the nutrient uptake by seedling was increased four times due to 1per cent P solution priming with KH_2PO_4.

Whereas, no effect on yield and micronutrient content of the progeny seeds was reported by Johnson *et al.* (2005) due to sowing of micronutrient primed seeds in most cases. An experiment conducted by Farooq *et al.* (2005) to study the use of fertilizers as osmotica for seed priming reported lowering of germination and seedling growth due to fertilizer based osmopriming treatments in rice.

Nutripriming with nitrogen source

Farooq *et al.* (2005) reported use of commercial fertilizers as osmotica for paddy seed priming as these are cheaper and easily available. It can also supply nitrogen and other nutrients for imbibing seeds. Higher leaf area ratio of 148.3 in red gram plants subjected to urea seed priming (10^{-4} M) was noticed by Mishra *et al.* (2007). Greatest coleoptile length was observed in maize seeds osmoprimed with -1.2 MPa urea solution for 96 h (Dezfuli *et al.*, 2008). Anosheh *et al.* (2011) recommended priming for enhancing growth responses of maize under stressed condition. They found that urea priming resulted in more germination per cent and length of seedling and KNO_3 priming led to higher root length compared to other primers. Srivastava and Bose (2012) opined that nitrate seed priming induces the grain filling and reduces the adverse effect of ethylene produced in floral part and flag leaf and deposited in basal part of panicle. Aboutalebian *et al.* (2012) reported priming with urea increased the grain yield of rain fed wheat by 16.9 per cent.

In contrast to these results Farooq *et al.* (2005) reported germination failure of coarse rice seeds subjected to urea priming due to toxicity. Hamidi and Anosheh (2013) also opined that urea priming did not show any improvement on germination of sunflower in a study conducted where germination percentage was markedly decreased at higher concentrations of urea. However, urea priming resulted in significant increase of seedling length, radicle length and seedling to radicle length ratio. It was also noticed that urea priming decreased per cent of germination with increase in osmotic potential.

Nutripriming with zinc

Zinc (Zn) in rice seed is important for its germination as well as for nutrition of rice consumers (Prom-u-thai and Rerkasem, 2012). Zinc can be applied by different methods such as soil application, foliar application, seed priming and root dipping (Johnson *et al.*, 2005; Cakmak, 2008). Seed priming is reported to increase yield and grain Zn concentration in cereals (Farooq *et al.*, 2006a; Harris *et al.*, 2008). Rice plants grown from seeds rich in Zn contents could manage limited Zn availability in soils (Tehrani *et al.*, 2003). Harris *et al.* (2004) found that priming seeds with Zn solutions could minimise external interactions of nutrients.

Twenty-two participatory farmer trials in wheat were completed in four villages of Peshawar during 2003-04 validated Zn seed priming effect. Experiments revealed that seeds could be primed safely with dilute solutions of zinc sulphate and that 0.4 per cent Zn was safe and effective. Mean yield of wheat was increased by 0.4 per cent Zn nutripriming in comparison with non-primed seeds (Harris *et al.*, 2004). Ajouri *et al.* (2004) reported improved germination and seedling development in barley after seed priming with zinc.

Further studies by Harris *et al.* (2007) reported that increasing Zn seed content by seed priming with solutions of $ZnSO_4$ was highly cost effective and enhancing maize yield. The apparent recovery of added Zn in the grain was much higher for seed priming than the less than one per cent for soil fertilisation. Significantly heavier and taller seedlings were produced from seeds primed with either 1 or 2 per cent Zn than from non-primed seeds. The Zn concentration of seedlings was increased significantly by Zn priming treatments. However, seedlings Zn content was not influenced by priming with water alone.

Wheat seeds were primed for 10 h in 0.3 per cent Zn and chickpea for 6 h in 0.05per cent Zn. Seed treatments increased seed Zn concentration in wheat from 27 to 470 mg/kg and in chickpea from 49 to 780 mg/ kg. In wheat, 0.3 per cent Zn priming significantly increased the mean shoot dry mass, Zn concentration and Zn uptake by 15 days old seedlings compared to non-primed controls and seeds primed with water alone (Harris *et al.*, 2008). Aboutalebian *et al.* (2012) found speed and percentage emergence, number of tillers per plant, number of spikes per square meter, 1000 grains weight, number of grains per spike, biological and grain yields were positively influenced by seed priming in wheat. They reported 26.3 per cent increase in grain yield of rain fed wheat by seed priming with zinc sulphate. Islam (2012) reported highest germination, vigour index, shoot length, root length, shoot dry weight, root dry weight and lowest mean germination time with 3 per cent $ZnSO_4$ seeds priming in rice cv. BRRI dhan 29.

The maximum value of germination count, leaf area index, leaf area duration, crop growth rate, net assimilation, biological yield, grain yield, stover yield and harvest index rate were observed with the treatment of maize seed priming with $ZnSO_4$ @ 1.5 per cent and was found to be the most promising, appropriate and economical technique for raising maize (*Zea mays* L.) hybrids (Afzal *et al.*, 2013).

Influence of seed priming with zinc, zinc + manganese, boron and phosphate on growth and nutritional status of maize were considered by Muhammad *et al.* (2015). The study showed that seed priming with Zn and Mn are perspectives to improve early seedling growth and establishment. Effective translocation of primed nutrients within the plant during early seedling development and increased contents of primed nutrients in seed were also noticed due to nutrient seed priming.

Despite the above beneficial effects of Zn-priming, some studies have mentioned that seed priming with Zn may not be effective in fulfilling Zn requirements of different crops. For example, seed priming with Zn alone could not fulfil crop Zn requirements in kidney beans (Rasmussen and Boawn, 1969). Harris *et al.* (2008) reported that using 0.4 per cent Zn had increased shoot Zn concentration but reduced shoot dry mass to the level of the non-primed control. Emergence percentage and vigour index were also reduced by increasing Zn concentration from 1.5 per cent to 2 per cent. However, no significant effect of increasing Zn concentration was observed on rate of emergence, root length and shoot length by Munawar *et al.* (2013).

Nutripriming with boron

Boron (B) is an important micronutrient required for rice from start till physiological maturity. Boron deficiency is emerging fast in many soils due to extensive depletion of native soil boron. Deficiency of boron ranked on top among micronutrients in the states of Karnataka, Kerala, Odisha, Jharkhand, West Bengal, Assam, Chhattisgarh (Singh and Wanjari, 2013).

In addition to its undesirable influence on grain set, B deficiency also depressed grain filling and weight of individual grains in rice (Lordkaew *et al.*, 2013). In this regard, seed priming is an effective method of B application in order to overcome its deficiency.

Seed priming in 0.001 and 0.1 per cent B solutions improved the time to 50 per cent germination, germination energy, final germination percentage, mean germination time, and germination index of fine grain aromatic rice cultivar Super Basmati (Farooq *et al.*, 2011). Among the different concentrations of boron seed priming, seed primed with 0.001 per cent B showed better and uniform stand, early seedling growth, improved root and shoot length and seedling dry weight in wheat in a study conducted by Iqbal *et al.* (2012). Substantial improvement in seedling emergence with seed priming of 0.001 per cent B was also noted by Rehman *et al.* (2012) in rice cultivars. They also observed rate of leaf emergence, elongation and tiller appearance and leaf chlorophyll content were also improved by seed priming with 0.001per cent B solution. At final harvest, all yield contributing parameters were improved by B priming.

Memon *et al.* (2013) reported that seed priming with boron is beneficial to improve germination and other growth related attributes of the seedlings of broccoli. However the increased levels of boron caused reduction in most of the evaluated parameters of broccoli seedlings. Rehman *et al.* (2014) reported that boron application through seed priming can be an economically viable option to reduce panicle sterility, improve kernel quality, rice growth and yield. They also reported that boron nutrition through seed priming is cost effective and may help in improving the productivity, quality, and boron grain contents in short-duration basmati rice under water-saving production systems (Rehman *et al.*, 2016).

Although seed priming with B is the most promising, convenient and cost-effective method of B application, concentration of solution is of vital significance and must be tested and optimized before field application. Seed priming in relatively concentrated B solution, *i.e.*, 0.5 per cent completely suppressed the germination and growth (Farooq *et al.*, 2011). Beyond 0.01 per cent B concentration, there was unfavourable effect on the germination and seedling growth of wheat cultivars. Seed priming with 0.1 per cent B significantly decreased the seedling dry weight than untreated control (Iqbal *et al.*, 2012).

Nutripriming with combination of nutrient sources

Use of seeds enriched with various nutrients is a better strategy in overcoming multi nutrient deficiency. Effect of seed priming in solution containing different nutrients was also studied by several researchers. Aboutalebian *et al.* (2012) found that priming with compound solution of zinc sulphate and urea increased the grain yield of rain fed wheat by 22.2 percent compared with control.

According to Mirshekari and Roudsari (2013) cumin seed and its essential oil yield could be improved by simultaneous seed priming with *Azospirillum* strain and nutrient priming with iron, zinc, manganese, boron and molybdenum in semi-arid and cold regions.

The influence of seed priming with water, 0.2 per cent Zn, 0.3 per cent P and 0.3 per cent P+ 0.2 per cent Zn was evaluated for yield and yield components of wheat. An increase was noticed in number of plants m^{-2}, number of tillers m^{-2}, number of grains $spike^{-1}$, thousand grain weight, grain yield and biological yield for primed seed as compared to control. Seed primed with 2 per cent P + 2 per cent Zn had a maximum increase in grain yield followed by 2 per cent P. Priming can be a method to supplement P application and can be used in combination with P application to obtain higher yields (Ali *et al.*, 2008).

A study conducted to assess physiological quality of seeds and the initial growth of lowland rice seedlings revealed that treatment of seeds with the product containing Zinc, Boron and Molybdenum promoted greater plant height, higher leaf area, higher production of dry phytomass and increase in growth rate until 42 days after emergence (Tavares *et al.*, 2013a).Seed treatment with zinc, boron, sulphur and molybdenum increased growth and vigour of rice in the initial phase of the cycle where the combination of Zn+B+S+Mo showed the best results, favouring the growth, mainly the root system of plants (Tavares *et al.*, 2013b). Muhammad *et al.* (2015) found that P and Zn+ Mn priming could mitigate P and Zn deficiency to some extent in soil culture of maize. Grain yield was also increased by 15 per cent with Zn+ Mn seed priming under field experiment.

Biopriming

Agricultural chemicals are becoming more restricted due to its impacts on health and environment. Biological seed treatments with beneficial microorganisms are found to be potential alternatives to traditional agricultural chemicals. Biopriming is technique for improving the reliability of biological seed treatments that refers to combination of biological seed treatment and preplant hydration of seed (Callan *et al.*, 1990). Synergism of priming effect with bacterial effect confers positive benefits. Seed priming with root colonizing Pseudomonas when treated to seeds have enhanced the host plant's resistance to pathogen attack in many host-pathogen interactions (Mathre *et al.*, 1999, Conrath *et al.*, 2002).

Effectiveness of bio-priming with *Pseudomonas fluorescens* in enhancement of growth of pearl millet was visible from the initial stages itself wherein seed germination, seedling vigour, seedling emergence and seedling stand were improved over the control (Raj *et al.*, 2004). Bio-priming with PGPR was more consistent in improving germination percentage and rate of radish (*Raphanus sativus* L.) seeds under high saline conditions (Kaymak *et al.*, 2009). Bennet *et al.* (2009) found that positive influence of different seed priming treatments with *Pseudomonas* on emergence or yield of carrot was not consistent across all sites and years.

Biopriming treatments have potential to promote rapid and more uniform seed germination and plants growth associated with bacterial coatings. It provides very well establishment and adherence of bacteria to the seed, before planting. Two strains of *Pseudomonas fluorescens* viz. UTPf76 and UTPf86 were applied to the sunflower seed during osmopriming with NaCl. The highest shoot height, root length and seedling weight were recorded due to biopriming compared to other treatments (Moeinzadeh *et al.*, 2010).

Sharifi (2011) observed increase in dry matter production and crop growth rate in maize due to seed biopriming. The highest dry matter accumulation in unit of area was noticed in seed biopriming with *Azotobacter.* Higher yield was obtained from safflower when seed was inoculated with *Pseudomonas* strain 186 along with field application of 180 kg N per hectare (Sharifi, 2012). Kokila and Bhaskaran (2014) reported increase in polyphenol oxidase activity in paddy seeds irrespective of cultivars compared to control due to biopriming.

Mirshekari *et al.* (2012b) found that yield and dry matter accumulation of barley were significantly influenced by nitrogen and phosphorus fertilizer levels and seed priming with PGPR. The maximum thousand grain weight, grain yield, biological yield and harvest index were observed in the plots with the highest levels of nitrogen and phosphorus fertilizers in the field along with seed priming with both *Azospirillum* + *Azotobacter* compared to control treatment.

An experiment was conducted by Karthika and Vanangamudi (2013) with COH (M) 5 maize hybrid seed to standardize seed biopriming technique with liquid biofertilizers (*Azospirillum* and phosphobacteria). Biopriming with liquid *Azospirillum* 20 per cent concentration for 12 h expressed superiority with respect to germination, speed of germination, shoot length, root length, dry matter production, total dry matter production and vigour index which accounted for 20, 82,24, 26,28, 58, and 59 per cent increase over non-primed seed.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

Field experiment for the research work entitled 'Nutripriming and mat thickness on tray nursery in rice' was conducted at Agricultural Research Station, Mannuthy in Thrissur district of Kerala. The research station is situated at a latitude 10°31'12.9" N, longitude 76°13'14.4" E and altitude 40.29 m above mean sea level. The materials used and methods followed to carry out the experiment are described in detail here.

The study was undertaken as three experiments

Experiment I	: Standardization of growing media and thickness of mat for tray nursery in rice
Experiment II	: Nutripriming of seed
Experiment III	: Field evaluation

3.1 EXPERIMENT I. STANDARDIZATION OF GROWING MEDIA AND THICKNESS OF MAT FOR TRAY NURSERY IN RICE

The objective of the experiment was to standardise the growing media and thickness of mat for tray nursery technique in rice. Six composition of media and three levels of thickness for tray nursery were studied in this experiment.

3.1.1 General details

Variety

The short duration rice variety Jyothi (Ptb-39) was used for the experiment. It is a popular variety as it is having red kernel and long bold grains. It is moderately tolerant to BPH and blast. This variety is suitable for direct seeding, transplanting and special systems of *Kole* and *Kuttanad.*

Nursery trays

Trays of dimension 60 x 30 cm were used to raise the seedlings of rice in nursery. The size of the tray is suitable for the dimension of the seedling platform of the self-propelled walk-behind mechanical transplanter.

Automatic rice mat nursery sowing machine

Automatic rice mat nursery sowing machine (Redlands automatic rice mat nursery sowing machine RNM 600) is necessary machine developed for the rapid preparation of mat nursery trays by distribution of media and sowing of seeds uniformly. Machine consists of three hoppers: one for media delivery, second for seed distribution and third one for covering the seeds with surface layer of media. Trays were filled by passing through the conveyor belts of this electric motor powered machine. Quantity of media and seeds were adjusted according to the treatment requirements. Water was sprinkled over the surface soil layer from the pipe system. Efficiency of the machine is about 600-800 trays/hour.

Components of growing media

The media for tray nursery were comprised of three components *viz.*, rice husk charcoal, soil and vermicompost or coir pith compost, mixed at different proportions. Rice husk charcoal (RHC) is available as a by-product of processing of rice and used as filler material. Rice husk charcoal used for the experiment was purchased from Veejay Rice Mill, situated at Angamaly south in Ernakulam district of Kerala. Coir pith compost (CPC) was obtained from coir pith compost unit of College of Horticulture, Vellanikkara. Source of vermi compost and soil were Agricultural Research Station, Mannuthy. Vermicompost (VC) and coirpith compost were the nutrient sources in the treatments and soil as the base material.

Thickness of growing media

Paddy mat nursery trays were filled with media at three levels of thickness i.e. 10 mm, 15 mm and 20 mm by adjusting delivery of media into the tray.

3.1.2 Experimental methods

The experiment I was conducted at Agricultural Research Station, Mannuthy from 28th February 2015 to 15th March 2015. The experimental design was factorial CRD with three replications.

Preparation of growing media

Various components of growing media such as rice husk charcoal, soil, vermicompost and coir pith compost were sieved to remove lumps and stones and were mixed manually in accordance with proportion of each treatment on volume basis.

Treatment details

Three levels (40%, 60% and 80%) of rice husk charcoal and two levels (20% and 40%) of soil with vermi compost or coir pith compost as nutrient source thus six levels of media compositions were selected for the study. Combinations of six levels of media composition and three levels of media thickness were studied in experiment I. Details regarding six levels of media composition and three levels of media thickness are given in Table 3.1 and treatment combinations in Table 3.2

Table 3.1 Details treatments of experiment I

No.	Media compositions	
1.	40 % RHC + 40 % Soil + 20 % VC	[M_1]
2.	60 % RHC + 20 % Soil + 20 % CPC	[M_2]
3.	60 % RHC+ 20 % CPC+ 20 % VC	[M_3]
4.	80 % RHC+ 20 % CPC	[M_4]
5.	80 % RHC + 20 % VC	[M_5]
6.	80 % RHC + 20 % Soil	[M_6]
	Media thickness	
1.	10 mm thickness	[S_1]
2.	15 mm thickness	[S_2]
3.	20 mm thickness	[S_3]

Filling of trays with media and seeds

Trays were filled using Automatic Rice Mat Nursery Sowing Machine. Seed metering mechanism was adjusted to deliver the seed @ 125 g per tray uniformly to all the trays. Thickness of media varied according to the treatments. Seeds were covered with a thin layer of media. After filling, the trays were covered with newspaper and removed on third day when seeds started sprouting.

Irrigation of nursery

The nursery was irrigated daily by sprinkling water using a rose can.

3.1.3 Observations

3.1.3.1 Biometric observations

Biometric observations on height of seedling, biomass production, shoot dry weight, root dry weight and dry matter production were recorded at 5 days interval. Days to 50 per cent germination, root length at transplanting and scoring of pest and disease incidence were also recorded.

Days to 50 per cent germination

The number of days taken to germinate 50 per cent of seeds in the tray was recorded from two spots each with 4 x 4 cm area.

Height of seedlings

Height was measured from collar region to the tip of the seedling using a ruler and expressed in cm. Ten normal seedlings were randomly selected from each nursery tray for measuring height and mean height was computed at five days interval.

Biomass production

Fresh weight of ten seedlings at random from each nursery tray was measured using precision balance. Mean fresh weight was computed and expressed in milligrams at five days interval.

Shoot dry weight

Above ground portion of seedlings were dried in hot air oven at 80 ± 5°C. Shoot dry weight of ten seedlings was measured in milligrams and mean weight was calculated at five days interval.

Root dry weight

Roots of seedlings were dried in hot air oven at 80 ± 5°C. Root dry weight of ten seedlings was measured in milligrams and mean weight was calculated at five days interval.

Dry matter production

Seedlings were dried in hot air oven at 80 ± 5°C. Dry weight of ten seedlings was measured in milligrams and mean weight was calculated at five days interval.

Root length at transplanting

On 15th day after sowing, ten single plants were separated out from each of the mat randomly and measured for root length using a ruler. Root length was measured from collar region to the tip of longest root. Mean was calculated to obtain the root length of the seedling and expressed in cm.

Disease and pest incidence scoring

There were no pest and disease incidence in the nursery. Hence, scoring of pest and disease was not done during nursery period.

3.1.3.2 Mat characteristics

Mat weight per unit area at transplanting

Strips of mat with size 100 cm^2 were cut from the whole mat on 15th day after sowing. Weight of the strip was quantified using a precision balance. Values were converted to weight of 1m^2 mat and expressed in kg m^{-2}.

Density of mat

Three strips of mat with size 100 cm^2 from each treatment was cut from the whole mat and recorded the weight. Volume of the strip was recorded by water displacement method. Density was calculated by dividing mass by volume and expressed in g cm^{-3}.

Shearing strength of mat at the time of transplanting

Shearing strength is an index of stiffness of mat. Shearing strength of mat was measured as the force required for tearing the nursery mat made up of different

Table 3.2 Details of treatment combinations in experiment I

Sl. No.	Treatment combinations	
1.	40 % RHC + 40 % Soil + 20 % VC with 10mm thickness	[M_1S_1]
2.	40 % RHC + 40 % Soil + 20 % VC with15 mm thickness	[M_1S_2]
3.	40 % RHC + 40 % Soil + 20 % VC with 20 mm thickness	[M_1S_3]
4.	60 % RHC + 20 % Soil + 20 % CPC with10mm thickness	[M_2S_1]
5.	60 % RHC + 20 % Soil + 20 % CPC with 15 mm thickness	[M_2S_2]
6.	60 % RHC + 20 % Soil + 20 % CPC with 20 mm thickness	[M_2S_3]
7.	60 % RHC + 20 % CPC + 20 % VC with 10mm thickness	[M_3S_1]
8.	60 % RHC + 20 % CPC + 20 % VC with 15 mm thickness	[M_3S_2]
9.	60 % RHC + 20 % CPC + 20 % VC with 20 mm thickness	[M_3S_3]
10.	80 % RHC + 20 % CPC with 10mm thickness	[M_4S_1]
11.	80 % RHC + 20 % CPC with 15 mm thickness	[M_4S_2]
12.	80 % RHC + 20 % CPC with 20 mm thickness	[M_4S_3]
13.	80 % RHC + 20 % VC with 10mm thickness	[M_5S_1]
14.	80 % RHC + 20 % VC with 15 mm thickness	[M_5S_2]
15.	80 % RHC + 20 % VC with 20 mm thickness	[M_5S_3]
16.	80 % RHC + 20 % Soil with 10mm thickness	[M_6S_1]
17.	80 % RHC + 20 % Soil with 15 mm thickness	[M_6S_2]
18.	80 % RHC + 20 % Soil with 20 mm thickness	[M_6S_3]

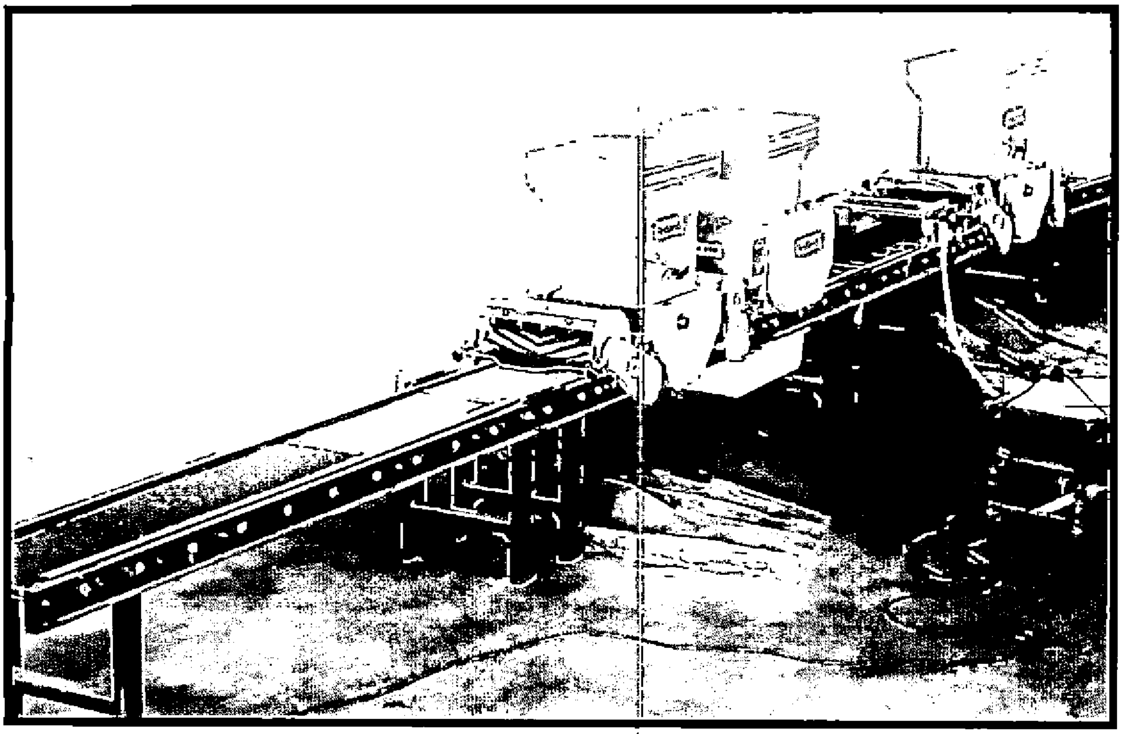

Plate 1. Filling of trays using Automatic Rice Mat Nursery Sowing Machine

Plate 2. Measurement of shearing strength

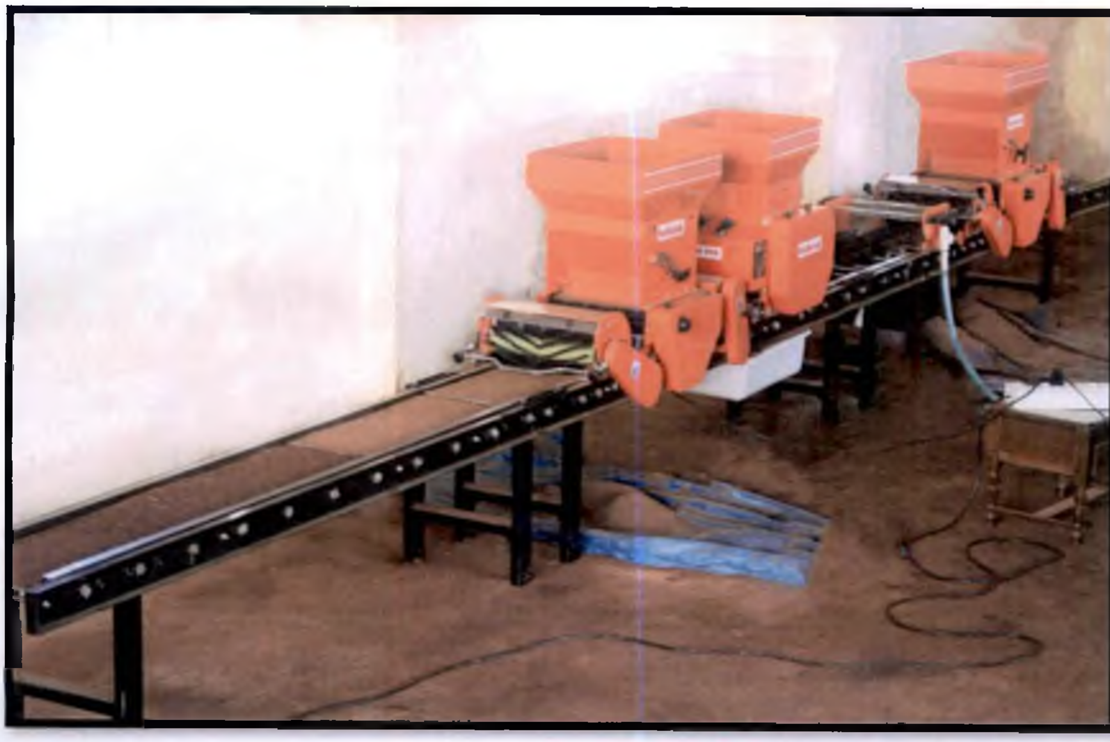

Plate 1. Filling of trays using Automatic Rice Mat Nursery Sowing Machine

Plate 2. Measurement of shearing strength

composition of media and with different mat thicknesses. A special device was fabricated for this purpose (Mathew, 2015) as shown in figure 3.1. The device consists of a rectangle base and a rectangle plate with nails facing upward. A weighing bag is hanging on a rope attached to the rectangle plate. Rectangle plate is having half the length of the rectangle base and can slide on rectangle base when a stress is created on rope. The mat is fixed on the nails of the device for measuring the shearing strength. On applying weight, the rectangle plate slides on rectangle base and the mat started to tear. The stress is created by providing weight on the opposite side till the mat tears. Weight applied at the time of breaking the mat was recorded and strength of the mat was calculated using the following equation.

Strength of mat (kg m^{-2}) = Force /Area

Slippage

Slippage indicates extend of slipping down of mat nursery from original position on seedling platform of mechanical transplanter during working of the machine. Nursery mats were kept on the seedling platform of transplanter and marked its original position. Transplanter was kept on movement for a specified period of time (1 min.) and distance of slipping from original position was measured using a ruler and expressed in cm min^{-1}.

3.1.4 Physico-chemical properties of components of growing media and their compositions

Representative samples of different components of growing media and their compositions were air dried. It was used for analyzing physico-chemical properties of the media composition. The various methods used for the analysis of physico-chemical properties of different components of growing media and their compositions are given in Table 3.3

3.1.5 Nutrient status of components of growing media and their compositions

Representative samples of different components of growing media and their compositions were air dried and passed through sieve. These samples were used for determining the nutrient status of the media i.e. organic carbon, N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu and B. The various methods used for the analysis of nutrient status of different components of growing media and their compositions are given in Table 3.4

Table 3.3 Methods for analyzing the physico-chemical properties of components of growing media and their compositions

Sl. No.	Properties	Method
1.	pH	Media water suspension of 1:2 and read in pH meter (FCO, 1985)
2.	Electrical conductivity	Media water suspension of 1:5 and read in EC meter (FCO, 1985)
3.	Water holding capacity	Keen and Raczksowski, 1921
4.	Bulk density	Keen and Raczksowski, 1921

3.1.6 Nutrient content of seedlings

Seedling samples were collected randomly from each tray on 15 DAS for analysis. The seedlings were dried in hot air oven at 80 ± 5°C, ground well and analyzed for different nutrients i.e. N, P and K. The procedures followed for the analysis of different nutrients are given in Table 3.5.

3.1.7 Nutrient uptake by seedlings

There were on an average of 4310 seedlings per tray, sown with 125 g seed. Nutrient content of the seedlings at the time of transplanting was multiplied with the dry matter production of total seedlings per tray at the time of transplanting to get nutrient uptake by the seedlings and expressed as g $tray^{-1}$.

3.1.8 Economics of nursery

The cost for paddy tray nursery was computed on the basis of current market price of different inputs used and labour charges required for raising nursery. Prevailing wages of labour at the time of experiment was considered for labour charges. Details regarding cost of inputs are given in appendix II.

3.1.9 Selection of best performing media from experiment I

From the six levels of media compositions and three levels of media thickness, the best performing three treatment combinations were selected based on seedling and mat characteristics using scoring technique. Ranking of the treatment combinations was done using scoring technique based on important parameters of seedling and mat. Seedling and mat characters at the time of transplanting (15DAS) selected for scoring were:

- Seedling height
- Biomass production
- Shoot dry weight
- Root dry weight
- Dry matter production
- Mat weight per unit area
- Shearing strength
- Slippage

The selected parameters were classified into three groups as high, medium and low based on range of values and scores of 5, 3 and 2 were given to high, medium and low classes respectively. The different treatments were classified based on recorded value and scores were given accordingly. The aggregate score for each treatment combination was calculated and were ranked based on the sum of scores obtained. Best performing three treatment combinations based on the rank were selected for experiment II.

Table 3.4 Methods used for nutrient analysis of components and combinations of growing media

No.	Nutrient	Method	References
1.	Organic carbon	Lose on ignition method	FCO, 1985
2.	N	Microkjeldhal digestion and distillation method	Jackson, 1958
3.	P	Diacid digestion of media sample followed by filtration. Vanado molybdate phosphoric yellow colour in nitric acid system	Piper, 1966
4.	K	Diacid extract using Flame Photometer	Piper, 1966
5.	Ca	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model : Perkin Elmer Optima 8000)	Piper, 1966
6.	Mg	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model : Perkin Elmer Optima 8000)	Piper, 1966
7.	S	Turbidimetry method using Spectronic 20	Williams and Steinsberg, 1958
8.	B	By dry ashing followed by extraction using HCl Estimated colorimetrically by Azomethine-H using spectrophotometer	Gaines and Mitchell, 1979 Bingham, 1982
9.	Fe, Mn, Cu & Zn	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model: Perkin Elmer Optima 8000)	Piper, 1966

Table 3.5 Methods used for chemical analysis of plant

No.	Nutrient	Method	References
1.	N	Microkjeldhal digestion and distillation method	Jackson, 1958
2.	P	Diacid digestion of plant sample followed by filtration. Vanadomolybdate phosphoric yellow colour in nitric acid system	Piper, 1966
3.	K	Diacid extract using Flame Photometer	Piper, 1966
4.	Ca	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model: Perkin Elmer Optima 8000)	Piper, 1966
5.	Mg	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model: Perkin Elmer Optima 8000)	Piper, 1966
6.	S	Turbidimetry method using Spectronic 20	Williams and Steinsberg, 1958
7.	Fe, Mn, Cu & Zn	Diacid extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model: Perkin Elmer Optima 8000)	Piper, 1966
8.	B	By dry ashing followed by extraction using HCl Estimated colorimetrically by Azomethine-H using spectrophotometer	Gaines and Mitchell,1979 Bingham, 1982

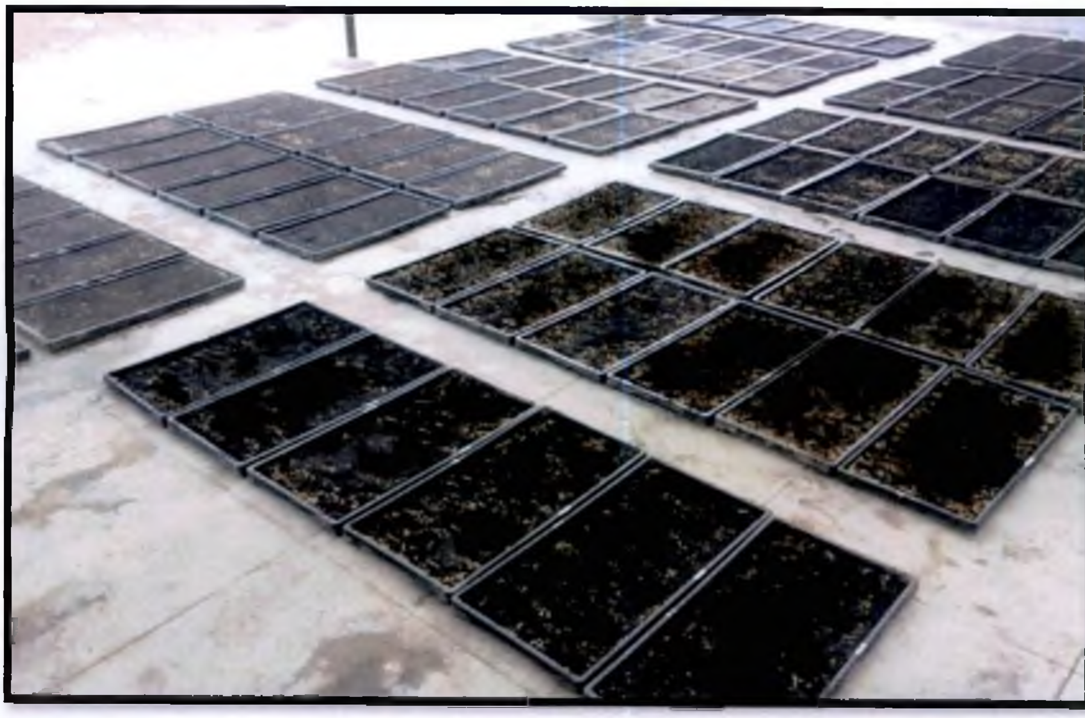

Plate 3. General view of trays after filling

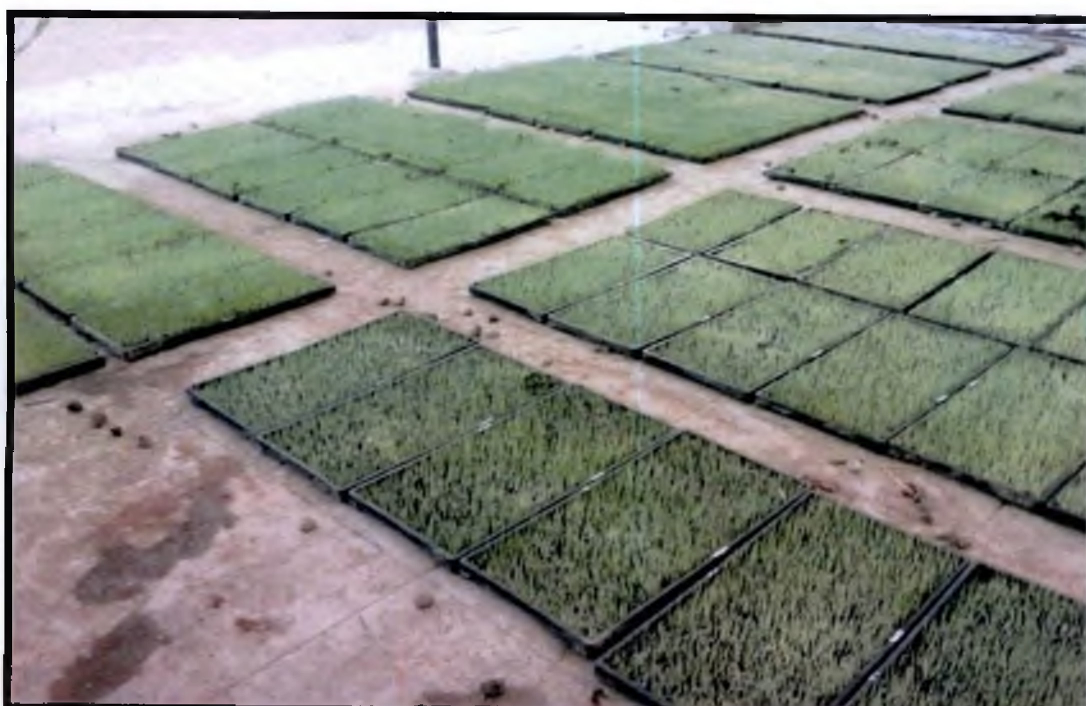

Plate 4. General view of nursery of experiment I at 5 DAS

Plate 5. General view of nursery of experiment I at 15 DAS

Plate 6. Close up view of nursery with different composition of media

3.2 EXPERIMENT II. NUTRIPRIMING OF SEED

Nutripriming was done to improve the seedling vigour. Macro and micro nutrients were delivered to seeds through nutripriming in experiment II. Urea, $ZnSO_4$, Borax, *Pseudomonas fluorescens* formulation and PGPR mix-I were used in this experiment for priming of paddy seeds.

3.2.1 General details

Three treatment combinations selected from experiment I were utilized as growing media for experiment II. Sources for each component were same as in experiment I. Trays of dimension 60 cm x 22 cm were used to raise the seedlings of rice. The size of the tray is suitable for the dimension of the seedling platform of the self-propelled 8-row *Yanji Shakthi* transplanter. Automatic rice mat nursery sowing machine was used for filling the nursery trays. The rice variety Jyothi was used for the experiment.

Chemicals and formulations used for nutripriming

Urea granules obtained as commercial fertilizer from the market, zinc sulphate heptahydrate ($ZnSO_4.7H_2O$- GR grade) and borax ($Na_2B_4O_7.10H_2O$- AR grade) were used for the experiment. Formulation of biocontrol agent *Pseudomonas fluorescens* was purchased from biocontrol lab, Mannuthy. PGPR mix –I, a product from KAU is a formulation of various microorganisms actively involved in plant growth promotion was collected from College of Agriculture, Vellayani.

3.2.2 Experimental methods

The experiment II was conducted at Agricultural Research Station, Mannuthy during July, 2015. The experimental design was factorial CRD with three replications.

Preparation of growing media

Various components of growing media such as rice husk charcoal, soil, vermicompost and coir pith compost were sieved to remove lumps and stones and were mixed manually in accordance with proportion of each treatment on volume basis.

Nutripriming of seed

Nutrient solutions were prepared by dissolving the required quantity of nutrient in required quantity of water to get desired concentration as per treatment. Seeds were soaked in the nutrient solutions of required concentration (w/v) for 12 h under room temperature. One litre of solution was used for soaking 1 kg of seed. Seeds were taken out of solution after 12 h and dried to its original weight under shade. Thereafter, dried seeds were packed in polythene bags.

Treatment details

Combinations of three levels of media and nine levels of nutripriming with twenty seven treatment combinations were studied in this experiment. The details regarding levels of media composition and nutripriming are given in Table 3.6 and treatment combinations in Table 3.7

Table 3.6 Treatments of experiment II

Sl.	**Media compositions**	
1.	40 % RHC + 40 % Soil + 20 % VC	[M_1]
2.	60 % RHC + 20 % Soil + 20 % CPC	[M_2]
3.	80 % RHC + 20 % Soil	[M_6]
	Nutripriming treatments	
1.	0.1 % Urea	[P_1]
2.	0.01 % Borax	[P_2]
3.	0.05 % $ZnSO_4$	[P_3]
4.	0.1 % Urea + 0.01 % Borax	[P_4]
5.	0.1 % Urea + 0.05 % $ZnSO_4$	[P_5]
6.	0.1 % Urea + 0.05 % $ZnSO_4$ + 0.01 % Borax	[P_6]
7.	1.0 % *Pseudomonas fluorescens*	[P_7]
8.	1.0 % PGPR mix-1	[P_8]
9.	Control (water soaking)	[P_9]

Table 3.7 Details of treatment combinations in experiment II

	Treatment combinations
1.	40 % RHC + 40 % Soil + 20 % VC+ 0.1 % Urea
2.	40 % RHC + 40 % Soil + 20 % VC+0.01 % Borax
3.	40 % RHC + 40 % Soil + 20 % VC+0.05 % $ZnSO_4$
4.	40 % RHC + 40 % Soil + 20 % VC+0.1 % Urea + 0.01 % Borax
5.	40 % RHC + 40 % Soil + 20 % VC+0.1 % Urea + 0.05 % $ZnSO_4$
6.	40 % RHC + 40 % Soil + 20 % VC+0.1 % Urea + 0.05 % $ZnSO_4$ + 0.01 % Borax
7.	40 % RHC + 40 % Soil + 20 % VC+ 1.0 % *Pseudomonas fluorescens*
8.	40 % RHC + 40 % Soil + 20 % VC+1.0 % PGPR mix-1
9.	40 % RHC + 40 % Soil + 20 % VC+ Control (water soaking)
10	60 % RHC + 20 % Soil + 20 % CPC+0.1 % Urea
11.	60 % RHC + 20 % Soil + 20 % CPC+0.01 % Borax
12.	60 % RHC + 20 % Soil + 20 % CPC+0.05 % $ZnSO_4$
13.	60 % RHC + 20 % Soil + 20 % CPC+0.1 % Urea + 0.01 % Borax
14.	60 % RHC + 20 % Soil + 20 % CPC+0.1 % Urea + 0.05 % $ZnSO_4$
15.	60 % RHC + 20 % Soil + 20 % CPC+0.1 % Urea + 0.05 % $ZnSO_4$ + 0.01% Borax
16.	60 % RHC + 20 % Soil + 20 % CPC+1.0 % *Pseudomonas fluorescens*
17.	60 % RHC + 20 % Soil + 20 % CPC+1.0 % PGPR mix-1
18.	60 % RHC + 20 % Soil + 20 % CPC+ Control (water soaking)
19.	80 % RHC + 20 % Soil+0.1 % Urea
20.	80 % RHC + 20 % Soil+0.01 % Borax
21.	80 % RHC + 20 % Soil+0.05 % $ZnSO_4$
22.	80 % RHC + 20 % Soil+0.1 % Urea + 0.01 % Borax
23.	80 % RHC + 20 % Soil+0.1 % Urea + 0.05 % $ZnSO_4$
24.	80 % RHC + 20 % Soil+0.1 % Urea + 0.05 % $ZnSO_4$ + 0.01 % Borax
25.	80 % RHC + 20 % Soil+1.0 % *Pseudomonas fluorescens*
26.	80 % RHC + 20 % Soil+1.0 % PGPR mix-1
27.	80 % RHC + 20 % Soil+ Control (water soaking)

Filling of trays with media and seeds

Trays were filled using Automatic Rice Mat Nursery Sowing Machine. Seed metering mechanism was adjusted to deliver seeds @ 110 g per tray. Seeds were covered with a thin layer of the same media composition.

Irrigation of nursery

Nursery was irrigated daily by sprinkling water using rose can.

3.2.3 Observations on tray nursery

Biometric observations and mat characteristics were recorded as in experiment I.

3.2.4 Physico-chemical properties of composition of growing media

Physico-chemical properties of different growing media were analysed as in experiment I.

3.2.5 Nutrient status of media

Nutrient content of the media i.e. organic carbon, N, P, K, Ca, Mg, S, B, Fe, Mn, Cu and Zn were determined as in case of experiment I.

3.2.6 Nutrient content of seedlings

Nutrient content of seedling i.e N, P, K, Ca, Mg, S, B, Fe, Mn, Cu and Zn were determined by following procedure given in Table 3.5.

3.2.7 Nutrient uptake by seedlings

There were on an average of 3794 seedlings per tray, sown with 110g seed. Nutrient content of the seedlings at the time of transplanting was multiplied with the dry matter production of total seedlings per tray at the time of transplanting to get nutrient uptake by the seedlings and expressed as g $tray^{-1}$.

3.2.8 Economics of nursery

The cost for paddy tray nursery was computed on the basis of current market price of different inputs used and labour charges required for raising nursery. Prevailing wages of labour at the time of experiment was considered for labour charges. Details of cost of nursery are given in appendix II.

3.2.9 Selection of best performing media from experiment II

From the three levels of media compositions and nine levels nutripriming, the best performing five treatment combinations were selected based on seedling and mat characteristics using scoring technique. Ranking of the treatment combinations was done using scoring technique based on important parameters of seedling and mat. Seedling and mat characters at the time of transplanting (15DAS) selected for scoring were:

- Seedling height
- Biomass production
- Shoot dry weight
- Root dry weight
- Dry matter production
- Mat weight per unit area
- Shearing strength
- Slippage

The selected parameters were classified into three groups as high, medium and low based on range of values and scores of 5, 3 and 2 were given to high, medium and low classes respectively. The different treatment combinations were classified based on recorded value and scores were given accordingly. The aggregate score for each treatment combination was calculated and were ranked based on the sum of scores obtained. Best performing five treatment combinations based on the rank were selected for experiment III.

a. Soaking in nutrient solution

b. Drying under shade

Plate 7. Steps involved in nutripriming of seeds

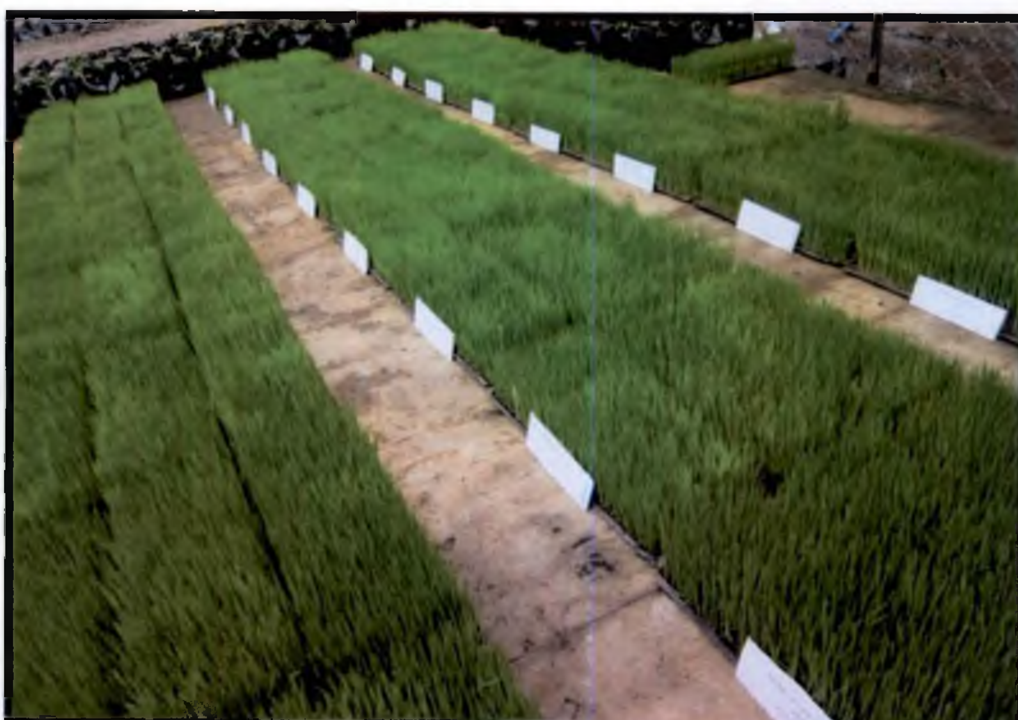

Plate 8. General view of nursery of experiment II at 15 DAS

3.3 EXPERIMENT III. FIELD EVALUATION

3.3.1 General details

Location

The experiment III was conducted in the wet land of Agricultural Research Station, Mannuthy during *virippu* season (21st July, 2015 to 29th October 2015).

Climate and weather conditions

The experimental site has typical humid tropical climate with mean annual rainfall of 219.5 mm during the year 2015. Mean maximum and minimum temperature during the year were 32.5^0C and 23.9^0 C respectively. Maximum rainfall was received during the month of June. The monthly averages of important meteorological parameters recorded during the year 2015 are given in appendix I.

Soil characters

The soil texture of the experimental site is sandy clay loam and belongs to the taxonomical order Oxisol. The physico-chemical characteristics of the soil of the experimental field are presented in Table 3.8

Cropping history of the experimental site

Single crop of wet land paddy followed by vegetable cultivation during the second and third season is the usual cropping pattern of the experimental site.

3.3.2 Experimental details

Five treatments combinations selected from the experiment II along with a control were evaluated under field condition in randomised block design. There were 6 treatments and 4 replications. The plot size was 5 m x 4 m. The layout of the experimental field is given in Fig.3.2. The details of treatments are given in Table 3.9

3.3.3 Crop culture

Land preparation

Land was ploughed thoroughly to incorporate the weeds using tractor. Lime was applied @ 350 kg/ ha after first ploughing. Puddling and levelling were done

Table 3.8 Physico-chemical characteristics of the soil before experiment

Properties	Value
a. Physical properties	
Bulk density (g cm^{-3})	1.35
Particle density (g cm^{-3})	2.16
Water holding capacity (%)	46.0
Particle size composition	
Coarse sand (%)	27.2
Fine sand (%)	23.9
Silt (%)	22.7
Clay (%)	26.2
Texture	Sandy clay loam
b. Chemical properties	
Soil reaction (pH)	4.40
Electrical conductivity (dS m^{-1})	0.25
Organic Carbon (%)	0.67
Available nitrogen(kg ha^{-1})	157.50
Available phosphorus (kg ha^{-1})	56.00
Available potassium (kg ha^{-1})	296.32
Available sulphur (mg kg^{-1})	7.86
Available calcium (mg kg^{-1})	516.55
Available magnesium (mg kg^{-1})	40.60
Available iron (mg kg^{-1})	39.41
Available zinc (mg kg^{-1})	3.30
Available manganese (mg kg^{-1})	112.60
Available copper (mg kg^{-1})	3.29
Available boron (mg kg^{-1})	0.95

Table 3.9 The details of treatments in experiment III

Treatments	
T_1	80% RHC + 20% Soil + 0.1% Urea
T_2	80% RHC + 20% Soil + 0.01% Borax
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax
T_6	Control (Soil media + without nutripriming of seed)

to ensure proper transplanting using mechanical transplanter. Plots of size 5m x 4m were laid out.

Nursery preparation and mechanical transplanting

Mat nursery raised in trays with the desired growing media and primed seeds as per the treatments was used for transplanting. Fifteen days old seedlings were transplanted to the main field using 8-row *Yanji Shakthi* transplanter by running length wise of the plot with a spacing of 23.8 cm x 14 cm. Nursery was prepared on 6^{th} July 2015 and transplanted in main field on 21^{st} July 2015.

Manuring and fertilizer application

Farm yard manure was applied @ 5t ha^{-1} as basal to the experimental area. Second dose of lime was applied @ 250 kg ha^{-1} at about one month after transplanting. Fertilizers were applied as per the package of practices recommendations of Kerala Agricultural University (KAU, 2011). Fertilizer sources of nitrogen, phosphorus and potassium were Urea (46 % N), Rajphos (18 % P_2O_5) and Muriate of potash (60 % K_2O). $2/3^{rd}$ of N, full dose P_2O_5 and ½ dose

K_2O were applied as basal. Remaining 1/3rd of N and ½ dose K_2O were applied 5 days before panicle initiation.

After cultivation

The cultural practices were done as per the Package of Practices recommendations of the Kerala Agricultural University (KAU, 2011). The plots were kept free of weeds by herbicide application followed by hand weeding. Londax power® @ 0.5 kg a.i./ ha was applied as pre-emergence herbicide on sixth day of transplanting.

Plant protection

Cartap hydrochloride (Top® 45) @ 1 kg a.i. ha^{-1} and Flubendiamide (Fame® 480 SC) @ 25g a.i. ha^{-1} were applied against incidence of stem borer. Thiamethoxam (Actara® 25 WG) @ 8 g/ 20L was sprayed when incidence of leaf folder was noticed. Rice bug was controlled by Cypermethrin 25 EC @ 20 ml L^{-1}.

Harvesting

The crop was harvested on 29th October 2015. Two border rows of plants from four sides of the plot were removed and then net plot area was harvested. Threshing and winnowing were done with mechanical thresher cum winnower (Redlands mechanical thresher cum winnower). The weight of grain and straw from net plot was recorded. The weight of grain was registered at 13 per cent moisture content and that of straw as air dry weight in t ha^{-1}.

3.3.4 Items of observations

3.3.4.1 Performance of transplanter

Number of hills planted per metre run

Number of hills planted per metre run of transplanter from ten random places per plot was enumerated using a ruler and the mean was calculated.

Number of seedlings planted per hill

Number of seedlings per hill was enumerated from adjacent hills planted in one metre run of transplanter from ten random places per plot and the mean was recorded.

Number of missing hills per m^2

Number of missing hills per m^2 was enumerated from four random places per plot using 1 m^2 quadrat and the mean was recorded.

Plant population per m^2 *at planting*

Number of plants per m^2 was counted from four random places per plot using 1 m^2 quadrat and the mean was recorded.

3.3.4.2 Biometric observations

Plant height

Height of ten plants was measured as distance from ground level to the tip of the tallest leaf at 30 and 60 DAS. At harvest, plant height was measured from ground level to the tip of tallest panicle and mean was worked out.

Number of tillers per m^2

The number of tillers per m^2 was counted using 1m^2 quadrat from four positions per plot at maximum tillering and panicle initiation and the mean was computed.

Weed count per m^2

The number of weeds per m^2 was counted using 1m^2 quadrat from four positions per plot at 20 and 40 DAS and the mean was computed.

3.3.4.3 Yield attributes

Number of panicles per m^2

The number of panicles per m^2 was counted using 1m^2 quadrat from four positions per plot and the mean was worked out.

Number of spikelets per panicle

Twenty panicles were selected randomly from each plot and number of spikelets per panicle was counted. Mean was computed and recorded.

Number of filled grains per panicle

Twenty panicles were selected randomly from each plot and number of filled grains per panicle was counted. Mean was computed and recorded.

Thousand grain weight

One thousand filled grains were counted from each plot randomly and weighed to get the test weight.

Spikelet sterility

Grains were collected from randomly selected twenty panicles and separated into filled grains and chaff. The number of unfilled grains of each panicle was counted and expressed as percentage of total grain.

$$\text{Spikelet sterility (\%)} = \frac{\text{No. of unfilled grains}}{\text{Total no. of grains}} \times 100$$

3.3.4.4 Grain and Straw yield

The crop harvested from each plot was threshed and winnowed. The weight of grain and straw from net plot was recorded and expressed in t ha^{-1}.

3.3.4.5 Harvest index

Harvest index (HI) is the ratio of economical yield to biological yield. The HI was calculated by the following formula (Redford, 1967).

$$HI = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

3.3.5 Analysis of physico-chemical properties

Soil analysis

Soil samples were collected from the plot before and after the experiment. Samples were air dried, powdered and passed through 2 mm sieve and were used for analyzing physico - chemical characteristics of the soil. The various methods used for the analysis are mentioned in Table 3.10.

Plant analysis

Plant samples were collected randomly from each plot. Samples were dried in a hot air oven at 80 ± 5°C, ground well and analyzed for different nutrients. The methods used for the analysis of different nutrients are given in Table 3.5.

3.3.6 Uptake of nutrients at harvest

Uptake of nutrients by grain and straw was calculated by multiplying the particular nutrient content of grain and straw at harvest with corresponding dry matter production at harvest. Total nutrient uptake was also calculated.

3.3.7 Economics of cultivation

Economics of cultivation was calculated on basis of input cost, labour charges and gross returns at prevailing market price. Benefit cost ratio was calculated by dividing the gross return with total expenditure per hectare. Prevailing wages of labour at the time of experiment was considered for labour charges. Details of cost of cultivation are given in Appendix IV.

3.3.8 Statistical analysis

Statistical packages such as Web Agri Stat Package (WASP 2.0), OPSTAT and Microsoft excel spread sheets were used for computation and analysis. Duncan's multiple range test (DMRT) was used to compare means (Duncan, 1955; Gomez and Gomez, 1984).

Table 3.10 Methods for chemical analysis of soil

No.	Particulars	Method	References
1.	Mechanical analysis	Robinson's International pipette method	Robinson, 1922
2.	pH	Soil water suspension of 1:2.5 and read in pH meter	Jackson,1958
3.	Electrical conductivity	Supernatant liquid from soil water suspension of 1:2.5 and read in conductivity meter	Jackson,1958
4.	Organic carbon	Walkley and Black method	Walkley and Black, 1934
5.	Available N	Alkaline permanganometry	Subbiah and Asija, 1956
6.	Available P	Extraction using Bray No.1 Estimated colorimetrically by ascorbic acid reduced molybdophosphoric blue colour method	Bray and Kurtz, 1945 Watanabe and Olsen, 1965
7.	Available K	Neutral normal ammonium acetate extract using flame photometer	Jackson, 1958
8.	Available Ca & Mg	Neutral normal ammonium acetate extract using Inductively Coupled Plasma Optical Emission Spectrometry (Model : Perkin Elmer Optima 8000)	Jackson, 1958
9.	Available S	$CaCl_2$ extract- turbidimetry method	Chesnin and Yien, 1951
10.	Available Fe, Mn, Cu & Zn	0.1M HCl acid extract method using Inductively Coupled Plasma Optical Emission Spectrometry (Model : Perkin Elmer Optima 8000)	Sims and Johnson, 1991
11.	Available B	Hot water extraction and Azomethine- H method using spectrophotometer	Berger and Truog, 1945; Gupta, 1967

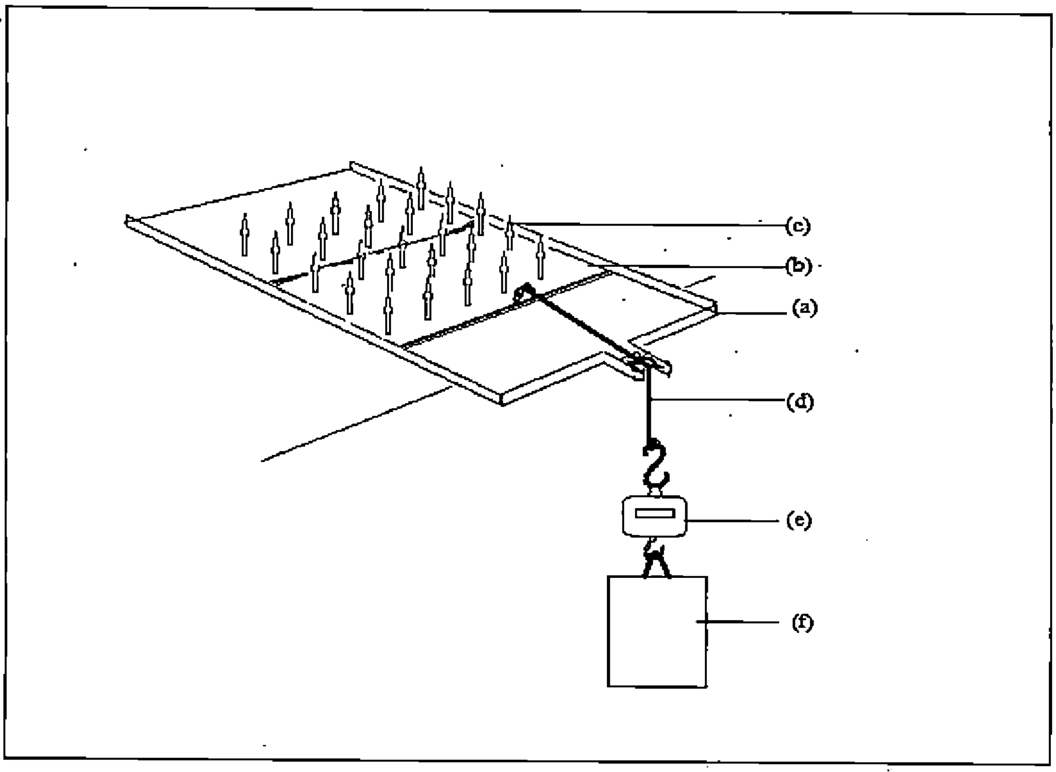

Figure 3.1 Device for measurement of mat shearing strength

a. Rectangle base b. Rectangle plate c. Nails d. Rope e. Weighing balance f. Weight bag

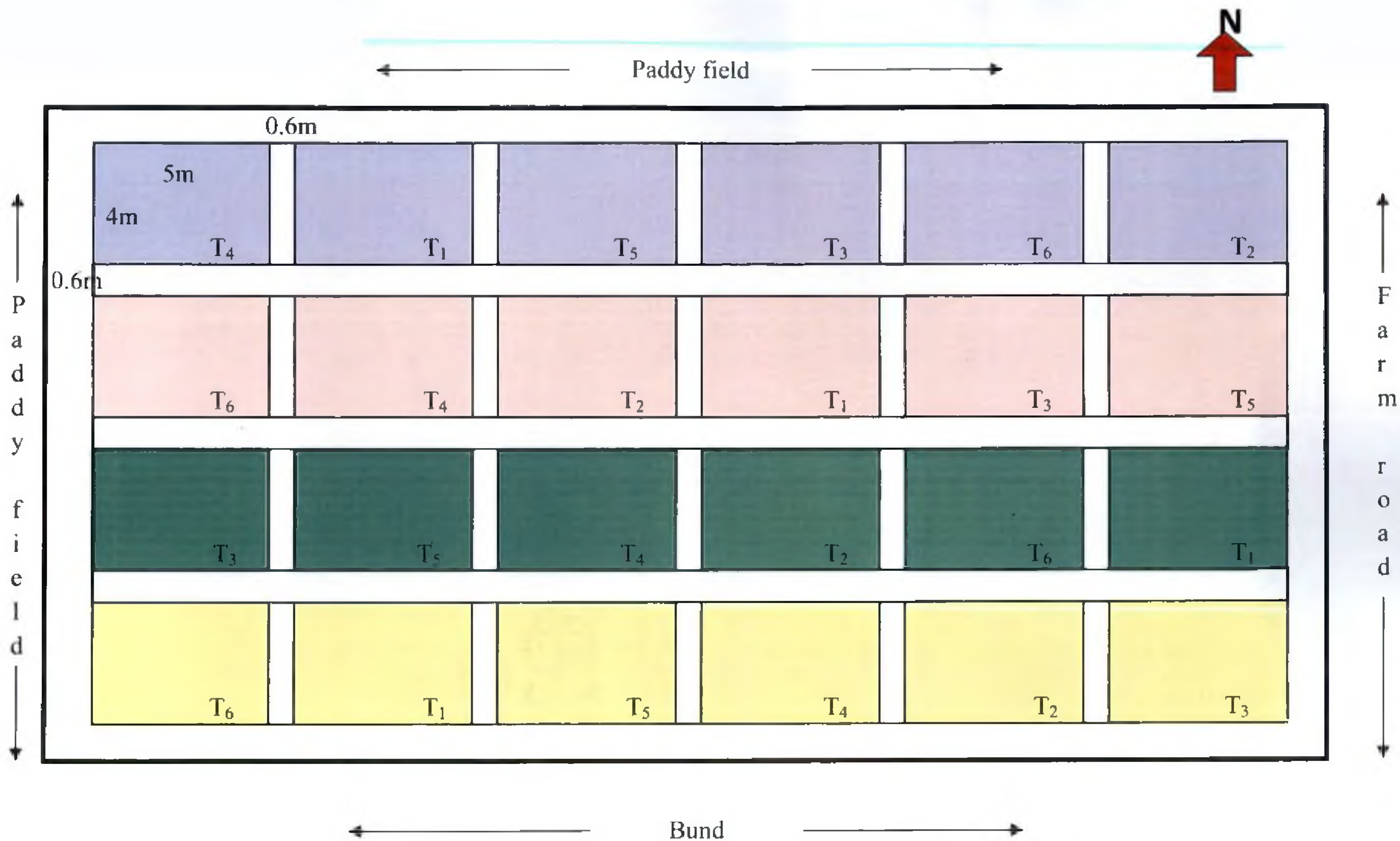

Fig. 3.2 Lay out of the experimental plot

Plate 9. Puddling of field

Plate 10. Mechanical transplanting

Plate 11. General view of crop at 30 DAT

Plate 12. General view of crop at dough stage

RESULTS

IV. RESULTS

Experiments on "Nutripriming and mat thickness on tray nursery in rice" was conducted during the year 2015-16 at Agricultural Research Station, Mannuthy in Thrissur district. The results obtained from the three experiments of the study are furnished in this chapter with relevant tables after statistical analysis.

4.1 STANDARDIZATION OF GROWING MEDIA AND THICKNESS OF TRAY NURSERY IN RICE

The Experiment I was carried out to standardise the composition and thickness of growing media for tray nursery technique of rice. Two factor ANOVA revealed differential response for the six media compositions over the three thickness of mat under consideration for the enlisted parameters.

The results of this experiment are mentioned here with pertinent parameters that contribute to the quality of a mat for rice nursery.

4.1.1 Biometric characters of seedlings

Days to 50 per cent germination

The data regarding the effect of composition and thickness of growing media on days to 50 per cent germination is given in table 4.1 and their interaction effect in table 4.2. The media compositions M_1 and M_2 attained 50 per cent germination within significantly short period of time (3.44 days) compared to other media compositions. Longest duration of 4.33 days was taken by M_3 and M_4. All the three media thicknesses were on par with regard to days to 50 per cent germination. Among the treatment combinations, M_1S_1, M_2S_1, M_1S_3 and M_2S_3 exhibited the shortest period for 50 per cent germination (3.33 days).

Height of seedlings

The data on height of seedlings as influenced by media composition and thickness at 5, 10 and 15 DAS are given in table 4.3 and their interaction effect in table 4.5. Media composition significantly influenced the height of seedlings at 5, 10 and 15 DAS.

Maximum seedling height (5.91 cm) was observed in M_2 and was significantly superior to all other media compositions at 5 DAS. Thickness of media also significantly influenced the height of seedlings. Maximum height (4.95 cm) was observed in S_1 which was on par with S_3 but significantly superior to S_2 (4.60 cm). The interaction between media composition and thickness was also found to be significant with regard to height of seedling at 5 DAS. The treatment combination M_2S_1 contributed to the greatest height (6.26 cm) which was on par with M_2S_3.

The greatest seedling height (13.89 cm) was observed in M_1 at 10 DAS which was significantly superior to all other media compositions. There was no significant effect on seedling height by media thickness. Treatment combination M_1S_2 was superior and on par with M_1S_3, M_2S_3 and M_1S_1 at 10DAS.

At transplanting (15 DAS), the tallest seedlings were produced in M_1 media and S_2 thickness which were significantly superior. The treatment combination M_1S_2 produced the tallest seedlings (19.15 cm) which was significantly superior to all other treatment combinations.

Biomass production

The data pertaining to biomass production of seedlings at 5, 10 and 15 DAS as influenced by media composition and thickness are presented in table 4.4. and their interaction effect in table 4.5

Significantly higher biomass (69.29 mg) was produced by seedlings in M_2 composition at 5 DAS. 20 mm (S_3) thickness of media produced the highest biomass (55.59 mg) which was on par with that produced in media with 10mm (S_1) and 15 mm (S_2) thickness.

The highest biomass (78.81mg) was produced in M_1which was on par with M_2 at 10 DAS. The levels of thickness did not produce any significant effect on biomass production at 10 DAS. The treatment combination M_1S_2 produced the highest biomass (87.43mg) which was on par with M_1S_3, M_2S_3 and M_5S_1.

Table 4.1 Effect of composition and thickness of media on days to 50 per cent germination

Treatments	Days to 50% germination
M_1	3.44
M_2	3.44
M_3	4.33
M_4	4.33
M_5	4.11
M_6	4.22
C.D. $_{(0.05)}$	**0.53**
S_1	4.00
S_2	4.00
S_3	3.94
C.D. $_{(0.05)}$	**NS**
Media x Thickness	S

Table 4.2 Interaction effect of composition and thickness of media on days to 50 per cent germination

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
	Days to 50% germination					
S_1	3.33	3.33	4.33	4.33	4.33	4.33
S_2	3.67	3.67	4.00	4.33	4.33	4.00
S_3	3.33	3.33	4.67	4.33	3.66	4.33
C.D. $_{(0.05)}$	0.92					

Table 4.3 Effect of composition and thickness of media on height of seedling at 5, 10 and 15 DAS

Treatments	5 DAS (cm)	10 DAS (cm)	15 DAS (cm)
M_1	4.88	13.89	17.11
M_2	5.91	12.34	14.95
M_3	4.28	9.47	12.48
M_4	4.16	10.42	13.77
M_5	4.85	10.34	13.61
M_6	4.88	12.08	16.12
C.D. (0.05)	**0.40**	**1.52**	**1.00**
S_1	4.95	11.57	14.56
S_2	4.60	11.12	15.36
S_3	4.94	11.58	14.11
C.D. (0.05)	**0.28**	**NS**	**0.71**
Media x Thickness	S	S	S

Table 4.4 Effect of composition and thickness of media on biomass production of seedling at 5, 10 and 15 DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	54.89	78.81	121.54
M_2	69.29	73.62	121.07
M_3	46.10	64.78	101.18
M_4	42.77	64.57	91.41
M_5	51.03	63.50	93.56
M_6	52.31	69.12	109.46
C.D. (0.05)	**6.27**	**6.28**	**7.17**
S_1	52.21	67.45	107.0
S_2	50.39	70.39	106.6
S_3	55.59	69.36	105.3
C.D. (0.05)	**NS**	**NS**	**NS**
Media x Thickness	NS	S	S

Table 4.5 Interaction effect of composition and thickness of media on height and biomass production of seedling of rice at 5, 10 and 15 DAS

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
Height of seedling at 5 DAS (cm)						
S_1	4.77	6.26	4.51	4.38	4.89	4.90
S_2	4.54	5.48	3.95	4.06	4.42	5.17
S_3	5.33	6.01	4.37	4.05	5.26	4.59
C.D. $_{(0.05)}$	0.70					
Height of seedling at 10 DAS (cm)						
S_1	12.86	11.77	9.17	11.87	11.20	12.57
S_2	15.22	12.36	9.23	9.80	11.52	11.95
S_3	13.59	12.89	10.03	9.60	11.63	11.71
C.D. $_{(0.05)}$	2.63					
Height of seedling at 15 DAS (cm)						
S_1	15.70	14.26	12.99	14.31	13.8	16.27
S_2	19.15	15.64	12.75	14.04	14.10	16.50
S_3	16.47	14.95	11.70	12.97	12.94	15.61
C.D. $_{(0.05)}$	1.73					
Biomass production at 10 DAS (mg)						
S_1	63.17	71.73	59.23	67.77	80.17	62.63
S_2	87.43	67.60	61.40	62.90	67.40	75.60
S_3	85.83	81.53	73.70	63.03	42.9	69.12
C.D. $_{(0.05)}$	10.88					
Biomass production at 15 DAS (mg)						
S_1	116.57	112.67	101.53	100.13	91.57	119.93
S_2	130.37	124.63	99.47	86.27	96.00	103.27
S_3	117.70	125.90	102.53	87.83	93.10	105.17
C.D. $_{(0.05)}$	12.43					

The media compositions M_1 and M_2 recorded higher biomass production (121.5 and 121 mg) at 15 DAS. M_1 and M_2 were on par to each other and significantly superior to all other media compositions at 15 DAS. However, levels of thickness did not show any significant variation. With respect to interaction, biomass produced by the treatment combination M_1S_2 was the highest which was on par with M_2S_2, M_2S_3 and M_6S_1.

Shoot dry weight

The data regarding influence of media composition and thickness on shoot dry weight at 5, 10 and 15 DAS are given in table 4.6 and its interaction effect on table 4.8.

The media composition M_2 produced the highest shoot dry weight (2.83mg) which was on par with M_6 and M_1 at 5 DAS. Highest shoot dry weight (2.54g) was recorded by the lowest media thickness (S_1) which was on par with S_3.

The highest shoot dry weight (10.16 mg) was observed in M_1 which was on par with M_2 and significantly superior to all other media compositions at 10 DAS. Thickness level S_2 was superior with respect to shoot dry weight. The highest and the lowest shoot dry weight were recorded by treatment combinations M_1S_2 and M_4S_3 respectively.

The media composition M_1 continued to be superior and on par with M_2 with respect to shoot dry weight at 15 DAS. No significant difference in shoot dry weight was observed with respect to the levels of media thickness. M_1S_2 treatment combination was found to contribute maximum towards higher shoot dry weight at 15 DAS also.

It is worthwhile to indicate that all media containing soil as one of the component produced (M_1, M_6 and M_2) higher shoot dry weight than soilless media at 5, 10 and 15 DAS.

Root dry weight

Effect of media composition and thickness on root dry weight 5, 10 and 15 DAS is reported in table 4.7 and interaction effect in table 4.8.

Media M_2 was found to be superior with respect to the root dry weight at 5 DAS. S_1 media thickness produced the highest root dry weight at 5 DAS and which was on par with S_3. Among the treatment combinations, M_2S_1 recorded the highest root dry weight (2.67 mg) which was significantly superior to all other combinations.

The highest root dry weight (3.56 mg) was produced by M_2 media composition at 10 DAS. Root dry weight was not significantly influenced by media thickness. Interaction effect was also not significant.

Media composition M_2 remained to register significantly highest root dry weight (4.5 mg) at 15 DAS also. Among the levels of thickness S_1 (10 mm) produced the highest root dry weight (3.42 mg). Similar to biomass production, root dry weight increased with decrease in media thickness at 15DAS.

Dry matter production

Data on influence of media composition and mat thickness on dry matter production of seedlings is given in table 4.9 and interaction effect in table 4.10

The highest dry matter (4.47 mg) was produced in M_2 which was significantly superior to all other media at 5 DAS. The highest dry matter (3.76 mg) among the levels of thickness was produced by the lowest media thickness (S_1). Treatment combination M_2S_1 produced the highest dry matter (5.70 mg) at 5 DAS which was on par with M_2S_3.

Media M_2 was found to be superior with respect to the dry matter production of seedlings at 10 DAS which was on par with M_1. Levels of thickness of media did not significantly influence the build up of dry matter. The highest dry matter (14.37 mg) was produced in M_1S_2 combination at 10 DAS.

Media compositions followed same trend at 15DAS also. Level of thickness had no significant effect on dry matter production at 15 DAS. M_2S_3 combination was superior in dry matter production (20.37 mg) at 15 DAS.

In general, as in case of root dry weight, the composition M_2 continued to record the highest dry matter production at 5, 10 and 15 DAS.

Table 4.6 Effect of composition and thickness of media on shoot dry weight of seedling at 5, 10 and 15 DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	2.29	10.16	14.50
M_2	2.83	9.74	14.53
M_3	1.98	6.91	9.70
M_4	2.11	7.16	10.07
M_5	2.22	7.32	9.21
M_6	2.71	8.79	11.40
C.D. $_{(0.05)}$	**0.50**	**0.53**	**0.94**
S_1	2.54	8.03	11.40
S_2	2.06	8.71	11.97
S_3	2.47	8.31	11.34
C.D. $_{(0.05)}$	**0.35**	**0.38**	**NS**
Media x Thickness	NS	S	S

Table 4.7 Effect of composition and thickness of media on root dry weight of seedling at 5, 10 and 15 DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	0.52	3.02	3.82
M_2	1.68	3.56	4.50
M_3	0.82	2.22	2.77
M_4	1.10	2.42	2.54
M_5	0.90	2.17	2.39
M_6	1.09	2.69	2.88
C.D. $_{(0.05)}$	**0.23**	**0.40**	**0.42**
S_1	1.24	2.69	3.42
S_2	0.74	2.51	3.08
S_3	1.08	2.84	2.94
C.D. $_{(0.05)}$	**0.16**	**NS**	**0.28**
Media x Thickness	S	NS	NS

Table 4.8 Interaction effect of composition and thickness of media on shoot dry weight of seedlings at 10 and 15 DAS and root dry weight of seedlings at 5 DAS

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
Shoot dry weight at 10 DAS (mg)						
S_1	8.87	9.17	7.17	7.87	6.73	8.37
S_2	11.70	10.17	6.97	7.53	6.97	8.90
S_3	9.90	9.90	6.60	6.07	8.27	9.10
C.D. (0.05)	0.93					
Shoot dry weight at 15 DAS (mg)						
S_1	13.93	13.40	9.60	10.17	10.10	11.20
S_2	16.23	14.20	9.87	10.33	8.83	12.33
S_3	13.33	16.00	9.63	9.70	8.70	10.67
C.D. (0.05)	1.64					
Root dry weight at 5 DAS (mg)						
S_1	0.47	2.67	0.47	1.27	1.33	1.23
S_2	0.70	0.50	0.97	0.50	0.40	1.37
S_3	0.40	1.87	1.03	1.53	0.97	0.67
C.D. (0.05)	0.39					

Table 4.9 Effect of composition and thickness of media on dry matter production of seedlings at 5, 10 and 15 DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	2.78	13.19	18.32
M_2	4.47	13.30	19.03
M_3	2.82	9.02	12.68
M_4	3.19	9.58	12.61
M_5	3.22	9.47	11.60
M_6	3.80	11.48	14.21
C.D. (0.05)	**0.65**	**0.68**	**1.09**
S_1	3.76	10.71	0.15
S_2	2.84	11.22	0.15
S_3	3.54	11.09	0.14
C.D. (0.05)	**0.46**	**NS**	**NS**
Media x Thickness	**S**	**S**	**S**

Table 4.10 Interaction effect of composition and thickness of media on dry matter production of seedlings at 5, 10 and 15 DAS

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
Dry matter production at 5 DAS (mg)						
S_1	2.53	5.70	3.03	3.80	3.83	3.63
S_2	2.80	2.80	2.70	2.27	2.50	4.00
S_3	3.00	4.90	2.73	3.50	3.33	3.77
C.D. (0.05)	1.13					
Dry matter production at 10 DAS (mg)						
S_1	11.90	12.73	9.03	10.23	8.97	11.40
S_2	14.37	13.47	9.23	9.97	8.97	11.30
S_3	13.30	13.70	8.80	8.53	10.47	11.73
C.D. (0.05)	0.17					
Dry matter production at 15 DAS (mg)						
S_1	18.00	17.93	13.10	12.87	12.93	14.73
S_2	19.93	18.80	12.70	13.03	11.17	14.67
S_3	17.03	20.37	12.23	11.93	10.71	13.23
C.D. (0.05)	1.88					

4.1.1.7 Root length at transplanting

The data presented in table 4.11 showed that the longest root of 10.14 cm was attained by seedlings in the M_2 media which was on par with M_3 and M_6. Variation in media thickness did not influence significantly on root length at transplanting. M_3S_2 treatment combination produced longest root (10.59 cm) at transplanting (Table 4.12).

4.1.1.8 Pest and disease incidence scoring

There was no pest and disease incidence in the nursery and hence scoring was not done.

4.1.2 Mat characteristics

4.1.2.1 Mat weight per unit area

The data on effect of media composition and thickness on weight of mat are given in table 4.13 and their interaction effect in table 4.14. Mat weight per unit area was ranged from 13.94 kg $m^{-2}$to 28.62 kg m^{-2}. Highest mat weight was recorded by the media composition containing 40 per cent soil (M_1) followed by media containing 20 per cent soil (M_2 and M_6). Soilless media compositions were found to have lower mat weight per unit area. An increase in the mat weight per unit area was observed with the increase in level of media thickness. M_1S_3 and M_4S_1 treatment combinations recorded the highest and the lowest mat weight per unit area respectively.

4.1.2.2 Density of mat

The data pertaining to the effect of media composition and thickness on density of mat are given in table 4.13 and their interaction effect in table 4.14. Media composition M_1 recorded the highest and M_4 recorded the lowest density of mat. Media (M_1) containing highest amount of soil (40%) was observed to have the highest density. Among various levels of media thickness S_1 showed superiority. The highest density of mat was reported by M_1S_1 treatment combination.

Table 4.11 Effect of composition and thickness of media on root length at transplanting

Treatments	Root length at transplanting (cm)
M_1	8.89
M_2	10.14
M_3	9.70
M_4	7.67
M_5	8.81
M_6	9.63
C.D. (0.05)	**0.98**
S_1	9.40
S_2	8.88
S_3	9.14
C.D. (0.05)	**0.51**
Media x Thickness	S

Table 4.12 Interaction effect of composition and thickness of media on root length at transplanting

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
Root length at transplanting (cm)						
S_1	9.05	10.36	9.82	8.62	8.23	10.34
S_2	8.45	10.37	10.59	7.49	8.17	8.21
S_3	9.16	9.7	8.68	6.91	10.02	10.34
C.D. (0.05)	1.70					

Table 4.13 Effect of composition and thickness of media on mat weight per unit area and density

Treatments	Mat weight per unit area (kg m^{-2})	Density of mat (g cm^{-3})
M_1	28.62	2.07
M_2	21.74	1.82
M_3	16.54	1.32
M_4	13.94	0.93
M_5	18.09	1.13
M_6	21.22	1.09
C.D. (0.05)	**1.46**	**0.19**
S_1	16.37	1.50
S_2	20.76	1.33
S_3	22.96	1.35
C.D. (0.05)	**1.03**	**0.13**
Media x Thickness	S	S

Table 4.14 Interaction effect of composition and thickness of media on mat weight per unit area and density

Thickness \ Media	M_1	M_2	M_3	M_4	M_5	M_6
Mat weight per unit area of 1m^2 (kg m^{-2})						
S_1	23.70	17.10	13.23	11.00	15.20	17.97
S_2	29.97	21.77	15.27	14.93	19.40	23.23
S_3	32.20	26.37	21.13	15.90	19.67	22.47
C.D. (0.05)	0.25					
Density of mat (g cm^{-3})						
S_1	2.85	1.65	1.65	0.97	0.98	0.91
S_2	1.73	1.85	1.12	1.00	1.24	1.03
S_3	1.62	1.96	1.19	0.83	1.18	1.34
C.D. (0.05)	0.33					

Shearing strength of mat

The data regarding influence of media composition and thickness on shearing strength of mat are given in table 4.15. Shearing strength of mat ranged from 34.39 kg m^{-2} to 92.33kg m^{-2}. The highest shearing strength (92.33kg m^{-2}) of mat was recorded by M_1S_1 treatment combination. However, M_3S_2 recorded weak mat strength of 34.39 kg m^{-2}.

Slippage of mat

The data regarding interaction effect of media composition and thickness on slippage of mat are given in table 4.15. Slippage of mat ranged from 0 cm $min.^{-1}$ to 2.5 cm $min.^{-1}$. No slippage was recorded by M_1S_3 and M_6S_3 treatment combinations. M_2S_1, M_3S_1, $M_5S_1$and M_6S_1 were also recorded the lower slippage of mat on seedling platform of the transplanter.

4.1.3 Physico-chemical properties of components of growing media

The data regarding physico-chemical properties of components of growing media such as water holding capacity, pH, bulk density and electrical conductivity are given in table 4.16. Rice husk charcoal was recorded water holding capacity of 305 per cent and bulk density of 0.21g cm^{-3}. It was alkaline in nature (pH- 7.1) and recorded the electrical conductivity of 0.023 dS m^{-1}. Vermicompost recorded water holding capacity of 69.8 per cent and bulk density of 0.68 per cent. Vermicompost was acidic in nature (pH-5.08). Electrical conductivity of vermicompost was found to be 1.89 dS m^{-1}. The lowest bulk density of 0.18g/cm^3 and the highest water holding capacity of 525.49 per cent was reported by coir pith compost. Coir pith compost was acidic in nature (pH- 4.75) and recorded the electrical conductivity of 0.043 dS m^{-1}.

4.1.4 Nutrient status of components of growing media

The data regarding nutrient status of components of growing media are given in table 4.17. Rice husk charcoal contained very less amount of nitrogen (0.02%). Nitrogen content of the vermicompost and coir pith compost was 1.9 % and 1.3 % respectively. Phosphorus content of all the three components did not showed much

Table 4.15 Effect of composition and thickness of media on shearing strength and slippage

Sl. No.	Treatment combinations	Shearing strength (kg m^{-2})	Slippage (cm min.$^{-1}$)
1.	M_1 S_1	92.33	1
2.	M_1 S_2	74.56	1
3.	M_1 S_3	77.50	0
4.	M_2 S_1	59.61	0.3
5.	M_2 S_2	73.06	0.5
6.	M_2 S_3	39.56	2
7.	M_3 S_1	39.67	0.3
8.	M_3 S_2	34.39	0.5
9.	M_3 S_3	36.89	1.5
10.	M_4 S_1	70.39	2.5
11.	M_4 S_2	65.39	0.8
12.	M_4 S_3	73.89	1.5
13.	M_5 S_1	66.44	0.3
14.	M_5 S_2	37.67	1.8
15.	M_5 S_3	45.56	1.3
16.	M_6 S_1	60.50	0.5
17.	M_6 S_2	55.83	0.2
18.	M_6 S_3	52:83	0

Table 4.16 Physico-chemical properties of rice husk charcoal, vermicompost and coir pith compost

Sl. No.	Parameters	Rice husk charcoal	Vermicompost	Coir pith compost
1.	Water holding capacity (%)	305.25	69.80	525.49
2.	Bulk density (g cm^{-3})	0.21	0.68	0.18
3.	pH	7.10	5.08	4.75
4.	Electrical conductivity (dS m^{-1})	0.023	1.89	0.043

Table 4.17 Nutrient status of rice husk charcoal, vermicompost and coir pith compost

Sl. No.	Parameters	Rice husk charcoal	Vermicompost	Coir pith compost
1.	Organic carbon (%)	9.23	32.62	48.86
2.	Nitrogen (%)	0.02	1.9	1.3
3.	Phosphorus (%)	0.27	0.37	0.23
4.	Potassium (%)	1.30	1.07	2.28
5.	Sulphur (%)	0.51	0.58	0.15
6.	Calcium (%)	0.97	2.15	0.37
7.	Magnesium (%)	0.26	0.55	0.16
8.	Iron (%)	0.79	2.66	0.31
9.	Zinc (mg kg^{-1})	27.33	93.92	26.33
10.	Manganese (mg kg^{-1})	138.67	931.00	300.50
11.	Copper (mg kg^{-1})	17.92	23.25	14.67
12.	Boron (mg kg^{-1})	24.91	41.43	69.15

variation. The potassium content of rice husk charcoal, vermicompost and coir pith compost were 1.3, 1.07 and 2.28 per cent respectively. Sulphur, calcium and magnesium content of rice husk charcoal were 0.51, 0.97 and 0.26 per cent respectively, while sulphur and magnesium content of vermicompost were 0.58 per cent and 0.55 per cent respectively. The highest Ca content (2.15 %) was registered by vermicompost. Coir pith compost was having 0.37 per cent of Ca, 0.16 per cent of Mg and 0.15 per cent of S. The highest Fe (2.66 %), Zn (93.92 mg kg^{-1}), Mn (931 mg kg^{-1}) and Cu (23.25 mg kg^{-1}) content was noticed in vermicompost while the highest boron content (69.15 mg kg^{-1}) was recorded by coir pith compost.

4.1.5 Physico-chemical properties of growing media

Data on physico-chemical properties of growing media such as water holding capacity, pH, bulk density and electrical conductivity are given in table 4.18. There was a wide variation in water holding capacity among different growing media. M_4 had significantly higher water holding capacity (337 %) and the lowest (62 %) was with M_1. All the media showed significant variation in water holding capacity. Bulk density of the media varied from 0.2 g cm^{-3} to 0.93 g cm^{-3}. M_1 showed the highest bulk density and the lowest was with M_4. Media containing soil as one of the component recorded higher bulk density than soilless media.

All the media were acidic in nature. M_4 recorded the lowest pH (4.99). The highest pH (6.29) was recorded by M_6. Media containing soil as one of the component recorded higher pH than rest of the media. Electrical conductivity of the media ranged from 0.26 dS m^{-1} to 1.07 dS m^{-1}. The highest EC was recorded by M_3 and the lowest by M_6.

4.1.6 Nutrient status of growing media

The data regarding nutrient status of growing media are given in table 4.19 and table 4.20.

Organic carbon, N, P and K contents of growing media

Organic carbon of the media showed wide variation from 9.20 per cent to 19.32 per cent. Media containing both coir pith compost and vermicompost (M_3)

recorded the highest organic carbon content of 19.32 per cent. The lowest organic carbon content (9.20%) was noticed in M_6. Nitrogen content in the media varied from 0.2 per cent to 0.6 per cent. In M_5, the N content was the highest (0.6 per cent). P content of the media varied from 0.20 per cent to 0.48 per cent. All soilless media (M_3, M_4 and M_5) recorded comparable values with respect to P content. Phosphorus content in the soilless media was significantly superior to the media with soil as one of the component. K content of the media varied from 1.03 per cent to 1.21 per cent. The higher value of K was noticed in media containing coir pith compost as one of the component. The highest K content (1.21 %) was observed in M_4 followed by M_3 and M_2.

Ca, Mg and S content of growing media

Calcium content of the media showed wide variation from 0.28 per cent to 1.23 per cent. Media containing both vermicompost and rice husk charcoal (M_5) recorded the highest calcium content (1.23%) which was on par with M_3. The highest Mg (0.31%) was recorded by the media with higher proportion of soil and vermicompost. Mg content of the media varied from 0.18 per cent to 0.31 per cent. The lowest Mg content was recorded by M_4. Sulphur content of the media ranged from 0.43 per cent to 0.64 per cent. The highest sulphur content (0.64%) was also observed in the media with higher content of soil and vermicompost. The lowest S content (0.43%) was noticed in the media containing vermicompost and rice husk charcoal (M_5).

Micronutrient content in growing media

The data regarding content of Fe, Mn, Zn, Cu and B of different growing media are shown in table 4. 20.

All the media containing soil as one of the component recorded the higher Fe content than media devoid of soil. Iron content showed wide variation from 1.01 per cent to 3.17 per cent. The highest Mn content (597 mg kg^{-1}) was observed in M_3 which was on par with M_5. Media containing soil and any of the compost as nutrient source along with rice husk charcoal (M_1 and M_2) registered the higher contents of zinc and copper. The highest amount of boron (55.56 mg kg^{-1}) was

Table 4.18 Physico-chemical properties of growing media composition

Growing media composition		Water holding capacity (%)	Bulk density (g cm^{-3})	pH	Electrical conductivity (dS m^{-1})
M_1	40% RHC + 40% Soil + 20% VC	62.55^{f}	0.93^{a}	5.87	0.80
M_2	60% RHC + 20% Soil + 20% CPC	114.64^{d}	0.54^{c}	5.72	0.45
M_3	60% RHC+ 20% CPC+ 20% VC	246.44^{b}	0.31^{d}	5.52	1.07
M_4	80% RHC+ 20% CPC	337.34^{a}	0.20^{e}	4.99	0.51
M_5	80% RHC + 20% VC	227.61^{c}	0.32^{d}	5.32	0.75
M_6	80% RHC + 20% Soil	102.43^{e}	0.60^{b}	6.29	0.26

* The means followed by common alphabets do not differ significantly at 5 % level in DMRT

Table 4.19 Organic carbon, Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and sulphur content of growing media composition

Growing media composition		Organic carbon (%)	N (%)	P (%)	K (%)	Ca (mg kg^{-1})	Mg (mg kg^{-1})	S (mg kg^{-1})
M_1	40% RHC + 40% Soil + 20% VC	9.62^{e}	0.50^{ab}	0.23^{b}	1.03^{c}	5206^{b}	3135^{a}	6375^{a}
M_2	60% RHC + 20% Soil + 20% CPC	10.82^{d}	0.20^{c}	0.20^{b}	1.12^{c}	4767^{bc}	2904^{ab}	5036^{b}
M_3	60% RHC+ 20% CPC+ 20% VC	19.32^{a}	0.30^{bc}	0.48^{a}	1.16^{b}	12233^{a}	2984^{ab}	4349^{bc}
M_4	80% RHC+ 20% CPC	18.16^{b}	0.40^{b}	0.42^{a}	1.21^{a}	5941^{b}	1798^{c}	3205^{d}
M_5	80% RHC + 20% VC	16.53^{c}	0.60^{a}	0.44^{a}	1.09^{d}	12341^{a}	3088^{ab}	5036^{b}
M_6	80% RHC + 20% Soil	9.20^{f}	0.20^{c}	0.21^{b}	1.09^{d}	2861^{c}	2254^{bc}	4075^{cd}

* The means followed by common alphabets in a column do not differ significantly at 5 % level in DMRT

Table 4.20 Iron, Manganese, Zinc, Copper and Boron content of growing media composition

Growing media composition		Fe (%)	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
M_1	40% RHC + 40% Soil + 20% VC	3.10^{a}	427^{b}	56.67^{a}	32.42^{a}	55.56^{a}
M_2	60% RHC + 20% Soil + 20% CPC	3.17^{a}	412^{b}	59.08^{a}	31.17^{a}	45.87^{ab}
M_3	60% RHC+ 20% CPC+ 20% VC	1.12^{b}	597^{a}	53.25^{ab}	17.17^{bc}	16.35^{d}
M_4	80% RHC+ 20% CPC	1.01^{b}	294^{c}	25.42^{c}	10.67^{c}	2.22^{e}
M_5	80% RHC + 20% VC	1.20^{b}	541^{a}	47.42^{ab}	15.25^{c}	40.95^{bc}
M_6	80% RHC + 20% Soil	2.36^{a}	307^{c}	35.25^{bc}	22.67^{b}	29.05^{c}

* The means followed by common alphabets in a column do not differ significantly at 5 % level in DMRT

noticed in the media containing the highest amount of soil along with vermicompost (M_1). Media containing vermicompost and coir pith along with rice husk charcoal compost recorded the lowest B content.

4.1.7 Nutrient content of seedlings

The data on influence of media composition and thickness on N, P and K content of seedlings are given in table 4.21 and their interaction effect on table 4.22.

Nitrogen

The highest N content of the seedling was recorded by the media containing vermicompost along with rice husk charcoal (M_5) which was on par with M_4, M_2 and M_6. S_3 and S_1 media thicknesses contributed significantly to the higher N content of the seedlings. Interaction between composition and thickness of media were also found to be significant. Among treatment combinations M_5S_3, was superior but on par with M_2S_3, M_6S_1, M_4S_1 and M_2S_1.

Phosphorus

Media composition, thickness and their interaction were significantly influenced on phosphorus content of the seedlings at 15 DAS. The highest P content was recorded by M_5 which was on par with M_4, M_3 and M_6. Media M_3 recorded the least P content. Thickest media (S_3) produced the highest P content of seedlings which was significantly superior to other levels. M_5S_3 treatment combination registered the highest P content of seedlings which was on par with M_4S_3 and M_5S_2.

Potassium

Seedlings grown in the M_3 and M_1 media were found to have higher K content. There was significant increase in K content of seedlings with increase in media thickness. Significant increase from 3.62 per cent to 4.22 per cent was noticed with increase in media thickness from 10mm to 20mm. Among the treatment combinations, M_1S_2 and M_2S_1 recorded the highest and the lowest K contents respectively.

Table 4.21 N , P and K content of seedlings at 15 DAS as influenced by variation in composition and thickness of media,

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
M_1	2.02	1.07	4.60
M_2	2.32	0.90	3.93
M_3	2.02	1.24	4.70
M_4	2.35	1.45	3.42
M_5	2.44	1.66	3.78
M_6	2.29	1.18	3.38
C.D. $_{(0.05)}$	**0.25**	**0.09**	**0.11**
S_1	2.28	1.20	3.62
S_2	2.09	1.24	4.07
S_3	2.36	1.31	4.22
C.D. $_{(0.05)}$	**0.18**	**0.06**	**0.08**
Media x Thickness	S	S	S

Table 4.22 N, P and K content of seedlings at 15 DAS as influenced by combination of composition and thickness of media

Media / Thickness	M_1	M_2	M_3	M_4	M_5	M_6
N content (%) of seedlings at 15 DAS						
S_1	2.13	2.42	2.07	2.45	2.10	2.51
S_2	2.05	1.81	1.84	2.39	2.42	2.04
S_3	1.87	2.74	2.16	2.22	2.80	2.34
C.D. $_{(0.05)}$	0.44					
P content (%) of seedlings at 15 DAS						
S_1	1.06	0.93	1.31	1.33	1.39	1.18
S_2	1.22	0.81	1.24	1.23	1.73	1.22
S_3	0.94	0.97	1.16	1.79	1.86	1.14
C.D. $_{(0.05)}$	0.19					
K content (%) of seedlings at 15 DAS						
S_1	4.41	3.01	4.49	3.02	3.70	3.10
S_2	4.91	3.40	4.75	3.71	3.20	3.83
S_3	4.49	4.79	4.86	3.54	4.46	3.20
C.D. $_{(0.05)}$	0.16					

4.1.8 Nutrient uptake by seedlings

The data on influence of media composition and thickness on N, P and K uptake by seedlings are given in table 4.23. and their interaction effect on table 4.24.

Nitrogen uptake

The highest uptake of N (1.92 g $tray^{-1}$) was observed in M_2 which was significantly superior to other media followed by M_1 and M_6. There was no significant difference among thickness of media with regard to the N uptake. M_2S_3 treatment combination reported significantly higher N uptake than other combinations.

Phosphorus uptake

M_1 media recorded the highest P uptake (0.85 g $tray^{-1}$) which was on par with M_5 and M_4. The uptake of phosphorus by the seedlings was on par at all levels of media thicknesses. Seedlings in the M_1S_2 treatment combination were superior with respect to uptake of phosphorus.

Potassium uptake

The highest (3.64 g $tray^{-1}$) uptake of K was observed in M_1 which was statistically superior. The highest K uptake by seedlings was recorded in 15mm media thickness which was on par with 20 mm thickness. M_1S_2 and M_2S_3 treatment combinations recorded the highest and the lowest K uptake respectively.

4.1.9 Cost of technology

The influence of various growing media compositions and thickness on economics of nursery is showed in table 4.25. With the increase in thickness of growing media there was increase in the cost of tray nursery in rice. The highest cost of tray nursery (Rs. 18.88 / tray) was for M_1S_3 treatment combination and the lowest (Rs. 15.41 / tray) with M_6S_1. Details on cost are given in appendix II and IV.

Table 4.23 N, P and K uptake by seedlings at 15 DAS as influenced by variation in composition and thickness of media

Treatment	Nitrogen uptake ($g\ tray^{-1}$)	Phosphorus uptake ($g\ tray^{-1}$)	Potassium uptake ($g\ tray^{-1}$)
M_1	1.60	0.85	3.64
M_2	1.92	0.74	3.26
M_3	1.10	0.68	2.57
M_4	1.28	0.78	1.86
M_5	1.21	0.82	1.89
M_6	1.41	0.72	2.07
C.D. $_{(0.05)}$	**0.215**	**0.08**	**0.22**
S_1	1.47	0.76	2.33
S_2	1.34	0.78	2.69
S_3	1.45	0.76	2.63
C.D. $_{(0.05)}$	**NS**	**NS**	**0.16**
Media x Thickness	S	S	S

Table 4.24 N, P and K uptake by seedlings at 15 DAS as influenced by combination of composition and thickness of media

Media / Thickness	M_1	M_2	M_3	M_4	M_5	M_6
N uptake by seedlings at 15 DAS ($g\ tray^{-1}$)						
S_1	1.65	1.87	1.17	1.36	1.17	1.60
S_2	1.76	1.49	1.00	1.34	1.17	1.29
S_3	1.39	2.41	1.14	1.14	1.26	1.33
C.D. $_{(0.05)}$	0.37					
P uptake by seedlings at 15 DAS ($g\ tray^{-1}$)						
S_1	0.82	0.71	0.74	0.74	0.78	0.75
S_2	1.05	0.66	0.68	0.69	0.83	0.77
S_3	0.69	0.85	0.61	0.92	0.86	0.65
C.D. $_{(0.05)}$	0.14					
K uptake by seedlings at 15 DAS						
S_1	3.42	2.33	2.54	1.68	2.06	1.97
S_2	4.21	3.25	2.60	2.09	1.54	2.42
S_3	3.30	4.21	2.57	1.82	2.06	1.82
C.D. $_{(0.05)}$	0.38					

Table 4.25 Cost of technology as influenced by variation in composition and thickness of growing media

Sl. No.	Treatment combinations	Cost of tray nursery (Rs.)
1.	40% RHC + 40% Soil + 20% VC with 10mm thickness [$M_1 S_1$]	17.19
2.	40% RHC + 40% Soil + 20% VC with15 mm thickness [$M_1 S_2$]	18.00
3.	40% RHC + 40% Soil + 20% VC with 20 mm thickness [$M_1 S_3$]	18.88
4.	60% RHC + 20% Soil + 20% CPC with10mm thickness [$M_2 S_1$]	15.69
5.	60% RHC + 20% Soil + 20% CPC with 15 mm thickness[$M_2 S_2$]	15.96
6.	60% RHC + 20% Soil + 20% CPC with 20 mm thickness[$M_2 S_3$]	16.20
7.	60% RHC + 20% CPC + 20% VC with 10mm thickness [$M_3 S_1$]	16.91
8.	60% RHC + 20% CPC + 20% VC with 15 mm thickness [$M_3 S_2$]	17.62
9.	60% RHC + 20% CPC + 20% VC with 20 mm thickness [$M_3 S_3$]	18.40
10.	80% RHC + 20% CPC with 10mm thickness [$M_4 S_1$]	15.50
11.	80% RHC + 20% CPC with 15 mm thickness [$M_4 S_2$]	15.69
12.	80% RHC + 20% CPC with 20 mm thickness [$M_4 S_3$]	15.89
13.	80% RHC + 20% VC with 10mm thickness [$M_5 S_1$]	16.75
14.	80% RHC + 20% VC with 15 mm thickness [$M_5 S_2$]	17.40
15.	80% RHC + 20% VC with 20 mm thickness [$M_5 S_3$]	18.12
16.	80% RHC + 20% Soil with 10mm thickness [$M_6 S_1$]	15.41
17.	80% RHC + 20% Soil with 15 mm thickness [$M_6 S_2$]	15.57
18.	80% RHC + 20% Soil with 20 mm thickness [$M_6 S_3$]	15.74

4.2 SELECTION OF BEST PERFORMING MEDIA FOR FIELD EVALUATION

Best performing three media compositions and one thickness were selected from experiment I for nutripriming in experiment II. The pertinent parameters of quality of seedling and mat for better performance of crop and transplanter in the field condition were selected for scoring.

The parameters of seedlings selected for scoring were seedling height, biomass production, shoot dry weight, root dry weight, dry matter production and root length at transplanting (15 DAS). Mat characters such as mat weight per unit area, density, shearing strength and slippage were also considered during selection process. Each parameter studied were categorised into three classes *viz.* high, medium and low based on range of values for each. For each class *viz.* low, medium and high, scores of 2, 3 and 5 were given respectively. The ranking was done based on the aggregate scores of the parameter selected for each treatment. Based on the aggregate score obtained, ranking was done. The data on aggregate score and rank are given in table 4.26

The aggregate scores calculated for each media composition and levels of media thickness were taken as the criteria for ranking. The treatment of media and thickness with higher ranks were selected as the best performing treatments. Among the levels of thickness, the lowest of 10mm thickness was selected which was found to be excellent in almost all the characters studied and the highest score of 47 was obtained. The treatment combinations with higher rank were selected for experiment II. Among the composition of media, the highest score was obtained for M_1 (50) followed by M_2 (47) and M_6 (35). Hence, the selected combinations were M_1S_1, M_2S_1 and M_6S_1 with lowest thickness of 10mm.

Table 4.26 Aggregate scores and rank obtained by different media composition and thickness

Sl. No.	Treatments	Aggregate score	Rank
Compositions of media			
1.	40 % RHC + 40 % Soil + 20 % VC with 10mm thickness [M_1]	50	1
2.	60 % RHC + 20 % Soil + 20 % CPC with10mm thickness [M_2]	47	2
3.	60 % RHC + 20 % CPC + 20 % VC with 20 mm thickness [M_3]	30	4
4.	80 % RHC + 20 % CPC with 20 mm thickness [M_4]	22	6
5.	80 % RHC + 20 % VC with 20 mm thickness [M_5]	28	5
6.	80 % RHC + 20 % Soil with 20 mm thickness [M_6]	35	3
Levels of thickness of media			
1.	10 mm [S_1]	47	1
2.	15 mm [S_2]	39	2
3.	20 mm [S_3]	26	3

4.3 NUTRIPRIMING OF SEED

Best performing three compositions of growing media and one level of thickness were selected from Experiment I for Experiment II. Nutriprimed seeds were sown in these selected growing media. Two factor ANOVA revealed differential response for the three growing media compositions over the nine nutripriming under consideration for the enlisted parameters.

The results of the experiment are mentioned here with pertinent parameters that contribute to the quality of a mat nursery for transplanting.

4.3.1 Biometric characters of seedlings

Days to 50 per cent germination

The data regarding the effect of growing media and nutripriming on days to 50 per cent germination is given in table 4.27 and their interaction effect in table 4.28. Early germination (3.04 days) was noted in M_1 media which was on par with M_2. Significant difference was observed between different nutripriming treatments also. P_1 recorded the lowest days to 50 per cent germination (2.89 days). Treatment combination M_1P_1 completed 50 per cent germination within shorter duration of time (2.33 days).

Height of seedlings

The data on height of seedling as influenced by media and nutripriming at 5, 10 and 15 DAS are given in table 4.29 and their interaction effect in table 4.31.

Tallest seedlings (6.85 cm) were produced by M_1 media which was significantly superior to other media at 5 DAS. Among nutripriming treatments, P_1 produced the tallest seedlings (6.87 cm) and the control (P_9) recorded the shortest plants (5.75 cm). P_1, P_6, P_3, P_5, P_7 and P_2 were significantly superior to control (P_9). The interaction between media and nutripriming was also found to be significant with respect to height of seedlings at 5 DAS. Seedling height was observed to be the greatest under M_1P_3 treatment combination which was on par with M_1P_5. Seedling height did not reveal any significant difference among media and nutripriming treatments. However, interaction effect was found to be significant. M2P6 produced the tallest seedlings at 10 DAS.

At transplanting (15 DAS), all the three media produced similar effect with regard to seedling height. Among nutripriming treatments, combined application of urea, $ZnSO_4$ and borax (P_6) recorded maximum seedling height (13.93 cm). P_1, P_8 and P_6 were significantly superior to control (P_9). M_1P_8 and M_3P_6 treatment combination produced the tallest seedlings.

Biomass production

The data pertaining to biomass production of seedlings at 5, 10 and 15 DAS as influenced by media and nutripriming are presented in table 4.30 and their interaction effect in table 4.31.

All the three media selected from Experiment I performed similarly with regard to the biomass production at 5, 10 and 15 DAS.

Nutripriming with 0.1 per cent urea (P_1) produced seedlings with the highest biomass at 5 DAS which was on par with combined application of urea, $ZnSO_4$ and borax through seed priming (P_6). M_2P_1 treatment combination was found to be superior at 5 DAS. P_6 produced the highest biomass at 10 DAS. Treatment combinations M_2P_6 and M_1P_2 produced seedlings with highest biomass (85.47 mg). P_1 produced the highest biomass at 15 DAS which was on par with P_6. M_1P_4, M_3P_1, M_1P_5, M_3P_6, M_3P_2 and M_2P_4 were on par with regard to biomass production at 15DAS. The nutripriming treatments P_1 and P_6 were on par at 5, 10 and 15DAS.

Shoot dry weight

The data regarding the influence of media and nutripriming on shoot dry weight at 5, 10 and 15 DAS are given in table 4.32 and its interaction effect in table 4.34.

Influence of media composition on shoot dry weight followed the same trend as that of seedling height at 5, 10 and 15 DAS in the nursery. M_1 was significantly superior at 5 DAS. Among nutripriming treatments, P_7 produced the highest shoot dry weight (4.42 mg) and control (P_9) recorded the lowest (3.56 mg). M_1P_7 was found to be superior at 5 DAS among interaction. Shoot dry weight did not reveal any significant difference between media, nutripriming treatments and their interactions at 10 DAS.

All the three media performed on par at 15 DAS with respect to the shoot dry weight. P_1 recorded the highest shoot dry weight at 15 DAS which was on par with P_6. Interaction between media and nutripriming was found significant on shoot dry weight at 15 DAS. The highest shoot dry weight was with M_1P_1 and the lowest with M_2P_7.

Root dry weight

Effect of media and nutripriming on root dry weight 5, 10 and 15 DAS is reported in table 4.33. All the three media produced similar effect on root dry weight throughout the nursery period (5, 10 and 15 DAS). At five days after sowing, maximum root dry weight (2.75mg) was observed in P_5 and the lowest (2.29 mg) in P_8. However interaction was not significant. Nutripriming treatments P_1 and P_5 reported to be the superior at 10 DAS and 15 DAS respectively.

Dry matter production

Data on influence of media and nutripriming on dry matter production of seedlings is given in table 4.35 and interaction effect in table 4.36.

Significantly higher dry matter (6.9 mg) was produced by seedlings in M_1 media at 5DAS. The highest dry matter production was registered by P_6 nutripriming treatment which was significantly superior to control (P_9).

P_2 produced highest dry matter at 10 DAS. Among the interaction, M_1P_2 was recorded to be superior compared to other treatment combinations at 10 DAS.

At transplanting (15 DAS), highest dry matter production was observed in M_1 media and P_1 nutripriming. P_1 was on par with P_5 and P_6. Treatment combination M_1P_3 and M_1P_1 contributed maximum to the dry matter production.

Root length at transplanting

Data regarding influence of media and nutripriming on dry matter production of seedlings is given in table 4.37 and interaction effect in table 4.38.

Table 4.27 Effect of media and nutripriming on days to 50 per cent germination

Treatments	Days to 50 % Germination
M_1	3.04
M_2	3.26
M_3	3.41
C.D. (0.05)	0.27
P_1	2.89
P_2	3.11
P_3	3.33
P_4	3.22
P_5	3.11
P_6	3.44
P_7	3.44
P_8	3.22
P_9	3.33
C.D. (0.05)	0.47
Media x Nutripriming	S

Table 4.28 Interaction effect of media and nutripriming on days to 50 per cent germination

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Days to 50 % germination								
M_1	2.33	2.67	3.33	3.00	3.00	3.33	3.33	3.33	3.00
M_2	3.00	3.67	3.33	3.00	3.33	3.00	3.67	3.00	3.33
M_3	3.33	3.00	3.33	3.67	3.00	4.00	3.33	3.33	3.67
C.D. (0.05)	0.81								

Table 4.29 Effect of media and nutripriming on seedling height of rice at 5, 10 and 15DAS

Treatments	5 DAS (cm)	10 DAS (cm)	15 DAS (cm)
M_1	6.85	11.95	13.40
M_2	6.08	11.46	13.15
M_3	6.24	11.94	13.23
C.D. (0.05)	0.32	NS	NS
P_1	6.87	12.21	13.89
P_2	6.39	11.89	12.64
P_3	6.58	11.70	12.94
P_4	6.14	11.53	13.30
P_5	6.58	11.46	13.27
P_6	6.59	12.42	13.93
P_7	6.41	11.38	12.86
P_8	6.23	12.15	13.72
P_9	5.75	11.31	12.79
C.D. (0.05)	0.56	NS	1.04
Media x Nutripriming	S	S	S

Table 4.30 Effect of media and nutripriming on biomass production of rice seedling at 5, 10 and 15DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	50.75	80.14	91.68
M_2	48.79	78.56	89.28
M_3	49.92	77.57	90.19
C.D. (0.05)	NS	NS	NS
P_1	55.14	78.98	96.71
P_2	48.81	81.07	89.69
P_3	49.72	74.97	87.69
P_4	46.38	80.12	89.97
P_5	49.29	79.80	92.00
P_6	51.19	81.26	93.04
P_7	49.48	80.04	86.57
P_8	50.51	77.88	90.87
P_9	47.89	76.71	86.92
C.D. (0.05)	5.0	7.0	9.0
Media x Nutripriming	S	S	S

Table 4.31 Interaction effect of media and nutripriming on height and biomass production of rice seedling at 5, 10 and 15 DAS

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Plant height at 5 DAS (cm)								
M_1	7.31	7.05	8.20	6.55	7.27	6.87	6.76	6.73	4.93
M_2	6.96	5.61	5.76	6.10	6.04	6.35	6.09	5.73	6.09
M_3	6.33	6.51	5.78	5.78	6.43	6.54	6.36	6.21	6.21
C.D. (0.05)	0.97								
	Plant height at 10 DAS (cm)								
M_1	11.56	11.90	11.09	11.63	12.16	12.49	11.27	13.01	12.41
M_2	12.66	11.05	11.23	11.15	10.82	13.08	11.80	10.67	10.68
M_3	12.41	12.73	12.77	11.79	11.39	11.68	11.08	12.77	10.84
C.D. (0.05)	2.00								
	Plant height at 15 DAS (cm)								
M_1	13.64	11.77	13.35	14.19	13.68	12.93	13.03	14.56	13.40
M_2	14.02	13.21	12.73	13.16	12.76	14.41	12.86	12.83	12.41
M_3	14.00	12.96	12.74	12.54	13.38	14.46	12.68	13.77	12.58
C.D. (0.05)	1.80								
	Biomass production at 5 DAS (mg)								
M_1	52.10	50.23	60.87	44.17	54.27	54.77	47.67	51.97	40.77
M_2	61.97	47.30	43.60	48.17	43.30	44.67	51.10	47.93	51.10
M_3	51.37	48.90	44.70	46.80	50.30	54.13	49.67	51.63	51.80
C.D. (0.05)	8.79								
	Biomass production at 10 DAS (mg)								
M_1	77.10	85.47	75.83	81.77	82.13	81.57	83.33	78.93	75.17
M_2	81.53	74.23	74.73	76.93	75.20	85.47	82.97	75.03	80.97
M_3	78.30	83.50	71.33	81.67	79.07	76.73	73.83	79.67	74.00
C.D. (0.05)	12.0								
	Biomass production at 15 DAS (mg)								
M_1	95.93	91.00	89.03	100.13	97.13	83.30	89.33	95.00	84.27
M_2	96.50	83.80	88.67	90.13	89.43	99.83	79.80	85.97	89.37
M_3	97.70	94.27	85.37	79.63	89.43	96.00	90.57	91.63	87.13
C.D. (0.05)	15.0								

Table 4.32 Effect of media and nutripriming on shoot dry weight of rice seedling at 5, 10 and 15DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	4.39	10.39	10.33
M_2	3.82	9.78	10.31
M_3	3.78	10.13	10.43
C.D. $_{(0.05)}$	**0.24**	**NS**	**NS**
P_1	4.28	10.45	11.29
P_2	3.93	10.42	10.13
P_3	4.11	9.77	10.21
P_4	3.66	10.06	10.37
P_5	3.98	9.72	10.63
P_6	4.12	10.69	10.99
P_7	4.42	9.67	9.41
P_8	3.92	9.84	9.86
P_9	3.56	10.26	10.32
C.D. $_{(0.05)}$	**0.47**	**NS**	**1.0**
Media x Nutripriming	**S**	**NS**	**S**

Table 4.33 Effect of media and nutripriming on root dry weight of rice seedling at 5, 10 and 15DAS

Treatments	5 DAS (mg)	10 DAS (mg)	15 DAS (mg)
M_1	2.47	3.44	3.93
M_2	2.57	3.35	3.94
M_3	2.39	3.42	3.95
C.D. $_{(0.05)}$	**NS**	**NS**	**NS**
P_1	2.39	3.45	4.44
P_2	2.60	3.64	4.10
P_3	2.37	3.19	3.87
P_4	2.41	3.52	3.78
P_5	2.76	3.52	4.38
P_6	2.73	3.13	3.83
P_7	2.39	3.61	3.60
P_8	2.29	3.23	3.80
P_9	2.37	3.33	3.64
C.D. $_{(0.05)}$	**0.40**	**NS**	**0.67**
Media x Nutripriming	**NS**	**NS**	**NS**

Table 4.34 Interaction effect of media and nutripriming on shoot dry weight of rice seedling at 5 and 15DAS

Media / Priming	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Shoot dry weight at 5 DAS (mg)								
M_1	4.87	4.67	5.17	3.73	4.77	4.10	5.23	3.87	3.10
M_2	4.40	3.63	3.67	3.53	3.10	3.93	4.13	4.10	3.87
M_3	3.57	3.50	3.50	3.70	4.07	4.33	3.90	3.80	3.70
C.D. $_{(0.05)}$	1.6								
	Shoot dry weight at 15 DAS (mg)								
M_1	11.60	9.50	10.30	10.70	10.83	10.40	9.23	10.53	9.87
M_2	10.77	9.77	10.17	10.83	10.60	11.40	9.13	9.37	10.77
M_3	11.50	11.13	10.17	9.57	10.47	11.17	9.87	9.67	10.33
C.D. $_{(0.05)}$	1.6								

Table 4.35 Effect of media and nutripriming on dry matter production of rice seedling at 5, 10 and 15DAS, mg

Treatments	5 DAS	10 DAS	15 DAS
M_1	6.9	13.8	14.3
M_2	6.4	13.1	14.2
M_3	6.2	13.6	14.3
C.D. (0.05)	**0.3**	**0.6**	**0.8**
P_1	6.7	13.9	15.7
P_2	6.5	14.1	14.2
P_3	6.5	13.0	13.9
P_4	6.1	13.6	14.1
P_5	6.7	13.2	15.0
P_6	6.9	13.8	14.8
P_7	6.8	13.3	13.0
P_8	6.2	13.1	13.7
P_9	5.9	13.6	14.0
C.D. (0.05)	**0.5**	**1.0**	**1.30**
Media x Nutripriming	**NS**	**S**	**S**

Table 4.36 Interaction effect of media and nutripriming on dry matter production of rice at 5, 10 and 15DAS, mg

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Dry matter production at 5 DAS (mg)								
M_1	7.3	7.2	7.7	6.3	7.6	6.5	7.6	6.1	5.4
M_2	7.0	6.2	6.4	5.9	6.1	6.5	6.6	6.4	6.4
M_3	5.7	6.1	5.4	6.0	6.4	7.6	6.2	6.1	6.0
C.D. (0.05)	0.9								
	Dry matter production at 10 DAS (mg)								
M_1	14.0	14.7	13.4	13.4	14.0	13.6	14.3	13.6	13.7
M_2	14.2	13.1	12.8	13.0	12.8	13.9	12.3	12.3	13.7
M_3	13.5	14.4	12.7	14.3	13.0	14.0	13.3	13.3	13.4
C.D. (0.05)	1.8								
	Dry matter production at 15 DAS (mg)								
M_1	16.1	13.3	14.3	14.8	15.8	13.8	12.9	14.2	13.1
M_2	15.0	13.6	14.5	14.5	14.7	15.3	12.1	13.5	15.0
M_3	16.1	15.8	13.0	13.1	14.5	15.4	14.0	13.2	13.8
C.D. (0.05)	2.3								

Table 4. 37 Effect of media and nutripriming on root length at transplanting

Treatments	Root length at transplanting (cm)
M_1	7.72
M_2	6.79
M_3	7.38
C.D. (0.05)	**0.25**
P_1	6.86
P_2	6.90
P_3	7.02
P_4	6.48
P_5	7.55
P_6	7.63
P_7	7.26
P_8	7.64
P_9	8.29
C.D. (0.05)	0.44
Media x Nutripriming	**S**

Table 4.38 Interaction effect of media and nutripriming on root length at transplanting

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Root length at transplanting (cm)								
M_1	7.68	7.26	7.55	6.67	7.42	8.77	8.11	7.36	8.63
M_2	6.88	6.03	7.01	6.17	7.48	6.95	6.85	6.87	6.84
M_3	6.02	7.40	6.51	6.60	7.74	7.18	6.83	8.71	9.39
C.D. (0.05)	0.76								

Effect of media on root length was observed to be significant at transplanting. M_1 was found to be significantly superior to M_3 and M_2. The lowest root length was recorded by M_2. Among nutripriming treatments, control (P_9) was significantly superior to all other treatments. Highest root length was recorded in M_3P_6 treatment combination and the lowest in M_3P_1.

Pest and disease incidence scoring

There was no pest and disease incidence in the nursery and hence scoring was not done.

4.3.2 Mat characteristics

Mat weight per unit area

The data on effect of media and nutripriming on weight of mat are given in table 4.39 and their interaction effect in table 4.40. Mat weight per unit area ranged from 8.1 kg $m^{-2}$to 16.0 kg m^{-2}. The lowest mat weight was recorded by the media composition containing 20 per cent soil (M_2 and M_3) followed by media containing 40 per cent soil (M_1). Among nutripriming treatment P_6 recorded the highest weight of mat and the lowest mat weight was recorded by P_7. M_1P_4 and M_2P_7 treatment combinations recorded the highest and the lowest mat weight per unit area respectively.

Density of mat

The data pertaining to the effect of media and nutripriming on density of mat are given in table 4.39. Media M_1 recorded the highest (1.16 g cm^{-3}) and M_2 recorded the lowest density (0.93g cm^{-3}) of mat. Media (M_1) containing the highest amount of soil (40%) was observed to have the highest density. Among various nutripriming treatments P_6 showed superiority. The highest density of mat was reported by M_1P_4 treatment combination.

Shearing strength of mat

The data regarding influence of media and nutripriming on shearing strength of mat are given in table 4.41.The shearing strength was ranged from 42.8

kg m^{-2} to 106 kg m^{-2}. Higher shearing strength was recorded by M_3P_1, M_3P_2, M_3P_5 and M_3P_6 whereas the lowest shearing strength was recorded by M_3P_4.

Slippage

The data on influence of media and nutripriming on slippage of mat are given in table 4.41. The slippage of mat was not observed in M_3P_1, M_3P_2, M_3P_5 M_3P_8 and M_3P_9 treatment combinations. The highest slippage (3.2 cm min^{-1}) was observed with M_1P_7. However, lower slippage was observed with M_1P_8, M_2P_7, M_2P_8 and M_3P_6.

4.3.3 Nutrient content of seedlings

Nitrogen

Nitrogen content of the seedlings as influenced by media and nutripriming is presented in table 4.42 and their interaction effect in table 4.43.The highest N content was observed in the seedlings grown in M_2 media. Nutripriming with 1 per cent *Pseudomonas fluorescens* recorded the highest N content in the seedlings which was on par with nutripriming with 1 per cent PGPR. The treatment combination M_1P_7 contributed to the highest N content of seedlings.

Phosphorus

The data regarding effect of media and nutripriming on P content of the seedlings are given in table 4.42 and their interaction effect in table 4.43. M_1 media composition was significantly superior to other media with respect to the P content of seedlings. 0.05 per cent $ZnSO_4$ nutripriming (P_3) and urea+ $ZnSO_4$ nutripriming contributed to the highest P content (1.21%) of the seedlings. The treatment combination M_1P_3 contributed to the highest P content of seedlings.

Potassium

Potassium content of the seedlings as influenced by media and nutripriming is presented in table 4.42 and their interaction effect in table 4.42. The highest K content (2.6%) was observed in M_2 media composition. 0.1 per cent urea nutripriming (P_3) recorded the highest K content of the seedlings which was on par with nutripriming of 0.1 % urea+0.01 % borax (P_4) and nutripriming of 0.1% urea+

Table 4.39 Effect of media and nutripriming on mat weight per unit area and density

Treatments	Mat weight per unit area (kg m^{-2})	Density of mat (g cm^{-3})
M_1	13.40	1.16
M_2	11.40	0.93
M_3	11.60	0.94
C.D. (0.05)	**0.90**	**0.18**
P_1	11.66	0.96
P_2	11.63	1.04
P_3	11.63	1.05
P_4	13.40	1.05
P_5	12.00	1.02
P_6	13.76	1.08
P_7	10.40	0.98
P_8	12.70	1.02
P_9	11.90	0.95
C.D. (0.05)	**1.75**	**NS**
Media x Nutripriming	**S**	**NS**

Table 4.40 Interaction effect of media and nutripriming on mat weight per unit area and density

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Mat weight per unit area (kg m^{-2})								
M_1	13.0	13.0	13.0	16.0	13.0	15.0	13.1	12.5	11.8
M_2	11.3	11.9	11.9	10.0	13.0	11.9	8.10	13.1	11.3
M_3	10.6	10.0	10.0	14.4	10.0	14.4	10.0	12.5	12.5
C.D. (0.05)	2.65								

Table 4.41 Effect of treatment combinations on shearing strength and slippage

Sl. No.	Treatment combinations	Shearing strength (kg m^{-2})	Slippage (cm/min)
1.	$M_1 P_1$	71.97	0.7
2.	$M_1 P_2$	74.02	2.0
3.	$M_1 P_3$	83.03	1.3
4.	$M_1 P_4$	63.33	0.8
5.	$M_1 P_5$	86.89	0.9
6.	$M_1 P_6$	51.21	0.9
7.	$M_1 P_7$	76.59	3.2
8.	$M_1 P_8$	83.18	0.2
9.	$M_1 P_9$	74.09	0.9
10.	$M_2 P_1$	68.41	1.0
11.	$M_2 P_2$	67.73	1.8
12.	$M_2 P_3$	73.33	1.0
13.	$M_2 P_4$	73.95	0.8
14.	$M_2 P_5$	73.41	1.4
15.	$M_2 P_6$	72.50	0.4
16.	$M_2 P_7$	71.06	0.2
17.	$M_2 P_8$	74.85	0.2
18.	$M_2 P_9$	69.39	0.7
19.	$M_3 P_1$	106.36	0
20.	$M_3 P_2$	101.36	0
21.	$M_3 P_3$	78.64	0.2
22.	$M_3 P_4$	42.80	0.2
23.	$M_3 P_5$	100.00	0
24.	$M_3 P_6$	88.86	0.3
25.	$M_3 P_7$	66.06	0.5
26.	$M_3 P_8$	63.26	0
27.	$M_3 P_9$	60.00	0

Table 4.42 N, P and K content of seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
M_1	2.72	1.26	2.34
M_2	3.07	1.13	2.60
M_3	2.71	1.03	2.51
C.D. $_{(0.05)}$	0.17	0.03	0.07
P_1	2.32	1.12	2.76
P_2	2.59	1.04	2.29
P_3	3.00	1.21	2.31
P_4	2.66	1.14	2.66
P_5	2.72	1.21	2.76
P_6	2.92	1.08	2.30
P_7	3.36	1.15	2.27
P_8	3.07	1.10	2.41
P_9	2.86	1.19	2.58
C.D. $_{(0.05)}$	0.29	0.06	0.13
Media x Thickness	S	S	S

Table 4.43 N, P and K content of seedlings at 15 DAS as influenced by combination of media and nutripriming

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	N content (%) of seedlings at 15 DAS								
M_1	2.34	2.33	2.57	2.89	2.16	2.45	3.65	3.30	2.74
M_2	2.83	2.92	3.59	2.25	3.05	3.59	3.62	3.12	2.68
M_3	1.78	2.51	2.83	2.83	2.95	2.71	2.80	2.80	3.15
C.D. $_{(0.05)}$	0.51								
	P content (%) of seedlings at 15 DAS								
M_1	1.39	1.17	1.45	1.28	1.31	1.15	1.14	1.19	1.28
M_2	1.19	1.09	1.08	1.04	1.23	1.07	1.18	1.05	1.19
M_3	0.78	0.84	1.10	1.09	1.08	1.03	1.12	1.07	1.11
C.D. $_{(0.05)}$	0.11								
	K content (%) of seedlings at 15 DAS								
M_1	2.21	2.10	2.17	2.37	3.13	2.40	2.27	1.98	2.38
M_2	2.93	2.58	2.33	3.33	2.69	2.14	2.19	2.51	2.72
M_3	3.13	2.18	2.43	2.29	2.46	2.36	2.33	2.75	2.64
C.D. $_{(0.05)}$	0.22								

0.05 per cent $ZnSO_4$ (P_5). M_2P_4 treatment combination was found to be superior with regard to K content of seedlings.

Calcium

The data regarding effect of media composition and nutripriming on Ca content of the seedlings are given in table 4.44 and their interaction effect in table 4.45. Media containing vermicompost and higher per cent of soil along with rice husk charcoal (M_1) produced seedlings with significantly higher Ca content (0.56%) which was on par with M_2. Combined application of urea, borax and $ZnSO_4$ through nutripriming (P_6) produced seedlings with the highest Ca content among priming treatments which was on par with priming with Pseudomonas. Interaction was also found to be significant. M_2P_6 treatment combination recorded the highest Ca content of seedlings (0.76%).

Magnesium

The data on effect of media composition and nutripriming on Mg content of the seedlings are given in table 4.44 and their interaction effect in table 4.45. Significant influence of media was observed on magnesium content of seedlings. Media containing vermicompost and higher per cent of soil along rice husk charcoal (M_1) also recorded the highest Mg content (705 mg kg^{-1}). Combined application of all the nutrients (P_6) as nutripriming produced seedlings with the highest Mg content also. Interaction was found to be non significant with respect to Mg content of the seedlings.

Sulphur

The data on influence of media composition and nutripriming on Mg content of the seedlings are given in table 4.44 and their interaction effect in table 4.45. Sulphur content of seedlings was significantly influenced by various media. The highest S content of seedlings (0.46%) was observed in M_1 media composition which was significantly higher than all other media. Seeds primed with urea and borax could build up significantly higher S content (0.5%) in the seedlings. Interaction was also found to be significant.

Table 4.44 Ca, Mg and S content of seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Calcium (%)	Magnesium (mg/kg)	Sulphur (%)
M_1	0.56	705	0.46
M_2	0.58	627	0.42
M_3	0.31	402	0.35
C.D. (0.05)	**0.03**	29	**0.02**
P_1	0.44	539	0.41
P_2	0.45	542	0.39
P_3	0.50	597	0.40
P_4	0.47	603	0.50
P_5	0.43	564	0.39
P_6	0.56	610	0.41
P_7	0.51	587	0.35
P_8	0.48	609	0.42
P_9	0.48	549	0.42
C.D. (0.05)	**0.05**	**51**	**0.03**
Media x Thickness	S	NS	S

Table 4.45 Ca, Mg and S content of seedlings at 15 DAS as influenced by combination of media and nutripriming.

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Ca content (%) of seedlings at 15 DAS								
M_1	0.50	0.58	0.64	0.60	0.42	0.62	0.55	0.62	0.53
M_2	0.56	0.47	0.56	0.47	0.58	0.76	0.71	0.52	0.55
M_3	0.28	0.30	0.31	0.33	0.30	0.31	0.29	0.30	0.35
C.D. (0.05)	0.08								
	S content (%) of seedlings at 15 DAS								
M_1	0.37	0.42	0.44	0.81	0.31	0.43	0.30	0.57	0.48
M_2	0.48	0.45	0.47	0.38	0.47	0.49	0.39	0.30	0.33
M_3	0.39	0.31	0.29	0.29	0.37	0.32	0.36	0.40	0.45
C.D. (0.05)	0.06								

M_1P_4 treatment combination produced seedlings with the highest content of sulphur (0.81%).

Iron

Iron content of the seedlings as influenced by composition and nutripriming is presented in tab ... raction effect in table 4.47. All the three media were ... h respect to Fe content of seedlings at 15 DAS ... and higher per cent of soil along rice husk ... (M_1) produced seedlings with significantly higher Fe content (500 mg kg^{-1}) than other two media. Media having coir pith compost as one of the component along with soil and rice husk charcoal (M_2) showed significantly superior Fe content of seedlings than media devoid of ... ong with borax nutripriming (P_4) showed significantly highe ... g kg^{-1}) of seedlings than all other priming treatments. Among the interaction, M_2P_4 and M_1P_4 ... with respect to Fe content of seedlings.

Zinc

... comp ... nutripriming on Zinc c... the seedlin... re given in table 4 ... their intera... effect in table 4.47. The highest Zn content of seedlings (100.18 ... observed in M_2 media composition. Media containing coir pith compo... micompost as one of the component (M_1 and M_2) were on par w... respect ... ontent of seedlings at 15 DAS. Nutripriming treatments also si...ificantly ... uenced Zn content of seedlings. P_4 recorded the highest Zn conte... (104.16 mg kg^{-1}) which was on par with P_6 and P_3. Treatment combination M_2P_4 recorded the highest Zn content (910.6 mg/kg) followed by M_1P_4 and M_1P_5 where ... M_2P_4 was significantly superior.

Manganese

Manganese content of the seedlings as influenced by composition and nutripriming is presented in table 4.46 and their interaction effect in table 4.47. The Mn content of seedlings at 15 DAS was found to be significantly superior

Table 4.46 Fe, Zn and Mn content of seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Iron (mg kg^{-1})	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})
M_1	500	97.76	226
M_2	408	100.18	330
M_3	226	55.54	301
C.D. $_{(0.05)}$	**50**	**6.74**	**19**
P_1	449	71.11	233
P_2	256	60.53	289
P_3	279	94.42	271
P_4	623	104.16	294
P_5	364	88.36	324
P_6	331	99.31	299
P_7	321	77.20	273
P_8	368	86.49	341
P_9	411	79.98	246
C.D. $_{(0.05)}$	**87**	**11.67**	**33**
Media x Thickness	S	S	S

Table 4.47 Fe, Zn and Mn content of seedlings at 15 DAS as influenced by combination of media and nutripriming

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Iron (mg kg^{-1}) of seedlings at 15 DAS								
M_1	478	245	312	802	578	522	413	610	542
M_2	471	288	322	911	332	316	326	308	406
M_3	399	237	205	159	184	157	224	187	286
C.D. $_{(0.05)}$	152								
	Zinc (mg kg^{-1}) of seedlings at 15 DAS								
M_1	73.73	86.67	101.53	112.27	92.93	123.47	79.13	109.00	101.07
M_2	76.93	65.00	115.20	131.33	110.93	111.07	99.20	104.27	87.67
M_3	62.67	29.93	66.53	65.47	61.20	63.40	53.27	46.20	51.20
C.D. $_{(0.05)}$	20.22								
	Manganese (mg kg^{-1}) of seedlings at 15 DAS								
M_1	150	225	179	211	257	285	221	253	249
M_2	348	296	285	349	391	300	291	455	252
M_3	202	345	348	321	323	311	306	315	236
C.D. $_{(0.05)}$	56								

(329 mg kg^{-1}) in M_2 media composition followed by M_3 and M_1. Among the nutripriming treatments P_8 recorded the highest Mn content which was on par with P_5. Priming with urea alone recorded significantly lowest Mn content than all other nutripriming treatments but was on par with the control. The highest Mn content of seedlings was reported by M_2P_8 which was significantly higher than all other treatment combination.

Boron

The data pertaining to boron content of the seedlings as influenced by composition and nutripriming is presented in table 4.48 and their interaction effect in table 4.49. The B content of seedlings in different media followed the same trend as that of Zn. Media containing coir pith compost or vermicompost as one of the component (M_1 and M_2) were on par with respect to B content of seedlings. Nutripriming treatment P_7 registered the highest B content of seedlings (11.93 mg kg^{-1}) which was on par with P_6 and P_5. The highest B content (14.25 mg kg^{-1}) was observed with seedlings grown in M_2P_7 treatment combination.

Copper

The data regarding effect of media composition and nutripriming on Cu content of the seedlings are given in table 4.48 and their interaction effect in table 4.49. The Cu content of seedlings in different media followed the same trend as Fe content of seedlings. All the three media were significantly different with respect to Cu content of seedlings. Media containing vermicompost and higher per cent of soil along with rice husk charcoal (M_1) recorded significantly higher Cu content of seedlings (20.67 mg kg^{-1}) than other two media. Media having coir pith compost as one of the component along with soil and rice husk charcoal (M_2) showed significantly superior Cu content of seedlings than media devoid of any compost (M_3). Urea along with borax nutripriming (P_4) showed significantly higher Cu content (25.71 mg kg^{-1}) of seedlings than all other priming treatments. Among the interaction, M_1P_4 was significantly superior to all other treatment combinations.

Table 4.48 B and Cu content of seedlings at 15 DAS as influenced by variation in media and nutripriming, mg kg^{-1}

Treatment	Boron (mg kg^{-1})	Copper (mg kg^{-1})
M_1	9.46	20.67
M_2	10.49	15.14
M_3	7.67	9.01
C.D. (0.05)	**1.51**	**1.93**
P_1	8.96	14.02
P_2	7.62	12.73
P_3	7.25	12.69
P_4	7.75	25.71
P_5	11.09	14.73
P_6	11.65	12.38
P_7	11.93	12.38
P_8	8.18	12.13
P_9	8.43	17.69
C.D. (0.05)	**2.62**	**3.35**
Media x Thickness	S	S

Table 4.49 B and Cu uptake by seedlings at 15 DAS as influenced by combination of media and nutripriming

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	B content (mg kg^{-1})of seedlings at 15 DAS								
M_1	3.23	9.00	6.58	10.75	11.42	11.16	13.84	7.66	11.47
M_2	14.13	9.30	11.95	6.03	12.56	13.04	14.25	5.24	7.93
M_3	9.52	4.57	3.23	6.45	9.27	10.75	7.70	11.62	5.88
C.D. (0.05)	4.54								
	Cu content (mg kg^{-1}) of seedlings at 15 DAS								
M_1	11.33	12.47	13.87	42.13	23.93	16.20	15.13	17.67	33.27
M_2	15.20	14.93	14.93	26.40	12.20	12.67	14.73	12.53	12.67
M_3	15.53	10.80	9.27	8.60	8.07	8.27	7.27	6.20	7.13
C.D. (0.05)	5.80								

4.3.4 Nutrient uptake by seedlings

Nitrogen

The data on influence of media and nutripriming on uptake of nitrogen by seedlings are presented in table 4.50 and their interaction effect in table 4.51. The highest uptake of N (1.92g tray^{-1}) was observed in M_2 which was statistically superior to other two media. There was no significant difference among nutripriming treatments with regard to the N uptake. However, the highest N uptake was observed with combined application of urea, $ZnSO_4$ and borax through nutripriming. The treatment combination M_2P_6 contributed to the highest N uptake (2.09g tray^{-1}).

Phosphorus

The data regarding influence of media and nutripriming on uptake of phosphorus by seedlings are presented in table 4.50 and their interaction effect in table 4.51. Effect of media composition on P uptake by the seedlings followed the similar trend as that of P content. M_1 media was significantly superior with respect to the P uptake by seedlings followed by M_2 and M_3. The highest P uptake (0.69g tray^{-1}) was observed in P_5 which was on par with P_1. The treatment combination M_1P_1 contributed to the highest P uptake by the seedlings which was on par with M_1P_5.

Potassium

The data on effect of media and nutripriming on potassium uptake by the seedlings are given in table 4.50 and their interaction effect in table 4.51. The media M_2 and M_3 recorded higher K uptake (1.41 and 1.37g tray^{-1}). Among nutripriming treatments, P_1 and P_5 were significantly superior to all other treatments. M_3P_1 treatment combination was found to be superior and on par with M_1P_5 and M_2P_4 with regard to uptake of K.

Calcium

The data on influence of media and nutripriming on uptake of calcium by seedlings are presented in table 4.52 and their interaction effect in table 4.53. The

Table 4.50 N, P and K uptake by seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Nitrogen uptake (g tray $^{-1}$)	Phosphorus uptake (g tray $^{-1}$)	Potassium uptake (g tray $^{-1}$)
M_1	1.46	0.69	1.27
M_2	1.66	0.61	1.41
M_3	1.46	0.55	1.37
C.D. $_{(0.05)}$	**0.134**	**0.03**	**0.07**
P_1	1.38	0.67	1.64
P_2	1.40	0.55	1.23
P_3	1.59	0.64	1.22
P_4	1.42	0.61	1.43
P_5	1.54	0.69	1.58
P_6	1.66	0.61	1.29
P_7	1.64	0.56	1.12
P_8	1.60	0.57	1.25
P_9	1.51	0.63	1.37
C.D. $_{(0.05)}$	**NS**	**0.06**	**0.13**
Media x Thickness	S	S	S

Table 4.51 N, P and K uptake by seedlings at 15 DAS as influenced by combination of media and nutripriming

Media \ Priming	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	N uptake (g tray^{-1}) by seedlings at 15 DAS								
M_1	1.43	1.17	1.39	1.62	1.29	1.29	1.78	1.78	1.37
M_2	1.62	1.51	1.99	1.24	1.69	2.09	1.66	1.61	1.52
M_3	1.09	1.51	1.40	1.40	1.62	1.58	1.49	1.40	1.65
C.D. $_{(0.05)}$	0.40								
	P uptake (g tray^{-1}) by seedlings at 15 DAS								
M_1	0.85	0.59	0.79	0.71	0.79	0.61	0.56	0.64	0.64
M_2	0.68	0.56	0.59	0.57	0.69	0.61	0.54	0.54	0.67
M_3	0.48	0.50	0.54	0.54	0.59	0.60	0.59	0.54	0.58
C.D. $_{(0.05)}$	0.11								
	K uptake (g tray^{-1}) by seedlings at 15 DAS								
M_1	1.35	1.06	1.17	1.33	1.87	1.26	1.11	1.07	1.18
M_2	1.67	1.33	1.28	1.83	1.50	1.24	1.00	1.29	1.55
M_3	1.91	1.31	1.19	1.14	1.36	1.37	1.24	1.38	1.38
C.D. $_{(0.05)}$	0.23								

highest Ca uptake (0.31g $tray^{-1}$) by seedlings was observed in M_2 media which was on par with M_1. Combined application of urea, borax and $ZnSO_4$ through nutripriming (P_6) was significantly superior to all other priming treatments. Interaction was also found to be significant. M_2P_6 treatment combination recorded the highest Ca uptake (0.44).

Magnesium

The data regarding magnesium uptake by the seedlings as influenced by media and nutripriming is presented in table 4.52. Magnesium uptake by the seedlings grown in all the media was significantly different. The highest Mg uptake (37.99 mg $tray^{-1}$) by seedlings was observed in M_1 which was significantly superior to other two media. Nutripriming treatments did not show any significant influence on magnesium uptake by the seedlings. Interaction was also found to be non significant.

Sulphur

The data on influence of media and nutripriming on uptake of sulphur by seedlings are presented in table 4.52 and their interaction effect in table 4.53. Media containing coir pith compost or vermicompost as one of the component (M_1 and M_2) were on par with respect to S uptake by seedlings. Among the nutripriming treatments, urea along with borax priming (P_4) recorded the highest sulphur uptake which was on par with urea alone priming (P_1) and combined application of urea, borax and $ZnSO_4$ through seed priming (P_6). M_1P_4 treatment combination was found to be superior with respect to S uptake by the seedlings.

Iron

The data on influence of media and nutripriming on uptake of iron by seedlings are presented in table 4.54 and their interaction effect in table 4.55. All the three media were significantly different with respect to Fe uptake by seedlings at 15 DAS. Media containing vermicompost and higher per cent of soil along rice husk charcoal (M_1) recorded significantly higher Fe uptake (27.28 mg $tray^{-1}$) than other two media. Media having coir pith compost as one of the component along

Table 4.52 Ca, Mg and S uptake by seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Calcium uptake (g tray^{-1})	Magnesium uptake (mg tray^{-1})	Sulphur uptake (g tray^{-1})
M_1	0.30	37.99	0.25
M_2	0.31	33.87	0.23
M_3	0.17	21.83	0.19
C.D. (0.05)	**0.02**	**2.48**	**0.02**
P_1	0.27	32.03	0.25
P_2	0.24	28.62	0.21
P_3	0.27	31.76	0.21
P_4	0.25	32.68	0.27
P_5	0.24	32.36	0.22
P_6	0.32	34.20	0.23
P_7	0.25	28.62	0.17
P_8	0.25	31.82	0.22
P_9	0.26	28.98	0.22
C.D. (0.05)	**0.04**	**NS**	**0.04**
Media x Thickness	S	NS	S

Table 4.53 Ca and Mg uptake by seedlings at 15 DAS as influenced by combination of media and nutripriming

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Ca uptake (g tray^{-1}) by seedlings at 15 DAS								
M_1	0.31	0.29	0.35	0.34	0.24	0.32	0.27	0.34	0.26
M_2	0.32	0.24	0.31	0.26	0.32	0.44	0.32	0.27	0.32
M_3	0.17	0.18	0.15	0.16	0.16	0.18	0.15	0.15	0.18
C.D. (0.05)	0.07								
	S uptake (g tray^{-1}) by seedlings at 15 DAS								
M_1	0.23	0.21	0.24	0.46	0.19	0.23	0.15	0.31	0.24
M_2	0.27	0.23	0.26	0.21	0.26	0.28	0.18	0.16	0.19
M_3	0.24	0.19	0.15	0.15	0.21	0.19	0.19	0.20	0.24
C.D. (0.05)	0.07								

with soil and rice husk charcoal (M_2) showed significantly superior Fe uptake by seedlings than media devoid of any compost (M_3). Urea along with borax nutripriming (P_4) showed significantly higher Fe uptake (34.10 mg tray^{-1}) than all other priming treatments. Among the interaction, M_2P_4 was superior with respect to Fe content of seedlings.

Zinc

The data regarding zinc uptake by the seedlings as influenced by media and nutripriming is presented in table 4.54. The highest Zn uptake by seedlings (5.42mg tray^{-1}) was recorded in M_2 media composition. Media containing coir pith compost or vermicompost as one of the component (M_1 and M_2) were on par with respect to Zn uptake by seedlings. Nutripriming treatments also significantly influenced Zn uptake by seedlings. P_4 recorded the highest Zn uptake by seedlings (5.69 mg tray^{-1}) which were on par with P_6, P_5 and P_3. Interaction was not significant with respect to Zn uptake by seedlings.

Manganese

The data on influence of media and nutripriming on uptake of manganese by seedlings are presented in table 4.54 and their interaction effect in table 4.55. The Mn uptake by seedlings at 15 DAS was found to be significantly superior (17.83 mg tray^{-1}) in M_2 media composition followed by M_3 and M_1. Among the nutripriming treatments P_5 recorded the highest Mn uptake (18.4mg tray^{-1}) which was on par to P_8 and P_6. Priming with urea alone recorded significantly lower Mn uptake than all other nutripriming treatments but was on par with control. The highest Mn uptake by seedlings was reported by M_2P_8.

Boron

The data on boron uptake by the seedlings as influenced by media and nutripriming is presented in table 4.56 and their interaction effect in table 4.57. Media containing coir pith compost or vermicompost as one of the component (M_1 and M_2) were on par with respect to B uptake by seedlings. Nutripriming treatment P_6 registered the highest B uptake by seedlings (0.65mg tray^{-1}) which were on par

Table 4.54 Fe, Zn and Mn uptake by seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Iron uptake (mg tray^{-1})	Zinc uptake (mg tray^{-1})	Manganese uptake (mg tray^{-1})
M_1	27.28	5.31	12.15
M_2	22.32	5.42	17.83
M_3	12.49	3.01	16.30
C.D. (0.05)	**3.38**	**0.49**	**1.44**
P_1	27.06	4.23	13.77
P_2	13.80	3.17	15.78
P_3	14.90	5.02	14.17
P_4	34.10	5.69	15.68
P_5	21.12	5.03	18.40
P_6	18.35	5.57	16.87
P_7	15.74	3.74	13.51
P_8	19.45	4.52	17.65
P_9	21.75	4.23	13.01
C.D. (0.05)	**5.85**	**0.85**	**2.50**
Media x Thickness	S	NS	S

Table 4.55 Fe and Mn uptake by seedlings at 15 DAS as influenced by combination of media and nutripriming

Media \ Priming	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	Iron uptake (mg tray^{-1}) by seedlings at 15 DAS								
M_1	29.14	12.24	16.90	44.72	34.56	27.36	20.26	33.17	27.16
M_2	27.70	14.90	17.66	49.69	18.69	18.48	14.86	15.80	23.14
M_3	24.34	14.26	10.14	7.90	10.11	9.21	12.10	9.38	14.95
C.D. (0.05)	10.14								
	Manganese uptake (mg tray^{-1}) by seedlings at 15 DAS								
M_1	9.15	11.28	9.74	11.79	15.46	14.98	10.86	13.69	12.39
M_2	19.83	15.30	15.59	19.21	21.99	17.52	13.27	23.44	14.31
M_3	12.33	20.74	17.18	16.02	17.76	18.11	16.41	15.81	12.33
C.D. (0.05)	4.33								

with P_5, P_7 and P_1. The highest B uptake (0.78mg tray^{-1}) was observed with seedlings grown in M_2P_1 treatment combination.

Copper

The data pertaining to copper uptake by the seedlings as influenced by media and nutripriming is presented in table 4.56 and their interaction effect in table 4.57. The Cu uptake by the seedlings in different media followed the same trend as that of Fe uptake by the seedlings. Media containing vermicompost and higher per cent of soil along rice husk charcoal (M_1) recorded significantly higher Cu uptake (1.13 mg tray^{-1}) than other two media. Media having coir pith compost as one of the component along with soil and rice husk charcoal (M_2) recorded significantly superior Cu uptake by seedlings than media devoid of any compost (M_3). Urea along with borax nutripriming (P_4) showed significantly higher Cu uptake (1.45 mg tray^{-1}) than all other priming treatments. Among the interaction, M_1P_5 was superior to all other treatment combination.

4.3.5 Cost of technology

The influence of various growing media and nutripriming on economics of nursery is showed in table 4.58. Cost of one tray nursery varied from Rs. 14.67 to Rs.15.87. The highest cost of nursery was for M_1P_8 treatment combination and the lowest for M_3P_9. Profound effect of media was observed on cost than nutripriming technique.

4.4 SELECTION OF BEST PERFORMING TREATMENT COMBINATION FOR FIELD EVALUATION

Best performing five treatment combinations were selected from experiment II for field evaluation in experiment III. The pertinent parameters of quality of seedling and mat for better performance of transplanter at transplanting were selected for scoring.

The parameters of seedlings selected for scoring were seedling height, biomass production, shoot dry weight, root dry weight, dry matter production and root length at transplanting (15 DAS). Mat characters such as mat weight per unit area, density, shearing strength and slippage were considered during selection process. Each parameter studied were categorised into three classes *viz.* such as high, medium and low based on range of values for each. For each class *viz.* low, medium and high, scores of 2, 3 and 5 were given respectively. The ranking was done based on the aggregate scores of the parameter selected for each treatment combination. Based on the aggregate score obtained for treatment combination ranking was done. The data on aggregate score and rank are given in table 4.59.

The aggregate scores calculated for each treatment combination were taken as the criteria for ranking. The rank varied from 1 to 13 out of 27 treatment combinations. The treatment combinations with higher ranks were selected as the best performing for experiment III. Along with four best performing treatment combinations treatment with boron as a component was also selected with expectation of its better performance at reproductive stage for experiment III. The selected treatment combinations were M_1P_5, M_3P_1, M_3P_2, M_3P_6 and M_2P_4 along with control.

Table 4.56 B and Cu uptake by seedlings at 15 DAS as influenced by variation in media and nutripriming

Treatment	Boron uptake (mg tray^{-1})	Copper uptake (mg tray^{-1})
M_1	0.51	1.13
M_2	0.56	0.82
M_3	0.42	0.50
C.D. (0.05)	**0.09**	**0.15**
P_1	0.52	0.84
P_2	0.40	0.68
P_3	0.40	0.68
P_4	0.43	1.45
P_5	0.63	0.85
P_6	0.65	0.69
P_7	0.58	0.60
P_8	0.42	0.63
P_9	0.44	0.92
C.D. (0.05)	**0.15**	**0.26**
Media x Thickness	S	S

Table 4.57 B and Cu uptake by seedlings at 15 DAS as influenced by combination of media and nutripriming

Priming / Media	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
	B uptake (mg tray^{-1}) by seedlings at 15 DAS								
M_1	0.20	0.45	0.36	0.62	0.69	0.59	0.68	0.40	0.57
M_2	0.78	0.48	0.66	0.34	0.69	0.75	0.65	0.27	0.45
M_3	0.58	0.25	0.16	0.32	0.52	0.62	0.41	0.58	0.31
C.D. (0.05)	0.26								
	Cu uptake (mg tray^{-1}) by seedlings at 15 DAS								
M_1	0.69	0.63	0.75	2.47	1.43	0.85	0.74	0.94	1.66
M_2	0.88	0.78	0.82	1.45	0.68	0.74	0.68	0.64	0.72
M_3	0.95	0.64	0.46	0.43	0.45	0.48	0.39	0.31	0.37
C.D. (0.05)	0.45								

Table 4.58 Cost of technology as influenced by variation in media and nutripriming

Sl. No.	Treatment combinations	Cost of tray nursery (Rs.)
1.	$M_1 P_1$	15.79
2.	$M_1 P_2$	15.80
3.	$M_1 P_3$	15.84
4.	$M_1 P_4$	15.80
5.	$M_1 P_5$	15.85
6.	$M_1 P_6$	15.85
7.	$M_1 P_7$	15.85
8.	$M_1 P_8$	15.87
9.	$M_1 P_9$	15.78
10.	$M_2 P_1$	14.82
11.	$M_2 P_2$	14.83
12.	$M_2 P_3$	14.87
13.	$M_2 P_4$	14.83
14.	$M_2 P_5$	14.87
15.	$M_2 P_6$	14.88
16.	$M_2 P_7$	14.89
17.	$M_2 P_8$	14.90
18.	$M_2 P_9$	14.82
19.	$M_3 P_1$	14..67
20.	$M_3 P_2$	14.68
21.	$M_3 P_3$	14.72
22.	$M_3 P_4$	14.68
23.	$M_3 P_5$	14.72
24.	$M_3 P_6$	14.73
25.	$M_3 P_7$	14.74
26.	$M_3 P_8$	14.75
27.	$M_3 P_9$	14.67

Table 4.59 Aggregate scores and ranks obtained by different treatment combinations

Sl. No.	Treatment combination	Aggregate score	Rank
1.	$M_1 P_1$	47	1
2.	$M_1 P_2$	33	9
3.	$M_1 P_3$	35	7
4.	$M_1 P_4$	37	6
5.	$M_1 P_5$	47	1
6.	$M_1 P_6$	34	8
7.	$M_1 P_7$	30	12
8.	$M_1 P_8$	41	3
9.	$M_1 P_9$	32	10
10.	$M_2 P_1$	40	4
11.	$M_2 P_2$	30	12
12.	$M_2 P_3$	37	6
13.	$M_2 P_4$	37	6
14.	$M_2 P_5$	33	9
15.	$M_2 P_6$	43	2
16.	$M_2 P_7$	28	13
17.	$M_2 P_8$	31	11
18.	$M_2 P_9$	37	6
19.	$M_3 P_1$	47	1
20.	$M_3 P_2$	47	1
21.	$M_3 P_3$	33	9
22.	$M_3 P_4$	26	13
23.	$M_3 P_5$	38	5
24.	$M_3 P_6$	43	2
25.	$M_3 P_7$	33	9
26.	$M_3 P_8$	35	7
27.	$M_3 P_9$	33	9

4.5 FIELD EVALUATION OF BEST PERFORMING TREATMENT COMBINATIONS SELECTED FROM EXPERIMENT II

Five best performing treatment combinations based on aggregate scores and ranking were selected for experiment III. The treatments selected for evaluation included T_1- 80 % RHC + 20 % Soil + 0.1% Urea , T_2- 80 % RHC + 20 % Soil + 0.01% Borax , T_3- 40 % RHC + 40 % Soil + 20 % VC + 0.1 % Urea + 0.05 % $ZnSO_4$, T_4- 60 % RHC + 20 % Soil + 20 % CPC + 0.1 % Urea + 0.01 % Borax and T_5- 80 % RHC + 20 % Soil + 0.1 % Urea+ 0.05 % $ZnSO_4$ + 0.01 % Borax. These treatments along with control (soil media + without nutripriming of seed) were evaluated under field condition.

4.5.1 Performance of transplanter

Number of hills planted per metre run

The data pertaining to the number of hills at planting by transplanter as influenced by nursery media is presented in table 4.60. The mean number of hills planted per metre run of transplanter was found to be 5.86 per m.

All treatment combinations selected from experiment II performed similarly with regard to number of hills planted per metre run and were on par with the control treatment. The treatment T_6 recorded the highest number of hills per metre run (5.98).

Number of seedlings planted per hill

The data on number of seedlings planted per hill are presented in table 4.60. The mean number of seedlings planted per hill was recorded to be 7.44. The five treatment combinations selected from experiment II behaved superior in comparison with control treatment. The highest number (8.86) of seedlings per hill was transplanted with respect to T_3.

Plant population per m^2 at planting

The plant population (number of hills) per m^2 is given in table 4.60. The mean plant population per m^2 at planting was 27.05. The highest plant population per m^2 (29 m^{-2}) was noted in control (T_6). The treatment T_5 recorded the lowest (25.80) plant population per m^2.

Number of missing hills per m^2

The number of missing hills per m^2 at planting by the various nursery treatments is presented in table 4.60. The various nursery treatments were significantly influenced the number of missing hills per m^2. The lowest number of missing hills due to mechanical transplanting per m^2 (1.00) was recorded by control treatment (T_6) and the highest (4.20) by T_5. Treatments T_2, T_3 and T_4 were comparable with regards to number of missing hills per m^2.

4.5.2 Biometric characters

Height of plant

Table 4.61 depicts the data on plant height at 30, 60 and at harvest. The mean plant height at 30 DAT was observed to be 70.42 cm. Even though the plant height was ranged from 68.60 cm to 71.89, all the treatments were significantly on par with respect to plant height at 30 DAT. The tallest plants (71.89) were produced by treatment T_1 at 30 DAT.

The taller plants at 60 DAT were observed in T_6. However treatments showed no significant variation with regard to plant height. Mean plant height at 60 DAT was 107.77 cm. At transplanting, the mean plant height was 119.83 cm. It was ranged from 118.78 cm to 121.48 cm. However, treatments did not significantly influence the plant height at harvest. The tallest (121.48 cm) plants were observed in T_2 treatment and the shortest in T_3.

Weed count per m^2

The weed count recorded from one square metre area at 20 and 40 DAT is presented in table 4.62. Irrespective of the treatments weed count was found to be the same in all the plots. It indicated that weed population was not affected by any treatment at 20 and 40 DAS.

Table 4.60 Performance of transplanter as influenced by nursery treatments

Treatments		Number of hills planted per metre run	Number of seedlings per hill	Plant population per m² at planting	Number of missing hills per m²
T_1	80% RHC + 20% Soil + 0.1% Urea	5.75[a]	7.90[a]	27.25[b]	2.75[b]
T_2	80% RHC + 20% Soil + 0.01% Borax	5.93[a]	7.71[a]	26.40[b]	3.60[ab]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	5.93[a]	8.86[a]	27.00[b]	3.00[ab]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	5.95[a]	7.44[a]	26.20[b]	3.78[ab]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	5.63[a]	7.73[a]	25.80[b]	4.20[a]
T_6	Control	5.98[a]	5.00[b]	29.00[a]	1.00[c]
Mean		**5.86**	**7.44**	**26.94**	**3.06**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Table 4.61 Plant height of rice as influenced by nursery treatments, cm

Treatments		30 DAT	60 DAT	At harvest
T_1	80% RHC + 20% Soil + 0.1% Urea	71.89[a]	107.90[a]	118.78[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	69.83[a]	106.75[a]	121.48[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	70.19[a]	106.34[a]	118.93[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	70.93[a]	107.21[a]	119.98[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	71.06[a]	109.06[a]	119.03[a]
T_6	Control	68.60[a]	109.34[a]	120.77[a]
Mean		**70.42**	**107.77**	**119.83**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Number of tillers per m^2

The data regarding number of tillers per m^2 at maximum tillering and panicle initiation are given in table 4.63.

The number of tillers per m^2 at maximum tillering and panicle initiation was the highest in T_3. There was no significant variation among treatments with regard to the number of tillers per m^2. At maximum tillering stage mean number of tillers per m^2 was 595. While, it increased to 606 at panicle initiation stage. The lowest number of tillers per m^2 was recorded by control treatment (T_6) at maximum tillering and panicle initiation.

4.5.3 Yield attributes

The data registered on yield attributes as influenced by the different nursery treatments are presented in table 4.64.

Number of panicles per m^2

The total number of panicles produced per m^2 was significantly influenced by treatments. The crop produced 292 panicles per m^2 on an average irrespective of the treatments with a variation from 290 to 310 panicles per m^2. All the treatments were significantly superior to the control treatment (T_6).

Number of spikelets per panicle

On an average, 147 spikelets were produced per panicle (Table 4.64). Even though the number of spikelets per panicle showed a variation from 136 to 160, all the nursery treatments were statistically comparable with respect to number of spikelets per panicle.

Number of filled grains per panicle

The data on number of filled grains per panicle as influenced by various treatments are shown in table 4.64. The mean number of filled grains per panicle was 102. The number of filled grains per panicle also remained on par with respect to different treatments.

Table 4.62 Weed count as influenced by nursery treatments

Treatments		Weed count at 20 DAT	Weed count at 40 DAT
T_1	80% RHC + 20% Soil + 0.1% Urea	0.98[a]	5.10[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	0.65[a]	3.00[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	0.48[a]	3.60[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	0.65[a]	5.20[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	0.55[a]	3.60[a]
T_6	Control	0.65[a]	6.40[a]
Mean		**0.66**	**4.48**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Table 4.63 Number of tillers per m^2 as influenced by nursery treatments

Treatments		At maximum tillering	At panicle initiation
T_1	80% RHC + 20% Soil + 0.1% Urea	591.74[a]	589.60[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	602.82[a]	639.21[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	660.01[a]	662.12[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	599.35[a]	575.16[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	605.71[a]	623.76[a]
T_6	Control	511.74[a]	551.28[a]
Mean		**595.23**	**606.86**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Thousand grain weight

The data presented on table 4.64 showed that thousand grain weights were similar under all treatments which indicate that it was not influenced by different treatments. The mean thousand grain weight was observed to be 29.56 g. It was ranged from 28.73 g to 30.10 g.

Spikelet sterility

The data regarding spikelet sterility as influenced by nursery treatments is given in table 4.64. The highest spikelet sterility (32.31) was reported in control (T_6). The spikelet sterility was found to be unaffected by the different treatments.

4.5.4 Yield

Grain yield

The data regarding grain yield ha^{-1} are given in table 4.65. The data showed that treatments did not significantly influence the total grain yield. The mean grain yield of the crop was 4.42 t ha^{-1}. The highest grain yield of 4.7 t ha^{-1} was recorded by T_4 and lowest grain yield (4.13 t ha^{-1}) by T_5.

Straw yield

The data pertaining to the yield of straw (Table 4.65) showed no significant difference among various treatments. The mean straw production by the crop under various treatments was 4.87 t ha^{-1} which ranges from 4.66 t ha^{-1} (T_4) to 5.28 t ha^{-1} (T_3).

4.5.5 Harvest index

The data on harvest index as influenced by nursery media and nutripriming is presented in table 4.65. There was no significant difference in the harvest index due to various nursery media. The mean harvest index was recorded to be 0.52 and the values ranged from 0.46 to 0.50.

Table 4.64 Yield attributes of rice as influenced by nursery treatments

Treatments		Panicles/ m^2	Spikelets /panicle	Filled grains/ panicle	1000 grain weight (g)	Spikele sterility (%)
T_1	80% RHC + 20% Soil + 0.1% Urea	290.90[a]	160.68[a]	110.93[a]	29.62[a]	31.41[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	291.92[a]	136.30[a]	91.93[a]	28.73[a]	33.35[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	307.77[a]	145.56[a]	102.09[a]	29.91[a]	29.43[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	302.50[a]	143.28[a]	102.63[a]	29.84[a]	28.37[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$+ 0.01% Borax	310.33[a]	150.62[a]	103.67[a]	29.18[a]	31.69[a]
T_6	Control	252.33[b]	148.40[a]	101.04[a]	30.10[a]	32.31[a]
Mean		**292.63**	**147.47**	**102.05**	**29.56**	**31.09**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Table 4.65 Grain yield, straw yield and harvest index as influenced by nursery treatments

Treatments		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index
T_1	80% RHC + 20% Soil + 0.1% Urea	4.22[a]	4.85[a]	0.46[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	4.28[a]	4.82[a]	0.47[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	4.67[a]	5.28[a]	0.47[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	4.70[a]	4.76[a]	0.50[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$+ 0.01% Borax	4.13[a]	4.85[a]	0.46[a]
T_6	Control	4.50[a]	4.66[a]	0.49[a]
Mean		**4.42**	**4.09**	**0.48**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

4.5.6 Nutrient content of grain and straw at harvest

Nitrogen content

The data pertaining to nitrogen content of grain and straw at harvest are given in table 4.66. The selected nursery treatments did not show any variation with regards to the N content of grain and straw. N content of grain varied from 1.20 per cent to 1.36 per cent and that of straw from 0.94 per cent to 1.20 per cent. In grain and straw the mean N content was 1.30 per cent and 1.11 per cent respectively.

Phosphorus content

The data on phosphorus content of grain and straw are given in table 4.66. Even though the various treatments did not significantly influence the P content of grain and straw, it varied from 0.33 per cent to 0.35 per cent in grain and from 0.25 per cent to 0.28 per cent in straw. The grain and straw was having mean P content of 0.34 per cent and 0.26 per cent respectively. The mean P content of grain was higher than that of straw.

Potassium content

Potassium content of grain and straw as influenced by different treatments is presented in table 4.66. The K content of grain was influenced by various treatments. T_3 produced grains with significantly higher content of K (0.35%) followed by T_2 with grain K content of 0.34 per cent. However, there was no significant influence of treatments on K content of straw. The K content of straw varied from 4.06 per cent to 4.84 per cent with mean value of 4.50 per cent. K content of straw was higher than that of grain.

Calcium content

The data regarding to nitrogen content of grain and straw at harvest are given in table 4.67. Calcium content of both grain and straw was influenced by various treatments. Significantly higher grain Ca content (568.8 mg kg^{-1}) was observed in T_5 followed by T_3. The lowest Ca content of grain was recorded in T_4. Straw with the highest Ca content (0.36%) was found in T_1. Calcium content of straw was also observed to be the lowest in T_4. Ca content of straw was higher than that of grain.

Table 4.66 N, P and K content of grain and straw as influenced by nursery treatments

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
		Grain	Straw	Grain	Straw	Grain	Straw
T_1	80% RHC + 20% Soil + 0.1% Urea	1.36[a]	1.16[a]	0.34[a]	0.27[a]	0.32[bc]	4.61[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	1.32[a]	1.20[a]	0.34[a]	0.25[a]	0.34[ab]	4.84[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	1.32[a]	1.12[a]	0.33[a]	0.26[a]	0.35[a]	4.49[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	1.31[a]	1.07[a]	0.34[a]	0.25[a]	0.31[c]	4.39[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	1.27[a]	0.94[a]	0.35[a]	0.28[a]	0.32[bc]	4.06[a]
T_6	Control	1.20[a]	1.16[a]	0.33[a]	0.27[a]	0.32[bc]	4.59[a]
Mean		**1.30**	**1.11**	**0.34**	**0.26**	**0.33**	**4.50**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Magnesium content

Magnesium content of grain and straw as influenced by different treatments is given in table 4.67. Magnesium content of grain was significantly influenced by various treatments. However, straw Mg content was unaffected due to treatments. T_1 and T_5 recorded the highest Mg content of the grain and the lowest by T_2. Mean Mg content of straw was 0.18 per cent. The highest Mg content of straw was observed in control treatment.

Sulphur content

The data on sulphur content of grain and straw are given in table 4.67. Sulphur content of grain and straw was remained unaltered by different treatment. The grain and straw were having mean S content of 881.4 mg kg^{-1} and 190.97 mg kg^{-1} respectively. The highest S content of grain and straw was observed in control and T_5 respectively.

Iron content

Iron content of grain and straw as influenced by different treatments is given in table 4.67. Iron content of grain and straw was observed to be unaffected by various treatments. Fe content of straw and grain was ranged from 374.94 mg kg^{-1} to 464.31 mg kg^{-1} and from 140.94 mg $kg^{-1}$to 241 mg kg^{-1}respectively. Mean Fe content of straw (429.6 mg kg^{-1}) was higher than that of grain (200.36 mg kg^{-1}).

Zinc content

The influence of various treatments on zinc content of grain and straw is showed in table 4.68. Various treatments were not significantly influenced on zinc content of both grain and straw. The highest zinc content of grain and straw were recorded by T_2. The grain and straw were having mean Zn content of 17.30 mg kg^{-1} and 19.70 mg kg^{-1} respectively.

Manganese content

Manganese content of grain and straw as influenced by different treatments is shown in table 4.68. Significant influence of various treatments was visible on manganese content of straw. However, grain Mn content was unaffected by these

Table 4.67 Ca, Mg, S and Fe content of grain and straw as influenced by nursery treatments

Treatments		Calcium (mg/kg)		Magnesium (mg/kg)		Sulphur (mg/kg)		Iron (mg/kg)	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	80% RHC + 20% Soil + 0.1% Urea	462.94[bc]	3661.88[a]	1179.00[a]	1834.25[a]	972.22[a]	208.33[a]	220.38[a]	430.75[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	507.94[abc]	2683.31[c]	1057.81[c]	1670.75[a]	777.78[a]	180.56[a]	174.38[a]	374.94[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	568.88[ab]	3230.63[ab]	1118.06[b]	1657.00[a]	923.61[a]	194.45[a]	220.06[a]	464.31[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	373.56[c]	2734.38[c]	1091.06[bc]	1737.88[a]	819.45[a]	145.83[a]	140.94[a]	407.06[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	646.13[a]	3495.63[ab]	1189.50[a]	1765.88[a]	979.17[a]	222.22[a]	241.19[a]	444.56[a]
T_6	Control	453.88[bc]	3076.88[bc]	1065.63[bc]	1919.75[a]	819.45[a]	194.45[a]	205.25[a]	455.69[a]
Mean		**502.22**	**3147.12**	**1116.84**	**1764.25**	**881.40**	**190.97**	**200.36**	**429.60**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

treatments. T_5 recorded the highest content of both grain and straw. Mean Mn content of straw (1415 mg kg^{-1}) was higher than that of grain (116.41 mg kg^{-1}).

Boron content

The effect of various treatments on boron content of grain and straw is reported in table 4.68.Significant influence of various treatments was visible on boron content of straw. However, grain boron content was unaffected by these treatments. The highest boron content of grain and straw was observed in T_4 and T_3 respectively. B content of grain varied from 25.82 mg kg^{-1} to 35.98 mg kg^{-1} and that of straw from 16.91 mg kg^{-1} to 32.64 mg kg^{-1}.

Copper content

The data on copper content of grain and straw are given in table 4.68. The copper content of straw was not significantly influenced by various treatments. The higher Cu content of straw was observed in T_4. Mean Cu content was 9.23mg kg^{-1}.

4.5.7 Nutrient uptake by the crop

Nitrogen uptake

The influence of various treatments on nitrogen uptake by the crop is showed in table 4.69. Various treatments were unable to produce significant influence on the uptake of N by the crop. However, total N uptake by the crop varied from 71.43 kg ha^{-1} to 87.79 kg ha^{-1}with mean N uptake of 80.67 kg ha^{-1}. The mean uptake of N by grain and straw were 44.98 kg ha^{-1} and 35.82 kg ha^{-1} respectively.

Phosphorus uptake

The data regarding uptake of phosphorus by the crop is given in table 4.69. The P uptake by the crop was not significantly varied among treatments. The mean uptake of P by grain and straw were 11.79 kg ha^{-1} and 8.43 kg ha^{-1} respectively. The mean total uptake of phosphorus by the crop was 20.22 kg ha^{-1}.

Potassium uptake

The effect of various treatments on potassium uptake by the crop is reported in table 4.69. Even though the K content of the grain showed significant difference

Table 4.68 Zn, Mn, B and Cu content of grain and straw as influenced by nursery treatments, mg/ kg

Treatments		Zinc		Manganese		Boron		Copper
		Grain	Straw	Grain	Straw	Grain	Straw	Straw
T_1	80% RHC + 20% Soil + 0.1% Urea	16.73[a]	18.41[a]	117.44[a]	1484.85[ab]	29.21[a]	16.91[c]	10.31[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	19.34[a]	21.20[a]	114.63[a]	1399.50[bc]	25.82[a]	27.88[ab]	8.94[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	17.45[a]	19.22[a]	115.31[a]	1381.44[bc]	27.34[a]	32.64[a]	7.94[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	19.03[a]	20.91[a]	106.44[a]	1343.75[c]	35.98[a]	25.24[b]	11.06[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	17.10[a]	18.82[a]	129.56[a]	1550.31[a]	33.41[a]	26.30[ab]	6.63[a]
T_6	Control	17.81[a]	19.53[a]	115.06[a]	1328.06[c]	31.08[a]	27.09[ab]	10.50[a]
Mean		**17.30**	**19.70**	**116.41**	**1415.00**	**30.47**	**26.01**	**9.23**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Table 4.69 N, P and K uptake as influenced by nursery treatments

Treatments		Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	80% RHC + 20% Soil + 0.1% Urea	45.73[a]	37.21[a]	82.94[a]	11.31[a]	8.44[a]	19.75[a]	10.55[a]	146.48[a]	157.03[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	44.40[a]	37.86[a]	82.26[a]	11.48[a]	7.99[a]	19.47[a]	11.47[a]	154.43[a]	165.89[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	48.31[a]	39.48[a]	87.79[a]	12.17[a]	9.01[a]	21.17[a]	12.89[a]	152.05[a]	164.94[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	48.59[a]	33.98[a]	82.57[a]	12.67[a]	7.97[a]	20.63[a]	11.40[a]	138.29[a]	149.69[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$+ 0.01% Borax	40.90[a]	30.54[a]	71.43[a]	11.43[a]	8.89[a]	20.32[a]	10.46[a]	130.66[a]	141.11[a]
T_6	Control	41.99[a]	35.88[a]	77.00[a]	11.70[a]	8.28[a]	19.98[a]	11.21[a]	142.33[a]	153.54[a]
Mean		**44.99**	**35.83**	**80.82**	**11.79**	**8.43**	**20.22**	**11.33**	**144.04**	**155.37**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

among the treatments, the K uptake by the grain was not significant. The mean uptake of K by grain and straw were 11.33 kg ha^{-1} and 144.21 kg ha^{-1} respectively. The mean total K uptake by the crop was 155.37 kg ha^{-1}.

Calcium uptake

The influence of various treatments on calcium uptake by the crop is showed in table 4.70. No significant influence of various treatments was observed in calcium uptake by the crop. The mean uptake of Ca by grain and straw were 1.74 kg ha^{-1} and 10.25 kg ha^{-1} respectively. The mean total K uptake by the crop was observed to be 11.99 kg ha^{-1}.

Magnesium uptake

The data regarding uptake of magnesium by the crop is given in table 4.70. The Mg uptake by the crop was not significantly varied among treatments. The mean uptake of Mg by grain and straw were 3.89 kg ha^{-1} and 5.71 kg ha^{-1} respectively. The mean total uptake of magnesium by the crop was 9.6 kg ha^{-1}.

Sulphur uptake

The data on sulphur uptake by the crop (Table 4.70) showed no significant variation between the treatments. However, total S uptake by the crop varied from 3.21 kg ha^{-1} to 4.12 kg $ha^{-1}$with mean S uptake of 3.71 kg ha^{-1}. The mean uptake of S by grain and straw were 3.09 kg ha^{-1} and 0.62 kg ha^{-1} respectively.

Iron uptake

The influence of various treatments on iron uptake by the crop is showed in table 4.70. The iron uptake by the crop was not significantly varied between treatments. The mean uptake of Fe by grain and straw were 0.69 kg ha^{-1} and 1.39 kg ha^{-1} respectively. The mean total uptake of iron by the crop was 2.08 kg ha^{-1}. The highest crop uptake of Fe was observed in T_3.

Zinc uptake

The data on zinc uptake by the crop are given in table 4.71. Zinc uptake by both grain and straw were not significantly influenced by various treatments. The mean uptake of zinc by the grain and straw were 0.61 kg $ha^{-1}$and 0.63 kg ha^{-1}

Table 4.70 Ca, Mg, S and Fe uptake as influenced by nursery treatments

Treatments		Calcium (kg/ ha)			Magnesium (kg/ ha)			Sulphur (kg/ ha)			Iron (kg/ ha)		
		Grain	**Straw**	**Total**	**Grain**	**Straw**	**Total**	**Grain**	**Straw**	**Total**	**Grain**	**Straw**	**Total**
T_1	80% RHC + 20% Soil + 0.1% Urea	1.55[a]	11.74[a]	13.29[a]	3.92[a]	5.86[a]	9.78[a]	3.21[a]	0.66[a]	3.87[a]	0.74[a]	1.39[a]	2.13[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	1.72[a]	8.61[a]	10.33[a]	3.58[a]	5.32[a]	11.24[a]	2.62[a]	0.59[a]	3.21[a]	0.59[a]	1.20[a]	1.79[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	2.04[a]	11.71[a]	13.75[a]	4.11[a]	5.92[a]	10.03[a]	3.42[a]	0.70[a]	4.12[a]	0.78[a]	1.61[a]	2.39[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	1.39[a]	8.64[a]	10.03[a]	4.05[a]	5.51[a]	9.56[a]	3.05[a]	0.46[a]	3.51[a]	0.53[a]	1.29[a]	1.82[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	2.11[a]	11.28[a]	13.39[a]	3.88[a]	5.70[a]	9.58[a]	3.30[a]	0.72[a]	4.02[a]	0.78[a]	1.44[a]	2.22[a]
T_6	Control	1.61[a]	9.51[a]	11.21[a]	3.79[a]	5.94[a]	9.73[a]	2.93[a]	0.60[a]	3.53[a]	0.74[a]	1.41[a]	2.15[a]
Mean		**1.74**	**10.25**	**11.99**	**3.89**	**5.71**	**9.60**	**3.09**	**0.62**	**3.71**	**0.69**	**1.39**	**2.08**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

respectively. The total uptake of zinc by the crop was observed to be 1.24 kg ha^{-1}.

Manganese uptake

The data regarding to manganese uptake by the crop are given in table 4.71.Various treatments were unable to produce significant influence on the uptake of Mn by the crop. However, total Mn uptake by the crop varied from 4.52 kg ha^{-1} to 5.38 kg ha^{-1}with mean Mn uptake of 5 kg ha^{-1}. The mean uptake of Mn by grain and straw were 0.41 kg ha^{-1} and 4.59 kg ha^{-1} respectively.

Boron uptake

Boron uptake by crop as influenced by different treatments is shown in table 4.71. Boron uptake by straw was observed to be significantly influenced by the treatments. The highest B uptake by the straw was recorded in T_3. However, no significant influence was noticed on B uptake by both grain and crop. The mean B uptake by the crop was 0.19 kg ha^{-1}.

Copper uptake

The influence of various treatments on copper uptake by the crop is showed in table 4.71. No significant variation was observed in copper uptake by straw. The mean Cu uptake by the crop was 0.06 kg ha^{-1}.

4.2.6 Chemical properties and nutrient status of soil before cultivation and after harvest of the crop

The data on chemical properties of soil before cultivation is given in table 3.8. Physico-chemical properties of soil after harvest of the crop are given in table 4.72. The nutrient status of soil after harvest of the crop is presented in table 4.73. Soil recorded pH of 5.67 and EC of 0.10 dS m^{-1} before cultivation of the crop. The pH and electrical conductivity (EC) of the soil after the harvest of the crop were 5.67 and 0.1 dS m^{-1} respectively. Soil organic carbon content was 0.67 per cent and 0.43per cent at before cultivation and after harvest of the crop respectively. Soil recorded 157.5 kg ha^{-1} of available nitrogen, 56 kg ha^{-1} of available phosphorus and 152.43 kg ha^{-1} of available potassium respectively. The available nitrogen,

Table 4.71 Zn, Mn, B and Cu uptake as influenced by nursery treatments, kg/ ha

Treatments		Zinc			Manganese			Boron			Copper
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Total
T_1	80% RHC + 20% Soil + 0.1% Urea	0.55[a]	0.58[a]	1.13[a]	0.39[a]	4.79[a]	5.18[a]	0.10[a]	0.05[c]	0.15[a]	0.07[a]
T_2	80% RHC + 20% Soil + 0.01% Borax	0.66[a]	0.68[a]	1.34[a]	0.37[a]	4.47[a]	4.84[a]	0.09[a]	0.09[ab]	0.18[a]	0.05[a]
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	0.65[a]	0.67[a]	1.32[a]	0.43[a]	4.93[a]	5.36[a]	0.10[a]	0.11[a]	0.21[a]	0.06[a]
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	0.69[a]	0.66[a]	1.35[a]	0.40[a]	4.25[a]	4.65[a]	0.13[a]	0.08[b]	0.21[a]	0.08[a]
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$ + 0.01% Borax	0.54[a]	0.61[a]	1.15[a]	0.42[a]	4.99[a]	5.41[a]	0.11[a]	0.09[b]	0.20[a]	0.04[a]
T_6	Control	0.63[a]	0.61[a]	1.24[a]	0.42[a]	4.10[a]	4.52[a]	0.11[a]	0.09[b]	0.20[a]	0.07[a]
Mean		**0.61**	**0.63**	**1.24**	**0.41**	**4.59**	**5.00**	**0.11**	**0.08**	**0.19**	**0.06**

* The means followed by common alphabets in a column do not differ significantly at 5% level in DMRT
RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

Table 4.72 Chemical properties of soil after cultivation

Sl. No.	Parameters	Value
1.	pH	5.67
2.	Electrical conductivity (dS/m)	0.10

Table 4.73 Nutrient status of soil after cultivation

Sl. No.	Parameters	Value
1.	Organic carbon (%)	0.43
2.	Available nitrogen (kg/ha)	142.80
3.	Available phosphorus (kg/ha)	99.29
4.	Available potassium (kg/ha)	152.43
5.	Available sulphur (mg/kg)	5.36
6.	Available calcium (mg/kg)	402.24
7.	Available magnesium (mg/kg)	33.49
8.	Available iron (mg/kg)	33.14
9.	Available zinc (mg/kg)	2.68
10.	Available manganese (mg/kg)	69.01
11.	Available copper (mg/kg)	3.14
12.	Available boron (mg/kg)	0.69

phosphorus and potassium content of soil after cultivation of the crop were 142.8 kg ha^{-1}, 35.46 kg ha^{-1} and 152.43kg ha^{-1} respectively. Available sulphur, calcium and magnesium content in the soil before cultivation were 7.86 mg kg^{-1}, 516.55 mg kg^{-1} and 40.6 mg kg^{-1} respectively. After harvest of the crop, available content of sulphur, calcium and magnesium content in the soil were 5.36 mg kg^{-1}, 402.24 mg kg^{-1} and 33.49 mg kg^{-1} respectively. Before cultivation of crop, soil had available iron, zinc, manganese and copper content of 39.4 mg kg^{-1}, 3.3 mg kg^{-1}, 112.6 mg kg^{-1} and 3.29 mg kg^{-1} respectively. Iron, zinc, manganese and copper content were found to be 33.14 mg kg^{-1}, 2.68 mg kg^{-1}, 69.01 mg kg^{-1} and 3.14 mg kg^{-1} respectively after completion of harvest.

4.2.7 Economics of cultivation

The influence of various treatments on the economics of cultivation is shown in table 4.7. Total cost of cultivation ranged from Rs. 151.94 / 20 m^2 to Rs.152.7 / 20 m^2. T_3 recorded the highest cost of cultivation and the lowest was with T_1. All the treatments except T_3 recorded lesser cost than control. The highest gross income (Rs.291) was observed with T_3 and the lowest (Rs.260.76) with T_5. Net benefit from T_3 and T_4 were higher than control treatment. All the treatments recorded B: C ratio of more than one. The highest B: C ratio (1.91) was observed in T_3.

Table 4.74 Economics of cultivation as influenced by nursery treatments

Treatments		Total cost (Rs./ 20 m^2)	Gross income (Rs./20 m^2)	Net income (Rs./20 m^2)	B:C ratio
T_1	80% RHC + 20% Soil + 0.1% Urea	151.94	264.54	112.60	1.74
T_2	80% RHC + 20% Soil + 0.01% Borax	151.94	266.52	114.57	1.75
T_3	40% RHC + 40% Soil + 20% VC + 0.1% Urea + 0.05% $ZnSO_4$	152.68	291.18	138.50	1.91
T_4	60% RHC + 20% Soil + 20% CPC + 0.1% Urea + 0.01% Borax	152.04	283.08	131.04	1.86
T_5	80% RHC + 20% Soil + 0.1% Urea+ 0.05% $ZnSO_4$+ 0.01% Borax	151.97	260.76	108.89	1.72
T_6	Control	152.70	272.88	120.18	1.79

RHC- Rice husk charcoal, VC- Vermicompost, CPC- Coir pith compost

DISCUSSION

V. DISCUSSION

The experiment on optimization of nutripriming technique and mat thickness on tray nursery in rice was conducted at Agricultural Research Station, Mannuthy. Rice cultivation in Kerala has been steadily declining due to shrinking agricultural lands and labour scarcity. In this situation, mechanisation of rice farming has become unavoidable in Kerala. Even though self propelled paddy transplanter is becoming popular actual adoption rate of this technology among paddy growers is low due to lack of proper standardization of tray nursery production technologies. Production of low cost nursery with easily available materials will lead to wider acceptance of the technology and cost reduction in rice cultivation. Standardisation of media and thickness for easy transport of mat nursery and smooth transplanting will pave way for increased area of cultivation. Transplanting of vigorous and good quality seedlings will also streamline enhancement of production.

Considering above facts, composition and thickness of media and nutripriming techniques in tray nursery were evaluated. Biometric characters of seedlings, mat characteristics, nutrient status of seedlings in nursery and performance of mat nursery under field condition with regard to growth, yield attributes, yield, performance of transplanter and nutrient status of soil and crop were studied.

5.1 EXPERIMENT I: STANDARDISATION OF GROWING MEDIA AND THICKNESS OF MAT FOR TRAY NURSERY IN RICE

Trays were filled with media, seeds were placed and covered with thin layer of using Automatic Rice Mat Nursery Sowing Machine. Trays with size of 60 cm x 30 cm, suitable for the dimension of the seedling platform of the self-propelled walk-behind mechanical transplanter was used as these trays could only provide depth according to the treatments. The experiment on optimization of media composition and mat thickness based on characteristics of seedlings and mat was explained.

5.1.1 Influence of growing media composition and thickness on biometric characters of seedlings

The shortest duration to attain 50 per cent germination indicates early and uniform germination of seeds. The data on days to 50 per cent germination revealed that the growing media comprised of rice husk charcoal and soil along with coir pith compost or vermicompost recorded the shortest duration for days to 50 per cent germination (Table 4.1; Fig. 5.1). Soil amended with compost and rice husk charcoal increased aeration and water holding capacity and that might induce germination process. Highest seedling emergence was reported in *Lycopersicon esculentum cv.* Rheinlands Ruhm when grown in a substrate containing 20 per cent VC by Zaller (2007). However, no significant influence of media thickness on days to 50 per cent germination was noticed. This indicated that it is better to select the lowest thickness which will reduce the mat weight and cost associated with it. According to Basmanj *et al.* (2016) an ideal growing media needs to be sufficiently light weight in order to handle easily and the transportation should be economically reasonable.

Seedling height could be considered as an indicator of healthy nursery (Dhananchezhian *et al.*, 2013). Media containing 20 per cent soil along with rice husk charcoal and coir pith compost produced the tallest plants at 5 DAS. However, the same media composition failed to maintain its superiority at 10 and 15DAS. Media containing highest percentage of soil (40 %) amended with vermicompost produced the tallest seedlings at 10 and 15 DAS. Seedlings with the height of 17.1 cm were produced by this media composition at the time of transplanting (Table 4.3; Fig. 5.2). According to Kitagawa *et al.* (2004) about three leaf stage and 12 to 15cm height of seedlings are suitable for machine transplanting. In the present study, media containing rice husk charcoal, vermicompost and 40 per cent soil along with 15mm media thickness produced maximum seedling height of 19.15 cm. Seedling height up to 20.5 cm was reported by Rajendran *et al.* (2005) in mat nursery at 15 DAS.

Media containing 40 % RHC+ 40 % Soil+ 20 % VC and 60 % RHC+ 20 % Soil+ 20 % CPC performed on par with respect to biomass production at transplanting. Biomass production was unaltered by different levels of media thickness. However, media containing less proportion of soil is more appreciable as it reduces the weight of mat (Table 4.4; Fig.5.3). Coir pith compost as a component of nutrient source instead of vermicompost without sacrificing seedling quality can reduce the cost of nursery production. Higher shoot dry weight was also observed in media of 40 % RHC+ 40 % Soil+ 20 % VC and 60 % RHC+ 20 % Soil+ 20 % CPC. It can be attributed to higher nutrient status of these media (Fig.5. 4).

Media containing 60 % RHC+ 20 % Soil+ 20 % CPC was superior with respect to root dry weight throughout the nursery period. Root dry weight produced the same trend as that of biomass production with respect to the media thickness at 15 DAS. The root dry weight increased with decrease in media thickness (Table 4.7; Fig. 5.5). Higher biomass production and root dry weight contributed positively to the increased dry matter production as observed in the media containing vermicompost or coir pith compost along with soil and rice husk charcoal. The ability of rice husk charcoal to retain the moisture, increased pH, availability of exchangeable potassium, available phosphorus and calcium as reported by Njoku and Mbah (2012) might have helped the seedlings to absorb more nutrients thereby increased growth and dry matter production. In the case of dry matter production, the media with rice husk charcoal, soil and coir pith compost in the ratio of 60: 20: 20 was superior (Table 4.9; Fig. 5.6).

Root length is considered as a key component in the formation of quality seedling mat. Mat stiffness is related to the length and thickness of root and entanglement of root. The media containing coir pith compost and soil along with rice husk charcoal produced maximum root length of 10.14 cm which was near to the value (10cm) reported by Dhananchezhiyan *et al.* (2013) in media of organic composites (Table 4.11; Fig. 5.7). Low bulk density, higher aeration and increased supply of nutrients due to the presence of coir pith compost and rice husk charcoal increased growth and penetration of roots to lower layers of media thereby

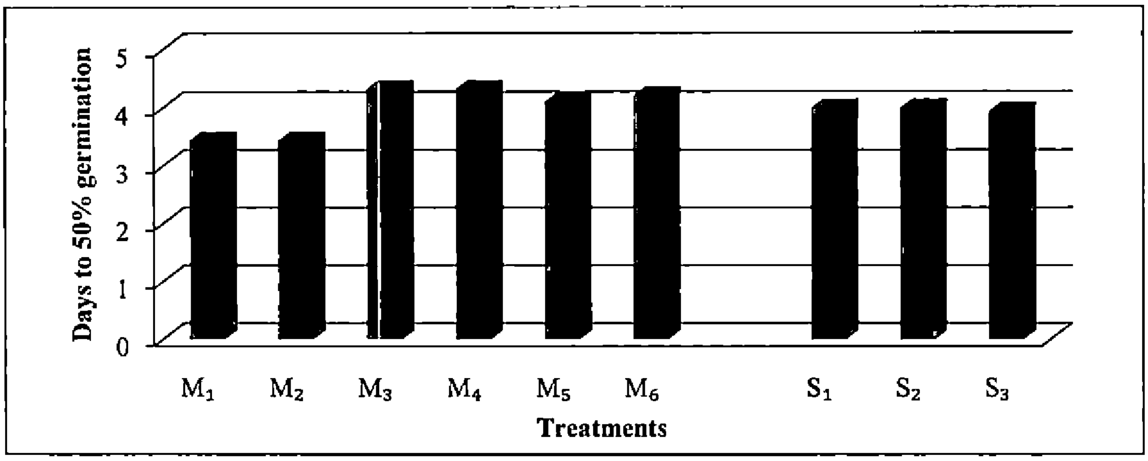

Fig. 5.1 Effect of composition and thickness of media on days to 50 per cent germination

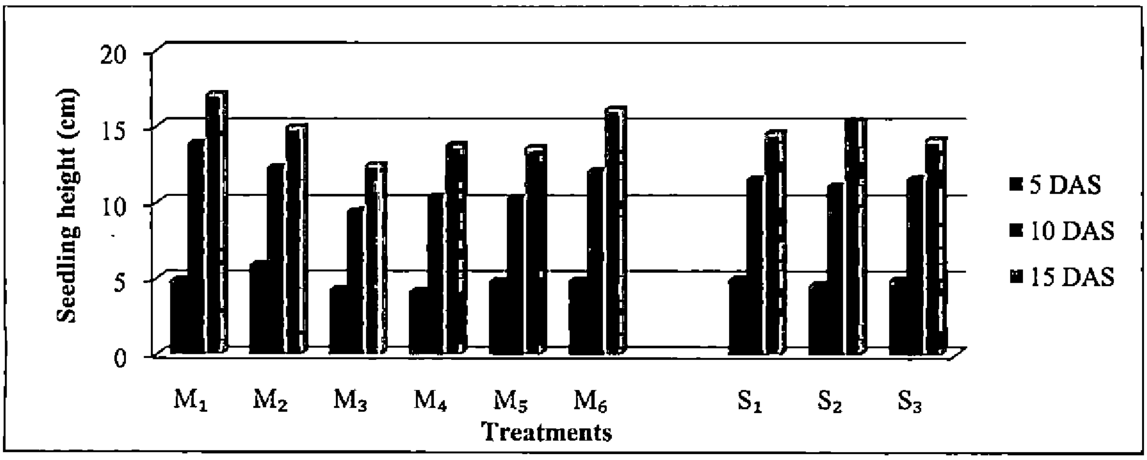

Fig. 5.2 Effect of composition and thickness of media on height of seedlings at 5, 10 and 15 DAS

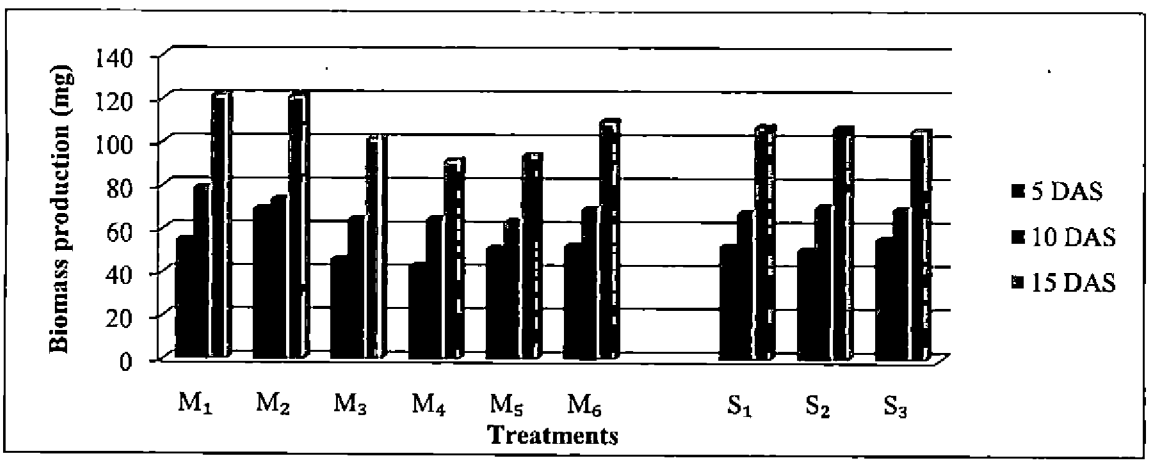

Fig. 5.3 Effect of composition and thickness of media on biomass production of seedlings at 5, 10 and 15 DAS

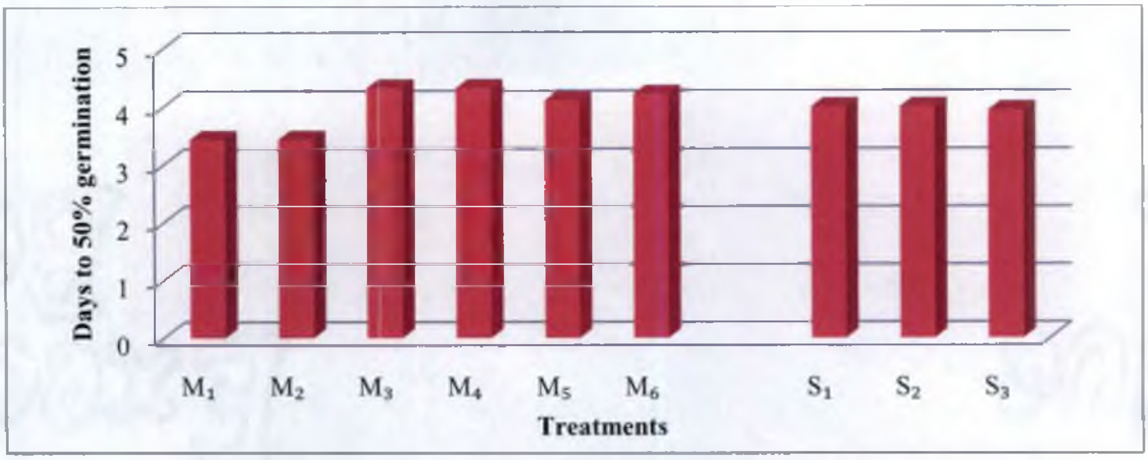

Fig. 5.1 Effect of composition and thickness of media on days to 50 per cent germination

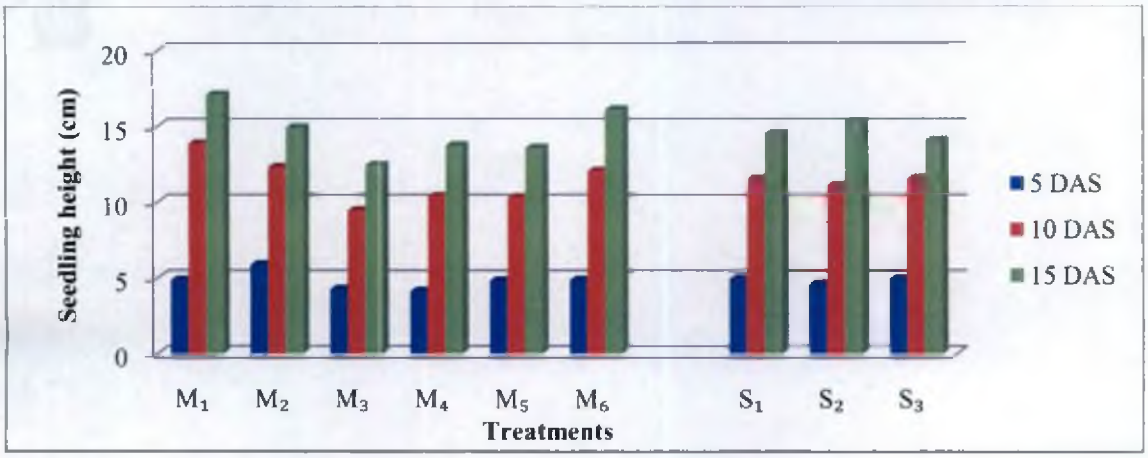

Fig. 5.2 Effect of composition and thickness of media on height of seedlings at 5, 10 and 15 DAS

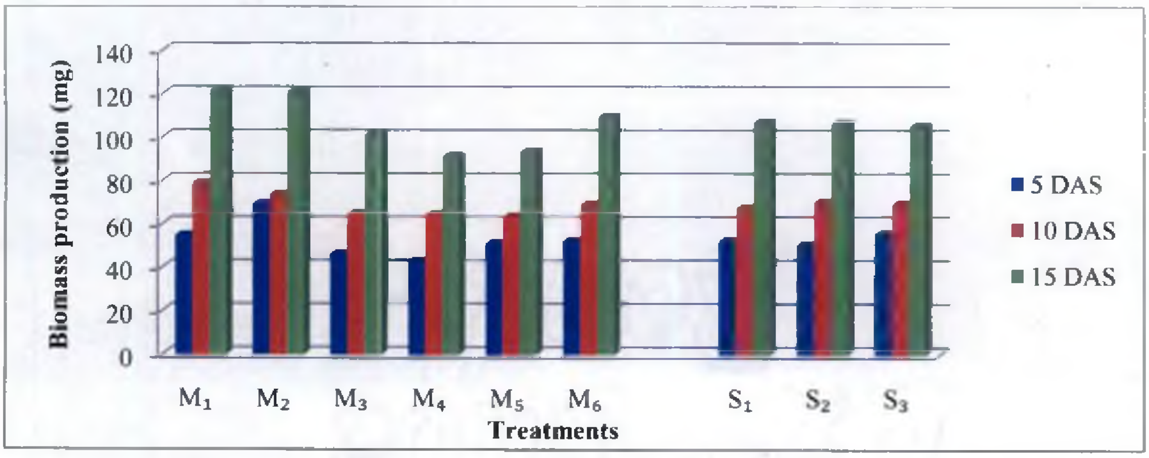

Fig. 5.3 Effect of composition and thickness of media on biomass production of seedlings at 5, 10 and 15 DAS

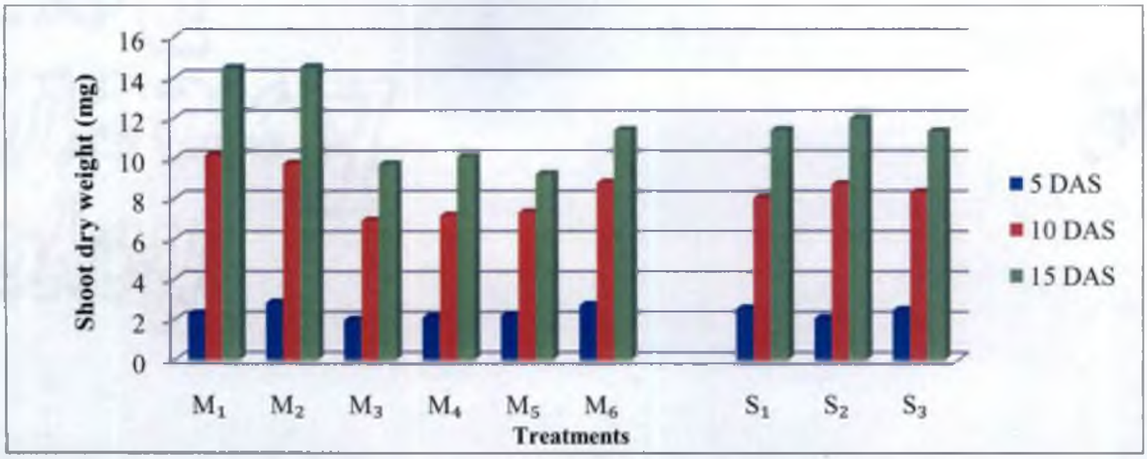

Fig. 5.4 Effect of composition and thickness of media on shoot dry weight of seedlings at 5, 10 and 15 DAS

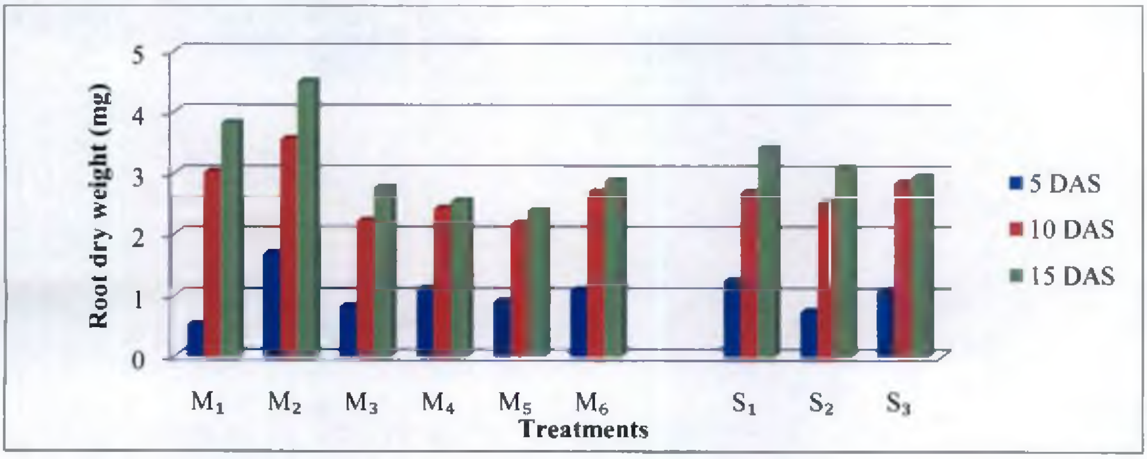

Fig.5.5 Effect of composition and thickness of media on root dry weight of seedlings at 5, 10 and 15 DAS

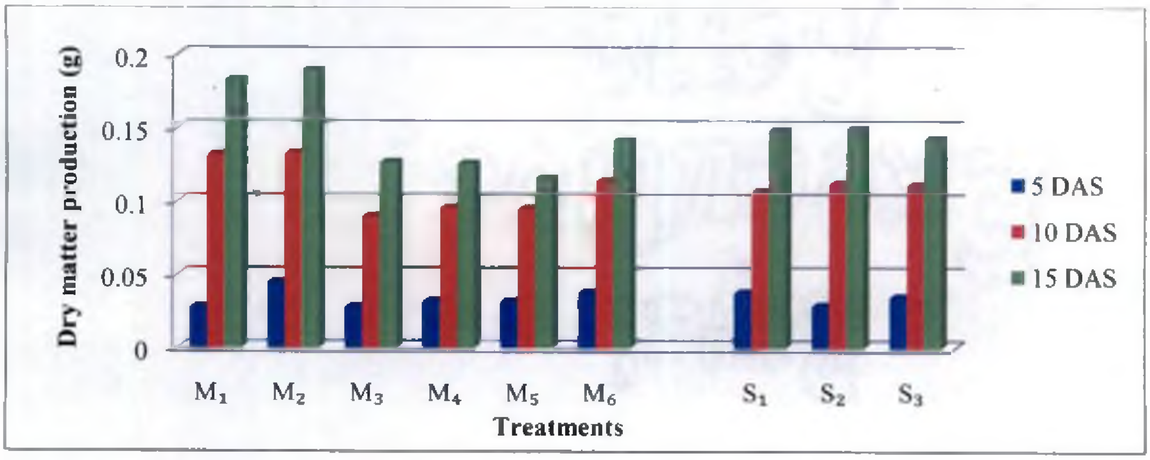

Fig.5.6 Effect of composition and thickness of media on dry matter production of seedlings at 5, 10 and 15 DAS

increased root length. Longer roots are advantageous character for mechanical transplanting.

In most of the above mentioned seedling characters, the superiority was observed with the media containing soil as one of the component. This might be due to the positive influence of soil in stimulating the supply of nutrients from the media for seedling growth as reported by Isaac *et al.* (2003). It clearly indicated that a soil component in the mat nursery media is pertinent for the quality seedling production. Seedling grown in the soilless media showed relatively yellow colour due to the deficient nutrient supply. A similar situation was also reported by Rajendran *et al.*, (2005) and Mamun *et al.* (2013). Vigorous seedlings in this experiment were produced by media with rice husk charcoal, coir pith compost and low proportion of soil.

5.1. 2 Influence of growing media composition and thickness on mat characteristics

Mat characteristics such as weight per unit area, mat density, shearing strength and slippage of mat play a pertinent role on the performance of transplanter in the field.

Significant influence of media composition was observed on mat weight per unit area. Each component of the media marked its profound influence on mat characteristics favourable for healthy mat nursery. Soilless media were found to have lower mat weight per unit area compared to other media (Table 4.13; Fig. 5.8). In this experiment, the media consisted of rice husk charcoal and coir pith compost recorded the least mat weight per unit area. The light weight and low bulk density of rice husk charcoal and coir pith compost resulted in light weight of media. Light weight mats are more preferred in commercial mat nursery production due to the easiness in transportation. Moreover, use of light weight material as growing media can reduce labour requirement because of less effort in handling of seedling trays (Ko *et al.*, 2005). However, total replacement of the soil with rice husk charcoal is not possible as this may lead to tendency of loosening of roots due to low binding capacity of rice husk charcoal. High proportion of rice husk charcoal which lacks cohesiveness might reduce stiffness of mat. This leads to difficulty during handling in the field and badly influences the performance of transplanter. Moisture retention capacity of the mat also has an effect on mat weight. The media with lesser proportion of soil and higher proportion of rice husk charcoal recorded lower mat weight which is a favourable character in commercial mat nursery production. In consequence to this fact, media with 60 % RHC+ 20 % CPC+ 20 %Soil recorded the lower mat weight and mat density in this experiment and at the same time favouring the character of mat stiffness also. The data on component wise analysis of different parameters revealed that water holding capacity of coir pith compost is higher and this leads to higher moisture retention compared to other media. A decrease in the mat weight per unit area was observed with the decrease in level of media thickness. However, Rajesh (2003) reported that thinner mats lead to slipping down of mat while placing in the seedling platform of the transplanter. Hence it is necessary to standardise the thickness of mat.

Denser mats have proper binding of particles and roots. Higher proportion soil produced comparatively denser mat compared to other media combination. The media consisted of rice husk charcoal and coir pith compost recorded the lowest mat density. This might be due to loosely packed light weight particles in the media which lead to the increase in volume and decrease in weight. Higher density at lower level of thickness might attribute to close arrangement of roots and further lowering of volume (Table 4.13; Fig. 5.9).

Shearing strength is an index of stiffness of mat. Mats should be stiff enough for easy handling and proper picking by finger of transplanter. Media containing rice husk charcoal, soil and coir pith compost showed higher shearing strength (Fig. 5.10). Fibrous texture of coir pith compost along with rice husk charcoal and soil might contributed towards better binding and stiffening of mat. Shiratsuchi *et al.* (2002) reported more tensile strength of mat prepared with chaff which had twice strength as that with soil alone. The shearing strength was increased with decrease in media thickness. It might be due to more interlocking of roots at lower media thickness. Dhananchezhiyan *et al.* (2013) reported maximum mat stiffness for a media containing field soil and coir pith at 1:1 and 2:1 ratio with a corrugated sheet base layer. In this experiment, the media containing 40 % RHC+ 40 % Soil+ 20 %

VC recorded the highest shearing strength followed by media with rice husk charcoal, soil and vermicompost in the ratio of 60: 20: 20.

Slippage indicates the extent of slipping of mat nursery from original place on seedling platform of mechanical transplanter during working of the machine. Seedling mat with less slippage was found to be ideal for smooth transplanting under mechanisation. The media containing rice husk charcoal, soil and vermicompost recorded no slippage and found more suitable for mechanical transplanting (Fig. 5.11). Slippage was observed to be increased with increase in media thickness. Folding of mat was not observed during the observation period of one minute. But, Rajesh (2003) noticed slipping down of thinner mat due to the lack of tenacity and strength. Low proportion of soil is inevitable for the favourable mat characteristics for mechanical transplanting. Paddy mat nursery with low mat weight and density, higher shearing strength and lower slippage was observed to be ideal for successful mechanical transplanting. Media containing 40 % RHC + 40 % soil + 20 % VC or 60 % RHC + 20 % soil + 20 % CPC and 80 % RHC+20 % soil were better with respect to performance of mechanical transplanter, quality seedling growth and mat characteristics. These media can be selected for commercial mat nursery production. It is noteworthy to mention that thickness of media exhibited much significant influence on mat characteristics than the seedling characters.

The scoring and ranking technique used in the study also recorded higher aggregate score and rank for three media *viz.* 40 % RHC + 40 % soil +20 % VC, 60% RHC + 20 % soil + 20 % CPC and 80 % RHC + 20 % soil. Among the levels of thickness, the lowest thickness of 10mm was found to be satisfying all the favourable characters for seedling growth and characteristics of mat. Hence, the three media with one level of thickness were selected as best for Experiment II.

5.1.3 Influence of media composition and thickness on nutrient content and uptake by the seedlings

The higher water holding capacity and low bulk density of the rice husk charcoal and coir pith compost are favourable characters while focussing on production of light weight tray nursery with robust seedlings. Microbial respiration

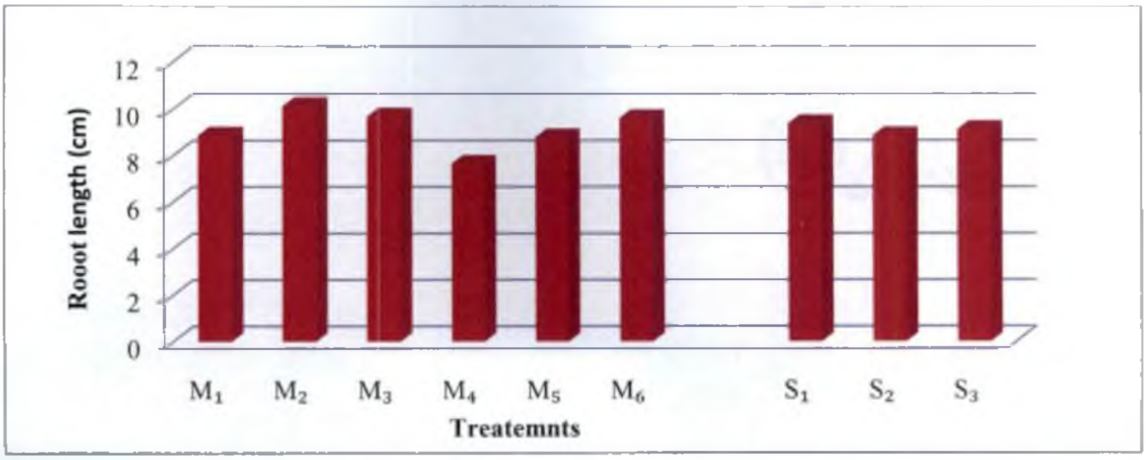

Fig.5.7 Effect of composition and thickness of media on root length at transplanting

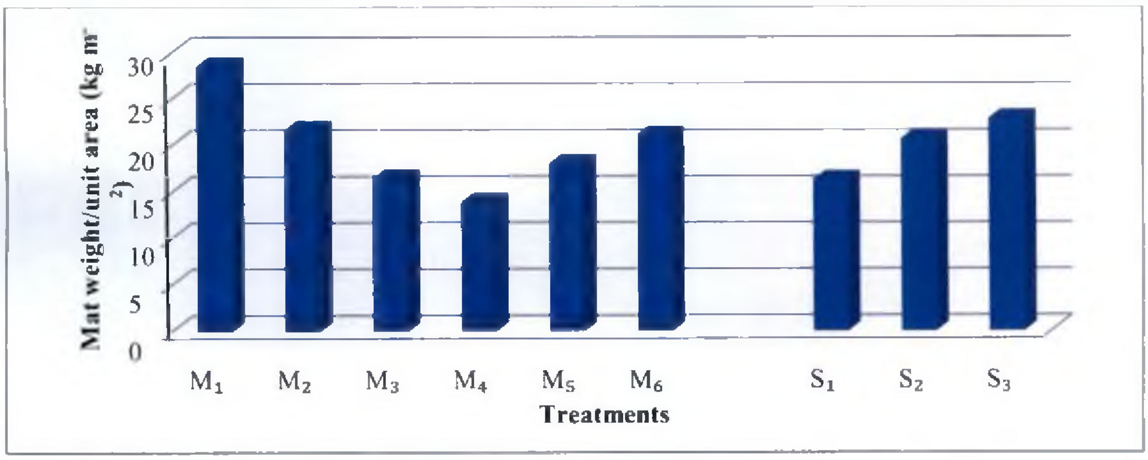

Fig.5. 8 Effect of composition and thickness of media on weight of mat

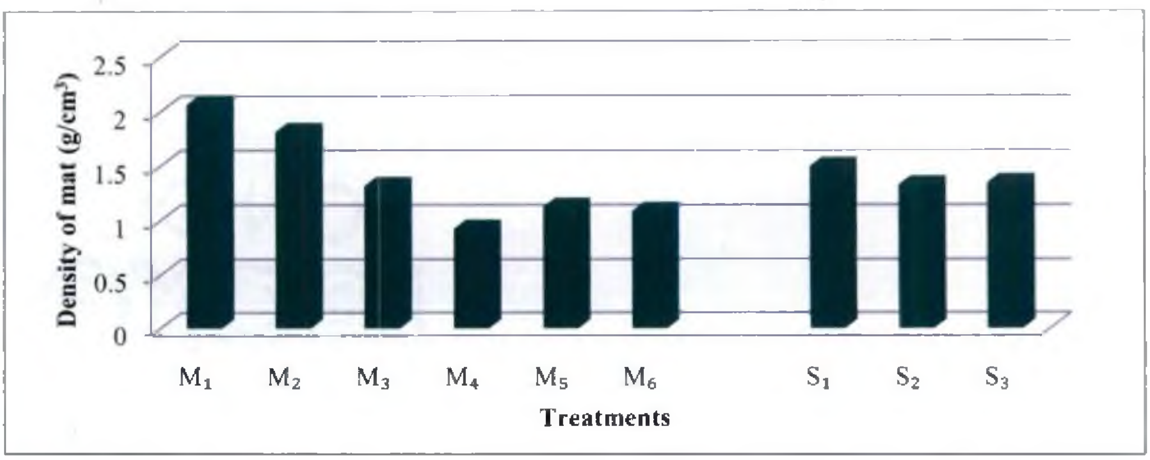

Fig.5.9 Effect of composition and thickness of media on density of mat

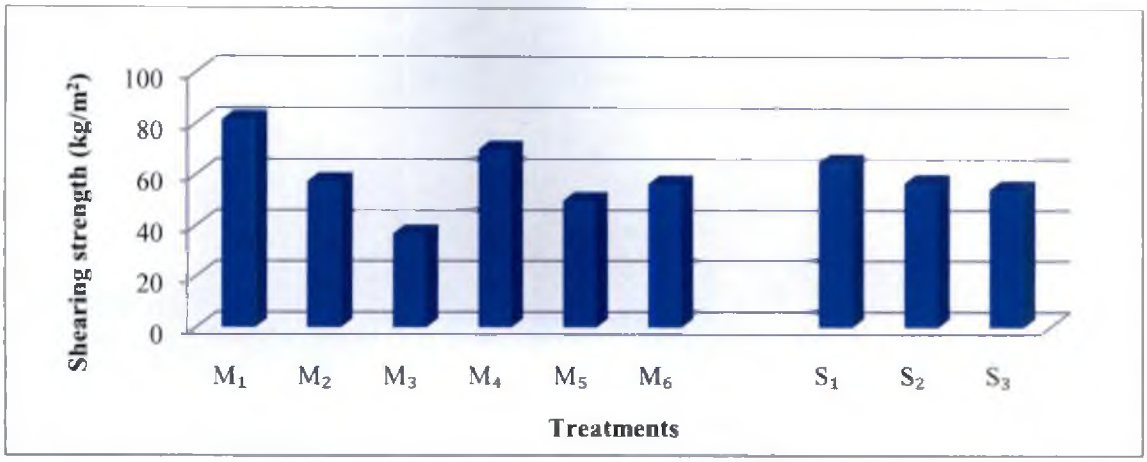

Fig.5.10 Effect of composition and thickness of media on shearing strength of mat

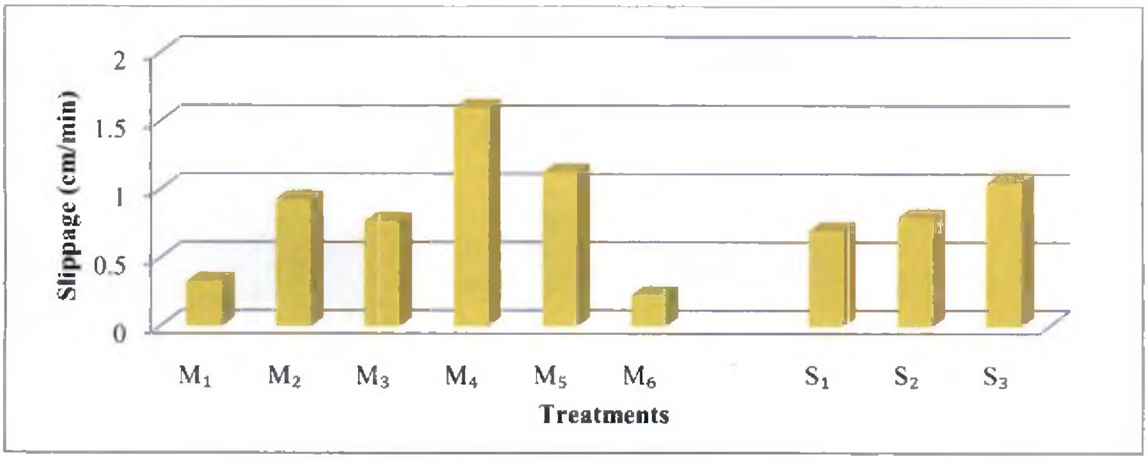

Fig.5.11 Effect of composition and thickness of media on slippage of mat

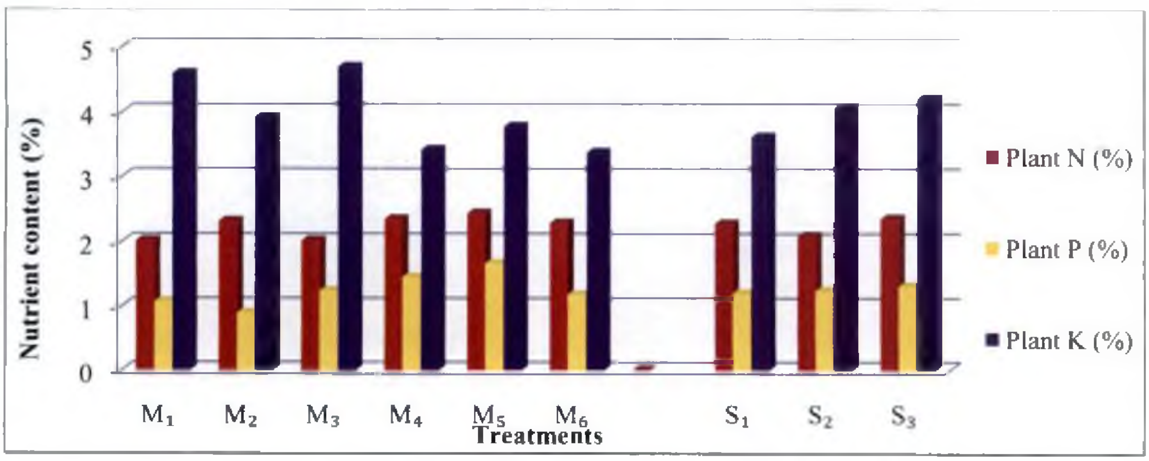

Fig. 5.12 N, P and K content of seedlings as influenced by variation in composition and thickness of media

rate increases under the optimum physico–chemical environment and will potentially lead to high rates of mineralization (Robertson and Groffman, 2007). Vermicompost was found to be the richest in nutrients compared to other components with regard to P, S, Ca, Mg, Fe, Zn, Mn and Cu. Hence, the combination of various components would favour the growth characteristics of rice seedlings. Nutrient status of growing media followed the trend in accordance with the components present in it. The highest water holding capacity and the lowest bulk density of media containing rice husk charcoal and coir pith compost can attribute to the physico-chemical properties of components. Media containing 40 % RHC + 40 % Soil + 20 % VC, 60 % RHC + 20 % Soil + 20 % CPC and 60 % RHC + 20 % CPC + 20 % VC were acidic in nature whereas 80 % RHC + 20 % CPC media and 80 % RHC + 20 % VC media were strongly acidic. The highest organic carbon content of the media containing coir pith compost and vermicompost along with rice husk charcoal was due to the high organic carbon content of the individual components. Media composed of soil as one of the component had high Fe content due to the characteristic laterite soil with rich in available Fe.

The media with higher N and P status produced seedlings with the highest N and P content. Higher N content and low K content were observed in 40 % RHC + 40 % Soil + 20 % VC and 60 % RHC + 20 % CPC +20 % VC media. The highest P and K uptake was observed in 15 mm thickness of media. The superior seedlings were produced at the highest level of media thickness (20mm) and this can be attributed to the increased availability of nutrients from higher volume of media (Table 4.12; Fig. 5.12).

5.2 EXPERIMENT II: NUTRIPRIMING OF SEED

Seed is the key input of agriculture. Seed deserves the most importance because quality seed in good growing media can yield profusely. In order to obtain healthy and vigorous seedlings proper nutrient management is inevitable. Early access of nutrients, influence on final yield of crop and cost involved are of important concern while considering the nutrient management techniques in the paddy nursery. In this regard nutripriming is found to be an effective way for nutrient supply. Seeds primed with nutrients act as a channel for the delivery of specified quantities of fertilizer and may help for proper exploitation of yield potential of rice crop. Supply of the nutrients adjacent to the seed is pertinent for immobile nutrients as well as micronutrients. In Experiment II, seeds were primed in different nutrient solutions before sowing and grown in the selected media for mat nursery production. Control treatment was soaking seeds in water (hydropriming).

5.2.1 Influence of growing media composition and nutripriming on biometric characters of seedlings

Media containing rice husk charcoal and soil led to short duration for 50 per cent germination which was statistically on par with media of rice husk charcoal, soil and coir pith compost (Table 4.27; Fig. 5.13). This might be due to increased water holding capacity and aeration of soil amended with rice husk charcoal and coir pith compost which triggered germination.

Height of seedlings is an important parameter for mechanical transplanting. Seedlings lacking required height as mentioned earlier may fall down while picking by finger of the transplanter. Seedlings grown in the media containing rice husk charcoal, soil and vermicompost were taller than other seedlings at 5 DAS (Table 4.29; Fig. 5.14). Soil amended with compost might increase the release of nutrients to the plants resulting in vigorous growth.

Although, media containing higher percentage of soil produced the highest shoot dry weight at 5 DAS, there was no significant difference between media with respect to the shoot dry weight at its further growth (Table 4.32; Fig. 5.16). Dry matter production was found to be the highest in the media comprised of high per cent of soil along with rice husk charcoal and vermicompost (Table 4.35; Fig. 5.18). Soil amended with vermicompost improved nutrient content resulting in increased shoot dry weight and thereby enhanced dry matter production. This media composition recorded the highest content of Mg, S, Fe, Zn, Cu and B as per the analysis of media for nutrients. Vermicompost was found to be rich in N, P, S, Ca, Mg, Fe, Zn, Mn and Cu than other components. The nutrient rich media as evidenced from nutrient analysis may be the reason for higher dry matter production. Hidalgo *et al.* (2006) also reported improvement in plant growth due to the incorporation of vermicompost in to the growing media. Media containing highest proportion of soil produced significantly higher root length at transplanting. Plant roots may tried to overcome the impedance from the soil as it is more cohesive compared to all other media components. All the three media selected from Experiment I performed similarly with regard to the biomass production at 5, 10 and 15 DAS and root dry weight throughout the nursery period (Table 4.30; Fig. 5.15; Table 4.33; Fig. 5.17).

Though 40 % RHC + 40 % soil +20 % VC was superior with respect to seedling characters, the other two media were also having comparable performance. The media showed superiority in mat characteristics also (Fig. 5.20; Fig. 5.21; Fig. 5.22; Fig. 5.23). Similar to the seedling parameters, the other two media were equally good in mat formation. With respect to the commercialization of mat nursery production, vigorous growth of seedlings, light weight and higher shearing strength with low slippage are the factors to be considered for media selection. Hence, the three media were selected for field evaluation as they had comparable performance with respect to seedling and mat characteristics.

Among the nutripriming treatments most of the priming treatments were on par with respect to the days for 50 per cent germination. Uniform germination of seeds was visible in all the treatments including control (hydroprimig). This might be due to the metabolic repair during imbibition of water (Bray *et al.*, 1989) and synthesis of germination enhancing metabolites in nutripriming (Basra *et al.*, 2005). Priming with urea recorded the shortest time to 50 per cent germination (Table 4.27; Fig. 5.13). This might be due to the stimulating effect of N on seed germination. Alboresi *et al.* (2005) and Bethke *et al.* (2006) reported stimulation of germination by several nitrogen containing compounds such as nitric oxide, nitrite and nitrate. Salt index of the urea is less compared to other N sources (Tisdale *et al.*, 1995). Anosheh *et al.* (2011) found that urea priming resulted in more germination per cent. The long duration for 50 per cent germination in priming with nutrient solution containing combination of 0.1 per cent urea, 0.05 per cent $ZnSO_4$ and 0.01

per cent borax might be due to the reduced osmotic potential of the solution at higher concentration of solutes. Biopriming with *Pseudomonas fluorescens* formulation also took more days to 50 per cent germination. However, Raj *et al.* (2004) reported improved seed germination and seedling emergence due to bio-priming with *Pseudomonas fluorescens* isolates.

All the priming treatments produced superior seedlings compared to the control with respect the height of seedlings at 5 DAS (Table 4.29; Fig. 5.14). This indicated positive influence of nutripriming over hydropriming on seedling height of rice at the early stages. Nutripriming not only introduces the nutrients but also may be confounded with 'priming' effects (Heydecker and Coolbear, 1977). Seedling height did not reveal significant difference among media composition, nutripriming and treatment combinations at 10 DAS. According to Whalley *et al.* (1966) seedlings grow as heterotroph at early stages of growth, entirely depending on the endosperm reserves and then enter a transition phase in which seedlings survive both by endosperm reserves and photosynthesis. Comparable growth at 5 and 10 DAS due to nutripriming may be due to the growth by endosperm reserves during the early period in the nursery. Yoshida (1981) reported that seedlings became autotrophic at 2.7 leaf age. Combined application of urea, zinc and borax through seed priming produced tallest seedlings at 15 DAS. Increased nutrient availability might have led to the increased height of seedlings in these treatments. Nutripriming with urea solution also produced significantly taller seedlings than control treatment. According to Marschner (1997) N related processes like protein and chlorophyll synthesis influence the photosynthesis and lead to the elongation of stem. B is an essential nutrient for the formation and development of new cell in the plant meristem (Tisdale *et al.,* 1995). Zn is involved in the cell proliferation and differentiation as it is an integral part of transcription factors (Vallee and Falchuk, 1993). All these might have contributed to the increased seedling growth in the combined nutripriming.

Seed primed with urea produced higher biomass of seedlings than control treatment. Effect of combined application of borax, urea and zinc through seed priming was comparable with urea priming with regard to biomass production at 5, 10 and 15 DAS (Table 4.30; Fig. 5.15). It indicated that N has more influence on vegetative growth of seedlings in nursery and application of urea can produce satisfactorily vigorous seedlings with less cost. Seeds primed with urea also produced significantly higher dry matter than control at transplanting (Table 4.35; Fig. 5.18). It indicates the superiority of urea in priming over hydropriming.

Seed primed with urea alone and urea with $ZnSO_4$ produced 22 per cent more root dry weight than that of control treatment at 15 DAS (Table 4.33; Fig. 5.17). Johnson *et al.* (2005) noticed increase of seed Zn content due to seed priming in zinc solution. Increased zinc content can act as starter-fertilizer dose for attaining better crop stand. Basu (1994) reported increased metabolic activity due to $ZnSO_4$ hardening. Jayaraj (1977) opined that Zn increased lipid utilization causing rapid growth and development of seedlings and reached at autotrophic stage at an advance stage which made them able to produce more dry matter. Here $ZnSO_4$ with urea might provide a synergistic effect to the significant seedling growth.

All the nutripriming treatments were significantly inferior to control with respect to the root length at transplanting (Table 4.37; Fig. 5.19). The highest root length of the control treatment can be due to the hydropriming effect. Kaur *et al.* (2002) reported 3 to 4 fold increases in root and shoot length under hydropriming compared to non-primed seeds. However among interaction of treatments rice husk charcoal and soil containing media with $ZnSO_4$ nutripriming produced longest roots which was on par with that produced in media containing rice husk charcoal, soil (40 %) and vermicompost with same priming treatment.

All the treatments under visual observation were healthier and without any chlorotic appearance or yellowing. None of the nutripriming treatments showed any adverse effect on seedling growth. No incidence of pest and disease was observed during nursery period. All the three media selected performed in comparison with respect to seedling growth. Though the media with higher proportion of soil had superiority in some of the seedling parameters and seedling growth, the mat characteristics and performance of transplanter are to be considered during final selection of media for commercial mat nursery production

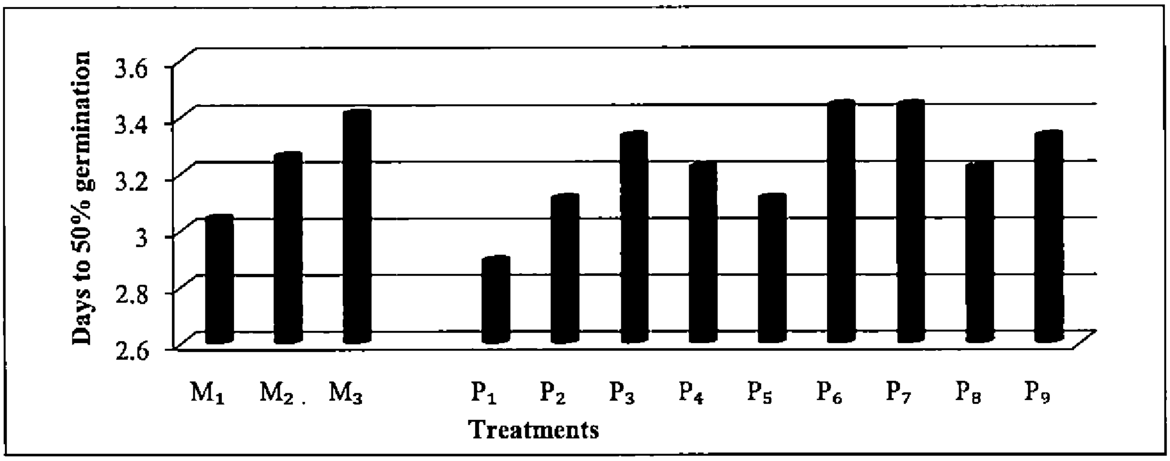

Fig. 5.13 Effect of media composition and nutripriming on days to 50% germination

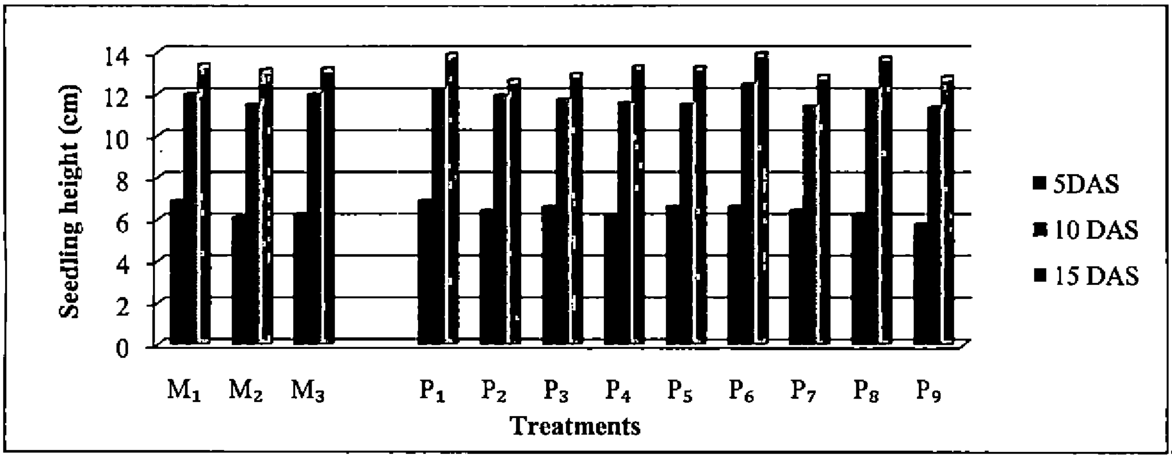

Fig. 5.14 Effect of media composition and nutripriming on seedling height of rice at 5, 10 and 15DAS

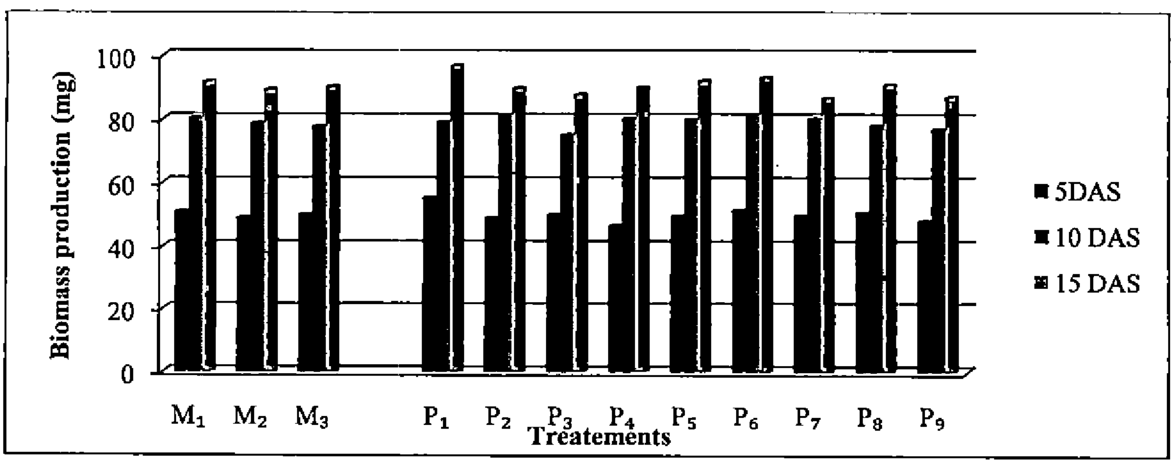

Fig. 5.15 Effect of media composition and nutripriming on biomass production of rice at 5, 10 and 15DAS

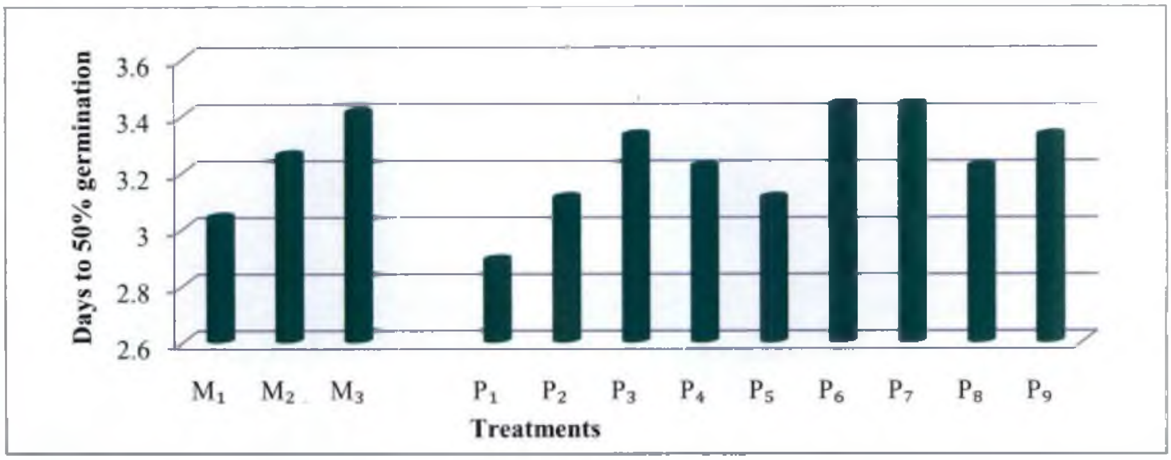

Fig. 5.13 Effect of media composition and nutripriming on days to 50% germination

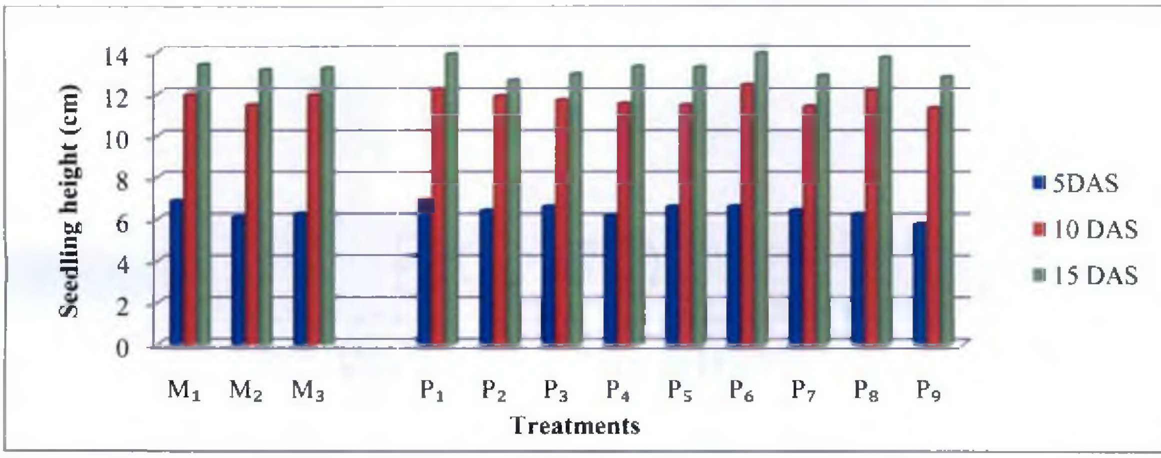

Fig. 5.14 Effect of media composition and nutripriming on seedling height of rice at 5, 10 and 15DAS

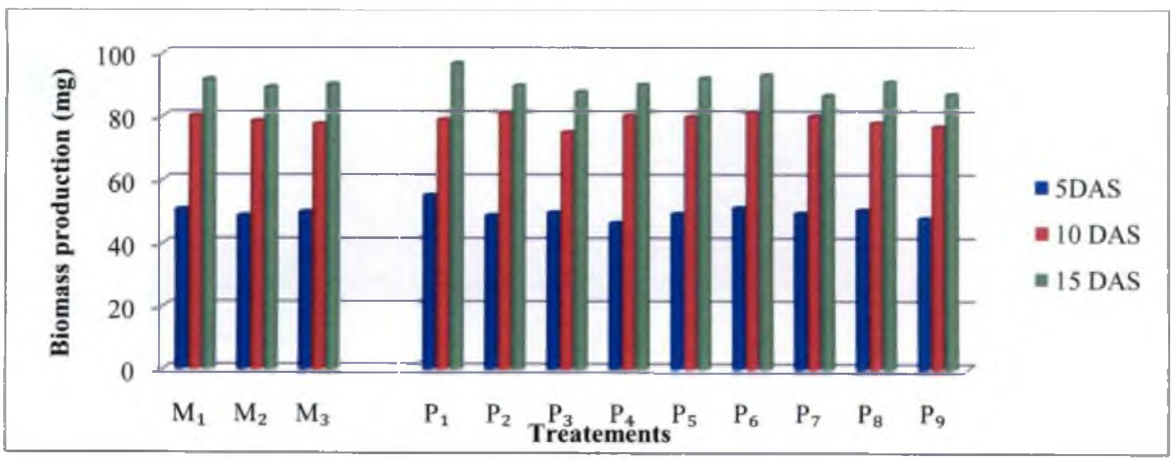

Fig. 5.15 Effect of media composition and nutripriming on biomass production of rice at 5, 10 and 15DAS

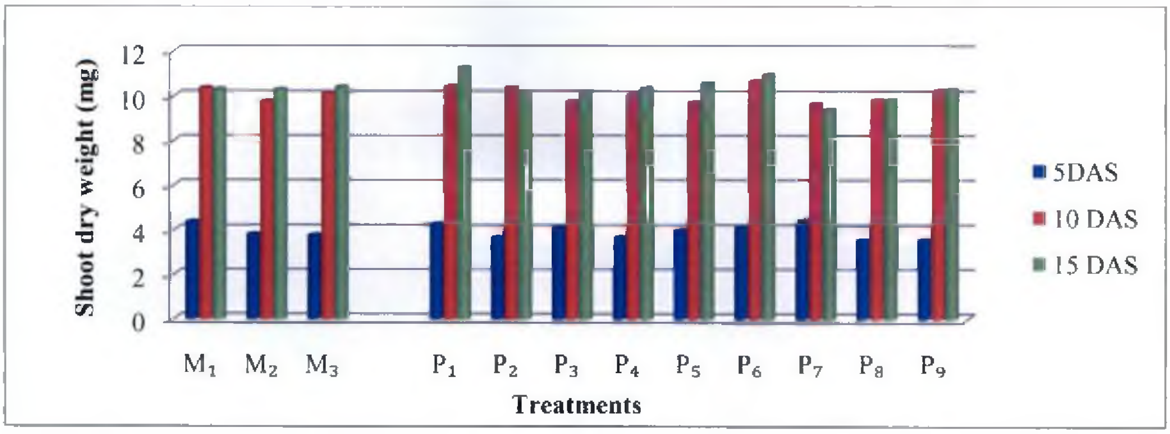

Fig. 5.16 Effect of media composition and nutripriming on shoot dry weight of rice at 5, 10 and 15DAS

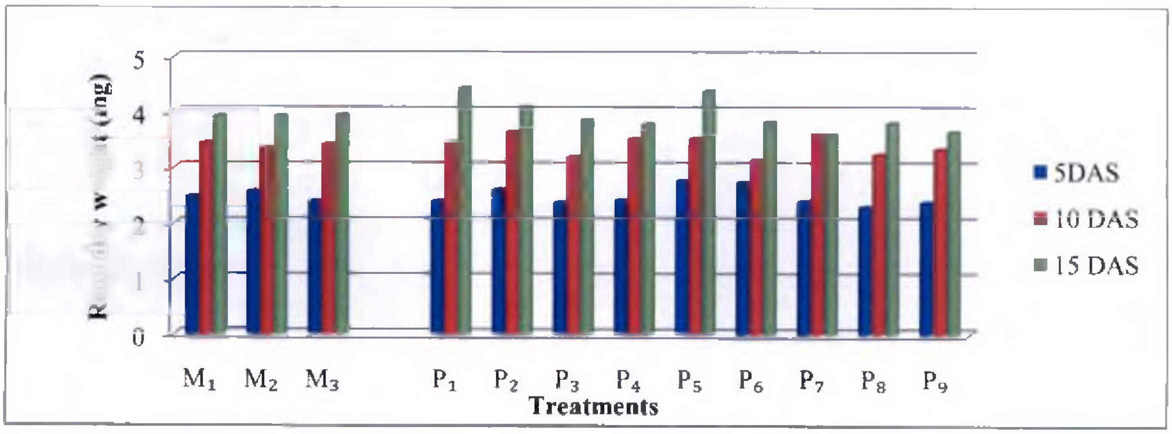

Fig. 5.17 Effect of media composition and nutripriming on root dry weight of rice at 5, 10 and 15DAS

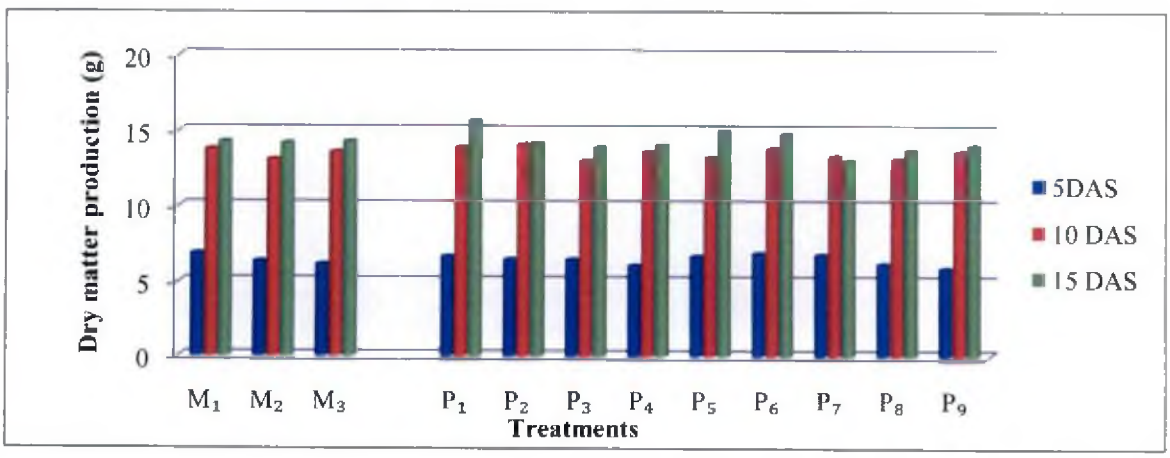

Fig. 5.18 Effect of media composition and nutripriming on dry matter production of rice at 5, 10 and 15DAS

5.2.2 Influence of growing media composition and nutripriming on characteristics of mat

The higher per cent of soil in the media might be the reason for the highest mat weight and density of mat in the media containing 40 % RHC + 40 % soil + 20 % VC. The same combination performed similarly in experiment I also (Fig. 5.20; Fig. 5.21). While considering shearing strength and slippage, media containing rice husk charcoal with soil showed superiority (Fig. 22). High shearing strength provides ease for handling. According to Mathew (2015) media comprising of 60 per cent rice husk charcoal + 30 per cent soil + 10 per cent vermicompost showed superiority with regard to the shearing strength.

The highest mat weight per unit area was observed in nutripriming treatment involving combined nutrient solution of urea, $ZnSO_4$ and borax. The vigorous growth of seedlings and resultant high biomass due to the release of nutrients by combined application of nutrients through priming had contributed to the higher mat weight. The highest shearing strength observed in the urea along with $ZnSO_4$ priming treatment can be attributed to high root dry matter production observed in this treatment. The higher root growth or root thickness might provide more entanglement of seedling roots which in turn led to more strength for mat.

Among the priming treatments, nutripriming was found to be superior over biopriming with respect to seedling and mat characteristics. Though priming in urea solution registered to be superior with respect to seedling characters, priming in the solution containing urea, $ZnSO_4$ and borax was also found to have comparable performance especially with respect to biomass and dry matter production. This treatment also showed higher strength and lower slippage. The mat weight was also low. Hence, priming with combination of urea, borax and $ZnSO_4$ was found to be excellent in quality of seedlings and mat characteristics. At the nursery stage the combined nutripriming can be selected for commercial mat nursery production. The nutripriming with micronutrients may also have effect to correct the deficiency at field level. So field testing is necessary to assess that there is any effect of micronutrient through seed priming at field level.

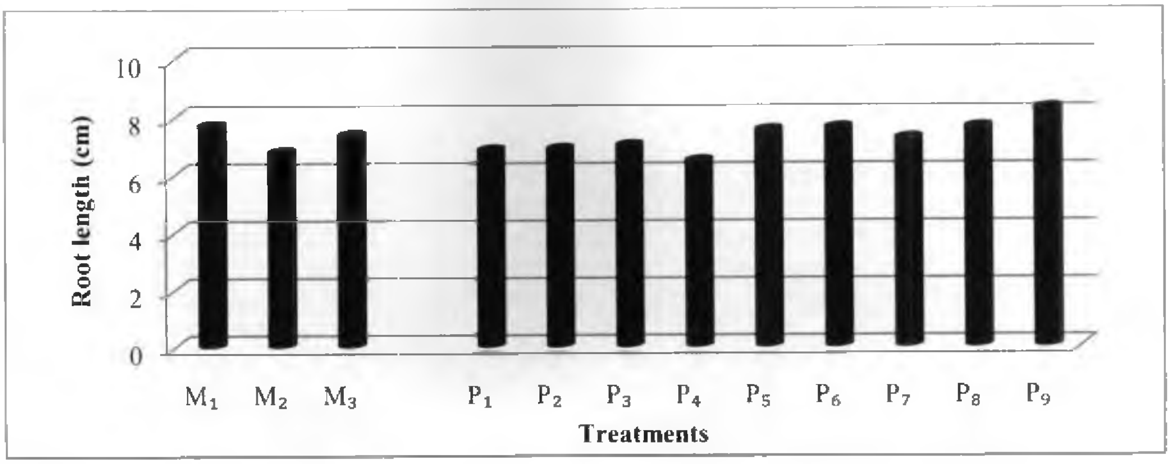

Fig. 5.19 Effect of media composition and nutripriming on root length at transplanting

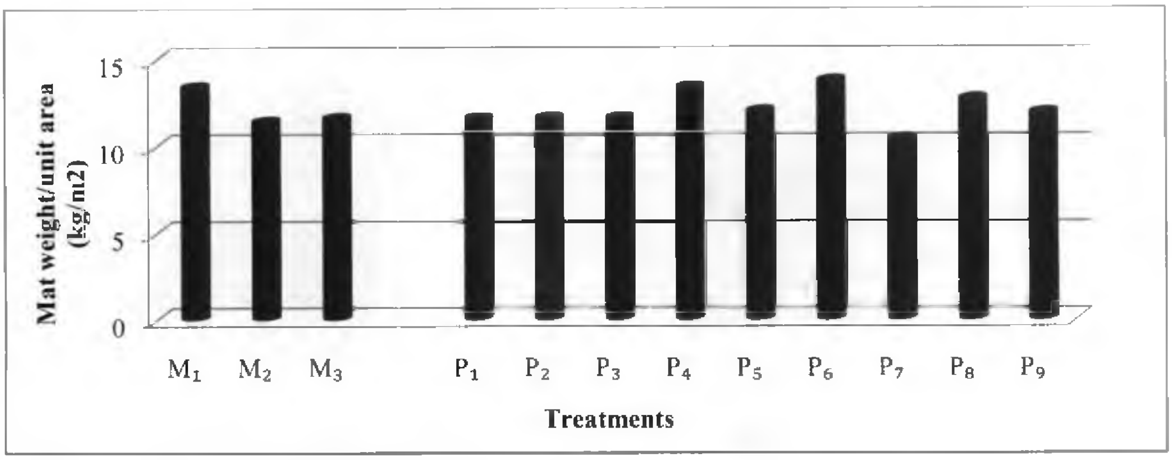

Fig. 5.20 Effect of media composition and nutripriming on mat weight per unit area

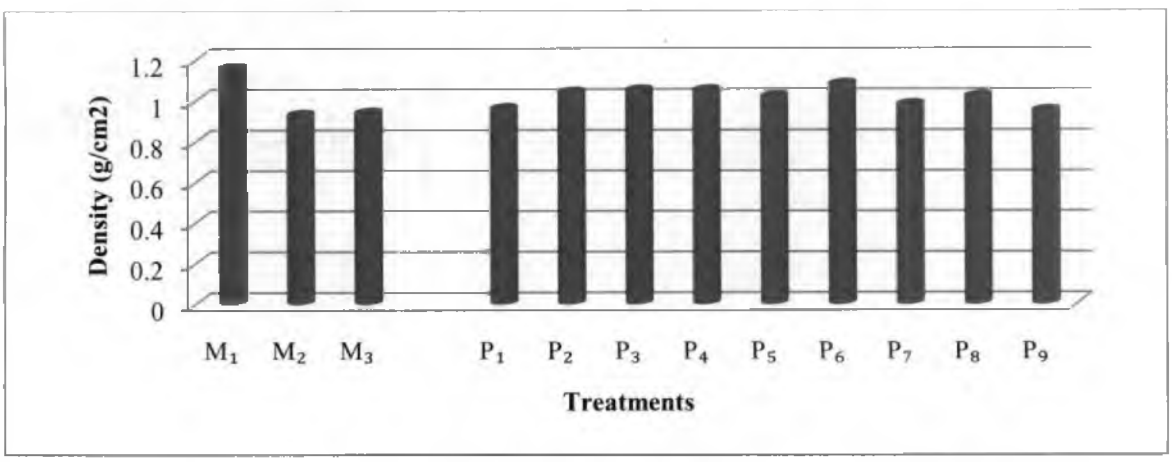

Fig. 5.21 Effect of media composition and nutripriming on density of mat

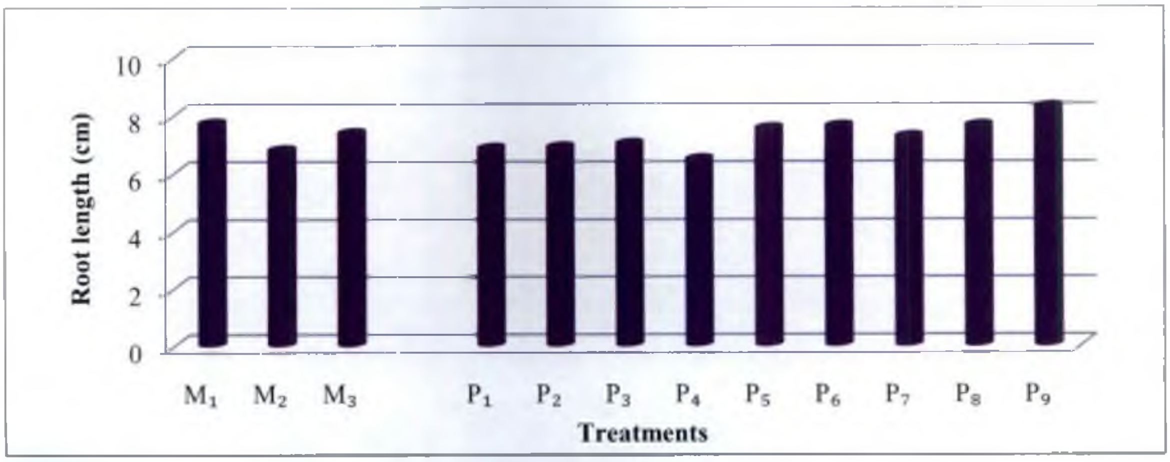

Fig. 5.19 Effect of media composition and nutripriming on root length at transplanting

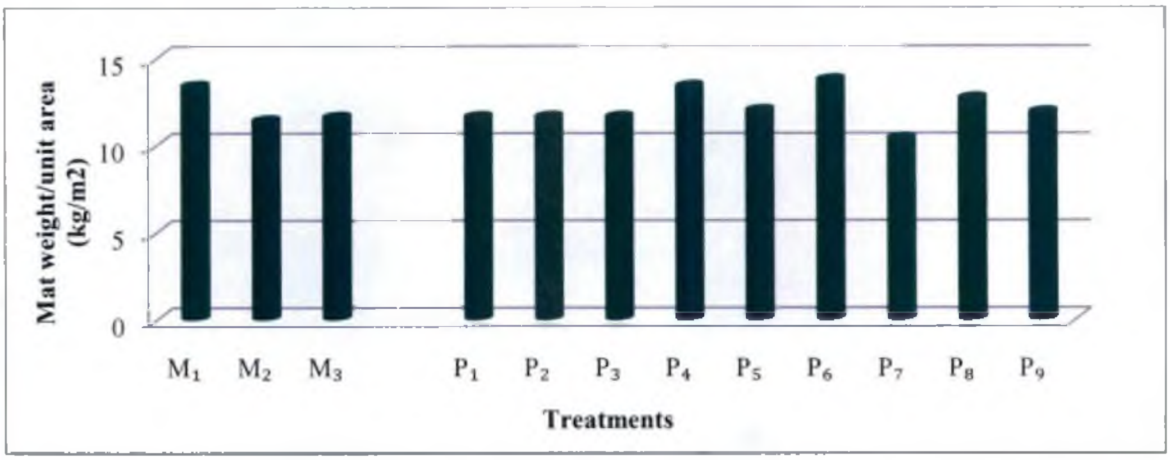

Fig. 5.20 Effect of media composition and nutripriming on mat weight per unit area

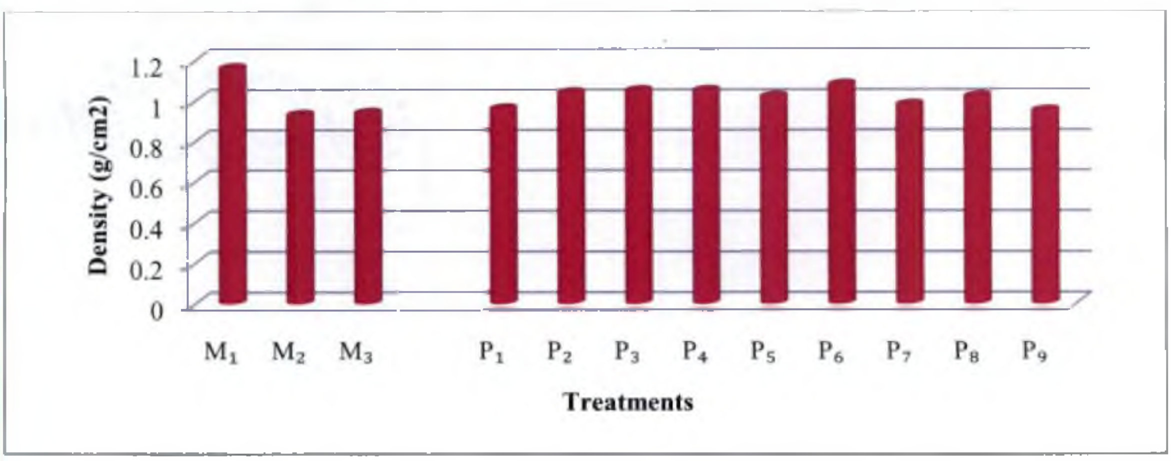

Fig. 5.21 Effect of media composition and nutripriming on density of mat

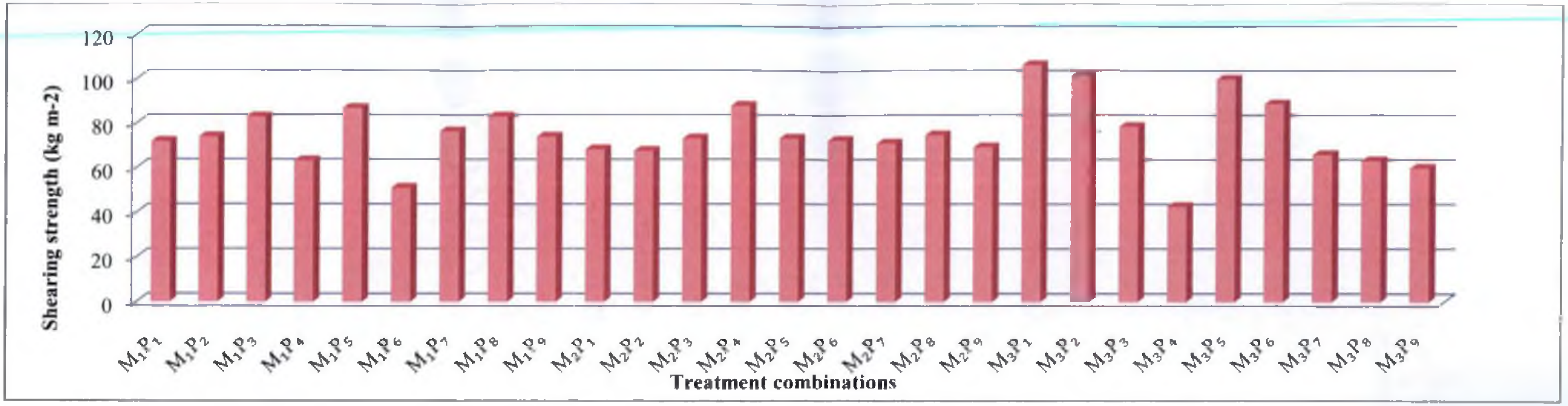

Fig. 5.22 Interaction effect of media composition and nutripriming on shearing strength of mat

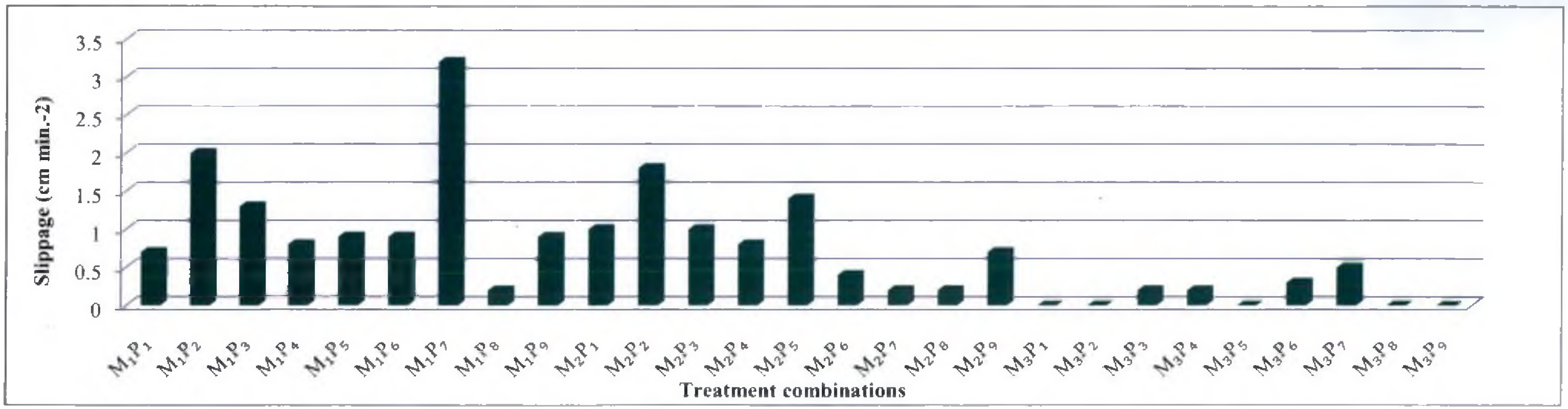

Fig. 5.23 Interaction effect of media composition and nutripriming on slippage of mat

5.2.3 Influence of media and nutripriming on nutrient content and uptake by the seedlings

Major sources of nutrients for growing seedlings in this experiment were both growing media and seed priming. Emergence and plant vigour of paddy seedlings can be improved by seed priming with different nutrient sources. Selection of appropriate nutrient sources and method of application is also proved to be a strategy to improve the nutrient availability. The highest uptake of N observed in the media containing coir pith compost along with rice husk charcoal and soil might be due to increased availability of nitrogen from the soil amended with coir pith compost and rice husk charcoal (Fig. 5.24). N, Ca, Mg and B content were highest in the seedlings primed with combined nutrient solution of urea, borax and $ZnSO_4$. The highest K uptake by the seedlings was observed in the urea priming treatment (Fig. 5.24). Urea along with zinc priming improved the uptake of S, Fe, Zn and Cu by the seedlings. Media containing vermicompost along with rice husk charcoal and soil increased the uptake of P, Mg, S and Cu. It can be attributed to the contribution vermicompost as source of nutrients (Fig. 5.24; Fig. 5.26; Fig. 5.27; Fig.5.32). Among the nutripriming treatments, seed priming in the combined a solution of urea + $ZnSO_4$ + borax were superior with respect to uptake of N, Ca, Mg, Zn and B by the seedlings (Fig. 5.24; Fig. 5.25; Fig. 5.26; Fig. 5.29; Fig. 5.31).

5.3 EXPERIMENT III: FIELD EVALUATION

Selected treatment combinations from experiment II were evaluated at field level in experiment III. Five media compositions were selected out of 27 treatment combinations from experiment II based on performance of seedlings and mat characteristics for field evaluation. The nursery treatments were evaluated under field condition based on the growth parameters and yield of crop and performance of transplanter.

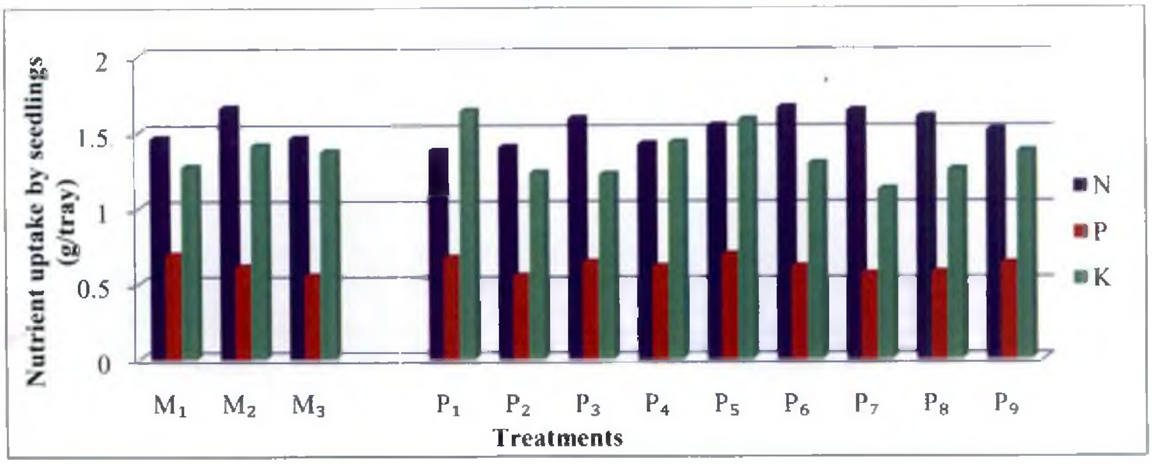

Fig. 5.24 N, P and K uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

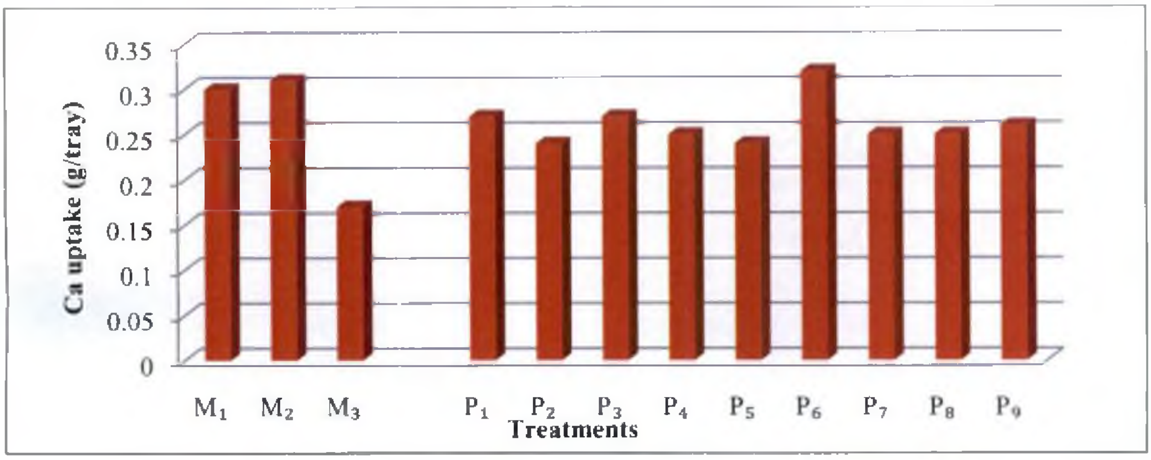

Fig. 5.25 Ca uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

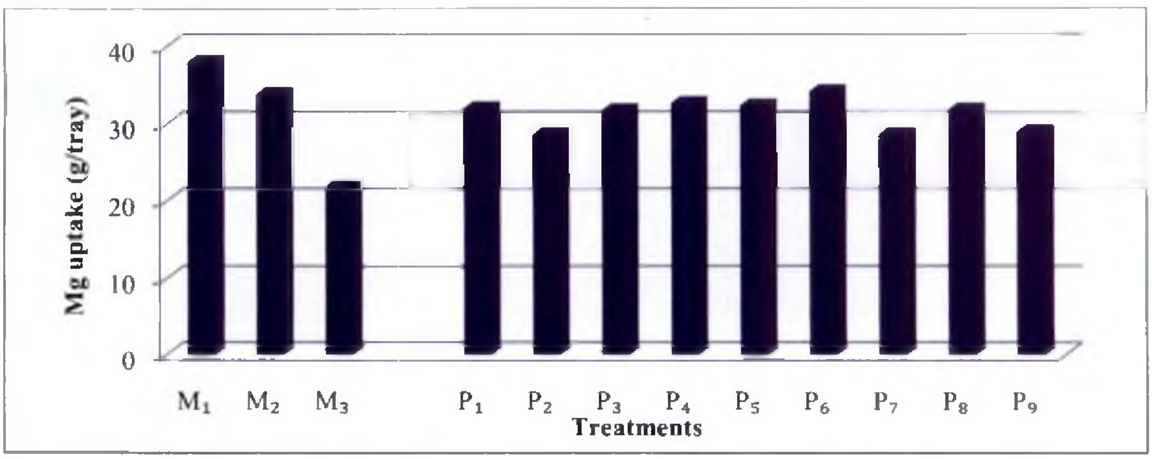

Fig. 5.26 Mg uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

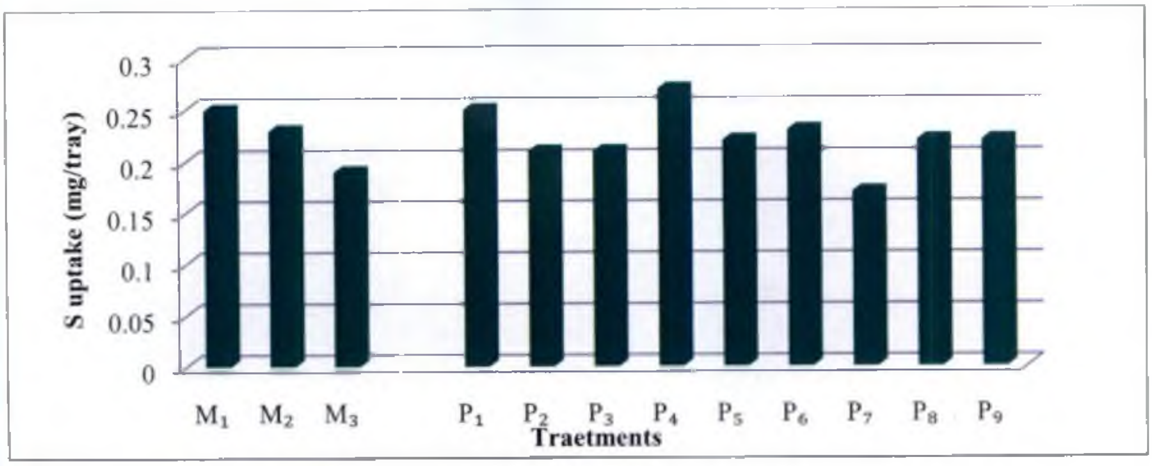

Fig. 5.27 S uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

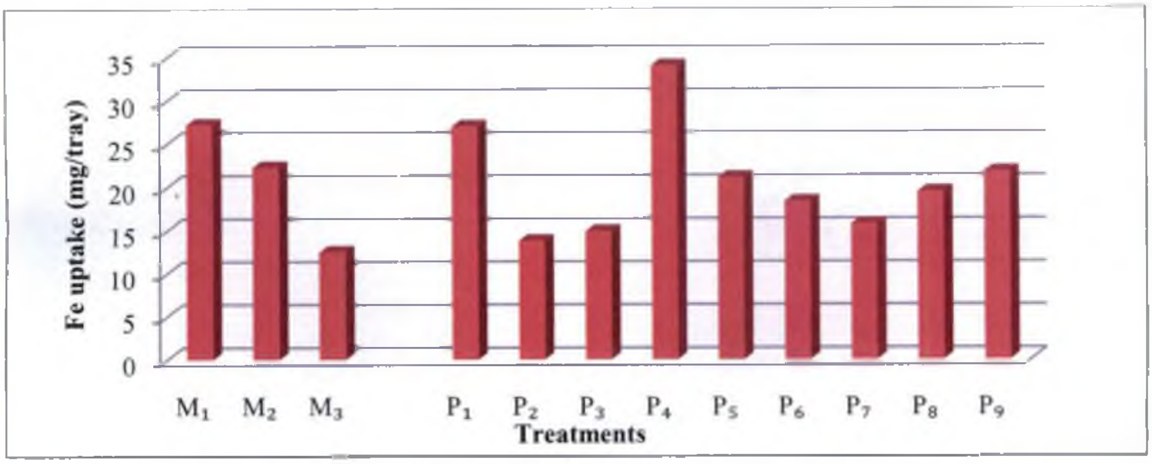

Fig. 5.28 Fe uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

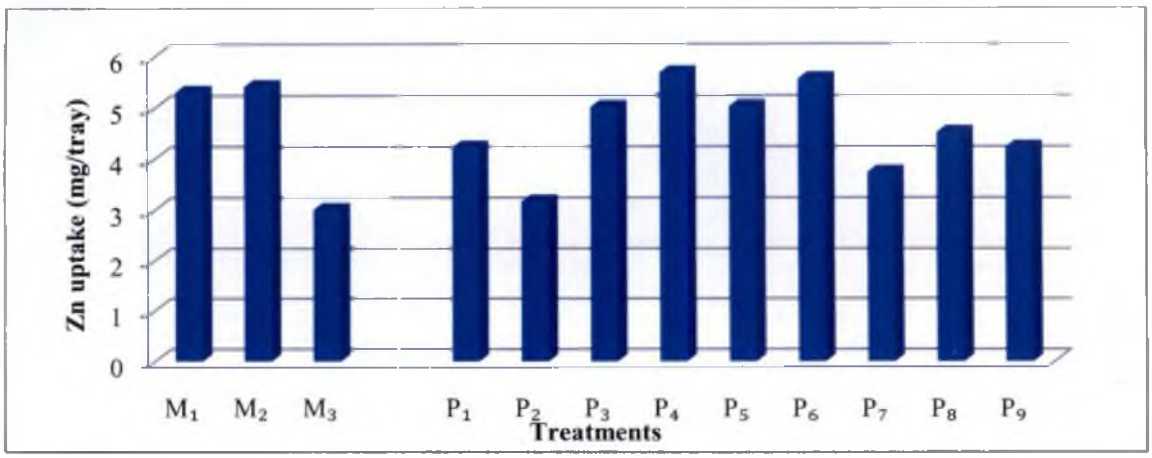

Fig. 5.29 Zn uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

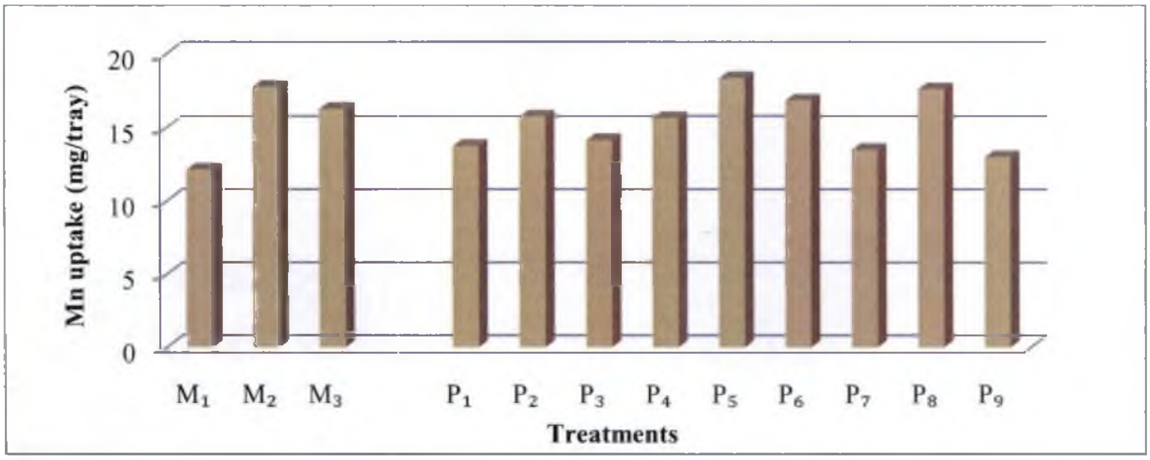

Fig. 5.30 Mn uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

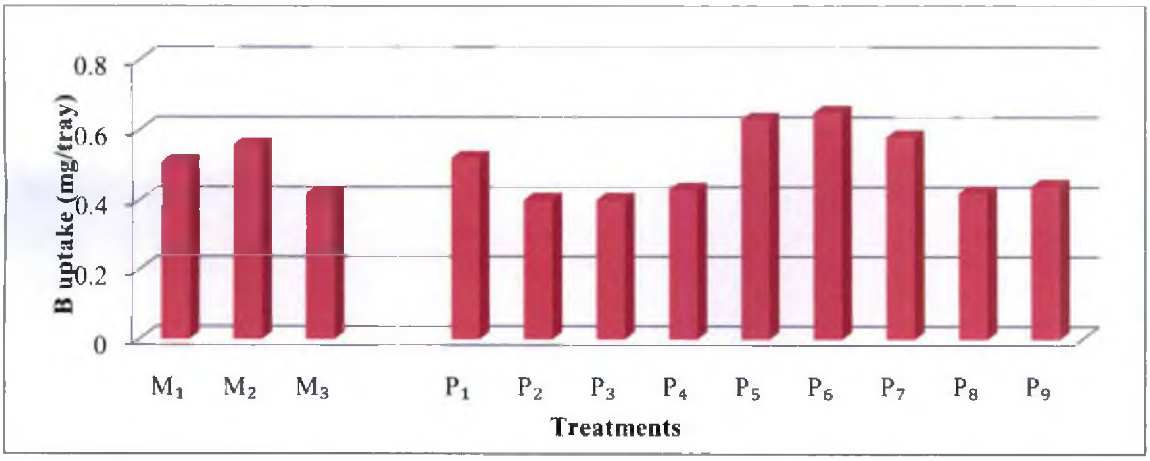

Fig. 5.31 B uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

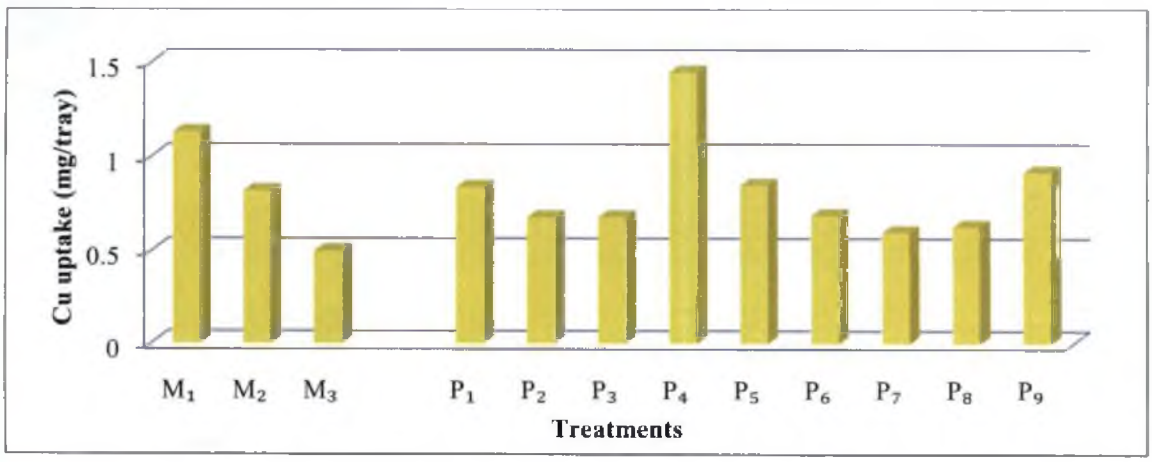

Fig. 5.32 Cu uptake by seedlings at 15 DAS as influenced by variation in media composition and nutripriming

5.3.1 Influence of media composition and nutripriming on performance of transplanter

Performance of mechanical transplanter is largely influenced by quality of mat nursery. Proper transplanting of seedlings has a pivotal role in the success of rice cultivation. According to Veeramani (2010) any improvement in the yield relies up on nursery techniques. Mechanical transplanting was done at 15 DAS. According to Rajendran *et al.* (2005) robust seedlings suitable for mechanical transplanting were produced within 15 DAS.

All the treatment combinations selected from experiment II were performed similarly with respect to the number of hills planted per metre run (Table 4.60; Fig. 5.33) Mechanical transplanter was adjusted to a spacing of 14 cm between hills in a row and has to plant seven hills per metre run theoretically. Several factors such as mat characteristics, machine condition and field situation influences actual field performance of paddy transplanter (Dixit *et al.*, 2007). In this experiment mean number of hills planted per metre run were 5.86.

All the five treatment combinations selected from experiment II showed superior performance compared to control with respect to the number of seedlings per hill (Table 4.60; Fig. 5.33). Number of seedlings per hill depends upon the seedling stand in the mat nursery. Less number of seedlings per hill in the control is attributed to the non-uniform seedling stand in the mat. The mean number of seedlings planted per hill was recorded to be 7.44 and the value was found to be slightly high. There is provision to adjust finger gap and number of seedlings planted per hill get increased with wider finger gap. This is attributed to higher number of seedlings /hill in the experiment in mechanical transplanting. Dewangan *et al.* (2005) found that more than five seedlings per pick were picked by transplanter. However, Behera *et al.* (2007) reported that number of seedlings per hill increases with increasing speed of mechanical transplanter and mat moisture content.

Missing hills per m^2 was ranged from 3.33per cent to 14 per cent (Table 4.60; Fig. 5.36). Tasaka (1999) registered minimum missing hill of 3 per cent when number of plants per hill ranged from 7 to 8. Least number of missing hills was observed in control (soil media and without nutripriming of seed). Mamun *et al.* (2013) also reported less number of missing hills with soil media. All the evaluated media were less compact compared to the soil media. Nursery mat is the combination of root mass and growing media. Mat should be stiff enough to sustain the impact of finger of mechanical transplanter. Less stiffness of mat might led to the loosening of seedlings while picking seedlings by the finger of transplanter. This also led to pulling of more seedlings during some of the seedling pick and lack of seedlings in succeeding picking. Among the selected treatments from experiment II, seeds primed with urea and grown in media containing rice husk charcoal and soil recorded less number of missing hills per m^2. Early germination as observed in the experiment II and vigorous growth due to priming effect might be the factors for reduction in missing hills.

There should be thirty hills per square metre (plant population per m^2) theoretically when spacing was adjusted to 23.8 x 14 cm. However, decreased number of plant population per m^2 was observed under actual field condition. Number of missing hills was found to have greater influence on the plant population. Plant population per m^2 was decreased with increase in number of missing hills per m^2. Mathew (2015) also reported the same situation under field condition. However, the decrease in plant population per square metre was compensated by the increased growth of plant in the field. The wider gap in the mechanical transplanting is effectively utilized by the plants for individual growth and thereby contributed to increased tiller production. This was also evidenced under field condition in this study.

5.3.2 Influence of media composition and nutripriming on growth and yield of rice

Treatments did not show any significant variation with regard to plant height at 30DAT, 60 DAT and at harvest (Table 4.62; Fig. 5.37). Examination of tillering is one of the important ways to examine the growth status of a rice crop. At maximum tillering stage mean number of tillers per m^2 was 595. Wider spacing adopted in

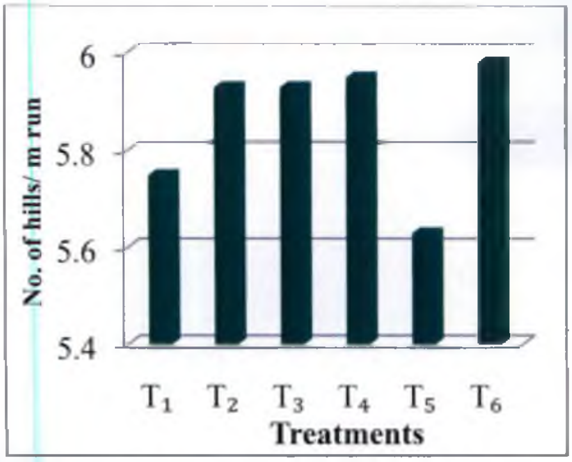

Fig.5.33 Number of hills planted/ metre run as influenced by nursery treatments

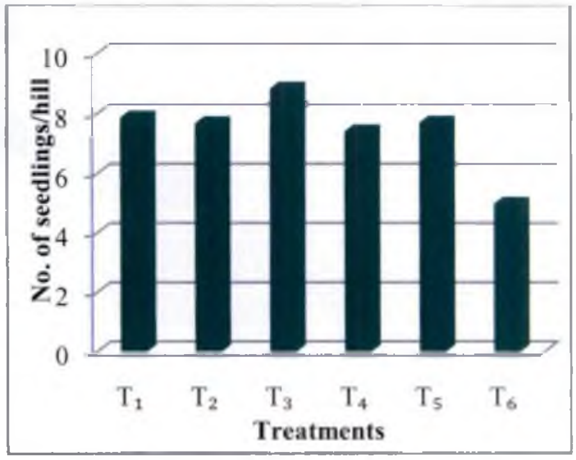

Fig. 5.34 Number of seedlings/ hill as influenced by nursery treatments

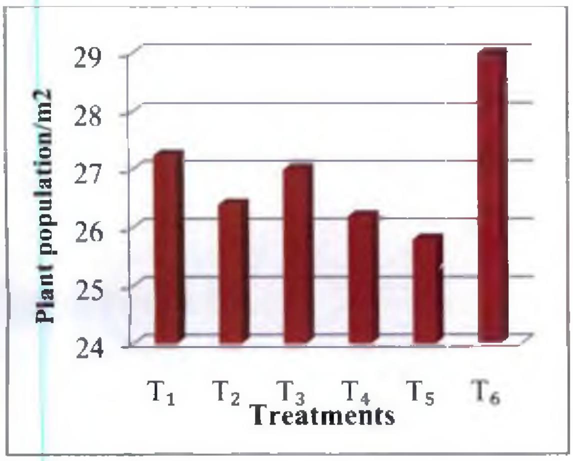

Fig.5.35 Plant population/ m^2 at transplanting as influenced by nursery treatments

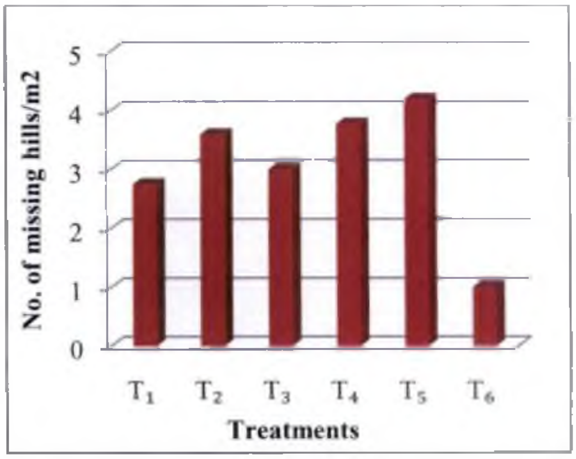

Fig.5. 36 Number of missing hills/ m^2 as influenced by nursery treatments

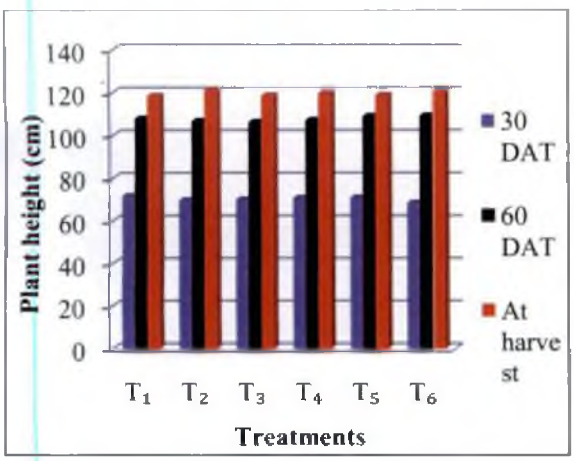

Fig.5.37 Plant height (cm) of rice as influenced by nursery media composition and nutripriming

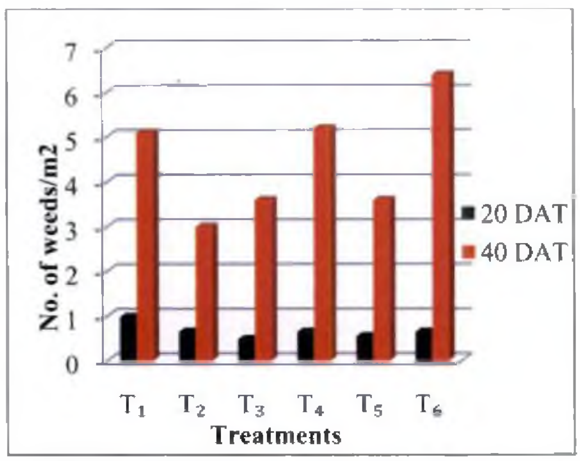

Fig. 5.38 Weed count as influenced by media composition and nutripriming

mechanical transplanting might have favoured production of more number of tillers. Even though there was significant variation in plant population and number of missing hills per m^2 no significant variation was observed in number of tillers per m^2. Increased spacing availed for plants adjacent to the missing hills might have led to more number of tillers and adjusted the adverse effect due to the variation in plant population (Fig. 5.39). Manian *et al.* (1987) reported that missing hills up to 15 per cent did not affect the final output.

The weed species *viz. Echinochloa crusgalli, Echinochloa glabrescens, Echinochloa colona, Sphenoclea zeylanica, Monochoria vaginalis, Ludwigia parviflora* and *Vallisneria* sp. were observed in the experimental field. These weeds were already reported in wet land paddy during the crop season by Thomas and Abraham (1998). Weed infestation was found to be unaltered by treatments at 20 and 40 DAT (Table 4.62; Fig. 5.38). However, Clark *et al.* (2001) and Ghiyasi *et al.* (2008) reported increased competitive ability of maize and wheat respectively against weeds. Incidence of stem borer, leaf folder and gundhi bug were observed during the crop period irrespective of the treatments.

Treatments did not show any significant difference with respect to the yield attributes except panicles per metre square. All the treatment combinations selected from experiment II were superior compared to the control treatment with respect to the number of panicles per metre square. This might be due to more number of tillers per square metre produced in these treatments compared to control. Mat nursery with soil media may lead to more root damage during mechanical transplanting due to more compact arrangement of root in highly cohesive soil. Hence the media with lower proportion of soil might have caused less damage compared to soil alone. Effect of seed priming might also have led to the production of more number of panicles. Increased number of panicles in rice due to seed priming was also reported by Mahajan *et al.* (2011). The crop produced 292 panicles per m^2 on an average irrespective of the treatments (Fig. 5.40). On an average, 147 spikelets were produced per panicle (Fig. 5.41). The mean number of filled grains per panicle was 102 (Fig. 5.42). There was no significant difference in 1000 grain weight between treatments (Fig. 5.43). 1000 grain weight of field crops

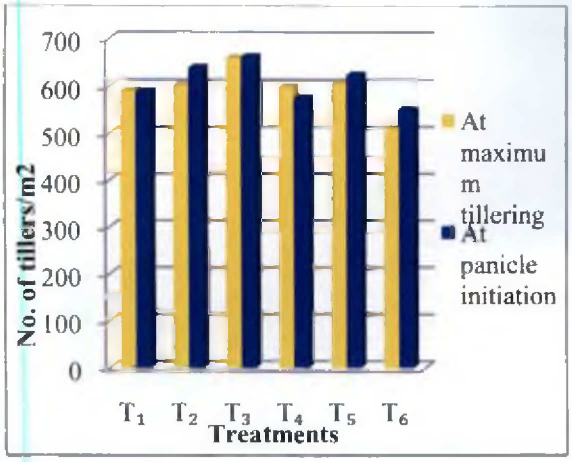

Fig. 5. 39 Number of tillers per m^2 as influenced by media composition and nutripriming

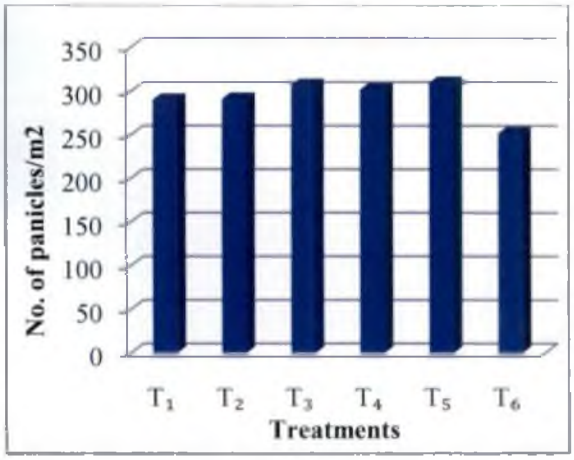

Fig. 5.40 Panicles/ m^2 as influenced by media composition and nutripriming

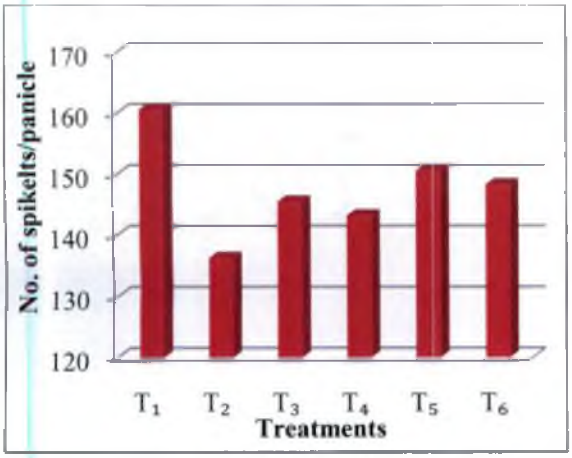

Fig.5.41 No. of spikelets/ panicle as influenced by media composition and nutripriming

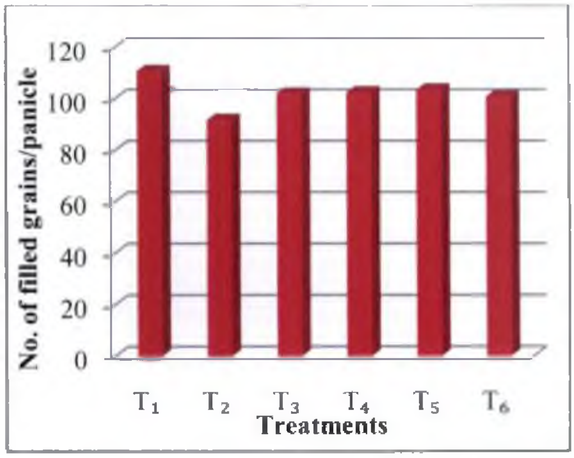

Fig.5.42 No. of filled grains/ panicle as influenced by media composition and nutripriming

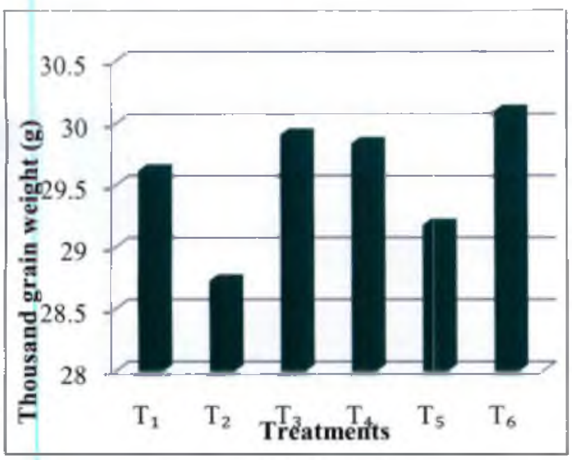

Fig.5. 43 Thousand grain weight as influenced by media composition and nutripriming

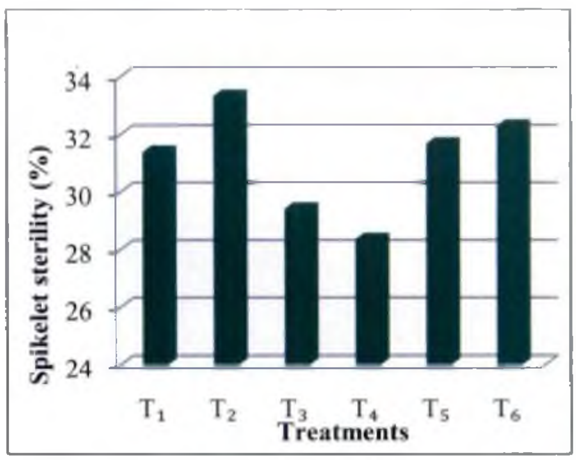

Fig. 5.44 Spikelet sterility of rice as influenced by media composition and nutripriming

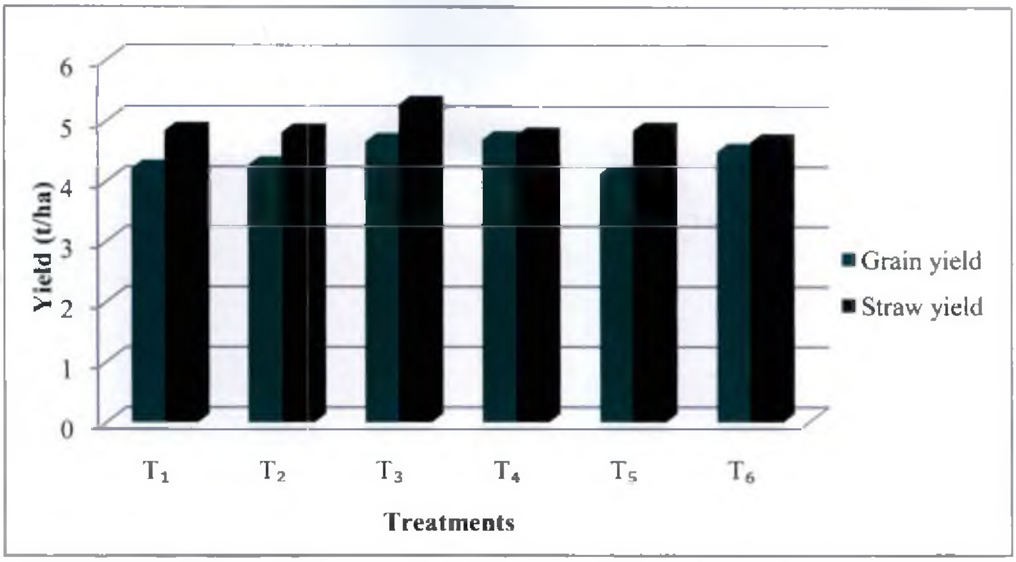

Fig. 5.45 Grain yield and straw yield as influenced by media composition and nutripriming

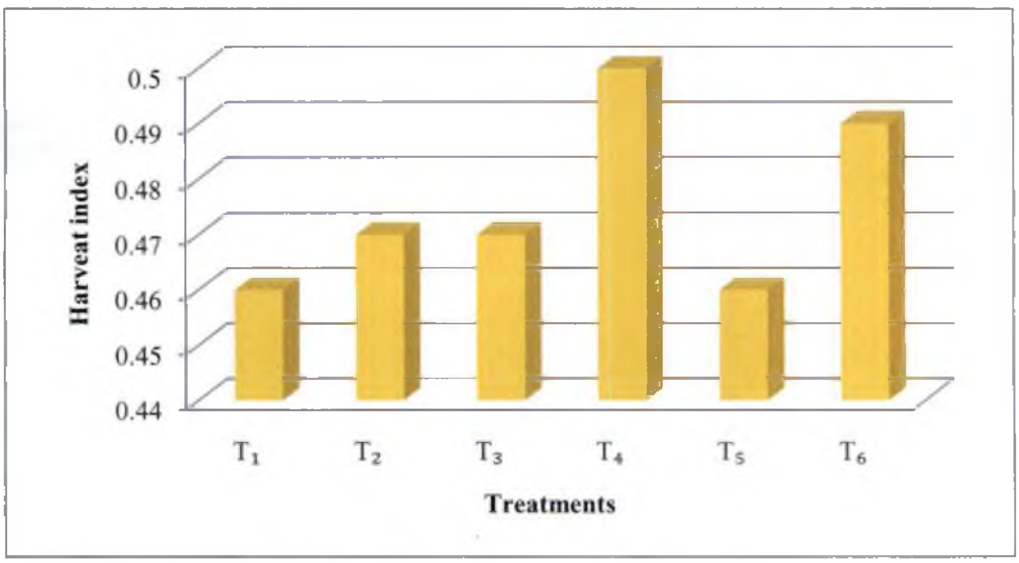

Fig. 5.46 Harvest index as influenced by media composition and nutripriming

is a very stable character under most of the condition (Yoshida, 1981). The mean spikelet sterility was observed to be 31per cent which indicated 69 per cent filling of the grain (Fig. 5.44). Both grain and straw yield were not varied significantly with respect to the nutripriming treatments (Fig. 5.45; Fig. 5.46). However, many researchers reported increased yield of rice (Harris *et al*, 2008; Farooq *et al*., 2006b) and maize (Shahid and Khan, 2007) due to seed priming. Difference in the concentration of nutrients, duration, temperature and condition of priming might be the reason for non significant variation in yield between treatments.

The treatment combinations selected did not produce significant variation under field condition with respect to the yield and performance of mechanical transplanter. This indicated that the media selection made based on scoring technique in Experiment I and II were more or less perfect. The result also indicated that since there is no variation under yield attributes and yield as well as the performance of transplanter under field situation, the treatments can be assessed at nursery level itself based on seedling and mat characteristics. Hence the media with higher rank in the Experiment I and II are the best performing media for mat nursery production in rice on commercial scale. When economics of nursery as well as cultivation were considered, the media containing 60 % RHC + 20 % soil + 20 % CPC was found to be cheaper. Under field condition also the same media produced higher grain and straw yield registering high net income and B:C ratio. The nutripriming with urea + $ZnSO_4$ or urea + borax registered higher net income and B: C ratio. However, further studies on type of priming, standardisation of nutrient concentration for priming etc. are required to finalise and confirm the results.

The nutripriming treatments were imposed to improve the seedling vigour at nursery stage and also to increase the availability of micronutrients. This may lead to correct the deficiency of micronutrients through seed priming rather than soil application and reduces the cost of production as well as soil pollution. But in this experiment though seedling vigour was increased in some of the nutripriming treatments, significant effect of micronutrients under field condition was not observed. This might be due to low concentration of nutrient given through seed priming and duration of seed priming. Hence, research on increased concentration of nutrients and duration through different types of seed priming techniques are needed to evaluate the release of micronutrients through seed priming of rice under field condition. Moreover, the increased Zn content of grain due to seed priming is an additional advantage to quality of grain and thereby the quality of human nutrition. Further studies are also needed in these areas.

5.3.3 Influence of nursery treatments on nutrient content and uptake by the crop

Various nursery treatments were unable to produce significant difference in the nutrient uptake by the crop. However, calcium content of grain and straw and Mn and B content of straw were found to be influenced by various treatments. Lower number of tillers and highest sterility in the control may be due to low nutrient status of the crop compared to other treatment due to devoid of nutrient rich media and nutripriming treatments. Due to nutripriming with Zn an increase in the Zn content of grain was noticed. Harris *et al.* (2007) reported enhanced Zn content of seed due to priming seeds with solutions of $ZnSO_4$ in maize. However, according to Johnson *et al.* (2005) Zn and B content of progeny seeds were not improved due to the seed B and Zn seed priming of rice seeds. Increased Zn content of grain is a source of Zn nutrition for human beings. Advanced techniques are being used to increase the Zn content of grain in rice. Hence, this can be effectively utilized as one of the viable technology for increased Zn content of grain thereby improving nutritional quality of grains in rice.

5.3.4 Nutrient status of soil after cultivation

Increase in soil pH after cultivation can be attributed to the addition of organic manure especially vermicompost which have buffering capacity and might cause quick release of the K^+ when added to acidic soil (Lund and Dass, 1980). Build up of available P status of the soil after cultivation of crop compared to initial soil nutrient status with recommended dose of fertilizer application indicated lower usage of phosphorus from applied sources of nutrients. The fixation of applied P as iron and aluminium phosphates in acid soil rich in sesquioxides might be a causal factor. This is in conformity with the results of Sharma (2009). Organic manure added to the soil had greater impact on productivity of crop and soil characters.

Reduction of organic carbon content in the soil after cultivation might be due to the loss of carbon in the form of CO_2 and CH_4. Flooded situation in the rice field maintains low redox potential which favours methane formation (Wang *et al.*, 1993). Considerable portion of all the other nutrients present in the soil might have up taken by the crop which led to reduced nutrient status of the soil after cultivation. Losses of nutrients through oxidation and reduction are also contributing to the reduction in nutrient status after cultivation of rice.

So from the studies at nursery level and under field condition it can be observed that since there is no significant difference between treatments under field condition, the selection done at I and II level experiments in nursery is perfect and selection of media and nutripriming treatments can be done at nursery level based on scoring and ranking. The media composition of 60 % RHC + 20 % Soil + 20 % CPC had higher score and rank in Experiment I with respect to favourable characters for commercial mat nursery production. In Experiment II the combined priming with urea + $ZnSO_4$ + borax had higher score and rank. So the combination of promising media with best nutripriming can be selected for quality mat nursery production on commercial basis.

SUMMARY

VI. SUMMARY

The present study "Nutripriming and mat thickness on tray nursery in rice" was conducted during the year 2015-16 at Agricultural Research Station, Mannuthy. The study was focused on standardization of composition and thickness of growing media, selection of suitable nutripriming technique and evaluation of selected treatments from the nursery experiments under field condition for production of best performing, low cost and light weight nursery. The study was conducted in three experiments. The variety Jyothi was used as test crop.

The Experiment I was carried out to standardize the composition and thickness of growing media for tray nursery technique of rice. Six media and three levels of thickness for tray nursery were studied in this experiment. The experimental design was factorial CRD with three replications. The biometric observations *viz.* days to 50% germination, height of seedlings, biomass production, shoot dry weight, root dry weight, dry matter production, scoring of pest and disease incidence and root length at transplanting were recorded. Mat characteristics *viz.* weight per unit area at transplanting, density, shearing strength and slippage were tested. Physico-chemical properties and nutrient status of growing media and components were analysed. Content and uptake of N, P and K were recorded. Cost of nursery production was also calculated for each treatment combinations.

Best performing three compositions of growing media and one level of thickness were selected from experiment I for conducting experiment II. Seeds primed with different nutrient sources were sown in these selected growing media. The experimental design was factorial CRD with three replications. Three compositions of media and nine nutripriming techniques were studied in this experiment. Observations on biometric and mat characters were done as in Experiment I. Content and uptake of N, P, K, Ca, Mg, S, Fe, Mn, Zn, B and Cu by the seedlings were analyzed. Cost of nursery production was also calculated for each treatment combinations.

Five best performing treatment combinations from experiment II were evaluated under field condition in experiment III. The experimental design was RBD with four replications. Observations on number of hills planted per metre run, number seedlings planted per hill, number of missing hills and plant population per square metre were recorded at planting to assess the influence of nursery treatments on performance of transplanter. Biometric characters *viz.* height of plant, number of tillers/ m^2, weed count, yield attributes, yield of grain and straw and harvest index were registered. Content of N, P, K, Ca, Mg, S, Fe, Mn, Zn, B and Cu in soil and plant samples were analyzed after harvest of the crop and uptake of these nutrients by the crop were calculated. Economics of cultivation was also computed for each treatment. The major findings of the study are summarized here:

Experiment I

1. The short duration for 50 per cent germination was recorded in media comprised of 40% RHC + 40% Soil + 20% VC and 60 % RHC + 20 % soil + 20 % CPC. The media containing 40 % RHC + 40 % soil + 20 % VC, 60 % RHC + 20% soil + 20 % CPC and 80 % RHC + 20 % Soil were superior with regard to height of seedlings, biomass production, shoot dry weight, root dry weight and dry matter production at transplanting. Seedling in the 60 % RHC + 20 % soil + 20 % CPC, 60 % RHC + 20 % CPC + 20 % VC and 80 % RHC + 20 % soil media produced longest roots at transplanting.
2. Among the mat characteristics media containing 40 % RHC + 40 % soil + 20 % VC was superior with respect to shearing strength, density and slippage. The light weight mats were produced with 80 %RHC+20 %CPC.
3. 10 mm thickness of media was superior with respect to biomass production, root dry weight, dry matter production and root length. All the mat characteristics were also superior with 10mm level of thickness. The shearing strength was increased with decrease in media thickness.
4. The highest water holding capacity and the lowest bulk density was recorded with media containing rice husk charcoal and coir pith compost.

5. Media containing 60 % RHC + 20 % CPC + 20 % VC were superior with respect to content of organic carbon, P, Ca, Mg, Mn and Zn. Higher content of Mg, S, Fe, Zn, Cu and B were noticed in the media containing 40 % RHC + 40 % soil + 20% VC.
6. Higher content and uptake of K was observed in seedlings produced in media containing 40 % RHC + 40 % Soil + 20 % VC. Nitrogen and phosphorus content of seedlings were higher in the media containing 80 % RHC+ 20 % VC. The highest N uptake by the seedlings was observed in 60 % RHC + 20 % Soil + 20 % CPC.
7. Higher N, P and K content were recorded in the seedlings grown in 20mm thickness.
8. Media containing rice husk charcoal and soil at 10mm thickness recorded the lowest cost of nursery production. Cost of production was increased with increase in level of thickness.

Experiment II

1. The lower days to 50 per cent germination was recorded in media comprised of 40 % RHC + 40 % Soil + 20 % VC and 60 % RHC + 20 % Soil + 20 % CPC. All the three media selected from Experiment I *viz.* 40 % RHC + 40 % Soil + 20% VC, 60 % RHC + 20 % Soil + 20 % CPC and 80 % RHC + 20 % Soil performed similarly with respect to seedling height, biomass production, shoot dry weight, root dry weight and dry matter production at 15DAS. Media containing 40 % RHC + 40 % Soil + 20 % VC produced longest root at transplanting.
2. Media containing 60 % RHC + 20 % Soil + 20 % CPC were produced seedlings with significantly higher content of N and K. The higher content of P in seedlings was noticed in 40 % RHC + 40 % Soil + 20 % VC media.
3. Shorter duration to 50% germination was observed in seeds primed with urea. Influence of nutripriming was noticed profoundly at early stages of seedling growth.
4. 0.1 % urea + 0.05 % $ZnSO_4$ + 0.01 % borax priming was superior with regard to seedling growth parameters and mat characteristics at transplanting.
5. Application of urea alone and combined application of urea, borax and $ZnSO_4$ through seed priming were on par with respect to seedling height, biomass production, shoot dry weight and dry matter production. Control treatment (hydropriming) produced seedlings with longer roots.

6. Light weight mats were produced in borax and $ZnSO_4$ seed priming. Priming with PGPR mix I recorded lower slippage. Priming with urea+ $ZnSO_4$ and urea + $ZnSO_4$ + borax solution were superior with regard to shearing strength and density of mat respectively.
7. Higher content of S, Fe, Zn and Cu was observed in seedlings in urea+ borax priming. However, seedlings produced under priming in urea+ $ZnSO_4$ + borax treatment were superior with respect to Ca, Mg and B content of seedlings. Urea + $ZnSO_4$ priming led to higher content of P, K and Mn.
8. Seeds primed in the solution containing urea, $ZnSO_4$ and Borax produced superior seedlings with respect to uptake of N, Ca, Mg and B by the seedlings. Urea with borax priming was superior with regard to S, Fe, Zn and Cu uptake by the seedlings. Urea with $ZnSO_4$ priming was superior with respect to P and Mn uptake by the seedlings.
9. The lowest cost of nursery production was recorded in the combination of 80 % RHC + 20 % Soil media with control (hydropriming) or urea priming.

Experiment III

1. The number of hills planted per metre run was statistically similar in all the treatments. Mean number of hills planted per metre run was 5.86. All the treatment combinations selected from Experiment II were on par and significantly superior than control with respect to number of seedlings per hill. Missing hills per m^2 was ranged from 3.33per cent to 14 per cent. The lowest number of missing hills was observed in control treatment.
2. Plant height at 30DAT, 60DAT and harvest were not significantly influenced by the nursery treatments. All the treatments were statistically on par with respect to number of tillers per square metre at maximum tillering and panicle initiation.
3. Irrespective of the treatments weed count was found to be similar in all the experimental plots.
4. Treatments did not show any significant difference with respect to the yield attributes except panicles per metre square. All the treatment combinations selected from Experiment II were superior compared to the control treatment with respect to the number of panicles per metre square.

5. Grain and straw yield were not significantly influenced by various treatments evaluated under field condition.
6. Content of N, P, S, Fe and Zn in both grain and straw were on par under all the treatments. Treatments showed significant influence on K content of grain, Ca content of grain and straw, Mg content of grain, Mn content of straw and B content of straw. Treatment combination of 80 % RHC + 20 % Soil with 0.1% Urea+ 0.05 % $ZnSO_4$ + 0.01% Borax seed priming recorded the highest content of Ca and Mg in grain and Mn in straw. The highest Ca content in the straw and Mg in grain was registered under 80 % RHC + 20% Soil with 0.1 per cent Urea seed priming. Treatment combination of 40 % RHC + 40 % Soil + 20 % VC with 0.1 % Urea + 0.05% $ZnSO_4$ recorded the highest content of K and B in straw.
7. No significant influence of treatments on total uptake of macronutrients, secondary nutrients, Fe, Zn, Mn, B and Cu was observed.
8. The highest B: C ratio of 1.91 was observed in treatment combination of 40 % RHC + 40 % Soil + 20 % VC with 0.1 % Urea + 0.05 % $ZnSO_4$ seed priming.

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APPENDIX

APPENDIX-1

Monthly weather data during experiment at ARS, Mannuthy from January 2015 to December 2015

(Latitude 10°31' N, Longitude 76°13' E and Altitude 40.29m above MSL)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days	Mean Evaporation (mm)	Sunshine (h)	Wind speed (km/h)
	Maximum	Minimum	Morning	Evening					
January	32.5	22.1	72	41	0.0	0	4.4	8.8	5.4
February	34.3	23.0	73	37	0.0	0	5.6	8.8	6.0
March	35.8	24.9	83	45	71.6	1	4.9	8.0	3.4
April	34.0	24.6	89	64	132.8	8	3.6	6.8	2.4
May	32.9	24.8	92	68	277.0	13	3.1	5.0	1.7
June	30.9	24.1	94	77	629.8	23	2.6	5.2	1.6
July	30.3	23.9	95	74	510.1	25	2.8	3.8	1.4
August	31.0	23.9	95	70	322.7	16	3.1	4.9	0.8
September	31.9	23.8	93	69	247.0	13	3.0	5.6	0.4
October	32.7	24.4	90	68	203.8	14	2.9	5.6	0.8
November	31.6	23.7	83	66	151.2	8	2.8	4.6	2.5
December	32.3	23.2	79	54	88.3	3	4.7	6.7	5.7
Mean	**32.5**	**23.9**	**86**	**61**	**219.5**	**10.33**	**3.6**	**6.2**	**2.7**

APPENDIX-II

Details of cost of nursery

Sl. No.	Particulars	Men/ha (Rs.460/day)	women/ha (Rs.350/day)	Amount (Rs/ha)
Nursery operations				
1	Automatic paddy mat nursery sowing machine	-	-	1376
2	Media preparation	-	1	350
3	Water management	-	2	700

APPENDIX-III

Details of cost of cultivation

Sl. No.	Particulars	Men/ha (Rs.460/day)	women/ha (Rs.350/day)	Amount (Rs/ha)
	Field operations			
1	Ploughing (machine)	-	-	1925
2	Lime application	2	-	920
3	Bund formation	8	-	3680
4	Transplanting (machine)	-	-	4000
5	Fertilizer application	1	1	810
6	Water management	3	-	1380
7	Weeding (Twice)	-	30	10500
8	Plant protection chemical spraying	3	-	1380
9	Harvesting (Combine harvester)	-	-	6800
10	Bailing (Bailer)	-	-	6000

APPENDIX-IV

Details of cost of inputs

Sl. No.	Particulars	Amount (Rs/kg)
1.	Seed	39
2.	Lime	13
3.	Farm yard manure	3
4.	Urea	6
5.	Rajphos	11
6.	MOP	18
7.	Seedling tray	2/ per tray
8.	Rice husk charcoal	0.5
9.	Vermicompost	7
10.	Coir pith compost	6
11.	Soil	0.75
12.	$ZnSO_4$	900
13.	Borax	780
14.	Pseudomonas formulation	60
15.	PGPR mix-I	70
16.	Lontax power	193
17.	Thiamethoxam (Actara)	5000
18.	Flubendiamide (Fame)	200/5ml
19.	Cartap hydrochloride (Top 45)	100

ABSTRACT

NUTRIPRIMING AND MAT THICKNESS ON TRAY NURSERY IN RICE

by

ANCY U. A.

(2014-11-125)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the

requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2016

ABSTRACT

Mechanized rice cultivation can play a vital role in transforming rice production of Kerala. In the context of labour shortage and growing commercialization of agriculture, mechanization is very important for ensuring timeliness and precision of operation. Mechanized transplanting is a key link to the entire mechanization of paddy cultivation. However, lack of standardization of tray nursery production technologies appears to be one of the major hurdles against the appropriate exploitation of transplanting machineries. Nutripriming is a novel seed invigoration technique which helps for early germination and quality seedling production.

The present study entitled "Nutripriming and mat thickness on tray nursery in rice" was carried out during 2015-2016 at Agricultural Research Station, Mannuthy with the objectives of standardization of production technology of tray nursery in rice for mechanical transplanting and evaluation of efficiency of nursery technique under field condition. The study was conducted in three experiments using variety Jyothi.

Experiment I was designed in factorial CRD with 18 treatment combinations, replicated thrice. Six media compositions *viz.* 40% rice husk charcoal (RHC) + 40 % Soil + 20 % vermicompost (VC), 60 %RHC+ 20 % Soil + 20 % coir pith compost (CPC), 60 % RHC+ 20 % CPC+ 20 % VC, 80 % RHC + 20 % CPC, 80 % RHC + 20 % VC, 80 % RHC + 20 % Soil and three levels of thickness *viz.* 10, 15 and 20 mm were studied in this experiment. The media composition 60 % RHC + 20 % Soil + 20 % CPC, 40 % RHC + 40 % Soil + 20 % VC and 80 % RHC + 20 % Soil with 10mm thickness of media were superior with regard to the biometric characters of seedlings and mat characteristics such as shearing strength and slippage. Cheap mat nursery was also produced by 60 % RHC+ 20 % Soil + 20 % CPC with10 mm thickness of media. The highest content of K was observed in seedlings produced with media of 40 % RHC + 40 % Soil + 20 % VC.

Best performing three media *viz.* 40 % RHC + 40 % Soil + 20 % VC, 60 % RHC + 20 % Soil + 20 % CPC and 80 % RHC + 20 % Soil with 10mm thickness were selected from Experiment I and nutripriming treatments were imposed on these media

in Experiment II. The experimental design was factorial CRD with three replications. Nutripriming treatments *viz.* priming with 0.1per cent urea, 0.01per cent borax, 0.05per cent $ZnSO_4$, combinations of urea with borax and $ZnSO_4$, combination of urea, borax and $ZnSO_4$, 1per cent *Pseudomonas fluorescens* and 1per cent PGPR mix I were studied. All the three media performed similarly with respect to biometric characters at 15DAS. Media containing 60 % RHC + 20 % Soil + 20 % CPC produced seedlings with significantly higher content of N and K. Priming with urea and urea+ $ZnSO_4$+ borax were superior with regard to biometric parameters and mat characteristics. Higher contents of K, S and Zn were observed in seedlings primed with urea + borax. However, seedlings produced by priming with urea + $ZnSO_4$ + borax were superior with respect to Ca, Mg, Zn and B content. The cheaper nursery was produced by the combination of 60 % RHC + 20 % Soil + 20 % CPC media with urea priming.

The best performing five treatment combinations *viz.* 80 % RHC + 20 % Soil + 0.1 % Urea, 80 % RHC + 20 % Soil + 0.01 % Borax , 40 % RHC + 40 % Soil + 20 % VC + 0.1 % Urea + 0.05 % $ZnSO_4$, 60 % RHC + 20 % Soil + 20 % CPC + 0.1 % Urea + 0.01 % Borax and 80 % RHC + 20 % Soil + 0.1 % Urea + 0.05 % $ZnSO_4$ + 0.01% Borax from Experiment II were evaluated under field condition in Experiment III. The experimental design was RBD with four replications. All the treatment combinations performed similarly and were significantly superior to control with respect to growth and yield attributes. Grain and straw yields were also not influenced by any of the treatment combinations studied. The tray nursery produced with different combinations of media did not show any significant variation with respect to the performance of the transplanter. The treatment combinations 40 % RHC + 40 % Soil + 20 % VC with 0.1 % Urea + 0.05 % $ZnSO_4$ and 60 % RHC + 20 % Soil + 20 % CPC with urea + borax recorded higher B: C ratio.

From the detailed assessment of three experiments it was concluded that media containing 60 % RHC+ 20 % Soil + 20 % CPC with 10mm thickness and seeds primed with 0.1% Urea + 0.05 % $ZnSO_4$ + 0.01 % Borax was effective for quality tray nursery production with respect to healthy seedlings, easiness in transport, performance of transplanter and cost of production.