STANDARDISATION OF MAT NURSERY FOR RICE

By

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THESIS

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DECLARATION

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

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CERTIFICATE

Certified that this thesis entitled **"Standardisation of mat nursery for rice"** is a record of research work done independently by **Mr. Rajesh.G** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Introduction

1.INTRODUCTION

Rice cultivation dates back to antiquity and rice has been the staple food and the first cultivated crop in Asia. Archaeological evidences indicate that rice has been cultivated in India since ancient times. About half of the world population is dependent on rice as their energy supplying food grain. Considering the importance of rice, it was described as the 'Grain of life' by the United Nations in 1966. Rice is the leading food crop, cultivated over an area of about 145 million hectares with a production of about 380 million tones globally. It is cultivated in almost all states in India (Singh, 1999). The area under rice cultivation in Kerala is declining at the rate of 4500 ha per annum for the past few decades. The major reasons for this are the non-availability of labour in time and the high labour wages prevailing in the state.

The crop is raised either by direct sowing or by transplanting. Transplanting paddy seedlings in puddle soils is one of the most widely accepted cultivation practices. Transplanting has several advantages combined with high productivity when compared to direct sowing. The commonly followed method of manual transplanting requires more than 50 man days per hectare and during period of requirement for labourers, farmers find it extremely difficult to transplant the seedlings at the optimum stage. Manual transplanting requires (3.5 to 10 times) more labour than direct sowing (Bainu, 1990). Because of these facts, research engineers all over the world are making efforts to develop labour saving and economically feasible farm machinery for paddy cultivation. Complete or partial mechanisation has thus become a necessity in rice cultivation, where labour input is very high from planting to harvest (Veerabadran and Pandian, 1999).

Mechanical transplanting provides health relief to agricultural workers from the tedious bending postures and strenuous dipping of fingers in the puddle field. It also reduces the expenditure of energy. So the paddy mechanical transplanters should be popularised among the farmers so as to reduce their workload and avoid situations like labour peak.

Specific rice nurseries are a prerequisite for transplanters and there are several types of nurseries viz., wet nursery, dry nursery, dapog nursery and mat nursery. The transplanters work most efficiently with mat nursery.

Mat nursery is a special type of nursery, raised in trays or sheets. Rooting media is filled in the tray or sheet and seeds are sown on it. Seedlings raised in beds can be rolled as mats. The mats are cut at appropriate size of trays of the transplanter and fed to it. Raising mat type of nursery offers several advantages over the conventional nursery. Conventional nursery needs 0.1 ha for planting seedlings for 1 ha of main field, while mat nursery needs only 0.016 ha. Mat nursery is very convenient to handle as the seedlings can be rolled and transported as a mat. It requires less labour for management and needs no pulling out operation. Mat nursery practice also provides immense job opportunities. The commonly experienced root damage during uprooting seedlings from conventional nursery bed is completely avoided, since the seedlings are fed to the transplanter without separation.

Research work regarding mat nursery is still in the infant stage, which is a major constraint in the large scale use of mechanical paddy transplanters. A suitable technology package for raising the mat nursery is the need of time to encourage the farmers to adopt mechanised transplanting operation. Possibilities of using mat nursery as an alternative to conventional root washed nursery and manual planting have not been studied so far. If mat nursery can replace conventional nursery, there would be considerable saving in area and labour involved in nursery raising and uprooting seedlings.

Hence the present attempt on standardisation of mat nursery for rice was taken up with the following objectives:

1) To provide package for commercial production of mat nursery
2) To evaluate mat nursery in the field by mechanical and manual transplanting and
3) To explore the feasibility of using mat nursery as an alternative to conventional root washed nursery.

Review of Literature

2. REVIEW OF LITERATURE

Rice is grown in a variety of ecosystems. The system of rice cultivation varies depending on land and soil situation as well as water regimes, primarily depending upon climate (Shekinah, 1996). An attempt has been made in this chapter to review the salient research findings on rice mechanisation, different systems of rice nurseries, performance of the crop under manual and mechanical transplanting and the economics of cultivation under these two systems of planting.

2.1 Rice mechanisation-General concepts

Farm mechanisation has caused a number of changes in the agrarian scenario of India. Studies on dynamics of leadership status roles of farmers in mechanised farms in Haryana by Sissodia (1978) revealed that farm mechanisation led to workspread of the farmers within agricultural and non-agricultural sectors and caused important organisational and functional changes in the rural system of social hierarchy and power. The status role structure was found integrative. The farmers with tractors gained in status in their communities and did various social and leadership functions for other farmers with no tractors.

According to Pandey and Panghal(1983), land preparation and sowing required 75 to 95 per cent of total bullock power in case of crops except sugar cane, wherein the requirement was 38 per cent. In case of paddy, harvesting, threshing, winnowing and transportation accounted for 45 per cent of the labour requirement. The study further revealed that with increase in tractorisation, the employment of human labour declined. Farm mechanisation needed improved technology and capital. Capital had a significant role in changing the cropping patterns. The huge investment on machinery and equipments had negative and non significant impact on the gross returns of mechanised and partially mechanised farms, which indicated that excessive investment on machinery ultimately reduced the gross returns (Tyagi and Pandey, 1984)

Igbeka (1984) held a different view. Farm power shortage has been a major constraint to agricultural development. Farmers in developing countries depended on expensive imported machinery. Complexity in the designs of the imported machinery, lack of spare parts and skilled labour to operate and maintain the machines were other constraints. Mechanisation was one of the major inputs which facilitated the increase of agricultural productivity.

According to Ojha (1988), the level of mechanisation in Indian agriculture is low compared to developed countries. There is a great need for mechanisation of operations like transplanting, interculture, weeding, harvesting and threshing, without serious displacement of labour. Mechanisation might reduce employment to some extend, but ultimately it would result in an increased land productivity, which would demand the engagement of more human labour. The operations which caused human drudgery (transplanting, weeding and transport) should be mechanised, and its success would be decided by the degree of seriousness attached to the demonstrations, training and after sale services.

Varghese(1995) observed that the use of farm machinery was very less in Kerala, when compared to other states, and the impact of agricultural mechanisation in the state was also marginal. The state is in its initial stages of mechanisation and there is immense scope for development. This could be achieved by a 3-tier mechanisation process, which could be accomplished through the rational use of small sized agricultural implements, tractors and tillers with accessories for tillage, sowing and harvesting and innovative technologies in irrigation, drainage, soil and water conservation.

A study conducted by Singh (1998) pointed that women were employed for raising of nursery for rice, uprooting, washing, carrying and transplanting. Rice transplanting, which required a continuous bending posture was largely performed by women in most parts of the country. So these operations should be mechanised to save them from the common health hazard. Social and technological efforts were required to persuade and train them to handle agricultural machinery.

Farm mechanisation should be adopted to remain globally competitive, as the labour charges are increasing at an alarming rate. Farm power availability is a major constraint to agricultural production, which needs to be increased from 1.15 kW ha^{-1} to 2 kW ha^{-1}. Electromechanical sources of farm power have replaced the traditional animate and organic sources. Development of rice transplanters, sugarcane harvesters and cotton pickers are the immediate need (Alam, 1999)

Veerabadran and Pandian (1999), estimated that 145 man days were required per hectare of rice in Tamil Nadu. Among the various operations, planting needed 21 per cent, while harvesting and threshing together required 43.4 per cent of total labour. Agriculture labour availability has declined due to the development of market economy and rural industries. Complete or partial mechanisation has become a necessity to solve this problem.

Jaikumaran *et al* (1999) suggested that the machinery developed must be suitable for the varying agro-ecological situations. Workability of transplanters on different agro-ecosystems, main field requirement, mat nursery techniques, varietal preference with respect to mechanical transplanting, modification of reapers to suit varying wet situations, harvesting of lodged paddy, mechanical means of pest control, workability of combines etc. were some of the areas where research should be strengthened. Research should also be concentrated on the development of customary service centres and entrepreneurship development programmes for unemployed youth to start these centres.

Bell and Cedillo (1999) reported that countries with few agricultural workers and well developed economies were highly mechanised. The focus would be in improving the existing systems, rather than shifting to a higher level of mechanisation in countries with abundant labour and low GDPPC. Appropriate mechanisation could be brought about only with the cooperation of private and public sectors. Mechanisation rarely resulted in labour displacement and any Government programme on mechanisation should consider the socio economic status of the people.

2.2 Seedling growth in nursery as influenced by growth media and management systems

Generally rice nursery is raised under three methods viz., (1) dry, (2) wet and (3) semidry (KAU, 2002). Mat nursery raising was necessitated with the introduction of mechanical transplanters. Mat nursery requires lesser area compared to the conventional wet nursery.

2.2.1 Nursery media

While comparing *Sathupai* nursery (double transplanting nursery) with conventional nursery, Arunachalam and Paul (1988) found that height, density and root length of seedlings in *Sathupai* method were superior to those in the conventional method. Sathupai system is a combination of dapog and field nursery methods. After keeping as dapog nursery for 10 to15 days initially, the 'pai' nursery seedlings are transplanted very closely in a nursery area prepared well in a conventional manner. The seedlings can be pulled out on 15th day of first planting and transplanted in main field.

Experiments conducted at Madurai for identifying nursery techniques for low land rice by Arunachalam *et al.* (1991) indicated that 'Sathupai' (double nursery) system of nursery raising of rice seedlings was better than conventional system. Manuring of nursery promoted tiller production as well as growth. Thirty days old seedlings were found ideal for transplanting to achieve higher grain yield.

Budhar *et al.* (1991) while studying effect of injury to roots of rice seedlings observed that seedling establishment was severely affected by root injury, which usually happened with conventional nursery. This warranted gap filling in the main field.

Rajendran (1991) while studying the effect of three forms of fertilizers viz. urea, superphosphate and DAP (Di Ammonium Phosphate) on rice nursery manuring observed that application of either of the fertilizers, 10 DAS (Days After Sowing) in nursery significantly increased shoot length of seedlings relatively more than that of root. This increase in shoot length, eased the pulling out operation and reduced snapping of seedlings.

The use of a nursery mat of rockwool made it possible to transplant very small seedlings at 4 to 7 DAS using machines. Raising such small seedlings required less space, labour and time and they produced higher yield due to production of more tillers than conventional seedlings (Hoshikawa, 1992)

Yang *et al.* (1998) observed that under mat nursery system, seedling height root dry weight and shoot dry weight per seedling during growth was slightly greater at lower sowing rate, while tension of root mat was greater at higher sowing rate.

Dapog system offered good scope to get a lot of fresh seedlings within 12 days during drought or failure of irrigation systems. Therefore a study was conducted by Venkataraman, (1999) to find out suitable management practices for raising dapog nursery in rice using three substrata (perforated polythene sheet, plain polythene sheet and gunny bit) and four media (clay + cowdung slurry, composted coir pith, raw coir pith and straw bit). Results showed that substrata did not influence germination percentage and the seedling growth upto 12 DAS. However among the media, clay + cowdung slurry and composted coirpith ensured higher germination percentage than the other two media. Higher dry matter production of seedlings (12 DAS) was achieved in composted coirpith media followed by clay + cowdung slurry. Straw media recorded lower dry matter production.

Tasaka (1999) from Japan proposed a new mat nursery 'long mat with hydroponically grown rice seedlings' (LMHS) for labour saving rice transplanting system. This mat nursery, grown in a size of 6 m x 2.28 m on non woven cloth and hydroponically fed with fertilizer nutrients, was found to be about five times lighter than conventional mat with young seedlings raised in a soil bed (CMSS). The mat could be rolled up easily and was fitting to mechanical transplanters. This could also dispense with high weight associated with CMSS, which was laborious to be carried to the field for mechanical transplanting.

2.2.2 Nursery systems

The seedling age for transplanting depends upon the genotype as well as the system of nursery raising. According to Rajagopalan and Palanisamy (1986) twenty five day old seedlings of TKM 9 and 35 day old seedlings of ASD 16 raised either in wet or semi dry nursery systems and 45 day old seedlings of ASD 16 raised in sathupai nursery system were ideal for transplanting to achieve maximum yield. Ayyaswamy *et al.* (1991) reported that when rice seedlings were raised under dry system of nursery and irrigated at an interval of once in 12 days, seedling transplanting could be delayed up to 50 days after sowing, without affecting yield.

According to Balakrishnan *et al.* (1994) wetting and drying in the nursery significantly reduced the height, dry weight and to a lesser extent leaf number of the nursery seedlings. Jinda *et al.*, (2002) has developed a device for growing and planting seedlings in aperture disc based on the planting requirements of rice seedlings.

2.3 Crop growth in mainfield as influenced by different nursery systems, media and planting methods

2.3.1 Nursery systems

Direct seeding and transplanting are the two main methods of rice crop establishment. Pioneer reports indicated that direct seeding by broadcasting on the puddle as well as planting with 'dapog' seedlings were as efficient as conventional transplanting under good management practices. The crop raised under direct seeding or from dapog seeding matured one week earlier than conventional planting (Rajagopalan *et al*, 1971). Arunachalam *et al* (1991) observed that height of crop at harvest and LAI of 30 day old seedlings was higher for sathupai nursery when compared to that of conventional nursery.

One of the recommended nursery systems by the Agricultural Department for Tamil Nadu is super nursery. It comprises of a seed rate of 50 kg per ha raised on 800 m^2 nursery area applied with twelve tonnes of FYM and 40 kg of DAP per ha and two seedlings planted per hill. Planting of 25 days old rice seedling, under super nursery led to enhanced tiller production and earlier establishment with good root proliferation when compared to the conventional nursery (Rajagopal *et al.*, 1995).

Shekinah (1996) reported that broadcasting of rice seedlings was economically better than transplanting. When transplanting was resorted to, nursery seedlings from wet or semi dry nursery, dipped in clay + cowdung slurry performed better than non dipped seedlings.

2.3.2 Nursery media

Earlier studies have revealed that rice seedlings in the unmanured nursery would be comparatively weak with slender stems and pale green leaves. Their establishment in the main field was slow, but once they were established, they tillered fast and produced nearly as much tillers as by the seedlings from the manured plots. At the end of the reproductive phase, there was no significant variation between the crop raised using manured and the unmanured seedlings in terms of production of ear bearing tillers per hill (Nair *et al.*, 1977). According to Rajagopalan *et al.* (1978) to improve the quality of dapog seedlings, 9^{th} day of fertilization to seedbed was found to be the best.

Preliminary testing of IRRI transplanter revealed that if the nursery was raised in clayey soil the seedlings sticked to the fingers. To eliminate this problem, raising of nursery with 50 per cent red soil + 50 per cent FYM was found to be the best. The optimum seed rate for nursery sowing was 70 g/mat of size 40 cm x 19 cm. When seedlings were raised exclusively under FYM, they were white and wilting occurred. The seedlings raised in 25 per cent field soil and 75 per cent FYM was not uniform. Missing hills was more than 30 per cent in the former two cases. The following media viz., 50 per cent field soil + 50 per cent FYM, 50 per cent field soil + 50 per cent sand, 50 per cent red soil + 50 percent FYM and 50 per cent red soil + 50 per cent sand were ideal for mat nursery used in IRRI transplanter. In these cases, missing hills were between 9 and 15 per cent and average hill population was 47 m^{-2}. A force of 120 Newton was required to detach seedlings from the mat (Manian *et al.*, 1987).

Thilagavathi and Mathan (1995) conducted field trials on sandy clay loam soil at the Agricultural College and Research Institute, Madurai to study the influence of application of raw, partially decomposed or fully decomposed coir pith in the mainfield on the performance of rice. The observation revealed that maximum plant height and root length was reached with 25 day and 30 day composted coir pith.

While studying performance of 8 row mechanical transplanter, Beena and Jaikumaran (1999) observed that density of the mat should be between 0.4 to

0.6 kg m^{-2} to obtain optimum seedling rate of 3-4 plants $hill^{-1}$ and also to reduce the number of missing hills to bare minimum.

According to Rani *et al.* (2000) mat nursery did not require any fertilizer, as the FYM provided necessary nutrients and the soil was enough for proper growth of roots. Five beds of 10 m x 1.2 m were sufficient to transplant one ha. The mixture of soil, FYM and sand in the ratio of 7:1:2 was better for heavy texture of soil, while for light soils, a mixture of 9:1 (soil and FYM) would be optimum. Perforated and transparent polythene sheet was laid on the seed bed and an iron frame of 50 cm x 21 cm x 2.5 cm was laid on the sheet. The prepared mixture was spread over it, maintaining a thickness of 1.5 cm. Sprouted seeds were broadcast sown uniformly over the soil mixture and covered with the same mixture upto another thickness of 0.5 cm so that the seeds are just covered. Seeds should be covered with wet gunny bags or rice straw. Water should always be there in the nursery to avoid heating up of nursery. After 22 to 25 days, the seedlings were at 4 to 5 leaf stage and were ready for transplanting.

2.3.3 Planting methods

Mat nursery is required for using IRRI manual transplanter. Punjab Agricultural University system of mat nursery raising has been described by Garg and Sharma (1984). As per this system, a wooden frame without base having 12 compartments of the size 40cm x 20cm x 2 cm is placed over the polythene sheet. Soil mixed with FYM in equal proportions is filled uniformly in this frame. About 60 to 70 g of pre-germinated seeds is evenly spread in each tray to achieve a uniform density of 2 seedlings cm^{-2} in the mats. Seeds are covered by a thin layer of soil. The seedling mats became ready after 20 to 25 days of sowing and can be uprooted easily without breaking the mats. While conducting trial with a 5 row manually operated IRRI paddy transplanter, the authors observed that only 2 to 3 frames for raising seedling mats were required, which could be relaid over plastic sheet, instead of a tray for each of the seedling mat. The average number of seedlings $hill^{-1}$ obtained was 4.

Directorate of Rice Research has standardised the size of mats to be used for 8-row mechanical transplanter. They have also developed a suitable frame to prepare mats, which dispensed labour for nursery pulling and cutting of mats. It also ensured uniformity of seedling density over mats (Murthy *et al.*, 2001).

2.4 Performance of the transplanter under different nursery systems

Mechanical transplanters with mat nursery were introduced in Japan in seventies. All these Japanese transplanters, which had passed the national tests,were engine driven machines of walking types with floats using mat nursery. The expenditure incurred in raising mat type nursery in Japan was generally lesser than that for other types(Yoshiakimori, 1975). Six row rice transplanter using mat type seedlings has been tried in Punjab in late seventies (Singh and Garg,1977).

Manually operated rice transplanter reduced human energy expenditure. Experiments conducted at Bangladesh Rice Research Institute by Baqui and Lantin (1982) revealed that the energy expenditure for transplanting rice using IRRI rice transplanter was 3.79 Kcal min^{-1} compared to 3.09 required for hand transplanting. However, the energy expenditure per plant was much lower in machine (0.019 kcal) than hand transplanting. (0.069 kcal)

A 5-row manually operated paddy transplanter of IRRI design, which was modified by Garg and Sharma (1984) transplanted about 0.3 to 0.4 hectares per day with the help of two persons. The average hill population was 26 m^{-2} with an average number of 4 seedlings per hill.

International Rice Research Institute, in cooperation with the scientists of the Chinese Academy of Agricultural Sciences, has developed a manually powered transplanter that utilised root washed seedlings. This was for those with a difficulty to prepare seedlings with a soil mat (IRRI, 1985). The IRRI rice transplanter planted an area of 0.133 ha in a day of 8 hours in clay loam soil conditions of Tamil Nadu. (Manian *et al.*, 1987)

A six row Korean transplanter was found to be more appropriate in Pakistan rice fields as it used conventional root washed seedlings. However, the machine needed improvement in feeding and transplanting mechanism. Certain modifications imparted to the machine led to decrease in the number of rice seedlings in a hill from 8 to 4 and improved seedling distribution pattern. The study further revealed that seedlings with 1 to 2 cm root lengths should be used with this transplanter for better seedling distribution. The performance of the transplanter depended upon thorough washing of the seedlings trimming of their stems and roots to 20 and 2 cm respectively and their careful placement in the seedling box (Khan and Gunkel, 1988)

According to Ravi *et al.*, (1994), the powertiller operated 8-row transplanter developed by the APAU, costing Rs. 6000/-, was very ideal to dispense with peak requirement of labour at transplanting stage and to avoid late transplanting due to paucity of labour. The study conducted using 25, 35,45 and 55 day old seedlings using either machine transplanting or manual planting, revealed that machine planting of young seedlings (25 and35 days) was very superior than planting of over aged seedlings (45 and 55 days) with respect to growth and yield attributes such as days to 50 percent flowering, panicle number, panicle weight, grain number panicle^{-1}, grain yield, straw yield, net returns and cost-benefit ratios.

The study on modification and performance evaluation of 6 row rice transplanter for conventional seedlings, conducted by Bainu *et al.*, (1994) at Tavanur, Kerala revealed that the modifications incorporated reduced number of seedlings from 6 to 2 and number of missing hills from 20.83 to 5.55 percent and that of floating hills from 10 to 5.5 percent. The field efficiency increased from 48.26 to 56.87 percent. The modification of the machine included raising the height of the feeding frame of the transplanter by 50 mm, reducing the mouth of the feeding frame from 8 to 5.4 mm, increasing the height of the partition wall of the nursery tray from 40 to 100 mm and introduction of a pressure plate to avoid spillage of seedlings from the seedling tray.

Prakash (1993) studied over power tiller operated APAU model paddy transplanter at Tavanur, Kerala. The conventional root washed paddy seedlings was used in the transplanter. When the power tiller was operated at a forward speed of 1.2 km h^{-1}, it transplanted seedlings at the rate of 2-4 seedlings hill^{-1}, with an average field capacity of 0.13ha h^{-1}.

The efficiency of the Yanmar transplater machine was 0.32 to 0.4 ha hr^{-1}, under different field conditions in Lahore, Pakistan. The number of missing hills with seedling mats grown in plastic trays and plastic sheets were about 5 percent. The labour requirement was 1/3rd of that of manual transplanting. A 30 percent increase in yield was recorded by machine transplanted crop compared to manual planted crop (Mufti and Khan, 1995)

Saha (1996) has reported about an automatic rice transplanter for root washed seedlings. It has no hand or foot controls and is simply towed. Performance testing revealed that the mechanism was satisfactory for transplanting seedlings.

A study report by Directorate of Rice Research, Hyderabad, stated that transplanters needed 214 manh ha^{-1} as against 347 manh ha^{-1} for manual transplanting, whereas paddy wet seeder needed only 8 h ha^{-1} (DRR,1996).

About 30 numbers of manually operated 6- row paddy transplanter, which used mat type seedlings were fabricated at PAU (Garg *et al,* 1997). Trials were conducted using the machines at 19 locations in 2 districts of Punjab. The machine transplanted 0.4 ha per day and only two people were needed for the work including uprooting and transporting mat from the nursery. The number of hills transplanted by the machine was 25.2 to $28.8m^{-2}$. The hill mortality, after 15 days of transplanting, was 12.1 percent. The average grain yield was 250 kg ha^{-1} more than the manually transplanted fields.

Cuevas (1997) while reviewing the various trends in mechanical transplanting of rice throughout the world described 4 different types of machines. Accordingly, the ideal stage for mechanical transplanting was 20 days after seeding.

A six row manually operated rice transplanter, developed by IRRI, was modified for Indian conditions at Bangalore. This transplanter, using mat type seedlings, (engaging 5-6 labourers) transplanted 1 ha of land in comparison to manual transplanting, which required 30 workers. The machine planted 46-47-rice hills m^{-2} compared to 39-40 for manual transplanting, leading to an increase of 361 kg grains ha^{-1} (Gowda and Rudradhya, 1998)

The results of the trials on mechanical transplanting of rice seedlings in dry seed bed in China summarized by Wang *et al*, (1999) indicated that rice yield increased by 657 kg ha^{-1} with 34.9 percent water saving. Crop raised under mechanical transplanting produced higher grain yield and higher number of seedlings m^{-2}, increased economic return and reduced labour requirement when compared to that under manual planting in Japan (Sharma *et al.*, 1999). Yan *et al*, (1999) at China observed that machine transplanted rice crop had higher leaf area and leaf number when compared to hand planted or broadcast crop, except at early growth stages. The former crop produced 8358 kg grain ha^{-1} when compared to 7761 and 8866 kg by the latter crops, respectively.

Trials with rice cv.ADT 36 in Kuruvai season(Sep-Oct) in Tamil Nadu, established that transplanting with mechanical transplanters gave high yields as good as that by line sowing or sowing by drum seeder (Pandiarajan *et al.*,1999). Trials conducted at Mannuthy, Kerala, showed that the 8-row Yanji Shakthi mechanical transplanter transplanted seedlings in rows of 22 cm apart, either at 10 cm or 12 cm spacing within the row (Beena and Jaikumaran, 1999).

Cakes of 50 cm x 21 cm containing rice seedlings were cut from the nursery to be fed into the machine. About 400 cakes were required for transplanting 1 ha (Rani *et al.*, 2000).

The 8 row rice transplanter, which transplanted at the rate of 0.8 ha day^{-1} was more suitable for light textured soils at Hyderabad (Murthy *et al.*, 2001). Ito (2001) described a paper mulch rice transplanter. The paper mulch gave a higher efficiency of weed control and the rate of working was 0.6 m s^{-1}.

2.5 Yield and yield attributes of paddy as influenced by different nursery systems and nursery media

2.5.1 Nursery media

Among the 3 seedling ages, viz, 15, 30 and 40 days, 40 day old seedlings produced the maximum grain yield of 4901 kg ha^{-1} (Rajagopalan *et al.*, 1978). Budhar *et al* (1991) observed that root injury did not affect the yield.

According to Rajendran (1991), nursery manuring though provided healthy seedlings, did not increase grain yield of rice. *Sathupai* system of nursery led to grain yields of 2706 and 6141 kg, respectively for summer and rabi seasons whereas the crop from conventional nursery produced only 2107 and 5115 kg (Arunachalam *et al.*, 1991)

Venkataraman(1999), while preparing dapog nursery in four media, viz., clay+ cow dung, composted coir pith, raw coir pith and straw bits, observed that composted coirpith (5.86 t ha^{-1}), clay+cowdung (5.85 t ha^{-1}) contributed to higher yields than others. Grain yield and yield components were not altered by any of the treatments of the substrata i.e., perforated polyethene sheet, plain polyethene sheet and gunny bits.

2.5.2 Nursery systems

Earlier reports indicated that direct seeding by broadcasting on the puddle and transplanting with dapog seedlings produced a greater yield than the conventional transplanting method (Rajagopalan *et al.*, 1971).

For early planting, 25 days old seedlings and for late planting, 35 to 45 days old seedlings were the optimum (Balasubramanian *et al.*, 1977).

Ayyaswamy *et al*, (1991) observed that under irrigated rice, transplanting of 50 day old seedlings of dry nursery and irrigating the crop at 12 days interval, produced a rice yield of 3.2 t ha^{-1} which was equivalent to crop raised using younger seedlings under same water management.

Rajagopal *et al*, (1995) reported that crop raised using 25 day old seedlings under super nursery out yielded that from conventional nursery. Crop raised under super nursery with 2 seedlings per hill, produced as much as that raised under conventional nursery with 4 seedlings (5.2 t ha^{-1}) when 45 days old seedlings were planted. But when young seedlings were used (25 DAS), crop raised under super nursery produced 5.3 t ha^{-1} against 4.9 t ha^{-1} produced by crop under conventional nursery.

A study conducted by Garg *et al*, (1997) at Punjab revealed that transplanting with a manually operated six row rice transplanter using mat type seedlings, produced 250 kg ha^{-1} more grain yield higher than the manually transplanted fields.

2.6 Cultivation economics as influenced by different systems and media of nursery

2.6.1 Nursery media

Garg and Sharma (1984) while studying the performance of a modified 5-row manually operated paddy transplanter of IRRI design using mat type seedlings, worked out a labour saving of 120 to 130 man h ha^{-1} and a financial saving of Rs.160-180 ha^{-1} over the conventional manual planting.

While recommending IRRI transplanter for mechanical transplanting in clayey soils, with modification of soil base and seed rate, Manian *et al*, (1987) reported that there was a labour saving of 43.6 per cent and financial saving of 15.8 per cent over the conventional method of planting.

Mufti and Khan (1995) at Lahore observed that the cost of mechanical transplanting using nursery seedlings grown in trays was high (Rs.1500 ha^{-1}) i.e., 50 per cent more than the present manual transplanting cost. However, this mechanical transplanting using Yanmar transplanter required only 1/3rd labour than that required for manual transplanting (17 man days ha^{-1}). The operating cost of the transplanter was the minimum, i.e., Rs.850 ha^{-1}, which included the expenditure incurred on all operations performed, from nursery raising until transplanting except land preparation. The study further revealed that mechanical transplanting using seedlings grown on plastic sheets was most feasible as it not only reduced the cost of transplanting to the minimum (Rs.850 ha^{-1}), but also minimised the labour requirement (5 days ha^{-1}).

According to Garg *et al*, (1997), transplanting using manually operated six-row transplanter with mat type seedlings, saved 45 per cent cost and 60 per cent labour compared to manual transplanting in Punjab.

2.6.2 Nursery systems

Performance evaluation of the modified six-row manual rice transplanter using conventional seedlings worked out a saving of Rs. 618 ha^{-1}, compared to hand transplanting giving a 2.4 times reduction in total cost (Bainu, 1990). As per Thakur (1993), transplanting gave the highest gross return and net return and showed superiority to direct seeding. However, cost:benefit ratio was almost alike under direct seeding and transplanting.

Ahamed and Sivaswami (1994) suggested a technically feasible and economically viable farm mechanization package for rice farms of Kerala. The medium and high mechanical packages were giving more net returns than the conventional package.

An improved version of power tiller operated rice transplanter was developed and fabricated at Tavanur, Kerala. The conventional root washed rice seedlings ready for manual transplanting were used in the study. A saving of Rs.800 ha^{-1}, which was 50 per cent and reduction of 296 manh ha^{-1}, which was 92.5 per cent was achieved for transplanting alone, compared to manual transplanting (Prakash, 1993). Mechanical transplanting required only Rs.530 ha^{-1} as against the manual cost of Rs.2300 ha^{-1} (Jaikumaran and Beena, 1996)

James *et al*, (1996) studied the effect of selective mechanisation on the economics of rice production. Human labour was responsible for the major production cost in all non-mechanised production systems. The mean benefit-cost ratio for non-mechanised system was only 1.24 as against 1.50 for partly mechanised.

Gowda and Rudradhya (1998) evaluated a six-row manually operated rice transplanter and found that the initial cost of transplanter (Rs.5500) could be recovered by planting 7 to 8 ha in 1 or 2 seasons. Labour saving due to mechanical transplanter amounted to Rs.885 ha^{-1}.

Mechanical and manual transplanting of rice, and harvesting with a combine or by a reaper followed by stationary threshing machine, was compared in field trials in Egypt. The most profitable system was mechanical transplanting and direct harvesting by combine (Megahed and El-Hameid, 1998). According to Pandiarajan *et al.*, (1999), transplanting with a power transplanter gave the best benefit:cost ratio each year, compared to drum seeder or line sowing or broadcasting .

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled "Standardisation of mat nursery for rice" was undertaken at the Agricultural Research Station, Mannuthy of Kerala Agricultural University from May to September 2002. The particulars of materials used and methods adopted in the conduct of the study are presented in this chapter.

3.1 Details of the experimental site

3.1.1 Location

The experiment was conducted at Agricultural Research Station Mannuthy, Thrissur. This station is situated at 10°31'N latitude, 76°13'E longitude and at an altitude of 40.29 m above mean sea level. It is located 6 km away from Thrissur, on the southern side of Thrissur-Palakkad National Highway No.47.

3.1.2 Soil

Soil of the experimental site is sandy clay loam belonging to the taxonomical order oxisol. The soil is acidic in reaction with average pH of 5.6. The physical and chemical properties of the soil before the start of the experiment are presented in Table 1.

3.1.3 Climate and weather conditions

The area belongs to a typical humid tropical climate. The normal weather of the area and the weather conditions prevailed during the experimental period are presented in Appendix I and Appendix II and illustrated in Figure 1 and Figure 2, respectively.

The normal annual rainfall of the area is 2669 mm, of which 75 per cent is received during Southwest monsoon (June to September) 16.6 per cent during Northeast monsoon (October to December) and the rest received as summer showers. During the cropping period, the nursery received 462.2 mm of rainfall in 13 rainy days and main crop received 1203.9 mm of rainfall in 59 rainy days.

The mean monthly maximum and minimum temperatures at the area during the cropping period was 32.6°C (May) and 22.9°C (August) respectively,

Table 1. Physico-chemical characteristics of the soil of the experimental site

Parameters	Value	Method used
a) Mechanical composition		Hydrometer method (Piper, 1966)
Sand (%)	75.9	
Silt (%)	4.4	
Clay (%)	18.4	
b) Physical composition		
Field capacity (0.3 bars)	19.68	
Permanent wilting point (15 bars)	11.32	
Bulk density (g cc^{-1})	1.33	
Water holding capacity (%)	49.1	
c) Chemical composition		
Organic C (%)	0.66	Walkley and Black method (Jackson, 1958)
Available N (kg ha^{-1})	257.6	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	11.4	Bray extractant - Ascorbic acid reductant method (Watenabe and Olsen, 1965)
Available K (kg ha^{-1})	98.8	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

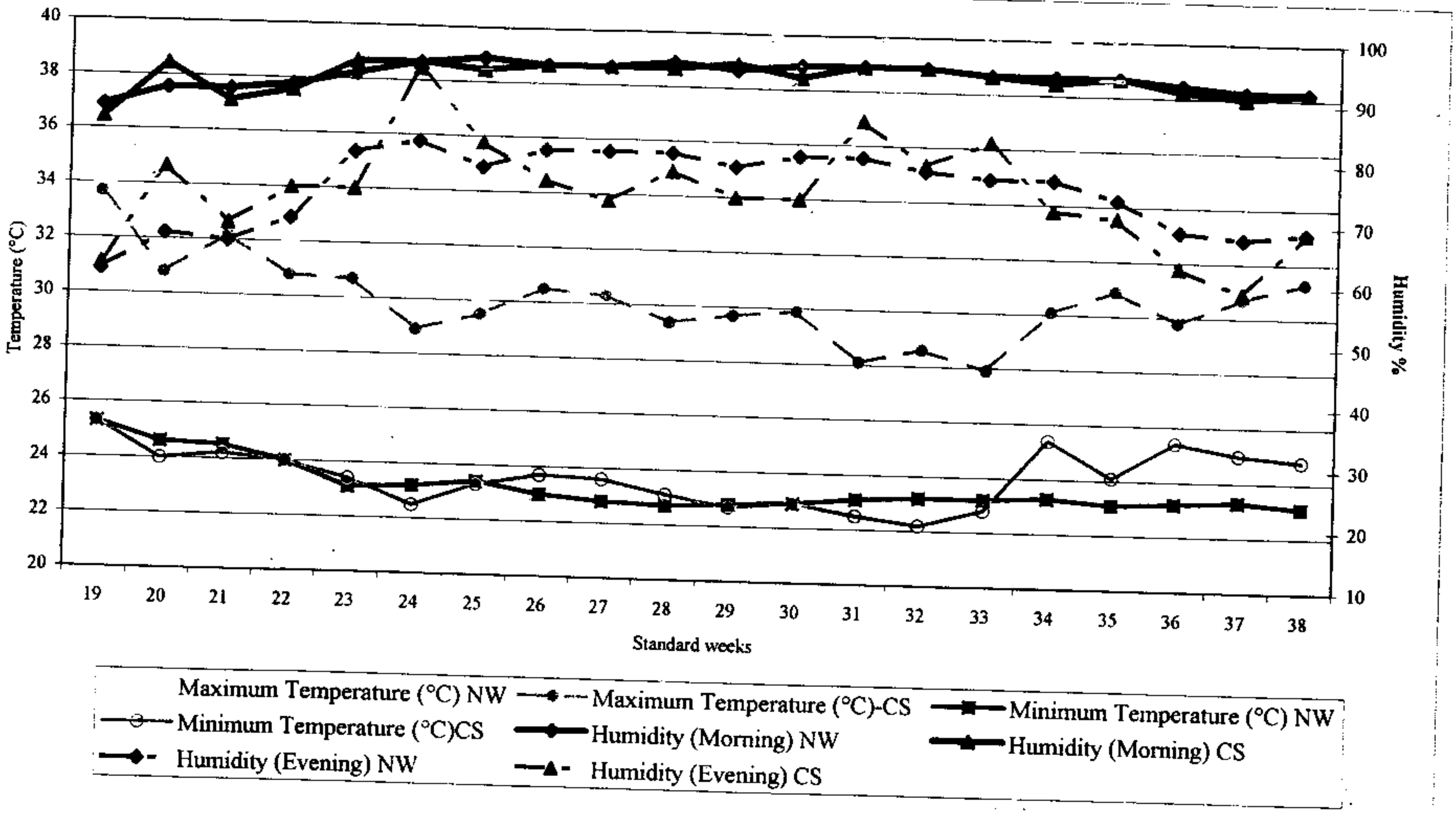


Fig. 1. Weather parameters during crop season (CS) v/s normal weather (NW)

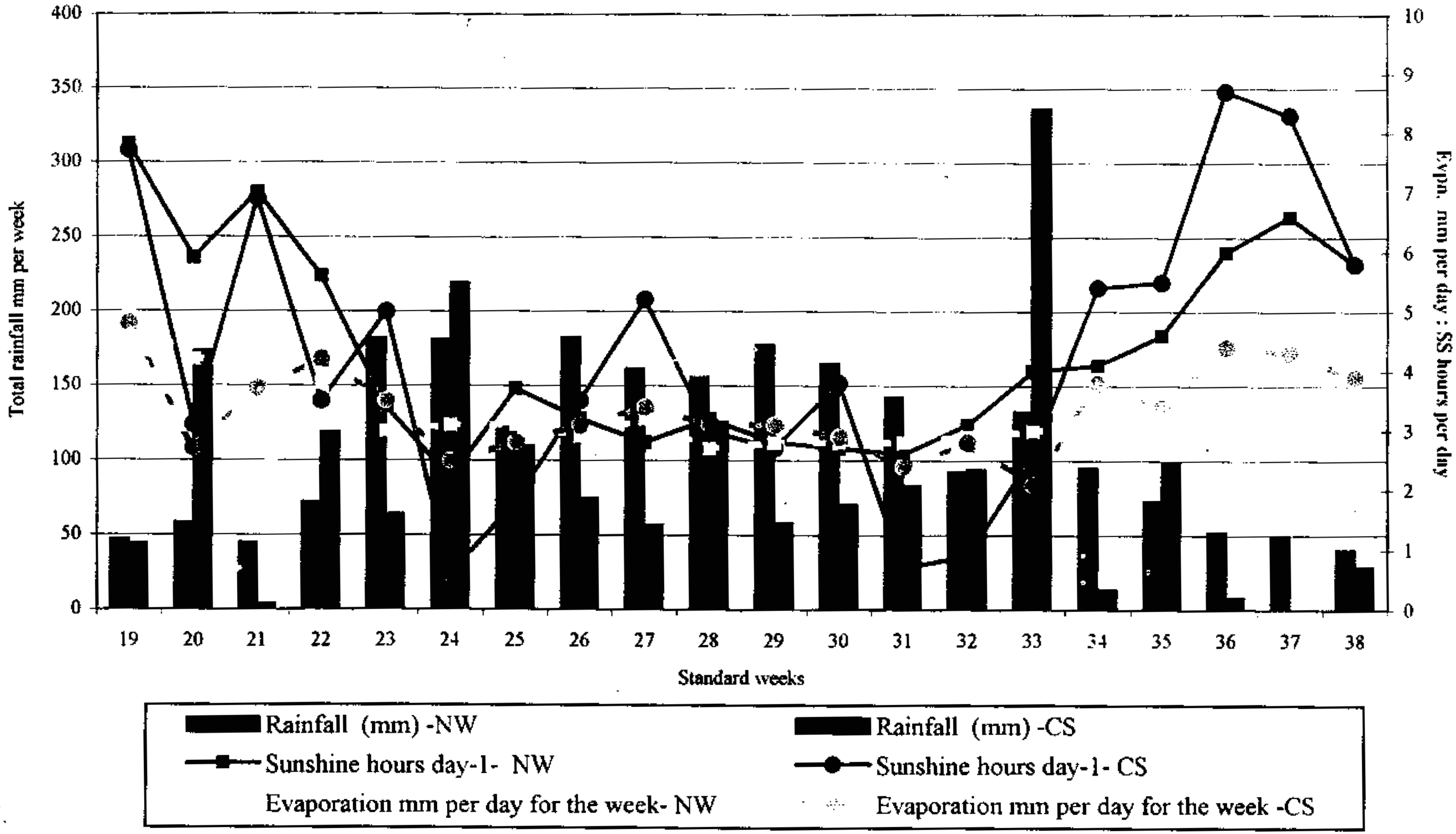


Fig. 2. Weather parameters during crop season (CS) v/s normal weather (NW)

while the mean weakly maximum and minimum temperatures recorded during the cropping period were 33.7°C (May) and 22.2°C (August) respectively.

The relative humidity of the area during Virippu season normally ranges from 73 (May) to 86 (July) per cent. The relative humidity during the cropping periods ranged from 77 (September) to 87 (May) per cent. The bright sunshine hours normally ranges from 3.4 (June-July) to 7.1 (May) whereas, the bright sunshine hours varied from 2.7 (July) to 7.8 (September) during the cropping period. This reveals that the weather was relatively normal during the cropping period.

3.2 Cropping history

The land selected for the experiment was single cropped paddy land, paddy crop limited to virippu season and kept fallow during the second crop season. Green manure crop daincha was raised in the third crop season.

3.3 Details of experiment

3.3.1 Technical programme

The experimental investigation consisted of 3 parts:

1) Mat nursery production
2) Field evaluation of mat nursery using mechanical transplanter
3) Field evaluation of mat nursery for manual transplanting

3.3.1.1 Mat nursery production

Design	-	CRD
Treatments	-	16

Combinations of 4 types of media in two ratios were tried under two systems viz., dry and wet.

Treatment combinations

(a) Dry nursery

Eight combinations of four media in two ratios:

T_1- Soil + cow dung at the ratio of 2:1 volume/volume

T_2 -Soil + cow dung at the ratio of 1:2 volume/volume

T_3 Soil + coir pith compost at the ratio of 2:1 volume/volume

T_4- Soil + coir pith compost at the ratio of 1:2 volume/volume

T_5- Soil + coir pith raw at the ratio of 2:1 volume/volume

T_6- Soil + coir pith raw at the ratio of 1:2 volume/volume

T_7- Soil + chaff at the ratio of 2:1volume/volume

T_8- Soil + chaff at the ratio of 1:2volume/volume

(b) Wet nursery

The above 8 combinations were tried in the wet system also.

T_9- Soil + cow dung at the ratio of 2:1volume/volume

T_{10}-Soil + cow dung at the ratio of 1:2 volume/volume

T_{11}- Soil + coir pith compost at the ratio of 2:1 volume/volume

T_{12}- Soil + coir pith compost at the ratio of 1:2 volume/volume

T_{13}- Soil + coir pith raw at the ratio of 2:1 volume/volume

T_{14}- Soil + coir pith raw at the ratio of 1:2 volume/volume

T_{15}- Soil + chaff at the ratio of 2:1volume/volume

T_{16}- Soil + chaff at the ratio of 1:2volume/volume

3.3.1.2 Field evaluation of mat nursery using mechanical transplanted (Experiment ii)

Design	-	RBD
Treatments	-	17
Replications	-	2
Gross plot size	-	8 x 3.6 m^2
Net plot size	-	7.52 x 2.7 m^2

Sixteen types of mat nursery (T_1 to T_{16}) were transplanted using 8 row Yanji Shakthi mechanical transplanter. This was compared with manually transplanted crop using conventional nursery (T_{17}). Layout plan is given in Figure 3.

3.3.1.3 Field evaluation of mat nursery for manual transplanting (Experiment iii)

Design	-	RBD
Treatments	-	17
Replications	-	2
Gross plot size	-	5 x 4 m^2
Net plot size	-	4.4 x 3.6 m^2

T_5- Soil + coir pith raw at the ratio of 2:1 volume/volume

T_6- Soil + coir pith raw at the ratio of 1:2 volume/volume

T_7- Soil + chaff at the ratio of 2:1volume/volume

T_8- Soil + chaff at the ratio of 1:2volume/volume

(b) Wet nursery

The above 8 combinations were tried in the wet system also.

T_9- Soil + cow dung at the ratio of 2:1volume/volume

T_{10}-Soil + cow dung at the ratio of 1:2 volume/volume

T_{11}- Soil + coir pith compost at the ratio of 2:1 volume/volume

T_{12}- Soil + coir pith compost at the ratio of 1:2 volume/volume

T_{13}- Soil + coir pith raw at the ratio of 2:1 volume/volume

T_{14}- Soil + coir pith raw at the ratio of 1:2 volume/volume

T_{15}- Soil + chaff at the ratio of 2:1volume/volume

T_{16}- Soil + chaff at the ratio of 1:2volume/volume

3.3.1.2 Field evaluation of mat nursery using mechanical transplanted (Experiment ii)

Design	-	RBD
Treatments	-	17
Replications	-	2
Gross plot size	-	8 x 3.6 m^2
Net plot size	-	7.52 x 2.7 m^2

Sixteen types of mat nursery (T_1 to T_{16}) were transplanted using 8 row Yanji Shakthi mechanical transplanter. This was compared with manually transplanted crop using conventional nursery (T_{17}). Layout plan is given in Figure 3.

3.3.1.3 Field evaluation of mat nursery for manual transplanting (Experiment iii)

Design	-	RBD
Treatments	-	17
Replications	-	2
Gross plot size	-	5 x 4 m^2
Net plot size	-	4.4 x 3.6 m^2

The above sixteen types of mat nursery (T_1 to T_{16}), were manually transplanted without uprooting and bundling of the seedlings. The mat strips were directly taken by labourers and seedlings were separated only while transplanting in the main field. This was compared with manual planting of conventional root washed seedlings, which were uprooted and bundled before transplanting (T_{17}). Layout of the plot is given in Fig.4.

3.4 Crop husbandry

3.4.1 Mat nursery raising

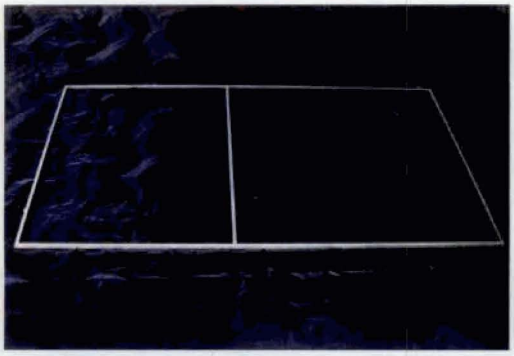
The nurseries were raised under combination of 4 different media at 2 ratios in two different systems i.e., wet and dry. The pictorial representation of the mat nursery is given in Plate 1.

3.4.1.1 Wet system

Nursery area was puddled and levelled. Two hundred gauge black polyethene sheets was spread and wooden frames of size 100 x 90 x 1.25 cm^3 were laid on the required area. Soil puddle was mixed with organics as per the treatment and soil mixture was filled into the frame upto 1.2 cm height. The soil in the frame was levelled. Pre-germinated seeds (just sprouted) were sown over the surface at the rate of 0.5 kg m^{-2}. The surface was mulched with green leaves. Water was sprinkled thrice a day. This practice continued for 4 days and on the 4^{th} day, mulch materials were removed. Thereafter nursery was impounded with water to keep the nursery bed submerged in water without drying. This practice continued till seedling mat was ready for transplanting (15 cm height).

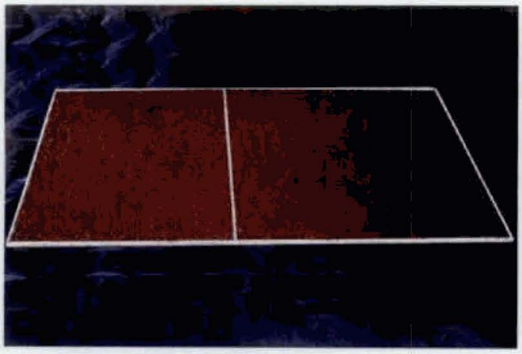
3.4.1.2 Dry system

Two hundred gauge black polythene sheet was spread and wooden frames of size 100 x 90 x 1.25 cm^3 were laid on the required area. Soil was mixed with organics under dry condition, as per the treatment and soil mixture was filled into the frame up to 1.2 cm height. Seeds (without pre-germination) were sown over the surface at the rate of 0.5 kg m^{-2} and covered with a thin layer of soil organic mixture. Soil surface was mulched with green leaves. Water was sprinkled thrice a day. This practice continued for 4 days and on the 4^{th} day, mulch materials were removed. Then, mat was kept under saturation for 4 days and thereafter under



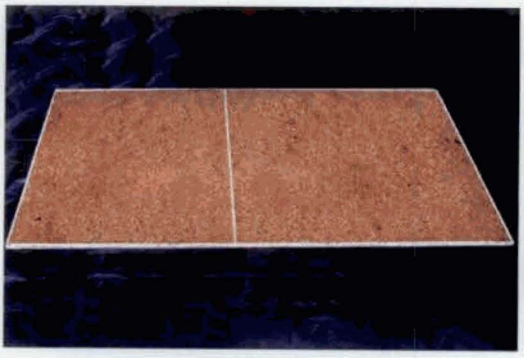
Frame and polythene sheet

Mixing of soil and organics

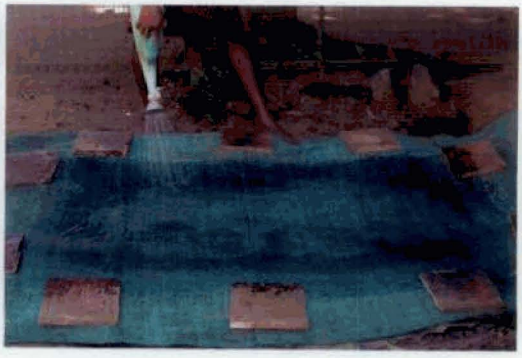


Filling of rooting media

Sowing of seeds



Covering with thin film of rooting media



Mulching

Plate 1. Preparation of mat nursery (Day 1)

5 days after sowing

10 days after sowing

21 days after sowing

Rolling of mat

Cutting of mat

Placing of mat in transplanter

Plate 1. Preparation of mat nursery

R_1T_{12}		R_1T_7		R_1T_4	R_1T_{16}	R_2T_2	R_2T_{10}	R_2T_{12}	R_2T_1
R_1T_6		R_1T_3		R_1T_1	R_1T_{11}	R_2T_6	R_2T_9	R_2T_{15}	R_2T_5
R_1T_2	Irrigation channel	R_1T_5	Drainage channel	R_1T_{10}	Bulk crop	R_2T_8	R_2T_3	R_2T_{17}	Bulk crop
R_1T_{13}		R_1T_8		R_1T_{17}	Bulk crop	R_2T_{11}	R_2T_7	R_2T_4	Bulk crop
R_1T_9		R_1T_{15}		R_1T_{14}	Bulk crop	R_2T_{14}	R_2T_{13}	R_2T_{16}	Bulk crop

8 m

3.6 m 0.9 m 0.3 m

Fig.3 Layout of Experiment II

T_1	-	DC_1	C_1	-	Soil + cowdung in 2:1 ratio
T_2	-	DC_2	C_2	-	Soil + cowdung in 1:2 ratio
T_3	-	$DCPC_1$	CPC_1	-	Soil + coirpith compost in 2:1 ratio
T_4	-	$DCPC_2$	CPC_2	-	Soil + coirpith compost in 1:2 ratio
T_5	-	$DCPR_1$	CPR_1	-	Soil + coirpith raw in 2:1 ratio
T_6	-	$DCPR_2$	CPR_2	-	Soil + coirpith raw in 1:2 ratio
T_7	-	DCF_1	CF_1	-	Soil + chaff in 2:1 ratio
T_8	-	DCF_2	CF_2	-	Soil + chaff in 1:2 ratio
T_9	-	WC_1	CC	-	Control
T_{10}	-	WC_2	D	-	Dry
T_{11}	-	$WCPC_1$	W	-	Wet
T_{12}	-	$WCPC_2$			
T_{13}	-	$WCPR_1$			
T_{14}	-	$WCPR_2$			
T_{15}	-	WCF_1			
T_{16}	-	WCF_2			
T_{17}	-	CC			

R_1T_8		R_1T_7		R_1T_3	R_2T_5	R_2T_9	R_2T_2
R_1T_1		R_1T_{11}		R_1T_9	R_2T_{10}	R_2T_6	R_2T_4
R_1T_5	Irrigation channel	R_1T_{17}	Drainage channel	R_1T_{13}	R_2T_{14}	R_2T_1	R_2T_{15}
R_1T_4		R_1T_{14}		R_1T_2	R_2T_3	R_2T_8	R_2T_{13}
R_1T_{10}		R_1T_6		R_1T_{16}	R_2T_{11}	R_2T_{16}	R_2T_7
R_1T_{12}		R_1T_{15}		Bulk crop	R_2T_{17}	R_2T_{12}	Bulk crop

5 m

4 m

Fig.4 Layout of Experiment III

T_1	-	DC_1
T_2	-	DC_2
T_3	-	$DCPC_1$
T_4	-	$DCPC_2$
T_5	-	$DCPR_1$
T_6	-	$DCPR_2$
T_7	-	DCF_1
T_8	-	DCF_2
T_9	-	WC_1
T_{10}	-	WC_2
T_{11}	-	$WCPC_1$
T_{12}	-	$WCPC_2$
T_{13}	-	$WCPR_1$
T_{14}	-	$WCPR_2$
T_{15}	-	WCF_1
T_{16}	-	WCF_2
T_{17}	-	CC

C_1	-	Soil + cowdung in 2:1 ratio
C_2	-	Soil + cowdung in 1:2 ratio
CPC_1	-	Soil + coirpith compost in 2:1 ratio
CPC_2	-	Soil + coirpith compost in 1:2 ratio
CPR_1	-	Soil + coirpith raw in 2:1 ratio
CPR_2	-	Soil + coirpith raw in 1:2 ratio
CF_1	-	Soil + chaff in 2:1 ratio
CF_2	-	Soil + chaff in 1:2 ratio
CC	-	Control
D	-	Dry
W	-	Wet

submergence. This continued till the seedling mat was ready for transplanting (15 cm height).

3.4.1.3 Conventional wet nursery

The field was ploughed, thoroughly puddled and levelled. Raised beds of 15 cm height, 1.5 m width and at required length were prepared with drainage channels on either sides. Cattle manure @ 1 kg m^{-2} was applied on the nursery bed and mixed with the soil at the time of puddling. Pre-germinated seed was sown on the third day @ 0.08 kg m^{-2}. Nursery bed was irrigated without drying and after 5 days it was submerged to a depth of 5 cm. This continued up to pulling out of seedlings on 18 DAS.

3.4.2 Season

The field trial was conducted during Virippu season from May to September 2002.

3.4.3 Seeds

The rice variety Kanchana was used for the experiment. It is a red kernelled short duration variety of 105-110 days duration, released from Regional Agricultural Research Station Pattambi, as PTB-50. The variety, suitable for all seasons is resistant to blast, blight and gall midge.

3.4.4 Land preparation

The experimental field was ploughed using tractor. It was puddled and levelled before transplanting.

3.4.5 Transplanting

In Experiment-II, plots alloted were transplanted using 8 -row Yanji Shakthi transplanter. The control plot was manually planted using seedlings from conventional nursery at a spacing of 15 cm x 10 cm. In the case of Experiment-III, seedlings from strips of sixteen types of mat nurseries (without doing separation of nursery seedlings and its bundling before planting) along with those from a conventional root wash nursery were transplanted manually in the plots at random.

3.4.5.1 Yanji Shakthi transplanter

Eight row Yanji Shakthi transplanter is a Chinese transplanter, which could transplant seedlings at a spacing of 22.5 x 12 cm (Plate 2). The machine needed mat type seedlings for transplanting. Nursery cut into mat pieces of size 22.5cm x 50 cm was rolled up and carried. The machine needed one driver and two labourers for feeding mat. Two more labourers were also needed for transporting the mat from the nursery site to the main field and to supply seedling mat for the uninterrupted run of the machine. The average fuel consumption was 500 ml of diesel per hour.

3.4.6 Chronological sequence of planting operations

Date of sowing in dry nursery-21-05-2002

Date of sowing in wet nursery-25-05-2002

Date of planting in Experiment- II -14-06-2002

Date of planting in Experiment-III -19-06-2002

Date of harvest of Experiment- II -20-09-2002

Date of harvest of Experiment- III -21-09-2002

3.4.7 Weeding

One hand weeding was done in both the experimental plots at 25 DAT.

3.4.8 Manures and fertilizers

Main field received FYM @ 5 t ha^{-1} at the time of last but one puddling. Basal dose of fertilizers were incorporated after the last puddling. The fertilizers @ 70:35:35 kg N, P_2O_5, K_2O ha^{-1} respectively as recommended by KAU (2002) for short duration varieties of rice was given. The entire quantity of P_2O_5, 50% N and 50% K_2O were applied basally. Among the remaining quantity of N, 50% was applied at active tillering stage and the remaining 50% at panicle initiation stage. Balance of 50% of K_2O was also applied at the time of panicle initiation. Urea (46% N), Rajphos (22% P_20_5) and Muriate of Potash (60% K_2O) were the fertilizer materials used for the experiment.

3.4.9 Water management

Water level was maintained at 5 cm and drainage was provided once in a week. The entire field was drained before harvest.

Plate 2. Eight - row Yanji Shakthi transplanter

3.4.10 Plant protection

Karate @ 1 ml per litre was sprayed to control the sucking pests during active tillering stage. Metacid @ 2 ml per litre was sprayed against rice bug.

3.4.11 Harvest

The crop was harvested at red ripe maturity. The crop in Experiment- II was harvested on 20-09-2002 and crop in Experiment III harvested on 21-09-2002. Field was drained fifteen days before harvest. In case of experiment III, excluding two periphery rows as border, crop from12 m^2 area was harvested to record the net plot yield.

3.5 Observations

Observations were recorded from individual nursery plots in case of mat nursery. Observations on growth and yield attributes from main field were recorded from 16 hills per plot by employing 4 x 4 hill techniques suggested by Gomez (1972). At the time of harvest, 1 m^2 area was randomly selected from each plot and post harvest observations were recorded using these plants.

3.5.1 Observations on mat nursery

3.5.1.1 Seedling height

Each mat nursery plot was divided into 8 segments of equal width. Three seedlings were selected at random from each segment and height i.e., from the base of the plant over the soil surface to the topmost leaf tip of the seedling, was measured. The mean of these 3 seedlings was worked out and reported as seedling height in cm.

3.5.1.2 Disease and pest incidence scoring (healthiness)

A scoring on the colour of the leaf was made to record the disease and pest incidence. Maximum greenish colour was assigned the score as 10 and the minimum colour as 0. This was recorded at the time of cutting of the mat for transplanting.

3.5.1.3 Thickness of the media (root zone mat) at the time of transplanting

Three strips of size 10 cm x10 cm were randomly cut at the time of cutting of the mat nursery for transplanting. The thickness of the root bed was measured from all the 4 sides and the mean reported as thickness of the media in cm.

3.5.1.4 Number of healthy and weak seedlings at the time of transplanting

Seedlings from the three strips of 10 cm x10 cm randomly cut mat nursery were separated. Seedlings were grouped into healthy tall seedlings and weak short seedlings and their total number per unit area was reported.

3.5.1.5 Number of seedlings damaged (floating) while transplanting

At the time of machine planting, the total number of seedlings planted was recorded. After 3 days, the number of seedlings survived and number of seedlings damaged (floating) were noted from an area of 1 m^2 in the main field selected at random. Mean number of seedlings floating per hill was worked out.

3.5.1.6 Mat weight per unit area after overnight draining

The three strips of 10 cmx10 cm randomly cut from the mat nursery were kept for overnight draining. Thereafter weight of the mat was recorded and reported.

3.5.1.7 Root length at the time of transplanting

Ten seedlings, selected at random, were carefully separated at the time of transplanting, from each mat nursery and root length was measured in cm.

3.5.1.8 Strength of the mat at transplanting

The three strips of 10 cmx10 cm randomly cut mat pieces were kept on a horizontal platform and fixed to it at 4 corners by nailing. The strips were subjected to a vertical force, by adding weights gradually till the mat started tearing. This weight was expressed as mat strength in grams.

3.5.2 Observations on the performance of transplanter

3.5.2.1 Forward speed of the transplanter and area transplanted at the forward speed

The time required by the transplanter to cover the plot was recorded and the area transplanted at this speed was worked out in sm^{-1}.

3.5.2.2 Plant population m^{-2}

Number of hills planted in one m^2 area was counted 3 days after transplanting and expressed as plant population m^{-2}.

3.5.2.3 Number of missing hills m^{-2}

From the plant population taken, the number of missing hills was worked out, based on the following computation. The mechanical transplanter is having row to row spacing of 22.5 cm and plant to plant spacing of 12 cm. Hence at 100 per cent planting (no missing hills), 37 hills are to be planted by the machine. Number of hills observed in 1 m^2, lesser than 37, is worked out as the number of missing hills.

3. 5.2.4 Number of seedlings $hill^{-1}$

The number of seedlings present per hill immediately after transplanting in 1 m^2 area was counted and the average number of seedlings $hill^{-1}$ was worked out. This was expressed as number of seedlings $hill^{-1}$.

3.5.2.5 Depth of planting

Four plants were pulled out at random from each plot and the depth of planting was measured.

3.5.3 Observations on performance of crop

3.5.3.1 Plant population

Number of hills standing in a randomly selected $1m^2$ area was counted in each plot at planting, maximum tillering and harvest.

3.5.3.2 Plant height

Sixteen hills were randomly selected adopting 4 x 4 hill technique. The plant height was measured from the base of the hill at the soil surface to the tip of the top most leaf at 15 days interval. At harvest, the height was recorded from the base of the plant to the tip of the longest panicle and the mean height was computed and expressed in cm.

3.5.3.3 Number of tillers $hill^{-1}$

Sixteen hills were randomly selected adopting 4 x 4 hill technique and the number of tillers in each hill was counted at 15 days interval.

3.5.3.4.1 RGR (Relative Growth Rate)

Four plants were uprooted at random from each plot, washed well and were separated into different plant parts like root, sheath, and leaf lamina. Its dry weight was recorded at active tillering stage and panicle initiation stage. Dry weight of each part was added to find out the total dry matter production.

RGR is worked out by employing the following formula proposed by Redford (1967)
wherein,

$$RGR = \frac{\log_e^{W_2} - \log_e^{W_1}}{t_2 - t_1}$$

W_1 and W_2 are the dry matter weights per hill, recorded at times t_1 and t_2 respectively.

3.5.3.4.2 CGR (Crop Growth Rate)

CGR was worked out using the dry matter value recorded for computing RGR by employing the following formula suggested by Watson (1952)

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

where, W_1 and W_2 are dry matter weights per plant recorded at the time of t_1 and t_2 respectively and P the spacing of the plant expressed in m^2.

3.5.3.4.3 LAI (Leaf Area Index)

LAI of the plant was computed using the four plants uprooted for computing RGR. Leaf area was worked out using the leaf area weight method suggested by Gomez (1972) and LAI was worked out by the formula,

$$\frac{Leafarea/plant}{Landarea/plant}$$

LAI was worked out at active tillering stage and panicle initiation stage.

3.5.3.4.4 LAD (Leaf Area Duration)

LAD was worked out using the plant uprooted for recording RGR, by adopting the method suggested by Power *et al* (1967) employing the formula,

$$\text{LAD} = \frac{(A_1 + A_2)(t_2 - t_1)}{2}$$

A_1 and A_2 are the leaf areas at times t_1 and t_2.

3.5.3.4.5 NAR (Net Assimilation Rate)

NAR was worked out at active tillering and panicle initiation stage. The dry matter production for computing RGR was used for computing NAR by adopting the following formula suggested by Gregory (1926)

$$\text{NAR} = \frac{(W_2 - W_1)(\log_e A_2 - \log_e A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

W_1 and W_2 – Plant dry weights at t_1 and t_2 times.

A_1 and A_2 - Leaf Area at t_1 and t_2.

3.5.3.5 Weed density

Total number of weeds species wise was recorded in mechanically transplanted plots from a quadrant of 50 cm x 50 cm (0.25 m^2) at 20 and 40 days after transplanting. The total number of weeds as well as population of major weeds per unit area was worked out and expressed.

(The observations on RGR, CGR, LAI, LAD, NAR and weed density were recorded only in case of Experiment- II)

3.5.3.6 Disease and pest incidence

The incidence of the important pests and diseases viz. thrips, stem borer, rice bug, green leaf hopper and bacterial leaf blight were recorded from each plot at 15 days interval as per the procedure suggested by TNAU Entomology Practical manual.

3.5.3.7 Yield attributes

3.5.3.7.1 Number of panicles m^{-2}

Total number of panicles from a random area of 1 m^2 was recorded from each plot.

3.5.3.7.2 Number of filled grains $panicle^{-1}$

After the observation on panicles per m^2, twelve panicles were randomly selected and threshed. The number of filled and unfilled grains was counted and the average was worked out and expressed.

3.5.3.7.3 1000 grain weight

After the observation of filled grains per panicle, 100 grains were counted from this lot and weighed. Thousand grain weight was computed from it.

3.5.3.7.4 Grain: Chaff ratio

From the paddy harvested from each net plot, grain and chaff yield was weighed separately, and grain: chaff ratio was worked out.

3.5.3.8 Number of late formed panicles

The panicles still remaining green at the time of harvest were counted and expressed as number of late formed panicles m^{-2}.

3.5.3.9 Yield of grain and straw

The paddy from each net plot area was harvested, threshed, cleaned, winnowed and sun dried till consecutive weights remained constant. This was expressed as yield of grain in kg ha^{-1}. Straw from each plot was also dried uniformly and weight was expressed in kg ha^{-1}.

3.5.3.10 Harvest index

Harvest index was calculated as per,

$$\text{Harvest Index} = \frac{Grainyield(kg/ha)}{Grainyield + Strawyield(kg/ha)}$$

3.5.3.11 Economics of cultivation

All the activities involved in crop production were listed and cost worked out, based on the prevailing wage rate as suggested by Acharya (1997). Thereafter the economics of cultivation of the crop treatment wise was worked out and the net income and benefit: cost ratio (BCR) was calculated as follows:

$$\text{BCR} = \frac{GrossIncome}{Total\cos tofcultivation}$$

3.5.4 Nutrient content

3.5.4.1 N, P and K content of grain and straw

Four sample plants were randomly drawn from each plot at harvest, grain and straw were separated, oven dried at 70°C to constant weight. These plant parts were ground and this powder was used for nutrient estimation. The N content was estimated by Microkjeldhal method, P content by vanado molybdophosphoric yellow colour method and K content by flame photometer separately for grain and straw (Jackson, 1973). The nutrient uptake was calculated from it, based on grain and straw yield.

3.6 Statistical analysis

Statistical analysis was done using the analysis of variance technique as suggested by Panse and Sukhatme (1985).

Results

4. RESULTS

4.1 Observations in mat nursery

4.1.1 Height of the seedlings in wet and dry mat nursery as influenced by media of mat

Under dry nursery system, 5 days after sowing (DAS) soil + coir pith compost at the ratio 2:1 (T_3) produced taller seedlings (Table 2) than other treatments, except soil + chaff in the ratio 2:1 (T_7). But 10 days after sowing (DAS), the other treatments (T_1, T_2, T_3 and T_8) produced taller seedlings similar to that of T_7. However, at the final stage of observation, i.e. 15 DAS mat nursery raised using soil + cow dung at the ratio 2:1 (T_1) produced taller seedlings than other combinations of the media. Soil + coir pith compost in the ratio 2:1 or 1:2 produced shorter seedlings.

Under wet system at 5 or 10 DAS, soil + chaff in the ratio 2:1 (T_{15}) led to taller seedlings than others except soil + cow dung in the ratio 1:2 (T_{10}) at 10 DAS. But as growth progressed to 15 DAS the treatments T_{10} and T_9 produced taller seedlings than others in the mat. Hence under both systems, taller seedlings were produced when mat was raised with soil + cow dung in the ratio 2:1 as the media and shorter seedlings were produced when soil + coir pith compost was used.

4.1.2 Disease and pest scoring (Healthiness) in dry and wet mat nursery

Scoring for healthiness of the seedlings in the mat nursery observed through variation in green colour score from 1 to10 revealed that no serious pest and disease incidence was observed in the mat nursery (Table 3).

Under dry system, mat nursery raised using soil along with chaff or cow dung, irrespective of their proportion, produced seedlings with dark green colour. When the media of the mat was coir pith in its raw or compost form, mixed with soil irrespective of proportion, produced seedlings with light green colour.

Under wet system, cow dung and soil mixture either 2:1 or 1:2 ratio, produced high greenish seedlings with the score value of 10. The other media of coir pith compost, coir pith raw or chaff with soil in 2:1 or 1:2 ratio, produced light greenish seedlings.

Table 2. Height of the seedlings (cm) in wet and dry mat nursery as influenced by media of the mat

Dry nursery	5DAS	10DAS	15DAS	**Wet nursery**	5DAS	10DAS	15DAS
T1-Soil + cow dung in 2:1 ratio	3.6 [b]	10.7 [ab]	16.0 [a]	T9-Soil + cow dung in 2:1 ratio	4.8 [d]	11.1 [c]	17.3 [a]
T2-Soil + cow dung in 1:2 ratio	3.6 [b]	10.9 [ab]	15.1 [b]	T10-Soil + cow dung in 1:2 ratio	5.8 [c]	12.3 [a]	17.9 [a]
T3-Soil + coir pith compost in 2:1 ratio	4.8 [a]	10.4 [ab]	13.7 [c]	T11-Soil + coir pith compost in 2:1 ratio	5.7 [c]	9.6 [e]	12.3 [d]
T4-Soil + coir pith compost in 1:2 ratio	3.6 [b]	10.0 [bc]	13.0 [d]	T12-Soil + coir pith compost in 1:2 ratio	6.8 [b]	10.5 [d]	12.1 [d]
T5-Soil + coir pith raw in 2:1 ratio	3.3 [b]	9.2 [cd]	13.0 [d]	T13-Soil + coir pith raw in 2:1 ratio	6.8 [b]	11.1 [c]	13.2 [c]
T6-Soil + coir pith raw in 1:2 ratio	2.5 [c]	8.2 [d]	13.2 [cd]	T14-Soil + coirpith raw in 1:2 ratio	5.2 [cd]	11.8 [ab]	13.8 [c]
T7-Soil + chaff in 2:1 ratio	4.7 [a]	11.5 [a]	15.0 [b]	T15-Soil+ chaff in 2:1 ratio	8.0 [a]	12.2 [a]	15.5 [b]
T8- Soil + chaff in 1:2 ratio	3.6 [b]	11.1 [ab]	14.6 [b]	T16-Soil+ chaff in 1:2 ratio	6.5 [b]	11.6 [b]	15.5 [b]
Mean	3.7	10.3	14.2	Mean	6.2	11.3	14.7

Treatments with the same alphabet do not differ significantly

The overall results indicated that both under wet and dry system, raising of mat nursery using soil cow dung mixture either in the ratio 2:1 or 1:2 produced seedlings with dark green colour.

4.1.3 Thickness of the root zone in wet and dry mat nursery as influenced by media of mat

Thickness of the root zone of the mat dismantled at the time of transplanting is given in Table 4.

Under dry nursery system a thicky mat of 21 mm was observed, when the media was soil with cow dung at the ratio of 2:1. A comparable thickness of the root zone was measured when the media of nursery was soil + coir pith raw 1:2 (T_6), and soil + chaff in the ratio of 2:1 (T_7) or 1:2 (T_8). A very thin root mat thickness of 15 mm was measured in case of soil + coir pith compost in the ratio of 1:2.

A root mat thickness of 24 mm was observed in case of soil + cow dung in 2:1 ratio in wet system. A comparable thicky mat was not produced by any of the other media. Lowest thickness under wet system was 16 mm observed when media was soil + coir pith compost in the ratio of 2:1.

The overall result indicated that a thicker root zone is formed in the mat when the media was prepared using soil + cow dung in the ratio of 2:1. A thinner root zone in both the situations was formed when soil and coir pith compost in the ratio of 1:2 was used as the media of the mat.

4.1.4 Number of healthy and weak seedlings per 100 cm^2 area at the time of transplanting as influenced by media of mat under wet and dry systems

The data on healthy and weak seedlings observed per unit area of 100 cm^2 of mat at the time of transplanting is given in Table 5.

The maximum number of healthy seedlings (124 per 100 cm^2) was observed in case of treatment T_3, wherein soil + coir pith compost at the ratio of 2:1 was prepared for mat under dry system. A comparable number of seedlings were

Table 3. Green colour scoring of the seedlings (1-10) as influenced by the media of the mat under wet and dry systems

Dry nursery T1-Soil +cow dung in 2:1 ratio	7
T2-Soil+ cow dung in 1:2 ratio	7
T3-Soil+ coir pith compost in 2:1 ratio	5
T4-Soil+ coir pith compost in 1:2 ratio	6
T5-Soil+ coir pith raw in 2:1 ratio	4
T6-Soil+ coir pith raw in 1:2 ratio	3
T7-Soil+ chaff in 2:1 ratio	7
T8-Soil+ chaff in 1:2 ratio	8
Wet nursery T9-Soil + cow dung in 2:1 ratio	10
T10-Soil+ cow dung in 1:2 ratio	10
T11-Soil+ coir pith compost in 2:1 ratio	5
T12-Soil+ coir pith compost in 1:2 ratio	6
T13-Soil+ coir pith raw in 2:1 ratio	6
T14-Soil+ coir pith raw in 1:2 ratio	7
T15-Soil+ chaff in 2:1 ratio	6
T16-Soil+ chaff in 1:2 ratio	6

Table 4. Thickness of the root zone (mm) of the mat at the time of transplanting as influenced by the media of the mat under wet and dry systems

Dry nursery	Thickness	Wet nursery	Thickness
T1-Soil+ cow dung in 2:1 ratio	21 [a]	T9-Soil+ cow dung in 2:1 ratio	24 [a]
T2-Soil+ cow dung in 1:2 ratio	15 [a]	T10-Soil+ cow dung in 1:2 ratio	17 [cd]
T3-Soil+ coir pith compost in 2:1 ratio	18 [a]	T11-Soil+ coir pith compost in 2:1 ratio	15 [d]
T4-Soil+ coir pith compost in 1:2 ratio	15 [a]	T12-Soil+ coir pith compost in 1:2 ratio	16 [d]
T5-Soil+ coir pith raw in 2:1 ratio	17 [a]	T13-Soil+ coir pith raw in 2:1 ratio	16 [d]
T6-Soil+ coir pith raw in 1:2 ratio	21 [a]	T14-Soil+ coir pith raw in 1:2 ratio	20 [b]
T7-Soil+ chaff in 2:1 ratio	18 [a]	T15-Soil+ chaff in 2:1 ratio	18 [bc]
T8-Soil+ chaff in 1:2 ratio	19 [a]	T16-Soil+ chaff in 1:2 ratio	16 [d]
Mean	18	Mean	18

Treatments with the same alphabet do not differ significantly

also produced when the media was prepared using soil and cow dung in the ratio 1:2 (T_2) or soil and chaff in the ratio 2:1 (T_7). Least number of weak seedlings was also seen in case of treatment T_3 and a comparably low number in case of treatment T_8. Very low number of healthy seedlings and high number of weak seedlings were observed in cases of soil-coir pith compost in the ratio 1:2 (T_4), soil + coir pith raw in the ratio 2:1 (T_5) or 1:2(T_6).

Under wet system, more number of healthy seedlings and very less number of weak seedlings were observed in the mat when soil + cow dung in the ratio of 2:1 (T_9) or 1:2 (T_{10}) was used. Low number of healthy seedlings and a high number of weak seedlings were observed when the media was soil + coir pith raw in the ratio 2:1 (T_{13}). Very high number of weak seedlings similar to the treatment T_{13} was also seen in case of T_{12} (soil + coir pith compost in the ratio of 1:2) and T_{14} (Soil+ coir pith raw in the ratio 1:2).

The overall results indicated that under dry system soil and cow dung in the ratio of 1:2 and soil and coir pith compost in the ratio 2:1 in the media produced maximum number of healthy seedlings and minimum number of weak seedlings, whereas in the wet system, such a situation is visible only in case of soil-cow dung mixture either in the ratio of 2:1 or 1:2.

4.1.5 Mat weight (g) per 100 cm^2 after overnight draining at transplanting as influenced by media of mat under wet and dry systems

The data on mat weight per unit area of 100 cm^2 after its overnight draining recorded at transplanting (Table 6) indicated that under dry system, the mat weight was not influenced by the different media in general. Maximum mat weight was recorded in case of treatment T_1 (Soil and cow dung in the ratio of 1:2) and the minimum in case of T_4 when the media was prepared using soil with coir pith compost in the ratio 1:2.

Under wet system, the mat of the treatment, T_9 weighed 332 g per 100 cm^2 area, which was significant over all other media tried except soil + chaff in the ratio 2:1. Mat raised using soil and coir pith compost in the ratio 2:1 had a medium weight and all other mat types were of light weight.

Table 5. Number of healthy and weak seedlings per 100 cm^2 at the time of transplanting as influenced by the media of the mat under wet and dry systems

Dry nursery	Healthy	Weak	**Wet nursery**	Healthy	Weak
T1-Soil+ cow dung in 2:1 ratio	84 ^{a}	37 ^{a}	T9-Soil+ cow dung in 2:1 ratio	114 ^{a}	17 ^{c}
T2-Soil+ cow dung in 1:2 ratio	100 ^{a}	43 ^{a}	T10-Soil+ cow dung in 1:2 ratio	132 ^{a}	31 ^{dc}
T3-Soil+ coir pith compost in 2:1 ratio	124 ^{a}	32 ^{a}	T11-Soil+ coir pith compost in 2:1 ratio	83 ^{a}	70 ^{b}
T4-Soil+ coir pith compost in 1:2 ratio	58 ^{a}	82 ^{a}	T12-Soil+ coir pith compost in 1:2 ratio	100 ^{a}	104 ^{a}
T5-Soil+ coir pith raw in 2:1 ratio	85 ^{a}	72 ^{a}	T13-Soil+ coir pith raw in 2:1 ratio	72 ^{a}	103 ^{a}
T6-Soil+ coir pith raw in 1:2 ratio	79 ^{a}	58 ^{a}	T14-Soil+ coir pith raw in 1:2 ratio	116 ^{a}	91 ^{a}
T7-Soil+ chaff in 2:1 ratio	106 ^{a}	63 ^{a}	T15-Soil+ chaff in 2:1 ratio	121 ^{a}	40 ^{cd}
T8-Soil+ chaff in 1:2 ratio	80 ^{a}	32 ^{a}	T16-Soil+ chaff in 1:2 ratio	100 ^{a}	57 ^{bc}
Mean	90	52	Mean	105	64

Treatments with the same alphabet do not differ significantly

Table 6. Mat weight (g) per 100 cm^2 after overnight draining at transplanting as influenced by the media of the mat under wet and dry systems

Dry nursery	Mat weight (g)	**Wet nursery**	Mat weight (g)
T1-Soil+ cow dung in 2:1 ratio	291 ^{a}	T9-Soil+ cow dung in 2:1 ratio	332 ^{a}
T2-Soil+ cow dung in 1:2 ratio	266 ^{a}	T10-Soil+ cow dung in 1:2 ratio	241 ^{c}
T3-Soil+ coir pith compost in 2:1 ratio	254 ^{a}	T11-Soil+ coir pith compost in 2:1 ratio	286 ^{b}
T4-Soil+ coir pith compost in 1:2 ratio	163 ^{a}	T12-Soil+ coir pith compost in 1:2 ratio	236 ^{c}
T5-Soil+ coir pith raw in 2:1 ratio	253 ^{a}	T13-Soil+ coir pith raw in 2:1 ratio	238 ^{c}
T6-Soil+ coir pith raw in 1:2 ratio	233 ^{a}	T14-Soil+ coir pith raw in 1:2 ratio	238 ^{c}
T7-Soil+ chaff in 2:1 ratio	268 ^{a}	T15-Soil+ chaff in 2:1 ratio	325 ^{a}
T8-Soil+ chaff in 1:2 ratio	269 ^{a}	T16-Soil+ chaff in 1:2 ratio	221 ^{c}
Mean	250	Mean	265

Treatments with the same alphabet do not differ significantly

The overall result indicated that under both systems, soil + cow dung in the ratio of 2:1 produced heavy mats and soil + coir pith compost in the ratio of 1:2 produced light mats.

4.1.6 Root length (mm) at transplanting

Root length recorded at the time of transplanting (Table 7) indicated that under dry system, the seedlings put up its root growth identically without any variation in its length with respect to the media for root growth. Root growth of seedlings ranged between 63 mm to 80 mm. Root length was not significantly influenced in wet system also by the different media.

The overall indication is that both under dry and wet systems, growth of the root was not influenced by the different media.

4.1.7 Strength of the mat (g) at transplanting

Mat with strong cohesiveness (Table 8) was developed when the media was soil and chaff in the ratio of 1:2 or 2:1 under dry system. When media was soil + cow dung either in 2:1 or 1:2 ratio, or soil coir pith raw in the ratio of 2:1 was used, the cohesiveness of the mat was lowest.

A reverse pattern in seen in the wet system. Soil and cow dung in the media either in the ratio 2:1 or 1:2 produced stronger mats than all other media, except soil + coir pith raw in the ratio of 1:2. Soil + coir pith compost in the ratio of 2:1 produced a mat with least cohesive strength.

The overall results indicated that a very cohesive mat can be prepared under dry system, if soil is mixed with chaff in the ratio of 2:1 or 1:2, while the mat media is prepared. If soil + cow dung is used either in the ratio 2:1 or 1:2, dry system offers mat with lesser strength, whereas the wet system offers mat with very cohesive strength.

4.2 Observations on performance of the transplanter

4.2.1 Transplanting time and area transplanted at the forward speed

The different systems of nursery or the media of the nursery mat did not affect forward speed of the transplanter and hence the transplanting time remained

Table 7. Root length (mm) at transplanting as influenced by the media of the mat under wet and dry systems

Dry nursery	Root length (mm)	Wet nursery	Root length (mm)
T1-Soil+ cow dung in 2:1 ratio	69 [a]	T9-Soil+ cow dung in 2:1 ratio	76 [a]
T2-Soil+ cow dung in 1:2 ratio	66 [a]	T10-Soil+ cow dung in 1:2 ratio	68 [a]
T3-Soil+ coir pith compost in 2:1 ratio	68 [a]	T11-Soil+ coir pith compost in 2:1 ratio	56 [a]
T4-Soil+ coir pith compost in 1:2 ratio	70 [a]	T12-Soil+ coir pith compost in 1:2 ratio	66 [a]
T5-Soil+ coir pith raw in 2:1 ratio	63 [a]	T13-Soil+ coir pith raw in 2:1 ratio	77 [a]
T6-Soil+ coir pith raw in 1:2 ratio	80 [a]	T14-Soil+ coir pith raw in 1:2 ratio	61 [a]
T7-Soil+ chaff in 2:1 ratio	64 [a]	T15-Soil+ chaff in 2:1 ratio	65 [a]
T8-Soil+ chaff in 1:2 ratio	73 [a]	T16-Soil+ chaff in 1:2 ratio	80 [a]
Mean	69	Mean	66

Treatments with the same alphabet do not differ significantly

Table 8. Strength of the mat at transplanting as influenced by the media of the mat under wet and dry systems

Dry nursery	Strength (g)	Wet nursery	Strength (g)
T1-Soil+ cow dung in 2:1 ratio	2433 [d]	T9-Soil+ cow dung in 2:1 ratio	4800 [a]
T2-Soil+ cow dung in 1:2 ratio	2967 [cd]	T10-Soil+ cow dung in 1:2 ratio	4833 [a]
T3-Soil+ coir pith compost in 2:1 ratio	4267 [b]	T11-Soil+ coir pith compost in 2:1 ratio	2367 [d]
T4-Soil+ coir pith compost in 1:2 ratio	3267 [c]	T12-Soil+ coir pith compost in 1:2 ratio	3433 [c]
T5-Soil+ coir pith raw in 2:1 ratio	2967 [cd]	T13-Soil+ coir pith raw in 2:1 ratio	3167 [c]
T6-Soil+ coir pith raw in 1:2 ratio	3333 [c]	T14-Soil+ coirpith raw in 1:2 ratio	5233 [a]
T7-Soil+ chaff in 2:1 ratio	5433 [a]	T15-Soil+ chaff in 2:1 ratio	4033 [b]
T8-Soil+ chaff in 1:2 ratio	4833 [ab]	T16-Soil+ chaff in 1:2 ratio	3033 [c]
Mean	3688	Mean	3863

Treatments with the same alphabet do not differ significantly

unaffected due to different treatments (Table 9). The transplanting time varied from the minimum of 3.6 s m^{-1} run to the maximum of 4.6 s m^{-1} run. The lowest time was required when the media was soil + chaff in the ratio 2:1 (T_{15}) under wet system and the highest, with the same media under dry system (T_7). The area transplanted by the machine using different mat nurseries ranged from 23m^2 min^{-1} as in case of T_7, to 30 m^2 min^{-1} in the case of T_{15}. The respective turnover for the machine was worked out to be 1.104 to 1.44 ha per day of 8 hours. However, there was no statistical difference between area transplanted by the machine using mat nursery having different media for sowing and systems of its raising, meaning that 7 hours 15 minutes and 5 hours 34 minutes were required for transplanting one hectare at the respective speeds.

4.2.2 Plant population

The overall mean of population under dry nursery was 29 hills m^{-2}, whereas under wet system, it was 27 hills m^{-2}. Even though the population varied between 21 to 32 hills m^{-2} depending upon the media and systems of nursery, the treatments had no influence on the plant population as per statistical analysis.

Under dry system, 32 hills m^{-2} was planted when the media was soil and chaff in the ratio of 2:1 (T_7) and the lowest population was when soil + chaff in 1:2 ratio (T_8) or soil + coir pith compost in 1:2 ratio (T_4) was used as the media.

Under wet system, mat produced using soil + chaff in the ratio 2:1 (T_{15}) or soil + coir pith compost in the ratio 1:2 (T_{12}) led to maximum plant population of 32 hills m^{-2}. The lowest population of 21 was seen when soil was mixed with cow dung in 1:2 ratio (T_{10}).

4.2.3 Missing hills

Row to row design spacing of the transplanter was 22.5 cm and it was run with the gear engaged for 12 cm within the row planting. Hence the total number of hills to be planted by the transplanter is 37 m^{-2}. The number of hills planted m^{-2} by the transplanter is given in Table 9 along with the number of missing hills. The results indicated that either the system of nursery or the different nursery media did not significantly affect the number of missing hills. The lowest number of missing hills (5 numbers m^{-2}) was seen both under dry and wet nursery systems, when the nursery media was prepared with soil and chaff in the ratio 2:1(T_7).

Under this situation, missing hills was only 14 per cent. The higher number of missing hills ranging from 14-16 m^{-2}, i.e., 38-43 per cent of the total to be planted was seen associated with the mat media soil + cow dung either in the ratio of 2:1 or 1:2 under wet nursery system. In general, the number of missing hills was lower under dry system, when compared to wet system.

4.2.3 Number of seedlings $hill^{-1}$

Neither the system of mat nursery nor the different media tried altered the number of seedlings $hill^{-1}$ transplanted, which ranged from 3 to 4.4 (Table 9). Similarly, the number of seedlings floating while transplanting, i.e. number of seedlings that are not firmly fixed to the soil and have fallen down from the hill, was also not varying due to nursery systems or media. The number of the fallen seedlings ranged from 1.5 to 2.2, which means 43 to 50 per cent of the seedlings of a hill were either falling down or not fixed to the soil by the fingers of the transplanter.

4.2.4 Planting depth

Planting depth (Table 9) was not affected by the nursery systems, or media of nursery. The average planting depth was 49 mm, ranging from 38 to 54 mm.

4.3 Observations on performance of the crop

4.3.1 Number of hills m^{-2}

Plant population observed through the number of hills m^{-2} (Table 10) indicated that the plant population obtained through mechanical planting was significantly lower compared to the plant population obtained by manual planting. This trend was visible at the three stages of the observation i.e. at planting, maximum tillering and also at harvest. While 65 hills m^{-2} were available in conventional nursery planted crop at harvest, the average density of population in the mechanically transplanted crop was 29 $hillsm^{-2}$. Even though initially there were slight differences in plant population, between mechanically transplanted crops with respect to the media of mat, this trend diminished with the advancement of growth and plant population of the mechanically transplanted crops did not show any significant difference between them. The system of nursery also did not

Table 9. Performance of transplanted as influenced by media and systems of nursery

Treatments	Time taken (seconds)	Transplanting time (S m^{-1})	Area transplanted (m^2 min^{-1})	Area planted (ha per hr)	Plant population m^{-2}	Missing hills m^{-2}	Missing hills (%)	Seedlings hill^{-1}	Seedlings damaged (floating)	Damage (%)	Planting depth (mm)
Dry nursery											
T1-Soil +cow dung in 2:1 ratio	64^{a}	4.0^{a}	27^{a}	0.162^{a}	31^{a}	6^{a}	16^{a}	4.2^{a}	2.1^{a}	50^{a}	54^{a}
T2-Soil+ cow dung in 1:2 ratio	63^{a}	3.9^{a}	28^{a}	0.168^{a}	30^{a}	7^{a}	19^{a}	4.1^{a}	2.0^{a}	49^{a}	49^{a}
T3-Soil+ coir pith compost in 2:1 ratio	65^{a}	4.1^{a}	26^{a}	0.156^{a}	29^{a}	8^{a}	22^{a}	3.8^{a}	1.9^{a}	50^{a}	49^{a}
T4-Soil+ coir pith compost in 1:2 ratio	62^{a}	3.9^{a}	28^{a}	0.168^{a}	26^{a}	11^{a}	30^{a}	3.8^{a}	1.7^{a}	45^{a}	54^{a}
T5-Soil+ coir pith raw in 2:1 ratio	65^{a}	4.1^{a}	26^{a}	0.156^{a}	31^{a}	6^{a}	16^{a}	4.0^{a}	2.1^{a}	53^{a}	38^{a}
T6-Soil+ coir pith raw in 1:2 ratio	63^{a}	3.9^{a}	28^{a}	0.168^{a}	29^{a}	8^{a}	22^{a}	3.0^{a}	1.5^{a}	50^{a}	43^{a}
T7-Soil+ chaff in 2:1 ratio	73^{a}	4.6^{a}	23^{a}	0.138^{a}	32^{a}	5^{a}	14^{a}	4.3^{a}	2.0^{a}	47^{a}	46^{a}
T8-Soil+ chaff in 1:2 ratio	65^{a}	4.0^{a}	27^{a}	0.162^{a}	26^{a}	11^{a}	30^{a}	3.5^{a}	1.8^{a}	51^{a}	54^{a}
Wet nursery											
T9-Soil + cow dung in 2:1 ratio	63^{a}	3.9^{a}	28^{a}	0.168^{a}	23^{a}	14^{a}	38^{a}	4.0^{a}	1.8^{a}	45^{a}	49^{a}
T10-Soil+ cow dung in 1:2 ratio	63^{a}	3.9^{a}	28^{a}	0.168^{a}	21^{a}	16^{a}	43^{a}	3.9^{a}	2.1^{a}	54^{a}	50^{a}
T11-Soil+ coir pith compost in 2:1 ratio	71^{a}	4.4^{a}	25^{a}	0.150^{a}	29^{a}	8^{a}	22^{a}	4.4^{a}	2.1^{a}	48^{a}	41^{a}
T12-Soil+ coir pith compost in 1:2 ratio	63^{a}	3.9^{a}	28^{a}	0.168^{a}	32^{a}	5^{a}	14^{a}	4.4^{a}	2.0^{a}	45^{a}	46^{a}
T13-Soil+ coir pith raw in 2:1 ratio	64^{a}	4.0^{a}	27^{a}	0.162^{a}	26^{a}	11^{a}	30^{a}	3.5^{a}	1.5^{a}	43^{a}	61^{a}
T14-Soil+ coir pith raw in 1:2 ratio	68^{a}	4.3^{a}	25^{a}	0.150^{a}	24^{a}	13^{a}	35^{a}	3.9^{a}	2.0^{a}	51^{a}	41^{a}
T15-Soil+ chaff in 2:1 ratio	57^{a}	3.6^{a}	30^{a}	0.180^{a}	32^{a}	5^{a}	14^{a}	4.3^{a}	2.0^{a}	47^{a}	54^{a}
T16-Soil+ chaff in 1:2 ratio	67^{a}	4.2^{a}	26^{a}	0.156^{a}	31^{a}	6^{a}	16^{a}	4.4^{a}	2.2^{a}	50^{a}	52^{a}
Mean	65	4.0	27	0.162	28	9	24	4.0	1.9	49	49

Treatments with the same alphabet do not differ significantly

influence the plant population at harvest. There was 22 per cent reduction in the number of hills in mechanically transplanted crop than that of manually planted crop.

4.3.2 Plant height

Plant height observed at 15 days interval from 15 DAT onwards revealed that (Table 11) only up to 30 DAT, there was significant variation in stature of the plant due to media as well as systems of nursery. Thereafter, neither the system of mat nursery, nor the different media used in it influenced the growth of the plants in terms of height. The crops transplanted mechanically as well as manually were of equal heights. The crop had on an average 65, 80.4, 92.7 and 89.1 cm height at 45, 60, 75 and 90 DAT.

4.3.3 Tillers hill^{-1}

Number of tillers produced hill^{-1} observed from active tillering stage onwards at 15 days interval revealed that (Table12) throughout the growth period, mechanically transplanted crop using wet mat nursery with soil + cow dung in the ratio 1:2 (T_{10}) as the media produced significantly higher number of tillers hill^{-1}. This crop had an average of 17.5 tillers hill^{-1} at 80 DAT. Throughout the growth period, crop raised by manual planting (T_{17}) using conventional nursery had a significantly lower number of tillers, which ranged from 6.5 tillers hill^{-1} at active tillering stage to 9.5 tillers hill^{-1} at 80 DAT. A consistently higher number of tillers similar to T_{10} was produced throughout the growth period by the mechanically transplanted crop, with dry mat nursery using soil + coir pith raw in the ratio 2:1 (T_5). Most of the treatments involving mechanical transplanting (T_1, T_4, T_8, T_{11}, T_{12}, T_{15} and T_{16}) were having comparably low production of tillers similar to that of manually planted crop (T_{17}) at the final observation, i.e., 80 DAT. However, these treatments were also comparable to all the other mechanically transplanted crops except T_5 and T_{10}.

Table 10. Plant population m^{-2} at planting, maximum tillering and harvest (Experiment II)

Treatments	Planting	Maximum tillering	Harvest
Dry nursery			
T1-Soil +cow dung in 2:1 ratio	31^{b}	31^{bc}	31^{b}
T2-Soil+ cow dung in 1:2 ratio	30^{bc}	28^{bc}	27^{b}
T3-Soil+ coir pith compost in 2:1 ratio	29^{bcd}	30^{bc}	27^{b}
T4-Soil+ coir pith compost in 1:2 ratio	27^{bcd}	26^{bc}	23^{b}
T5-Soil+ coir pith raw in 2:1 ratio	31^{b}	34^{b}	32^{b}
T6-Soil+ coir pith raw in 1:2 ratio	29^{bcd}	30^{bc}	29^{b}
T7-Soil+ chaff in 2:1 ratio	32^{b}	32^{bc}	32^{b}
T8-Soil+ chaff in 1:2 ratio	26^{bcd}	27^{bc}	23^{b}
Wet nursery			
T9-Soil + cow dung in 2:1 ratio	23^{cd}	28^{bc}	30^{b}
T10-Soil+ cow dung in 1:2 ratio	22d	24^{c}	25^{b}
T11-Soil+ coir pith compost in 2:1 ratio	29^{bcd}	32^{bc}	32^{b}
T12-Soil+ coir pith compost in 1:2 ratio	32^{b}	32^{bc}	30^{b}
T13-Soil+ coir pith raw in 2:1 ratio	26^{bcd}	26^{bc}	25^{b}
T14-Soil+ coir pith raw in 1:2 ratio	25^{bcd}	29^{bc}	27^{b}
T15-Soil+ chaff in 2:1 ratio	33^{b}	32^{bc}	32^{b}
T16-Soil+ chaff in 1:2 ratio	32^{b}	33^{b}	33^{b}
T17- Conventional nursery	67^{a}	67^{a}	65^{a}
Mean	31	32	31

Treatments with the same alphabet do not differ significantly

Table 11. Plant height (cm) at 15 days interval (Experiment II)

Treatments	Plant height (cm)					
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Dry nursery T1-Soil +cow dung in 2:1 ratio	31.1 a	46.9 abc	67.5 a	83.8 a	96.1 a	91.8 a
T2-Soil+ cow dung in 1:2 ratio	31.6 a	51.0 a	68.7 a	86.1 a	99.3 a	95.6 a
T3-Soil+ coir pith compost in 2:1 ratio	29.4 abc	44.7 cd	62.8 a	78.0 a	92.5 a	89.1 a
T4-Soil+ coir pith compost in 1:2 ratio	29.4 abc	45.9 bc	66.3 a	82.4 a	93.6 a	89.4 a
T5-Soil+ coir pith raw in 2:1 ratio	31.3 a	50.6 a	67.0 a	81.8 a	92.9 a	89.9 a
T6-Soil+ coir pith raw in 1:2 ratio	30.0 ab	45.3 c	65.2 a	81.1 a	93.3 a	90.1 a
T7-Soil+ chaff in 2:1 ratio	29.1 abc	44.1 cd	61.2 a	76.2 a	88.7 a	86.5 a
T8-Soil+ chaff in 1:2 ratio	28.7 abc	44.2 cd	64.1 a	78.8 a	90.6 a	86.7 a
Wet nursery T9-Soil + cow dung in 2:1 ratio	30.0 ab	44.6 cd	63.5 a	79.7 a	92.6 a	89.1 a
T10-Soil + cow dung in 1:2 ratio	31.2 a	49.7 ab	69.8 a	84.9 a	98.1 a	94.5 a
T11-Soil+ coir pith compost in 2:1 ratio	29.1 abc	45.9 bc	65.0 a	80.0 a	92.0 a	88.9 a
T12-Soil+ coir pith compost in 1:2 ratio	27.2 bc	40.7 d	61.1 a	76.9 a	88.1 a	85.4 a
T13-Soil+ coir pith raw in 2:1 ratio	26.9 c	44.0 cd	63.9 a	80.0 a	92.7 a	89.9 a
T14-Soil+ coir pith raw in 1:2 ratio	29.4 abc	44.5 cd	65.7 a	81.4 a	92.9 a	89.5 a
T15-Soil+ chaff in 2:1 ratio	29.2 abc	45.4 c	65.6 a	81.0 a	93.0 a	90.0 a
T16-Soil+ chaff in 1:2 ratio	30.8 a	48.0 abc	65.9 a	80.1 a	92.0 a	89.0 a
T17- Conventional nursery	27.0 c	43.9 cd	62.1 a	75.7 a	87.1 a	85.0 a
Mean	29.5	45.8	65.0	80.4	92.7	89.1

Treatments with the same alphabet do not differ significantly

Table 12. Tillers hill^{-1} at 15 days interval (Experiment II)

Treatments	Tillers hill^{-1}				
	20 DAT	35 DAT	50 DAT	65 DAT	80 DAT
Dry nursery					
T1-Soil +cow dung in 2:1 ratio	12.9^{bcd}	15.6^{cd}	14.5^{d}	13.2^{cd}	11.6^{cd}
T2-Soil+ cow dung in 1:2 ratio	15.9^{ab}	18.8^{abc}	16.7^{cd}	15.3^{bc}	13.5^{bc}
T3-Soil+ coir pith compost in 2:1 ratio	12.5^{cd}	16.3^{bcd}	16.5^{cd}	15.3^{bc}	14.1^{bc}
T4-Soil+ coir pith compost in 1:2 ratio	11.9^{d}	15.7^{bcd}	14.6^{d}	12.9^{cd}	11.0^{cd}
T5-Soil+ coir pith raw in 2:1 ratio	15.4^{abc}	19.1^{ab}	19.3^{ab}	17.3^{ab}	15.2^{ab}
T6-Soil+ coir pith raw in 1:2 ratio	11.6^{d}	17.4^{bcd}	17.4^{bc}	15.4^{bc}	13.5^{bc}
T7-Soil+ chaff in 2:1 ratio	12.9^{bcd}	17.3^{bcd}	17.0^{bcd}	15.4^{bc}	13.8^{bc}
T8-Soil+ chaff in 1:2 ratio	14.2^{bcd}	17.9^{bcd}	16.2^{cd}	13.7^{cd}	11.9^{cd}
Wet nursery					
T9-Soil + cow dung in 2:1 ratio	12.2^{cd}	17.3^{bcd}	16.5^{cd}	15.0^{bc}	13.8^{bc}
T10-Soil+ cow dung in 1:2 ratio	18.0^{a}	21.4^{a}	21.2^{a}	19.4^{a}	17.5^{a}
T11-Soil+ coir pith compost in 2:1 ratio	12.4^{cd}	16.4^{bcd}	16.2^{cd}	14.1^{bcd}	12.3^{bcd}
T12-Soil+ coir pith compost in 1:2 ratio	11.1^{d}	15.2^{d}	15.4^{cd}	13.3^{cd}	11.9^{cd}
T13-Soil+ coir pith raw in 2:1 ratio	13.4^{bcd}	18.6^{abcd}	16.8^{bcd}	14.9^{bc}	13.4^{bc}
T14-Soil+ coir pith raw in 1:2 ratio	12.8^{bcd}	18.4^{abcd}	16.9^{bcd}	15.4^{bc}	13.9^{bc}
T15-Soil+ chaff in 2:1 ratio	12.1^{cd}	16.9^{bcd}	15.9^{cd}	14.7^{bc}	12.5^{bcd}
T16-Soil+ chaff in 1:2 ratio	10.9^{d}	16.0^{bcd}	14.7^{d}	13.5^{cd}	11.6^{cd}
T17- Conventional nursery	6.5^{e}	10.2^{e}	11.3^{e}	11.0^{d}	9.5^{d}
Mean	12.8	17.0	16.3	14.7	13.0

Treatments with the same alphabet do not differ significantly

4.3.4 Physiological growth attributes

4.3.4.1 CGR

Crop growth rate at active tillering stage was distinctively lower in case of manually planted crop using conventional nursery compared to most of the mechanically transplanted crops using either dry or wet mat nursery (Table 13). Exception to this was in case of soil + coir pith raw in the ratio 2:1 (T_5) or 1:2 (T_6) in dry nursery and soil and coir pith raw (T_{12}) or compost (T_{14}) in the ratio 1:2 in wet system. But this distinctiveness of low CGR for manually planted crop disappeared as growth progressed to panicle initiation stage. The mechanically transplanted crop, using wet or dry nursery, irrespective of root zone media and the manually planted crop with conventional nursery had similar crop growth rate between active tillering and panicle initiation stage. The value ranged between 4.73 to 6.5 g m^{-2} day^{-1}.

4.3.4.2 RGR

Relative growth rate values (Table 13) also indicated a very low growth rate for manually transplanted crop (T_{17}) during the period from seedling to active tillering stage. The mechanically transplanted crop had significantly higher RGR than the manually planted crop, except in cases of soil + cow dung in the ratio 2:1 (T_1), soil + coir pith raw in the ratio 2:1 (T_5) or 1:2 (T_6) under dry nursery system and soil + coir pith compost (T_{12}) soil+ coir pith raw in 1:2 ratio (T_{14}), both under wet nursery system. But during the period from active tillering to panicle initiation stage, the relative growth rate of the crop was similar, disregarding the method of planting and system as well as media of nursery. RGR varied from 0.042 to 0.056 g g^{-1} day^{-1} with an average of 0.088 g g^{-1} day^{-1} at panicle initiation stage.

4.3.4.3 NAR

Net assimilation rate worked out at active tillering stage (Table 13) showed a different picture in comparison to CGR and RGR. NAR was significantly higher in crops mechanically transplanted using dry nursery with soil + chaff in the ratio 2:1 as media (T_7) or wet nursery with soil + coir pith raw in the ratio 2:1 (T_{13}) or soil + chaff in the ratio 2:1 (T_{15}). NAR was also significantly lower in case of

Table 13. Physiological growth attributes at active tillering and panicle initiation stages (Experiment II)

Treatments	CGR (g m^{-2} day^{-1})		RGR(g g^{-1} day^{-1})		NAR(g m^{-} day^{-1})		LAI		LAD(m^{2} days)	
	Active tillering stage	Panicle initiation stage	Active tillering stage	Panicle initiation stage	Active tillering stage	Panicle initiation stage	Active tillering stage	Panicle initiation stage	Active tillering stage	Panicle initiation stage
Dry nursery										
T1-Soil +cow dung in 2:1 ratio	2.390^{bcd}	4.730^{a}	0.0820^{def}	0.0420^{a}	0.0670^{e}	0.0140^{a}	2.695^{a}	4.595^{a}	2.430^{a}	3.617^{a}
T2-Soil+ cow dung in 1:2 ratio	2.725^{ab}	5.405^{a}	0.0910^{abcde}	0.0470^{a}	0.0830^{b}	0.0180^{a}	2.815^{a}	4.460^{a}	2.570^{a}	3.615^{a}
T3-Soil+ coir pith compost in 2:1 ratio	2.950^{a}	6.035^{a}	0.0990^{ab}	0.0550^{a}	0.0860^{b}	0.0230^{a}	2.500^{a}	4.125^{a}	2.376^{a}	3.442^{a}
T4-Soil+ coir pith compost in 1:2 ratio	2.610^{abc}	5.270^{a}	0.0890^{bcde}	0.0470^{a}	0.0790^{cd}	0.0170^{a}	2.745^{a}	4.145^{a}	2.510^{a}	3.584^{a}
T5-Soil+ coir pith raw in 2:1 ratio	2.255^{cde}	4.960^{a}	0.0800^{ef}	0.0440	0.0610^{f}	0.0150^{a}	2.975^{a}	4.140^{a}	2.706^{a}	3.783^{a}
T6-Soil+ coir pith raw in 1:2 ratio	1.960^{e}	4.745^{a}	0.0720^{f}	0.0430^{a}	0.0570^{h}	0.0140^{a}	2.945^{a}	4.205^{a}	2.658^{a}	3.698^{a}
T7-Soil+ chaff in 2:1 ratio	2.980^{a}	6.530^{a}	0.1000^{a}	0.0560^{a}	0.0890^{a}	0.0260^{a}	3.065^{a}	3.870^{a}	2.740^{a}	3.336^{a}
T8-Soil+ chaff in 1:2 ratio	2.650^{abc}	5.675^{a}	0.0880^{bcde}	0.0490^{a}	0.0780^{cd}	0.0190^{a}	3.015^{a}	3.930^{a}	2.792^{a}	3.337^{a}
Wet nursery										
T9-Soil + cow dung in 2:1 ratio	2.615^{abc}	5.635^{a}	0.0870^{cde}	0.0500^{a}	0.0780^{d}	0.0190^{a}	3.380^{a}	4.395^{a}	2.965^{a}	3.658^{a}
T10-Soil+ cow dung in 1:2 ratio	2.850^{a}	6.365^{a}	0.0950^{abc}	0.0530^{a}	0.0850^{d}	0.0250^{a}	3.460^{a}	4.485^{a}	3.013^{a}	4.021^{a}
T11-Soil+ coir pith compost in 2:1 ratio	2.680^{ab}	6.025^{a}	0.0920^{abcde}	0.0520^{a}	0.0800^{c}	0.0230^{a}	2.515^{a}	3.850^{a}	2.361^{a}	3.386^{a}
T12-Soil+ coir pith compost in 1:2 ratio	2.345^{bcde}	5.225^{a}	0.0810^{def}	0.0470^{a}	0.0680^{e}	0.0160^{a}	2.880^{a}	4.150^{a}	2.658^{a}	3.706^{a}
T13-Soil+ coir pith raw in 2:1 ratio	2.835^{a}	6.370^{a}	0.0960^{abc}	0.0550^{a}	0.0890^{a}	0.0250^{a}	2.815^{a}	3.725^{a}	2.626^{a}	3.247^{a}
T14-Soil+ coirpith raw in 1:2 ratio	2.010^{de}	4.355^{a}	0.0730^{f}	0.0410^{a}	0.0570^{gh}	0.0140^{a}	3.130^{a}	4.400^{a}	2.789^{a}	3.836^{a}
T15-Soil+ chaff in 2:1 ratio	2.965^{a}	6.290^{a}	0.0980^{abc}	0.0550^{a}	0.0910^{a}	0.0220^{a}	2.645^{a}	4.090^{a}	2.456^{a}	3.463^{a}
T16-Soil+ chaff in 1:2 ratio	2.855^{a}	6.370^{a}	0.0950^{abc}	0.0550^{a}	0.0850^{b}	0.0240^{a}	2.430^{a}	3.720^{a}	2.386^{a}	3.229^{a}
T17- Conventional nursery	2.035^{de}	5.240^{a}	0.0730^{f}	0.0470^{a}	0.0590^{fg}	0.0170^{a}	2.790^{a}	3.770^{a}	2.615^{a}	3.270^{a}
Mean	2.571	5.601	0.0880	0.0490	0.0760	0.0190	2.871	4.121	2.627	3.543

Treatments with the same alphabet do not differ significantly

mechanically transplanted crop, when the media used was soil + coir pith raw in the ratio 1:2 both under dry (T_6) and wet system (T_{14}).

However, during the period from active tillering to panicle initiation stage, net assimilation rate was not altered by the different treatments. The crop under manual or mechanical transplanting irrespective of the system and media of the mat nursery raised for mechanical transplanting showed a similar assimilation rate.

4.3.4.4 LAI

The values of leaf area per unit land area were not affected by the different treatments when observed both at active tillering and panicle initiation stages. Crop under mechanical transplanting and manual planting produced a similar LAI, at both the stages with an average value of 2.87 at active tillering and 4.12 at panicle initiation stage. The value ranged from 2.5 to 3.5 at active tillering stage and from 3.72 to 4.6 at panicle initiation stage.

4.3.4.5 LAD

Leaf area duration showed a similar pattern as that of LAI. The average LAD was 2.63 m^2 days for the crop at active tillering stage and the different treatments did not alter LAD at active tillering stage. The average value of LAD at panicle initiation stage was 3.543 m^2 days, which was also not affected by different treatments.

4.3.5 Number of weeds m^{-2}

The weed count taken from one square metre area both at 20 and 40 DAT (Table 14) indicated that weed population was not significantly altered by the different treatments. The overall mean weed density at 20 DAT was 130 and at 40 DAT, 94. The corresponding weed density for conventionally planted crop was 156 and 106 respectively. The predominant weed species present in the area were *Cyperus iria, Isachne miliacea, Ludwigia parviflora, Echinochloa* sp., *Mollugo sp., Nymphaea stellata, Schoenoplectus lateriflorus* and *Sphenoclea zeylanica*

Table 14. No. of weeds m^{-2} at 20 and 40 days after planting (Experiment II)

Treatments	Weed No. m^{-2}	
	20 DAT	40 DAT
Dry nursery		
T1-Soil +cow dung in 2:1 ratio	140 ^{a} (11.84)	162 ^{a} (12.75)
T2-Soil+ cow dung in 1:2 ratio	62 ^{a} (7.82)	106 ^{a} (10.24)
T3-Soil+ coir pith compost in 2:1 ratio	180 ^{a} (12.96)	56 ^{a} (7.40)
T4-Soil+ coir pith compost in 1:2 ratio	130 ^{a} (11.16)	70 ^{a} (7.75)
T5-Soil+ coir pith raw in 2:1 ratio	102 ^{a} (9.74)	62 ^{a} (7.91)
T6-Soil+ coir pith raw in 1:2 ratio	70 ^{a} (8.33)	50 ^{a} (7.04)
T7-Soil+ chaff in 2:1 ratio	72 ^{a} (8.50)	64 ^{a} (7.97)
T8-Soil+ chaff in 1:2 ratio	184 ^{a} (13.37)	68 ^{a} (8.14)
Wet nursery		
T9-Soil + cow dung in 2:1 ratio	188 ^{a} (13.52)	106 ^{a} (10.18)
T10-Soil+ cow dung in 1:2 ratio	92 ^{a} (9.54)	84 ^{a} (8.04)
T11-Soil+ coir pith compost in 2:1 ratio	124 ^{a} (11.09)	66 ^{a} (8.04)
T12-Soil+ coir pith compost in 1:2 ratio	140 ^{a} (11.64)	110 ^{a} (10.41)
T13-Soil+ coir pith raw in 2:1 ratio	106 ^{a} (10.01)	96 ^{a} (9.19)
T14-Soil+ coirpith raw in 1:2 ratio	88 ^{a} (9.25)	74 ^{a} (8.45)
T15-Soil+ chaff in 2:1 ratio	200 ^{a} (14.14)	194 ^{a} (13.88)
T16-Soil+ chaff in 1:2 ratio	174 ^{a} (13.02)	124 ^{a} (11.14)
T17- Conventional nursery	156 ^{a} (12.41)	106 ^{a} (10.32)
Mean	130 (11.08)	94 (9.41)

Treatments with the same alphabet do not differ significantly

Values in parentheses denote transformed value

4.3.6 Disease and pest incidence

The scoring done for the pest and disease attack is given in Table 15. Among the diseases bacterial leaf blight (BLB) was the only problem during the course of study. Incidence of BLB was to the tune of 13.9 and 13.3 per cent respectively in mechanically transplanted crop, when the mat used was with soil + coir pith compost in 2:1 ratio (T_3) under dry system of nursery or soil + coir pith compost in 2:1 ratio (T_{13}) in wet nursery. The remaining treatments had fairly low bacterial leaf blight incidence. The overall incidence percentage was on 7.3.

The insect pest incidence was uniform, the insect pests showing no discrimination over the crop based on different treatments. None of the pests observed showed any preference over the treatments. The average number of thrips per hill was 47 at 20 DAT. The average number of rice bug per hill was 1.8 at 69 DAT and that of green leafhopper was 3.1 and 3.4 respectively at 22 and 54 DAT. The average stem borer percentage at 70 and 85 DAT was 1.9 and 2.9 respectively.

4.3.7 Yield components

4.3.7.1 Total number of panicles m^{-2}

The data recorded on yield attributes as influenced by the different treatments are given in Table 16. The total number of panicles m^{-2} formed remained unaffected due to various treatments. The crop raised under manual planting using conventional nursery produced 284 panicles m^{-2}. Under mechanised transplanting using different types of mat nurseries, the panicle production ranged from 309 panicles m^{-2} as in case of soil + coir pith raw in the ratio 1:2 (T_6) in dry nursery to 220 panicles m^{-2} as in case of soil + cow dung in the ratio 2:1 (T_9) in wet nursery system.

4.3.7.2 Late formed panicles m^{-2}

Data on late formed panicles m^{-2} (those panicles which remained greenish at the time of harvest) given in Table 16, indicated that high number of late formed panicles were seen only in 3 mechanised planting situations i.e., when soil + coir pith raw in the ratio of 1:2 (T_6) under dry system or soil + coir pith compost in the

Table 15. Disease and pest incidence at 15 days interval (Experiment II)

Treatments	Bacterial leaf blight (%) 51 DAT	Thrips hill^{-1} 20 DAT	Rice bug hill^{-1} 69 DAT	Green leaf hopper hill^{-1}		Stem borer (%)	
				22 DAT	54 DAT	70 DAT	85 DAT
Dry nursery							
T1-Soil +cow dung in 2:1 ratio	4.4^{c}	50^{a}	2.0^{a}	2.6^{a} (1.7)	3.8^{a} (2.1)	1.1^{a} (0.1)	3.1^{a} (0.1)
T2-Soil+ cow dung in 1:2 ratio	6.4^{c}	46^{a}	2.0^{a}	2.9^{a} (1.8)	4.6^{a} (2.2)	2.7^{a} (0.2)	0.4^{a} (0.1)
T3-Soil+ coir pith compost in 2:1 ratio	13.9^{a}	44^{a}	1.9^{a}	3.1^{a} (1.9)	3.7^{a} (2.0)	2.2^{a} (0.1)	3.5^{a} (0.2)
T4-Soil+ coir pith compost in 1:2 ratio	7.8^{c}	49^{a}	1.4^{a}	4.2^{a} (2.2)	4.4^{a} (2.2)	0.4^{a} (0.1)	1.5^{a} (0.1)
T5-Soil+ coir pith raw in 2:1 ratio	6.5^{c}	50^{a}	2.0^{a}	4.3^{a} (2.2)	1.7^{a} (1.5)	1.4^{a} (0.2)	2.9^{a} (0.2)
T6-Soil+ coir pith raw in 1:2 ratio	8.2^{c}	41^{a}	1.9^{a}	2.2^{a} (1.6)	3.7^{a} (1.9)	2.1^{a} (0.1)	3.4^{a} (0.2)
T7-Soil+ chaff in 2:1 ratio	3.2^{c}	46^{a}	2.1^{a}	1.7^{a} (1.5)	3.3^{a} (1.8)	3.5^{a} (0.2)	0.4^{a} (0.1)
T8-Soil+ chaff in 1:2 ratio	3.5^{c}	48^{a}	1.7^{a}	2.0^{a} (1.5)	3.3^{a} (1.8)	1.8^{a} (0.1)	3.4^{a} (0.2)
Wet nursery							
T9-Soil + cow dung in 2:1 ratio	7.2^{c}	45^{a}	1.4^{a}	2.8^{a} (1.8)	2.7^{a} (1.8)	2.0^{a} (0.1)	5.2^{a} (0.2)
T10-Soil+ cow dung in 1:2 ratio	7.3^{c}	34^{a}	2.5^{a}	3.6^{a} (2.0)	3.8^{a} (2.1)	2.7^{a} (0.2)	1.9^{a} (0.1)
T11-Soil+ coir pith compost in 2:1 ratio	7.1^{c}	47^{a}	1.7^{a}	2.9^{a} (1.8)	2.6^{a} (1.7)	1.2^{a} (0.1)	4.4^{a} (0.2)
T12-Soil+ coir pith compost in 1:2 ratio	6.2^{c}	49^{a}	2.3^{a}	3.8^{a} (2.0)	3.7^{a} (2.0)	3.2^{a} (0.2)	5.7^{a} (0.2)
T13-Soil+ coir pith raw in 2:1 ratio	13.3^{a}	51^{a}	2.4^{a}	3.5^{a} (2.0)	2.4^{a} (1.7)	1.5^{a} (0.1)	2.6^{a} (0.2)
T14-Soil+ coirpith raw in 1:2 ratio	7.8^{c}	57^{a}	1.9^{a}	3.4^{a} (1.7)	4.4^{a} (2.2)	0.6^{a} (0.1)	1.7^{a} (0.1)
T15-Soil+ chaff in 2:1 ratio	7.9^{c}	49^{a}	1.6^{a}	2.4^{a} (2.2)	3.4^{a} (2.0)	0.7^{a} (0.1)	1.3^{a} (0.1)
T16-Soil+ chaff in 1:2 ratio	8.6^{bc}	45^{a}	1.7^{a}	4.3^{a} (2.2)	2.6^{a} (1.7)	2.1^{a} (0.2)	4.7^{a} (0.2)
T17- Conventional nursery	5.1^{c}	53^{a}	1.6^{a}	3.8^{a} (2.0)	3.8^{a} (2.1)	3.0^{a} (0.2)	3.4^{a} (0.2)
Mean	7.3	47	1.8	3.1 (1.9)	3.4 (1.9)	1.9 (0.1)	2.9 (0.2)

Treatments with the same alphabet do not differ significantly
Values in parentheses denote transformed value

ratio 2:1 (T_{11}) and soil + coir pith raw in the ratio 2:1 (T_{13}), both under wet nursery systems was used for mat nursery. In these 3 cases, the respective number of late formed panicles m^{-2}were 29.7,18.6 and 25.1.The overall mean of late formed panicles m^{-2} was 12.5 which was only 4.8 per cent of the total number of panicles.

4.3.7.3 Number of filled grains panicle^{-1}

On an average, 44 numbers of filled grains were formed panicle^{-1} (Table 16). Manually planted crop using conventional nursery, produced 47 grains panicle^{-1}. The number of filled grains panicle^{-1} showed variation from 24 to 61 due to various treatments. The highest number of 61 was produced by the crop mechanically transplanted with soil + cow dung in the ratio 2:1 as the media. However, this highest number was statistically comparable to all the other treatments except in case of mechanically transplanted crop with soil+ cow dung in the ratio 1:2 (T_2) or soil + coir pith raw in the ratio of 2:1 (T_5), both under dry nursery system and soil + coir pith compost in the ratio of 1:2 (T_{12}) soil + coir pith raw in 2:1 ratio (T_{13}), soil + chaff in 2:1 ratio (T_{15}) or 1:2 (T_{16}) all under wet nursery system.

4.3.7.4 1000 grain weight

The test weight of the grain recorded as 1000 grain weight (Table 16) showed that this yield component was not influenced by the various treatments. The overall mean 1000 grain weight was 28.1 g and the value changed from 26.5 to 29.

4.3.7.5 Grain:Chaff ratio

The ratio of the weight of the tilled grains to the weight of the chaff computed (Table 16) and the analysis indicated that the grain: chaff ratio on weight/weight basis remained unaffected by the different treatments. The ratio ranged from 9:1 as in case of the treatment T_{11} to 19:1 as in case of treatment T_{12}. The overall mean grain: chaff ratio was 14:1, which indicated 93 per cent filling in the crop.

Table 16. Yield components (Experiment II)

Treatments	No. of panicles m^{-2}	No. of late formed panicles m^{-2}	No. of filled grains $panicle^{-1}$	1000 grain weight (g)	Grain: chaff ratio (W/W)
Dry nursery					
T1-Soil +cow dung in 2:1 ratio	296 ^{a}	3.9^{d}	61^{a}	28.7^{a}	14:1 ^{a}
T2-Soil+ cow dung in 1:2 ratio	289 ^{a}	8.9^{cd}	40^{bcd}	28.5^{a}	11:1 ^{a}
T3-Soil+ coir pith compost in 2:1 ratio	254 ^{a}	10.0^{cd}	46^{abc}	28.6^{a}	15:1 ^{a}
T4-Soil+ coir pith compost in 1:2 ratio	278 ^{a}	9.5^{cd}	47^{ab}	29.0^{a}	13:1 ^{a}
T5-Soil+ coir pith raw in 2:1 ratio	242 ^{a}	16.5^{bc}	40^{bcd}	28.6^{a}	16:1 ^{a}
T6-Soil+ coir pith raw in 1:2 ratio	309 ^{a}	29.7^{a}	50^{ab}	28.0^{a}	15:1 ^{a}
T7-Soil+ chaff in 2:1 ratio	244 ^{a}	18.0^{bc}	47^{ab}	26.5^{a}	18:1 ^{a}
T8-Soil+ chaff in 1:2 ratio	246 ^{a}	6.5^{cd}	50^{ab}	28.3^{a}	10:1 ^{a}
Wet nursery					
T9-Soil + cow dung in 2:1 ratio	220 ^{a}	11.9^{cd}	46^{abc}	27.5^{a}	13:1 ^{a}
T10-Soil+ cow dung in 1:2 ratio	238 ^{a}	12.2^{cd}	47^{ab}	27.8^{a}	20:1 ^{a}
T11-Soil+ coir pith compost in 2:1 ratio	266 ^{a}	18.6^{abc}	48^{ab}	27.4^{a}	9:1 ^{a}
T12-Soil+ coir pith compost in 1:2 ratio	242 ^{a}	7.2^{cd}	39^{bcd}	28.2^{a}	19:1 ^{a}
T13-Soil+ coir pith raw in 2:1 ratio	279 ^{a}	25.1^{ab}	42^{bcd}	28.0^{a}	14:1 ^{a}
T14-Soil+ coir pith raw in 1:2 ratio	242 ^{a}	6.4^{cd}	51^{ab}	28.6^{a}	15:1 ^{a}
T15-Soil+ chaff in 2:1 ratio	262 ^{a}	6.1^{cd}	28^{cd}	26.4^{a}	14:1 ^{a}
T16-Soil+ chaff in 1:2 ratio	238 ^{a}	10.6^{cd}	24^{d}	28.4^{a}	11:1 ^{a}
T17- Conventional nursery	284 ^{a}	11.9^{cd}	47^{abc}	28.8^{a}	14:1 ^{a}
Mean	261	12.5	44	28.1	14:1

Treatments with the same alphabet do not differ significantly

4.3.8 Grain and straw yield

The data on grain yield ha^{-1}, given in Table 17 showed that the ultimate grain output of the crop was not at all influenced by the methods of planting i.e. mechanical or manual, and between the mechanically transplanted crops, the media of nursery or the system of mat raising. The overall mean yield of the crop was 4344 kg of grains $ha^{-1}$and the manually planted crop using conventional nursery produced 4447 kg grains ha^{-1}. The yield level of mechanically transplanted crop using different types of mat nursery produced grains ranged from 3552 kg ha^{-1} as in case of T_9 to 5209 kg ha^{-1}as in case of T_7.

Straw weight also showed a similar trend as that of grains. The various treatments did not influence straw production by the crop. The overall mean production of straw by the crop under various treatments was 7464 kg ha^{-1}, the manually planted crop produced 8178 kg straw ha^{-1}. The straw yield ranged from 6243 to 8748 $kgha^{-1}$.

4.7.5 Harvest Index

Harvest index remained unaltered due to various treatment effects. The overall mean index was 0.31 and the same value was recorded in case of conventionally planted crop. Harvest index ranged from 0.26 to 0.39 in case of mechanically transplanted crops.

4.4 Nutrient uptake

4.4.1 N, P and K content of grain

Nitrogen content of grain ranged between 0.18 to 0.44 per cent, with a mean of 0.34 per cent (Table 18). The different treatments involving systems and media of nursery as well as planting methods altered the grain nitrogen content. When the crop was mechanically transplanted using dry nursery, with soil and chaff in the ratio of 2:1 (T_7) or 1:2 (T_8) or wet nursery with soil+ coir pith compost (T_{12}) and soil + coir pith raw in 1:2 (T_{14}) had low N content in the grain. In these three cases, the nitrogen content of the grain was significantly low and ranged from 0.18 to 0.25 per cent.

Table 17. Grain yield, straw yield and harvest index (Experiment II)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Dry nursery			
T1-Soil +cow dung in 2:1 ratio	4348 ^{a}	6882 ^{a}	0.33 ^{a}
T2-Soil+ cow dung in 1:2 ratio	4241 ^{a}	8029 ^{a}	0.29 ^{a}
T3-Soil+ coir pith compost in 2:1 ratio	4068 ^{a}	6759 ^{a}	0.34 ^{a}
T4-Soil+ coir pith compost in 1:2 ratio	4262 ^{a}	8266 ^{a}	0.30 ^{a}
T5-Soil+ coir pith raw in 2:1 ratio	4607 ^{a}	8748 ^{a}	0.31 ^{a}
T6-Soil+ coir pith raw in 1:2 ratio	4370 ^{a}	7276 ^{a}	0.33 ^{a}
T7-Soil+ chaff in 2:1 ratio	5209 ^{a}	6243 ^{a}	0.39 ^{a}
T8-Soil+ chaff in 1:2 ratio	3746 ^{a}	7943 ^{a}	0.26 ^{a}
Wet nursery			
T9-Soil + cow dung in 2:1 ratio	3552 ^{a}	6436 ^{a}	0.31 ^{a}
T10-Soil+ cow dung in 1:2 ratio	4973 ^{a}	7556 ^{a}	0.35 ^{a}
T11-Soil+ coir pith compost in 2:1 ratio	4822 ^{a}	8933 ^{a}	0.31 ^{a}
T12-Soil+ coir pith compost in 1:2 ratio	4370 ^{a}	6479 ^{a}	0.34 ^{a}
T13-Soil+ coir pith raw in 2:1 ratio	4348 ^{a}	7151 ^{a}	0.32 ^{a}
T14-Soil+ coir pith raw in 1:2 ratio	4413 ^{a}	8115 ^{a}	0.28 ^{a}
T15-Soil+ chaff in 2:1 ratio	3789 ^{a}	6286 ^{a}	0.32 ^{a}
T16-Soil+ chaff in 1:2 ratio	4262 ^{a}	7685 ^{a}	0.29 ^{a}
T17- Conventional nursery	4477 ^{a}	8178 ^{a}	0.31 ^{a}
Mean	4344	7464	0.31

Treatments with the same alphabet do not differ significantly

Similarly in case of phosphorus content of the grain, most of the treatments led to high concentration of phosphorus in grain, ranging from 0.24 to 0.30 per cent. But the treatments like T_1 (soil +cow dung in 2:1 ratio), T_2 (soil+ cow dung in 1:2 ratio), T_4 (soil+ coir pith compost in 1:2 ratio), T_5 (soil + coir pith raw in 2:1 ratio), T_{11} (soil+ coir pith compost in 2:1 ratio) T_{13} (soil + coir pith raw in 2:1 ratio) and T_{17} (conventional nursery) had a low P content, which ranged from 0.18 to 0.21 per cent.

Potassium content also showed the trend of phosphorus. Treatments like T_5, T_{10}, T_{13}, T_{16} and T_{17} had high content of potassium in their grain ranging from 0.31 to 0.41 per cent. This content was significantly superior to all the other treatments and the lowest value of 0.21 per cent of potassium in grain was recorded in T_4, where soil+ coir pith compost in the ratio 1:2 was used as the rooting media. The overall mean K content of the grain was 0.29 per cent.

4.4.2 N, P and K content of straw

NPK content of the straw remained unaltered (Table 18) without any significant variation due to various treatments incorporated. The mean content of N, P and K of straw were 0.22, 0.11 and 2.2 per cent respectively. The range for respective nutrient contents in straw was 0.14 to 0.49, 0.007 to 0.017 and 1.38 to 2.93 per cent.

4.4.3 NPK uptake

The NPK uptake by the crop, worked out based on its content both in grain and straw, is given in Table 18. Total N uptake was not affected by the treatments tried in the investigation. The overall mean total uptake of N was 32 kg ha^{-1} ranging between 20.4 and 46.3 kg ha^{-1}.

Difference in uptake of P was observed due to the treatments. The crop on an average consumed 19 kg P ha^{-1}. Low uptake of P ranging between 10.21 to 15.7 kg ha^{-1} was observed in the crops raised by manual planting (T_{17}) or mechanical planting with dry mat nursery with soil+ cow dung in the ratio 2:1(T_1) or soil+ chaff in the ratio 1:2 (T_8) as the media. Low level uptake was also observed in the mechanically planted crop using wet nursery, with soil+ chaff in

Table 18. N, P and K content of grain and straw and its uptake by the crop (Experiment II)

Treatments	N, P and K content of Grain (%)			N, P and K content of Straw (%)			N, P and K uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
Dry nursery									
T1-Soil +cow dung in 2:1 ratio	0.35^{ab}	0.23^{bc}	0.24^{de}	0.22^{a}	0.07^{a}	2.35^{a}	32.8^{a}	14.83^{bcd}	193.5^{abcde}
T2-Soil+ cow dung in 1:2 ratio	0.40^{a}	0.23^{bc}	0.25^{cde}	0.20^{a}	0.10^{a}	2.18^{a}	39.3^{a}	20.46^{abcd}	204.5^{abcd}
T3-Soil+ coir pith compost in 2:1 ratio	0.38^{ab}	0.26^{ab}	0.24^{de}	0.21^{a}	0.12^{a}	2.33^{a}	27.0^{a}	17.86^{abcd}	164^{bcde}
T4-Soil+ coir pith compost in 1:2 ratio	0.41^{a}	0.19^{c}	0.21^{e}	0.19^{a}	0.12^{a}	2.05^{a}	32.1^{a}	16.89^{abcd}	161^{bcde}
T5-Soil+ coir pith raw in 2:1 ratio	0.34^{ab}	0.23^{bc}	0.31^{abcde}	0.16^{a}	0.14^{a}	1.65^{a}	25.8^{a}	19.35^{abcd}	138.8^{de}
T6-Soil+ coir pith raw in 1:2 ratio	0.41^{a}	0.29^{ab}	0.27^{cde}	0.18^{a}	0.14^{a}	2.93^{a}	35.7^{a}	26.53^{a}	253.3^{a}
T7-Soil+ chaff in 2:1 ratio	0.25^{bc}	0.24^{ab}	0.30^{bcde}	0.24^{a}	0.09^{a}	2.60^{a}	33.5^{a}	19.92^{abcd}	233.6^{ab}
T8-Soil+ chaff in 1:2 ratio	0.25^{bc}	0.18^{c}	0.26^{cde}	0.21^{a}	0.07^{a}	2.48^{a}	30.1^{a}	14.17^{bcd}	233.5^{ab}
Wet nursery									
T9-Soil + cow dung in 2:1 ratio	0.34^{ab}	0.30^{a}	0.34^{abcd}	0.25^{a}	0.14^{a}	2.33^{a}	33.3^{a}	23.86^{ab}	193.8^{abcde}
T10-Soil+ cow dung in 1:2 ratio	0.44^{a}	0.24^{ab}	0.35^{abc}	0.20^{a}	0.13^{a}	2.70^{a}	38.5^{a}	22.33^{abc}	223.5^{abc}
T11-Soil+ coir pith compost in 2:1 ratio	0.39^{a}	0.21^{bc}	0.25^{cde}	0.14^{a}	0.11^{a}	2.45^{a}	21.2^{a}	13.03^{cd}	133.8^{de}
T12-Soil+ coir pith compost in 1:2 ratio	0.18^{c}	0.26^{ab}	0.28^{bcde}	0.15^{a}	0.11^{a}	2.00^{a}	20.4^{a}	21.53^{abc}	175.2^{bcde}
T13-Soil+ coir pith raw in 2:1 ratio	0.37^{ab}	0.22^{bc}	0.34^{abcd}	0.20^{a}	0.14^{a}	1.38^{a}	34.9^{a}	21.70^{abc}	125.9^{e}
T14-Soil+ coirpith raw in 1:2 ratio	0.25^{bc}	0.24^{ab}	0.27^{cde}	0.28^{a}	0.17^{a}	2.00^{a}	35.8^{a}	26.40^{a}	177.8^{bcde}
T15-Soil+ chaff in 2:1 ratio	0.36^{ab}	0.24^{ab}	0.25^{cde}	0.24^{a}	0.07^{a}	2.13^{a}	37.1^{a}	17.99^{abcd}	197^{abcde}
T16-Soil+ chaff in 1:2 ratio	0.37^{ab}	0.28^{ab}	0.41^{a}	0.49^{a}	0.07^{a}	2.05^{a}	46.3^{a}	15.71^{bcd}	154.6^{cde}
T17- Conventional nursery	0.32^{ab}	0.21^{bc}	0.38^{ab}	0.19^{a}	0.07^{a}	2.20^{a}	20.7^{a}	10.21^{d}	149.5^{cde}
Mean	0.34	0.24	0.29	0.22	0.11	2.20	32.0	19.0	183.1

Treatments with the same alphabet do not differ significantly

the ratio of 1:2 (T_{16}) or soil+ coir pith compost (T_{11}) in the ratio of 2:1 as the media. All the other treatments had significantly higher uptake ranging from 16.89 to 26.5 3 $kgha^{-1}$.

Uptake of K was also affected by the treatments (Table 18). The crop on an average consumed 183.1 kg ha^{-1} of K. Significantly higher uptake in the range of 194 to 253 $kgha^{-1}$ were seen in mechanically transplanted crop using dry mat nursery with soil+ cow dung in the ratio of 2:1 (T_1) or 1:2 (T_2), soil+ chaff in the ratio of 2:1(T_7) or 1:2(T_8) and soil+ coir pith raw in the ratio of 1:2(T_6). The lowest uptake of 126 kg ha^{-1} K was noted in case of the crop mechanically transplanted using wet mat nursery with soil+ coir pith raw in the ratio 2:1(T_{13}) as the media.

Experiment III

4.5 Observations on the performance of manually transplanted crop

4.5.1 Time taken for manual planting

Data on time taken by women labour to transplant unit area of $100m^2$ using mat nursery strips as well as conventionally uprooted nursery seedlings are given in Table 19. The Table also provides the labour requirement per hectare for manual transplanting of the mat nursery strips and conventional nursery. The analysis of the data indicated that the transplanting operation was unaffected due to the type of nursery used, whether it was mat nursery strips or conventionally pulled out nursery seedlings.

The transplanting time by manual labour for a unit area of $100m^2$ using conventional nursery was 7800 seconds for random planting. While using mat nursery strips raised either under wet or dry system using different media, the time ranged between 7363 seconds as in case of soil + coir pith raw (T_6) in the ratio 1:2 to 11100 seconds as in case of mat nursery strips made of soil + chaff in the ratio of 1:2 (T_{16}) in wet system.

The extrapolation of the data further indicated that the average labour requirement for transplanting alone using conventional nursery was 27 man days ha^{-1}, whereas while using mat nursery it ranged between 26 man days ha^{-1} as in

Table 19. Time taken (seconds) for planting 100 m^2 and labour days ha^{-1} (Experiment III)

Treatments	Time taken (seconds) for 100 m^2	Labour days ha^{-1}
Dry nursery		
T1-Soil +cow dung in 2:1 ratio	10038 [a]	35 [a]
T2-Soil+ cow dung in 1:2 ratio	10913 [a]	38 [a]
T3-Soil+ coir pith compost in 2:1 ratio	9873 [a]	34 [a]
T4-Soil+ coir pith compost in 1:2 ratio	10440 [a]	36 [a]
T5-Soil+ coir pith raw in 2:1 ratio	9565 [a]	33 [a]
T6-Soil+ coir pith raw in 1:2 ratio	7363 [a]	26 [a]
T7-Soil+ chaff in 2:1 ratio	10825 [a]	38 [a]
T8-Soil+ chaff in 1:2 ratio	9750 [a]	34 [a]
Wet nursery		
T9-Soil + cow dung in 2:1 ratio	10278 [a]	36 [a]
T10-Soil+ cow dung in 1:2 ratio	7925 [a]	28 [a]
T11-Soil+ coir pith compost in 2:1 ratio	9813 [a]	34 [a]
T12-Soil+ coir pith compost in 1:2 ratio	9608 [a]	33 [a]
T13-Soil+ coir pith raw in 2:1 ratio	8590 [a]	30 [a]
T14-Soil+ coir pith raw in 1:2 ratio	9140 [a]	32 [a]
T15-Soil+ chaff in 2:1 ratio	10400 [a]	36 [a]
T16-Soil+ chaff in 1:2 ratio	11100 [a]	39 [a]
T17- Conventional nursery	7800 [a]	27 [a]
Mean	9613	33

Treatments with the same alphabet do not differ significantly

case of T_6 (soil + coir pith raw in the ratio 1:2) to 39 man days in case of soil + chaff in the ratio of 2:1 under mat nursery system (T_{16}).

4.5.2 Plant population m^{-2}

Transplanting using the conventional or mat nursery was done at random by the labour as done in farmers field. Hence no restriction was imposed on the population at the time of planting. The plant population observation taken at planting, maximum tillering and harvest stages (Table 20) indicated that the population remained unaffected due to the system of nursery used. At the time of harvest, the mean population was 28 hills m^{-2}. The conventional nursery planted crop had a population of 24 hills m^{-2} whereas the crop transplanted using mat nursery ranged between 19 as in the case of T_{16} i.e., soil + chaff in the ratio 1:2 in wet system to 37 plants as in case of T_8 when mat nursery using the same media was raised under dry system.

4.5.3 Height of the plants

The stature of the plants observed at 15 days interval from 15 DAT up to harvest (Table 21) indicated that the height of the plants was not affected due to the different types of nurseries used. The crop planted using mat nursery or conventional nursery had an even growth rate at these stages of crop growth and at the time of harvest, the overall mean height of the plant was 81.2 cm.

4.5.4 Tillers hill^{-1}

Tiller production remained unaffected up to maximum tillering stage (Table 22) due to the various treatments incorporating different systems of nurseries for manual planting. At the stages of flowering and harvest, there was a reduction in tiller count and the different treatments had varied effects in the retention of effective tillers. At the time of flowering, 14 tillers per hill were there in case of treatment T_8, where soil + chaff in the ratio 1:2 under dry system was used for the mat nursery. All the other treatments also had a similar tiller production, except in cases of treatments T_{14}, T_{15}, T_{16} and T_{17}. The trend remained the same at the time of harvest also. The treatment T_5 (soil + coir pith raw in 2:1 ratio in dry system) produced 12 tillers per hill and all the other treatments except T_{14}, T_{15}, T_{16} and T_{17}

Table 20. Plant population m^{-2} at planting, maximum tillering and harvest (Experiment III)

Treatments	Planting	Maximum tillering	Harvest
Dry nursery			
T1-Soil +cow dung in 2:1 ratio	31 [a]	29 [a]	26 [a]
T2-Soil+ cow dung in 1:2 ratio	36 [a]	36 [a]	34 [a]
T3-Soil+ coir pith compost in 2:1 ratio	28 [a]	29 [a]	29 [a]
T4-Soil+ coir pith compost in 1:2 ratio	41 [a]	36 [a]	35 [a]
T5-Soil+ coir pith raw in 2:1 ratio	36 [a]	33 [a]	33 [a]
T6-Soil+ coir pith raw in 1:2 ratio	24 [a]	25 [a]	23 [a]
T7-Soil+ chaff in 2:1 ratio	30 [a]	33 [a]	28 [a]
T8-Soil+ chaff in 1:2 ratio	41 [a]	37 [a]	37 [a]
Wet nursery			
T9-Soil + cow dung in 2:1 ratio	35 [a]	30 [a]	28 [a]
T10-Soil+ cow dung in 1:2 ratio	35 [a]	36 [a]	34 [a]
T11-Soil+ coir pith compost in 2:1 ratio	30 [a]	30 [a]	27 [a]
T12-Soil+ coir pith compost in 1:2 ratio	31 [a]	26 [a]	26 [a]
T13-Soil+ coir pith raw in 2:1 ratio	31 [a]	28 [a]	26 [a]
T14-Soil+ coir pith raw in 1:2 ratio	21 [a]	21 [a]	20 [a]
T15-Soil+ chaff in 2:1 ratio	39 [a]	39 [a]	36 [a]
T16-Soil+ chaff in 1:2 ratio	20 [a]	19 [a]	19 [a]
T17- Conventional nursery	27 [a]	24 [a]	24 [a]
Mean	31	30	28

Treatments with the same alphabet do not differ significantly

Table 21. Plant height (cm) at 15 days interval (Experiment III)

Treatments	Plant height (cm)				
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Dry nursery					
T1-Soil +cow dung in 2:1 ratio	31.8 a	52.9 a	67.9 a	83.4 a	80.7 a
T2-Soil+ cow dung in 1:2 ratio	36.9 a	58.7 a	73.7 a	89.5 a	85.9 a
T3-Soil+ coir pith compost in 2:1 ratio	30.5 a	46.7 a	65.2 a	79.4 a	76.8 a
T4-Soil+ coir pith compost in 1:2 ratio	34.8 a	54.2 a	69.3 a	86.5 a	83.0 a
T5-Soil+ coir pith raw in 2:1 ratio	35.0 a	54.3 a	70.3 a	88.0 a	84.5 a
T6-Soil+ coir pith raw in 1:2 ratio	32.7 a	49.2 a	67.5 a	84.2 a	81.0 a
T7-Soil+ chaff in 2:1 ratio	34.0 a	54.9 a	70.0 a	84.2 a	81.2 a
T8-Soil+ chaff in 1:2 ratio	36.0 a	56.0 a	70.3 a	84.9 a	81.2 a
Wet nursery					
T9-Soil + cow dung in 2:1 ratio	34.7 a	55.0 a	69.7 a	86.2 a	82.2 a
T10-Soil+ cow dung in 1:2 ratio	36.0 a	57.6 a	72.2 a	91.2 a	86.1 a
T11-Soil+ coir pith compost in 2:1 ratio	32.2 a	51.0 a	66.8 a	83.6 a	80.8 a
T12-Soil+ coir pith compost in 1:2 ratio	34.1 a	57.5 a	71.0 a	85.9 a	83.1 a
T13-Soil+ coir pith raw in 2:1 ratio	34.2 a	52.0 a	68.3 a	83.5 a	80.1 a
T14-Soil+ coirpith raw in 1:2 ratio	33.2 a	52.8 a	67.7 a	83.0 a	80.7 a
T15-Soil+ chaff in 2:1 ratio	34.0 a	51.5 a	68.4 a	83.7 a	79.9 a
T16-Soil+ chaff in 1:2 ratio	35.8 a	55.5 a	70.4 a	85.9 a	82.9 a
T17- Conventional nursery	34.4 a	53.2 a	68.7 a	84.4 a	81.7 a
Mean	34.1	53.7	69.2	85.1	81.8

Treatments with the same alphabet do not differ significantly

had a significantly lower number of tillers than this. Tiller production in the latter cases ranged from 7.3 to 8.8. The overall mean number of tillers $hill^{-1}$ at flowering and harvest stages were 12 and 10.2 respectively.

4.5.5 Pest and disease incidence

The observations on pest and diseases given in Table 23 indicated that the crop was fairly free from major pest and disease attack. The observations on bacterial leaf blight (BLB) indicated that the average BLB attack at maximum tillering stage was to the tune of 9.6 per cent and the crop raised under different systems of nursery did not cause much variation in BLB incidence.

The observation on population of thrips at active tillering stage indicated that the system of nursery used for manual planting did not influence the thrip population. The average population of thrips per hill was 49.

The population of rice bug observed at flowering stage indicated that a fairly higher number of (2.7 bugs $hill^{-1}$) was seen only in plot, which was manually planted using soil + chaff in the ratio of 1:2 in the mat under dry system. The lowest population of 1.3 bugs $hill^{-1}$ was seen in case of the treatment T_9 (soil + cow dung in the ratio 1:2 under wet nursery). A statistically similar lower population was also seen in T_4 and T_5. The overall mean rice bug population in the crop was 1.8.

The population of GLH at maximum tillering stage indicated that the system of nursery used for manual planting of crop had no bearing on the population of GLH. The overall general mean was 3.2 and 3.7 GLH per hill at 17 and 49 DAT. The percentage of stem borer (dead heart) observation at flowering and harvest stages indicated that the treatments did not influence the incidence of stem borer viz., the dead heart occurrence. The overall mean percentage of dead hearts was 1.7 and 2.6 respectively at the stages of flowering and harvest.

Table 22. Tillers $hill^{-1}$ at 15 days interval (Experiment III)

Treatments	Tillers $hill^{-1}$				
	20 DAT	35 DAT	50 DAT	65 DAT	80 DAT
Dry nursery					
T1-Soil +cow dung in 2:1 ratio	8.2^{a}	13.5^{a}	13.2^{a}	11.6^{abcd}	9.5^{abc}
T2-Soil+ cow dung in 1:2 ratio	8.7^{a}	13.7^{a}	14.2^{a}	12.5^{abc}	10.7^{ab}
T3-Soil+ coir pith compost in 2:1 ratio	6.4^{a}	12.5^{a}	12.7^{a}	10.9^{abcd}	9.4^{abc}
T4-Soil+ coir pith compost in 1:2 ratio	10.7^{a}	15.7^{a}	13.5^{a}	12.0^{abcd}	10.0^{ab}
T5-Soil+ coir pith raw in 2:1 ratio	8.3^{a}	14.4^{a}	14.2^{a}	13.3^{ab}	11.8^{a}
T6-Soil+ coir pith raw in 1:2 ratio	8.7^{a}	14.7^{a}	14.9^{a}	13.1^{ab}	11.4^{ab}
T7-Soil+ chaff in 2:1 ratio	9.8^{a}	14.2^{a}	14.0^{a}	12.7^{ab}	10.9^{ab}
T8-Soil+ chaff in 1:2 ratio	9.2^{a}	13.6^{a}	14.7^{a}	14.0^{a}	10.8^{ab}
Wet nursery					
T9-Soil + cow dung in 2:1 ratio	7.3^{a}	12.7^{a}	13.9^{a}	12.9^{ab}	11.0^{ab}
T10-Soil+ cow dung in 1:2 ratio	9.2^{a}	13.4^{a}	14.9^{a}	13.3^{ab}	11.4^{ab}
T11-Soil+ coir pith compost in 2:1 ratio	10.9^{a}	15.7^{a}	14.5^{a}	13.0^{ab}	11.2^{ab}
T12-Soil+ coir pith compost in 1:2 ratio	9.2^{a}	14.4^{a}	14.3^{a}	12.9^{ab}	10.9^{ab}
T13-Soil+ coir pith raw in 2:1 ratio	8.9^{a}	13.8^{a}	15.2^{a}	13.2^{ab}	11.4^{ab}
T14-Soil+ coir pith raw in 1:2 ratio	7.9^{a}	13.0^{a}	13.0^{a}	9.1^{cd}	7.7^{c}
T15-Soil+ chaff in 2:1 ratio	7.8^{a}	13.8^{a}	14.1^{a}	10.0^{bcd}	8.8^{bc}
T16-Soil+ chaff in 1:2 ratio	7.1^{a}	11.9^{a}	12.5^{a}	8.6^{d}	7.3^{c}
T17- Conventional nursery	7.7^{a}	13.4^{a}	13.8^{a}	10.0^{bcd}	8.8^{bc}
Mean	8.6	13.8	14.0	12.0	10.2

Treatments with the same alphabet do not differ significantly

Table 23. Disease and pest incidence at 15 days interval (Experiment III)

Treatments	Bacterial leaf blight (%) 46DAT	Thrips hill^{-1} 15 DAT	Rice bug hill^{-1} 64 DAT	Green leaf hopper hill^{-1}		Stem borer (%)	
				17 DAT	49 DAT	70 DAT	85 DAT
Dry nursery							
T1-Soil +cow dung in 2:1 ratio	5.9^{a} (0.3)	46^{a}	1.8^{bcd}	3.7^{a} (2.0)	2.7^{a} (1.8)	1.3^{a} (0.1)	1.0^{a} (0.1)
T2-Soil+ cow dung in 1:2 ratio	11.5^{a} (0.3)	50^{a}	2.3^{abc}	3.2^{a} (1.9)	4.7^{a} (2.3)	0.7^{a} (0.1)	1.6^{a} (0.1)
T3-Soil+ coir pith compost in 2:1 ratio	10.6^{a} (0.3)	51^{a}	2.0^{abcd}	3.9^{a} (2.1)	4.7^{a} (2.2)	1.2^{a} (0.1)	1.1^{a} (0.1)
T4-Soil+ coir pith compost in 1:2 ratio	5.6^{a} (0.2)	44^{a}	1.4^{d}	5.7^{a} (2.5)	3.7^{a} (2.0)	1.9^{a} (0.1)	1.6^{a} (0.1)
T5-Soil+ coir pith raw in 2:1 ratio	11.6^{a} (0.3)	52^{a}	1.4^{d}	2.3^{a} (1.7)	3.9^{a} (2.1)	1.5^{a} (0.1)	2.7^{a} (0.2)
T6-Soil+ coir pith raw in 1:2 ratio	8.9^{a} (0.3)	50^{a}	1.6^{cd}	3.7^{a} (2.0)	3.4^{a} (2.0)	2.7^{a} (0.2)	5.0^{a} (0.2)
T7-Soil+ chaff in 2:1 ratio	7.0^{a} (0.3)	50^{a}	1.6^{cd}	4.1^{a} (2.1)	3.4^{a} (2.0)	2.5^{a} (0.2)	4.6^{a} (0.2)
T8-Soil+ chaff in 1:2 ratio	4.2^{a} (0.2)	49^{a}	2.7^{a}	2.8^{a} (1.8)	4.1^{a} (2.0)	2.5^{a} (0.1)	1.7^{a} (0.1)
Wet nursery							
T9-Soil + cow dung in 2:1 ratio	9.6^{a} (0.3)	41^{a}	1.3^{d}	3.4^{a} (1.9)	4.3^{a} (2.1)	1.6^{a} (0.1)	3.6^{a} (0.2)
T10-Soil+ cow dung in 1:2 ratio	10.0^{a} (0.3)	39^{a}	1.6^{cd}	2.8^{a} (1.8)	4.6^{a} (2.2)	1.8^{a} (0.1)	1.6^{a} (0.1)
T11-Soil+ coir pith compost in 2:1 ratio	16.4^{a} (0.4)	50^{a}	1.8^{bcd}	2.2^{a} (1.6)	5.4^{a} (2.4)	1.3^{a} (0.1)	1.1^{a} (0.1)
T12-Soil+ coir pith compost in 1:2 ratio	5.0^{a} (0.2)	44^{a}	2.4^{ab}	3.5^{a} (1.9)	3.1^{a} (1.9)	3.6^{a} (0.2)	5.2^{a} (0.2)
T13-Soil+ coir pith raw in 2:1 ratio	10.6^{a} (0.3)	50^{a}	1.9^{abcd}	2.4^{a} (1.7)	3.0^{a} (1.8)	0.7^{a} (0.1)	2.3^{a} (0.1)
T14-Soil+ coirpith raw in 1:2 ratio	13.2^{a} (0.4)	56^{a}	1.9^{abcd}	2.3^{a} (1.6)	4.3^{a} (2.2)	2.2^{a} (0.1)	1.8^{a} (0.1)
T15-Soil+ chaff in 2:1 ratio	8.1^{a} (0.3)	51^{a}	2.0^{abcd}	3.1^{a} (1.9)	2.8^{a} (1.8)	1.4^{a} (0.1)	2.8^{a} (0.2)
T16-Soil+ chaff in 1:2 ratio	11.9^{a} (0.4)	55^{a}	1.7^{bcd}	2.6^{a} (1.7)	3.7^{a} (2.0)	1.8^{a} (0.1)	2.9^{a} (0.2)
T17- Conventional nursery	12.2^{a} (0.3)	55^{a}	1.6^{cd}	2.4^{a} (1.7)	2.3^{a} (1.7)	2.3^{a} (0.1)	3.5^{a} (0.2)
Mean	9.6 (0.3)	49	1.8	3.2 (1.8)	3.7 (2.0)	1.7 (0.1)	2.6 (0.2)

Treatments with the same alphabet do not differ significantly
Values in parentheses denote transformed value

4.5.6 Yield components

4.5.6.1 Number of panicles m^{-2}

The number of panicles m^{-2} was visibly influenced due to the difference in the raising of the mat nursery (Table 24). The overall mean of the number of panicles m^{-2} was 275. The highest number of 352 m^{-2} was produced by the crop raised using the dry mat nursery with soil + coir pith raw in the ratio of 2:1 (T_5). Statistically equal number of panicles was also produced by the crop raised using mat nursery with soil + chaff in 2:1 ratio under dry system (T_7) or soil + coir pith raw in the ratio of 2:1 under wet system (T_{13}). Significantly lowest number of panicles m^{-2} (146) was recorded in the crop using mat nursery with soil + chaff in the ratio of 1:2 under dry system (T_8). Such a lower number of panicles were also recorded in case of T_{11} and T_9. The crop raised using conventional nursery produced 254 panicles m^{-2}.

4.5.6.2 Late formed panicles m^{-2}

Data on late formed panicles m^{-2} showed that, on an average 7 panicles m^{-2} were formed late and remained greenish at the time of harvest (Table 24). The various treatments did not affect the number of late formed panicles. It ranged from 4 as in case of T_1 to 12 as in case of T_9.

4.5.6.3 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} was variably influenced by the treatments (Table 24). The experimental crop had on an average 37 filled grains per panicle and the lowest was recorded in case of crop using conventional nursery (T_{17}), which had only 31 filled grains panicle^{-1}. A similar lower number was also observed in T_2 (soil + cow dung in the ratio 1:2), T_5 (soil + coir pith raw in the ratio 2:1) and T_7 (soil + chaff in the ratio 2:1) under dry nursery. The highest number of 50 filled grains panicle^{-1} was seen when the crop was raised using soil + coir pith raw in 1:2 ratio under dry system (T_6) and a similar number in case of T_{12} when the mat nursery was raised under wet system using soil + coir pith compost in the ratio of 1:2.

Table 24. Yield components (Experiment III)

Treatments	No. of panicles m^{-2}	No. of late formed panicles m^{-2}	No. of filled grains $panicle^{-1}$	1000 grain weight (g)	Grain: chaff ratio (W/W)
Dry nursery					
T1-Soil +cow dung in 2:1 ratio	264^{bcdef}	4.0^{a}	46^{abc}	28.0^{a}	$16:1^{a}$
T2-Soil+ cow dung in 1:2 ratio	292^{abcde}	6.1^{a}	31^{d}	27.8^{a}	$24:1^{a}$
T3-Soil+ coir pith compost in 2:1 ratio	229^{def}	5.7^{a}	46^{abc}	27.4^{a}	$16:1^{a}$
T4-Soil+ coir pith compost in 1:2 ratio	311^{abcd}	7.7^{a}	34^{cd}	28.2^{a}	$19:1^{a}$
T5-Soil+ coir pith raw in 2:1 ratio	352^{a}	10.1^{a}	31^{d}	27.4^{a}	$.7:1^{a}$
T6-Soil+ coir pith raw in 1:2 ratio	290^{abcde}	5.9^{a}	50^{a}	27.9^{a}	$20:1^{a}$
T7-Soil+ chaff in 2:1 ratio	338^{ab}	7.8^{a}	27^{d}	26.8^{a}	$21:1^{a}$
T8-Soil+ chaff in 1:2 ratio	146^{g}	6.1^{a}	33^{cd}	26.8^{a}	$18:1^{a}$
Wet nursery					
T9-Soil + cow dung in 2:1 ratio	220^{efg}	12.0^{a}	38^{abcd}	28.1^{a}	$20:1^{a}$
T10-Soil+ cow dung in 1:2 ratio	284^{abcdef}	4.8^{a}	37^{abcd}	27.6^{a}	$15:1^{a}$
T11-Soil+ coir pith compost in 2:1 ratio	205^{fg}	7.7^{a}	38^{abcd}	28.7^{a}	$19:1^{a}$
T12-Soil+ coir pith compost in 1:2 ratio	293^{abcde}	4.1^{a}	49^{ab}	28.0^{a}	$13:1^{a}$
T13-Soil+ coir pith raw in 2:1 ratio	341^{ab}	5.2^{a}	32^{cd}	30.4^{a}	$18:1^{a}$
T14-Soil+ coirpith raw in 1:2 ratio	283^{abcdef}	4.4^{a}	36^{bcd}	28.4^{a}	$12:1^{a}$
T15-Soil+ chaff in 2:1 ratio	322^{abc}	9.2^{a}	38^{abcd}	28.6^{a}	$14:1^{a}$
T16-Soil+ chaff in 1:2 ratio	263^{bcdef}	7.2^{a}	37^{abcd}	28.4^{a}	$16:1^{a}$
T17- Conventional nursery	254^{def}	10.5^{a}	31^{d}	28.8^{a}	$8:1^{a}$
Mean	275.0	7.0	37	28.1	16:1

Treatments with the same alphabet do not differ significantly

4.5.6.4 1000 grain weight

The test weight of the grain was not influenced by the treatments (Table 24). The average 1000 grain weight was 28.1 g, which ranged between 26.8 to 30.4 g, based on treatments.

4.5.6.5 Grain : chaff ratio

Similar to test weight, grain: chaff ratio was not affected by the various treatments (Table 24). The overall mean ratio was 16:1 ranging from 24:1 in case of T_2 to 7:1 in case of treatment T_5.

4.5.7 Grain and straw yield

The final grain yield of the crop remained unaffected due to the influence of nursery used for manual planting (Table 25). The crop on an average produced 4441 kg of grain ha^{-1}. The manually planted crop using conventional nursery produced 2788 kg of grain ha^{-1}. Grain yield of the crop raised by manual planting with mat nursery ranged between 3588 to 5368 kg ha^{-1}.

Straw weight was influenced by the different treatments. The crop raised through conventional nursery by manual planting produced straw 6325 kg ha^{-1}, which was significantly below the yields of all manually planted crop using mat nurseries, except that of T_{11} (soil+ coir pith compost in 2:1 ratio), which produced only 5107 kg of straw. The overall mean straw yield was 7726 kg ha^{-1}. The yield of straw of manually planted crop using mat nursery except T_{11} ranged from 6732 to 8956 kg ha^{-1}.

4.5.8 Harvest index

The harvest index values showed (Table 25) that the various treatments did not alter harvest indices. The overall mean harvest index was 0.3, which ranged between 0.27 as in case of T_{17} to the maximum of 0.32 as in case of T_7, T_9 and T_{13}.

Table 25. Grain yield, straw yield and harvest index (Experiment III)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
Dry nursery			
T1-Soil +cow dung in 2:1 ratio	4152^{a}	7947^{ab}	0.28^{a}
T2-Soil+ cow dung in 1:2 ratio	5368^{a}	8803^{a}	0.30^{a}
T3-Soil+ coir pith compost in 2:1 ratio	3826^{a}	6732^{abc}	0.31^{a}
T4-Soil+ coir pith compost in 1:2 ratio	4478^{a}	7444^{ab}	0.31^{a}
T5-Soil+ coir pith raw in 2:1 ratio	3885^{a}	7681^{ab}	0.28^{a}
T6-Soil+ coir pith raw in 1:2 ratio	5042^{a}	8263^{ab}	0.30^{a}
T7-Soil+ chaff in 2:1 ratio	5309^{a}	8393^{ab}	0.32^{a}
T8-Soil+ chaff in 1:2 ratio	4300^{a}	8956^{a}	0.27^{a}
Wet nursery			
T9-Soil + cow dung in 2:1 ratio	4360^{a}	7592^{ab}	0.32^{a}
T10-Soil+ cow dung in 1:2 ratio	5220^{a}	7602^{ab}	0.31^{a}
T11-Soil+ coir pith compost in 2:1 ratio	3588^{a}	5107^{c}	0.30^{a}
T12-Soil+ coir pith compost in 1:2 ratio	4834^{a}	8096^{ab}	0.30^{a}
T13-Soil+ coir pith raw in 2:1 ratio	5100^{a}	7960^{ab}	0.32^{a}
T14-Soil+ coir pith raw in 1:2 ratio	4656^{a}	8660^{a}	0.29^{a}
T15-Soil+ chaff in 2:1 ratio	4804^{a}	8897^{a}	0.30^{a}
T16-Soil+ chaff in 1:2 ratio	3796^{a}	6880^{abc}	0.29^{a}
T17- Conventional nursery	2788^{a}	6325^{bc}	0.27^{a}
Mean	4441	7726	0.30

Treatments with the same alphabet do not differ significantly

Discussion

5. DISCUSSION

Rice cultivation in the state is at a declining trend at the rate of 4500 hectare per annum. Mechanisation of rice cultivation has become imperative to sustain it and to make it economically viable as well as ecologically harmonious (Jaikumaran *et al.*, 1999). Several types of mechanical rice transplanters are available elsewhere, perfectly designed to suit the rice eco-system prevailing in the native places of its design origin. Though the machines are technically perfect, their performance depends upon the land situation on which it is operated and the mat nursery prepared and fed to the machine. Mat nursery production is a technically competitive job, the success of which decides the acceptance of the mechanical transplanter by the farming community.

Mat nursery has several advantages. However, its appreciation depends upon whether it is easy to produce, cut and transport; the root media has enough tenacity to hold it properly and economically competitive to conventional nursery. As it requires lesser area and labour for production, its alternative use in place of conventional root wash nursery has tremendous potential.

With the above objectives in mind, the present investigation on 'standardisation of mat nursery' for rice was carried out in 3 parts.

1. Develop package for commercial production of mat nursery
2. Evaluate the nursery in the field by mechanical transplanting
3. Explore the feasibility of using mat nursery as an alternative to conventional root washed nursery.

5.1 Experiment I

Raising mat nursery either in the wet or dry system was equally successful in the present investigation. Mat nursery raising using soil and cow dung in the ratio of 2:1, both under dry and wet system produced taller seedlings with high green colour and the root zone thickness ranging from 20 to 24 mm (Table 2 to 4), (Fig.3). More number of healthy seedlings were also seen with this root media under wet system or with soil + cow dung in the ratio 1:2 or soil + coir pith compost in the ratio of 2:1 under dry system. Heavier mats were produced under 1:2 soil cow dung ratio in dry system or 2:1 soil cow dung ratio in wet system (Table 6). Stronger mats using soil+ chaff in 2:1 ratio under dry system (T_9) and soil+ coir pith raw in the ratio of 1:2 (T_{14}) under wet system (Fig.6).

A good growing medium is needed to produce good seedlings in the mat nursery production system. A medium favouring high root zone thickness will be hindering to the transplanter, as it may clog fingers. A mat with very strong cohesion between seedlings in the root mat may cause seedling injury and clogging of transplanter fingers. A thickness above 25 mm will be interfering with the performance of the transplanter. A heavier mat will be difficult to be handled for transportation. At the same time, a thinner mat without enough tenacity and strength will lead to slipping down of mat while placing in the transplanter tray. This will also cause high number of floating seedlings. Adequate root length is required for good anchorage and establishment of seedlings after transplanting. In the present investigation soil + cow dung or soil + chaff in the ratio 2:1 in dry system or soil + chaff in the ratio 2:1 or 1:2 in wet system are found feasible for mat nursery raising for mechanical transplanting. Venkataraman (1999) found that while raising dapog nursery, when the media tried was clay + cow dung slurry, there was very high germination percentage. Clay + cow dung slurry or composted coir pith had the highest dry matter production at 12 DAS.

5.2 Performance of the transplanter

The performance of the transplanter(Table 9) revealed that, the time taken for transplanting was not altered by the different types of mat nurseries fed to it (Fig.7). Performance of the machine basically depend upon the speed of the machine and we never expect a change in the performance of the machine, due to mat nursery, except the number of hills transplanted and the number of missing hills. The data on population also revealed this fact (Table-9). The number of hills planted varied from 21 to 32 m^{-2} without any statistical difference between the treatments. The data on number of seedlings per hill transplanted and the number of floating seedlings per hill also did not show any variation indicating that all the mat nursery media tried are equally effective but for the economics (Table 26). The rate of damaged or floating seedlings immediately after transplanting was 50

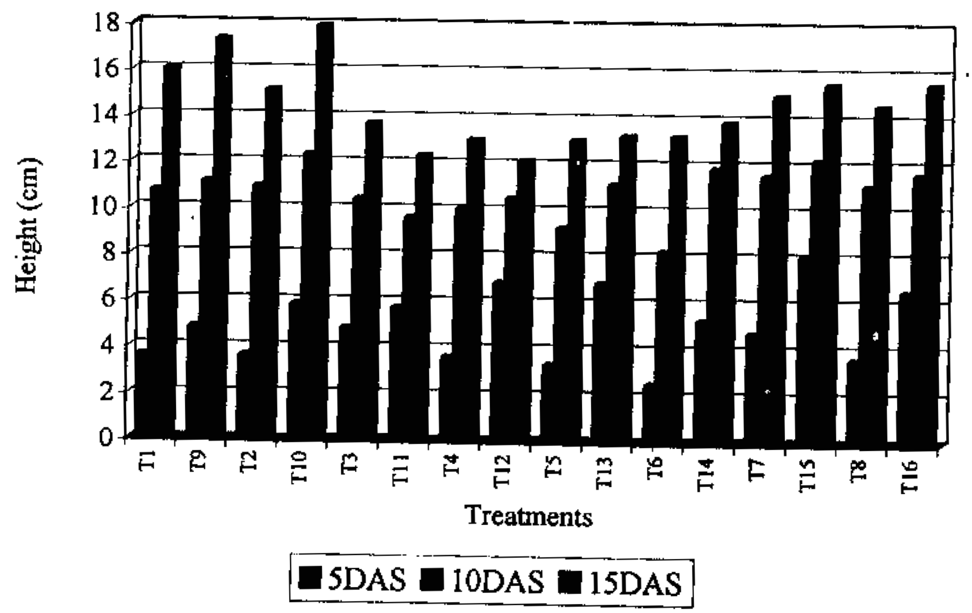


Fig. 5. Height of seedlings at 5 days interval

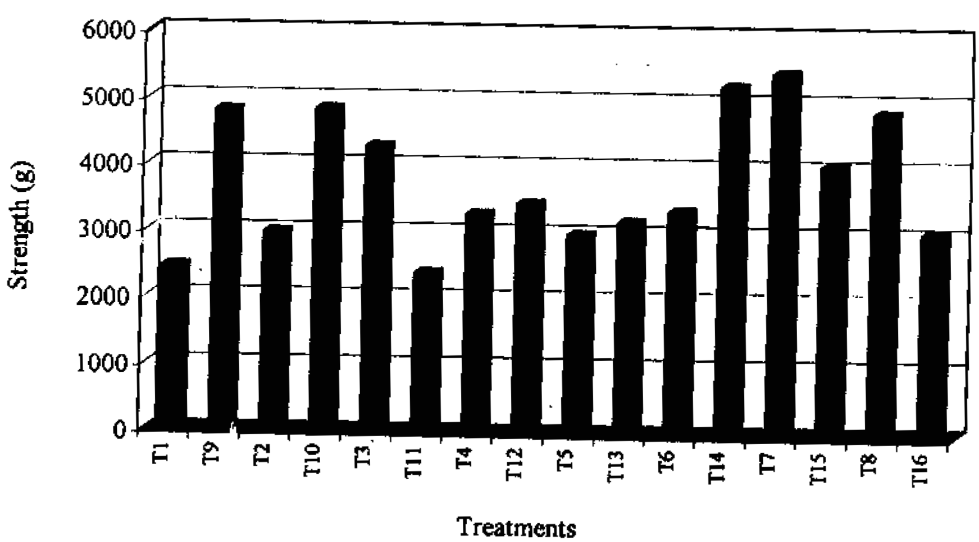


Fig. 6. Strength of the mat at transplanting as influenced by the media of the mat under wet and dry systems

per cent, which was in close conformity to the findings by Tasaka (1999). The planting depth varied between 38 and 54 mm, with no significant difference between the treatments, which is a fixed parameter for the machine. In case of the 8 row rice transplanter, with a row to row distance of 23.8 cm and plant to plant distance of 12 cm, the planting depth could be adjusted to 0 to 6 cm (Rani *et al.*, 2000).

The analysis of the nursery cost provided in the Table 26 gives a detailed economic picture. The total nursery cost for the conventional nursery is Rs.2,865/- . But when cost of uprooting in conventional nursery was considered (Rs. 300 ha^{-1}), the nursery raising becomes expensive in conventional nursery. Further when transplanting cost is considered (Table 27) conventional nursery becomes more uneconomic. Several workers have reported about economic advantage of mechanical planting using mat nursery (Garg and Sharma, 1984, Mufti and Khan 1995, Garg *et al.*, 1997).

Mat nursery system using coir pith compost, as the media either in the ratio 2:1 or 1:2 has not established any definite advantage over other media except for the high number of healthy seedlings under dry system. When coir pith raw is used as the media along with soil, it worked out cheaper than cow dung soil combinations, but produced more number of weaker seedlings. Soil with chaff was also worked out to be cheaper, but its definite advantage was seen only in case of dry nursery system to produce very strong mat. It has also the definite advantage of least number of missing hills under wet system.

The different mat nurseries have not influenced the performance of the transplanter, (Table 9) as well as the final yield of the crop (Table 17). A similar trend is seen in manual planting trial in experiment- III. When the mat nursery was used for manual planting, the yield was not affected due to the various treatments in the 3rd experiment (Table 25). Root injury did not affect the grain yield of rice to any significant extent (Budhar *et al.*, 1991). The time taken for manual planting using different mat nurseries (26 to 39 man day ha^{-1}) did not statistically differ from that for manual planting using conventional nursery (i.e. 27 man day ha^{-1}).

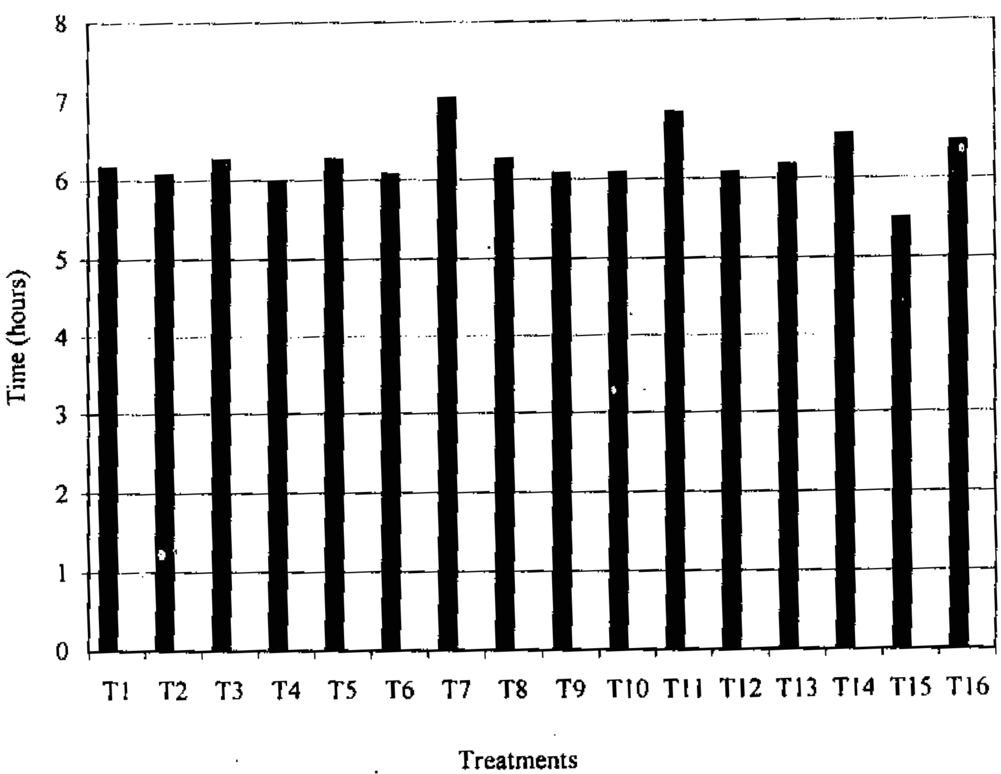


Fig. 7. Mean time required (hours) for transplanting 1 ha by 8 row transplanter using various types of nursery

The data on percentage of missing hills indicated that a lower number of missing hills in the dry nursery system was associated with soil + cow dung in the ratio of 1:2 or soil + chaff in the ratio of 2:1 (Fig 8). But while using wet nursery, very low number of missing hills were seen associated with soil + chaff in the ratio of 2:1 or 1:2. The mat nursery used did not influence the performance of the transplanter, which was observed through several parameters, indicated that the mat nursery system selected for mechanical planting may be based on economic consideration.

5.3 Experiment II

The experiment II was designed mainly to compare the performance of the mechanically transplanted crop using different types of mat nursery with that of manual planting with conventional nursery. Manual planting led to a recommended population of 65 hills m^{-2} at a spacing of 15 cm x 10 cm, since row planting was resorted to. According to Garg *et al.* (1997) the plant population was higher for manually transplanted crop. But in mechanical planting, without differentiating between types of mat nursery, the plant population was low ranging from 23 to 32 with an average of 29 hills m^{-2} (Table 10); (Fig.9). There were 22 per cent missing hills in the mechanically transplanted crop at the time of harvest (Table 10). A maximum of 22 per cent of missing hills has been observed by Garg and Sharma (1984). More number of missing hills in the mat nursery system without variation between the different types of media used in the mat indicated that the density of seeding in the nursery media would be regulated such that the percentage of missing hills is reduced to the minimum. According to Manian *et al.* (1987) missing hills up to 15 per cent did not affect the final output of the crop.

In the present study, the density of seeding in the mat was 0.5 kg m^{-2}. Beena and Jaikumaran (1999) have reported that a seeding rate between 0.4 to 0.6 kg m^{-2} would be optimum for having a good mat. Hence if the seed rate could be enhanced, the number of missing hills would have been further reduced. However, in the present investigation, the final grain and straw yield of the crop was not affected due to the various treatments (Table 17).

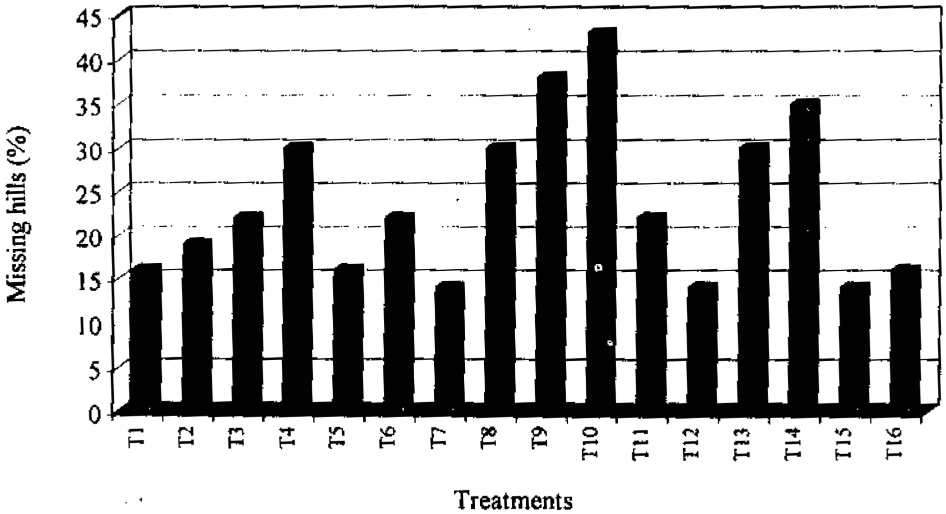


Fig. 8. Percentage of missing hills as influenced by media and systems of nursery

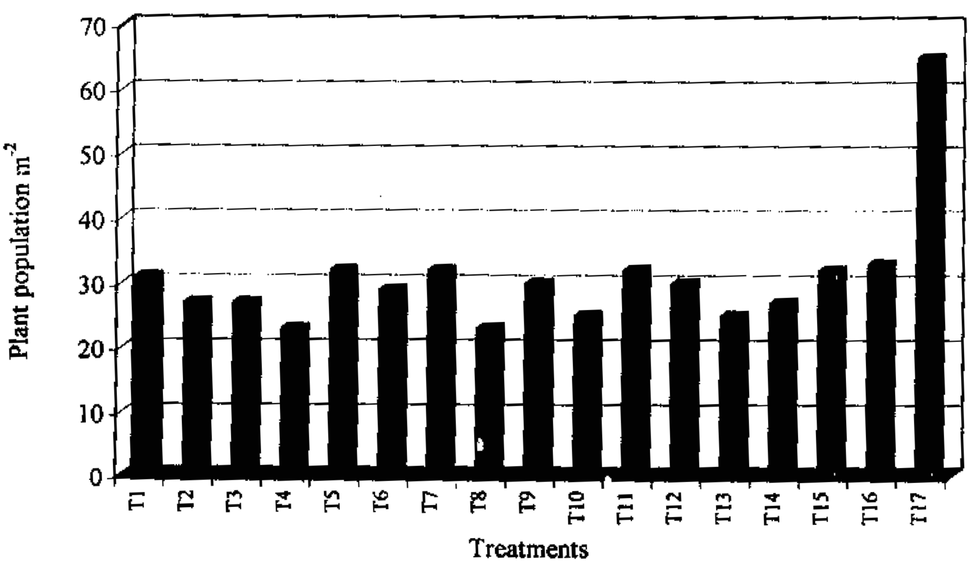


Fig. 9. Plant population at harvest (Experiment II)

Though there was considerable variation between the plant population of mechanically and manually planted crop, the growth of the crop in terms of the height of the plant was not at all affected (Table 11). Though some variations were there in the stature of the plant up to 30 DAS thereafter the growth of the plant was identical in terms of height and at the time of harvest, the average height was 89 cm. Height of the plant is basically governed by the genetics of the plant and environmental alteration is possible within the community, provided the horizontal spacing of the plant is varied.

In case of mechanically transplanted crop, more horizontal space per unit area was available at early stages of crop growth, compared to manually planted crop. It helped to produce more tillers hill^{-1} (Table 12); (Fig.10). This might have caused equal horizontal spacing for the manually planted as well as mechanically planted crop as the growth advanced leading to equal height of the plant at the time of harvest.

Throughout the crop growth, conventional nursery planted crop had a low number of tillers when compared to mechanically planted crop (Table 12); (Fig.10). Since there was a high density of population in the manually planted crop, there was a restriction for tillering and only 9.5 tillers hill^{-1} were available at the time of harvest. With more space available due to low density of plant population, the mechanically transplanted crop profusely tillered throughout its vegetative growth period. The mechanically transplanted crop using wet mat nursery with soil + cow dung in the ratio 1:2 (17.5 tillers hill^{-1} at harvest) or dry nursery with soil + coir pith raw (15.2 tillers hill^{-1} at harvest) in the ratio 2:1 consistently produced more tillers throughout the growth period (Fig 10). More tillers for the mechanically transplanted crop is generally observed probably due to a wider spacing and line planting. Garg and Sharma, (1984) has observed that the average number of tillers hill^{-1}, in case of mechanically planted crop was (28) and higher than in the manually transplanted crop (13).

When the relative performance of the crop observed through CGR, RGR, NAR, LAI and LAD, was analysed (Table 13), it was seen that though there was difference in CGR, RGR and NAR up to active tillering stage of the crop, thereafter these growth parameters were uniform without much difference. At the

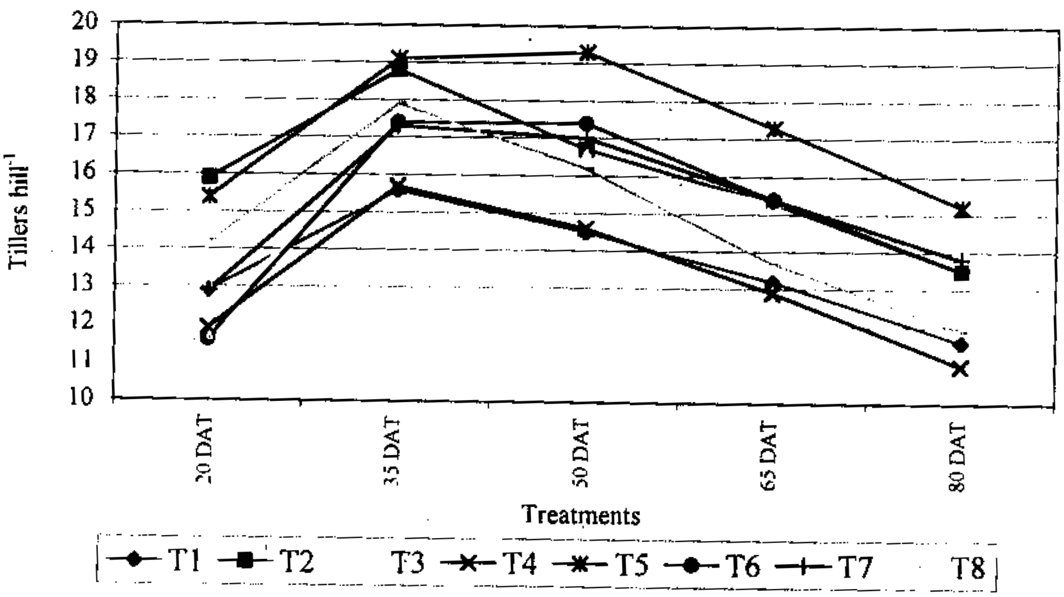


Fig. 10a. Effect of treatments on tiller production (Experiment II)

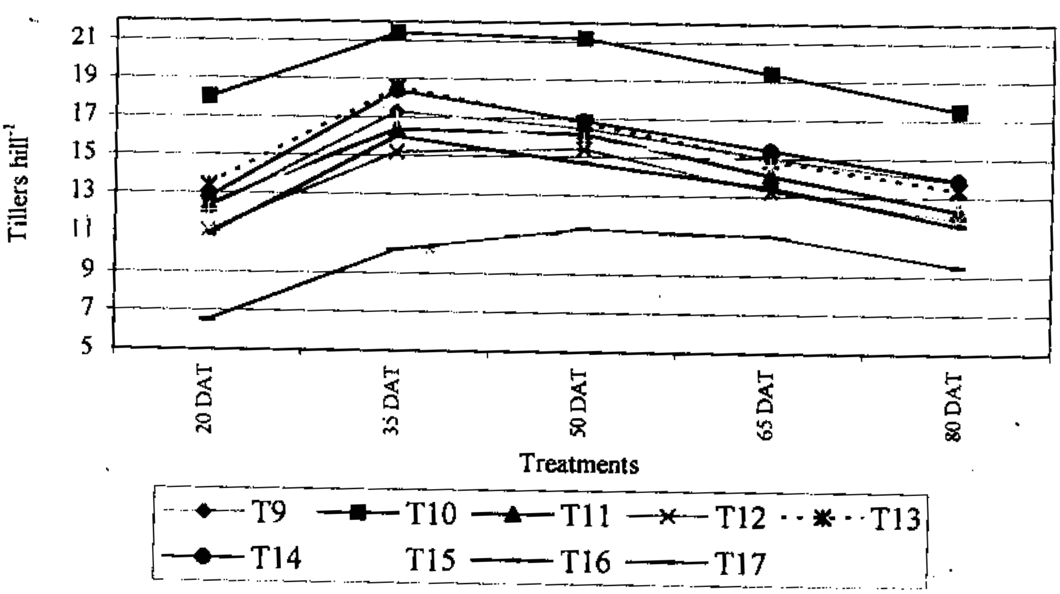


Fig. 10b. Effect of treatments on tiller production (Experiment II)

time of planting, number of seedlings planted in the mechanically planted crops ranged from 3.3 to 4.4 without any significant difference between the mechanically transplanted crops (Table 9). Garg and Sharma (1984) observed a similar condition wherein a 5-row paddy transplanter, which covered 0.3 to 0.4 hectares per day planted on an average, 4 seedlings per hill. In the manually planted crop, the seedlings planted were 3 seedlings $hill^{-1}$. This meant that all the 17 treatments had similar number of seedlings per hill at the time of planting. As more space was available to the mechanically planted crop due to low plant population, more tillering had occurred during active tillering stage (Table 12) and more biomass has accumulated. Hence CGR, RGR and NAR were higher in these treatments compared to the manually planted crop using conventional nursery, which had the lowest of these parameters. When these parameters were observed for the period from active tillering to panicle initiation stage, the dry matter accumulation and build up of biomass was at an even rate without discriminating between manually and mechanically planted crops. This also indicated that the crop had no variable influencing through horizontal or vertical spacing and the crop was not subjected to any external influence like biotic or abiotic stresses. This may be the reason why CGR, RGR and NAR remained uniform for all the crops after active tillering stage. Change in CGR, RGR and NAR indicated the variable influence of the external or internal factors on crop growth (Reddy and Reddy, 2001).

The observations on LAI and LAD are further substantiating the above argument. Though the mechanically and manually planted crops had varying horizontal space available at its initial stages, the production of photosynthetic apparatus viz., leaves for utilising the solar energy commensurate with the space available. The mechanically transplanted crop, though the population density was much lower, produced more tillers and more leaves utilising the space around the plant and the leaves produced were sustained successfully as that of manually planted crop. Such a compensating mechanism by the plant to produce more tillers to provide more photosynthetic area and retain it sufficiently longer indicated that mechanically transplanted crop would grow and produce as much tillers per unit area as that of manually planted crop, even if the population is lesser in the former case.

The system of planting, whether it was mechanical or manual that provided differential interspaces, has not affected the weed species prevalent in the locality (Table 14). The weeds *Cyperus iria, Isachne miliacea, Echinochloa* sp., *Mollugo sp., Nymphaea stellata, Schoenoplectus lateriflorus* and *Sphenochlea zeylanica* were found in the field irrespective of the plot. These are the predominant weed species during first crop season, as per the reports of Thomas and Abraham (1998). The mean weed density i.e., number of weeds m^{-2} was 130 and 94 respectively at 20 and 40 DAT and the weed count at both the stages has not differentiated between mechanically and manually planted crops. This indicated that as observed in physiological growth parameters the mechanically planted crop had a vigorous growth during active tillering stage smothering the weed growth. From the time of active tillering to panicle initiation, the growth pattern between these two were uniform (Table 13) and hence the weed growth was limited to uniform in all the plots. Hence the general apprehension that the mechanically planted crop, due to its wider spacing than the recommended one, might favour intensive weed growth was found baseless from this observation.

During the course of investigation, as an auxiliary observation, disease and pest incidence were observed to study whether the mechanically and manually planted crop put forth differential tolerance mechanism against biotic stresses (Table 15). Among the diseases, BLB was the only problem observed that too mainly in 2 mechanically transplanted plots, one using the mat prepared out of soil + coir pith compost in the ratio 2:1 under dry system and the second one in soil + coir pith raw in wet system. The incidence of BLB in the respective plots was to the tune of 13.9 and 13.3 per cent. A fairly low incidence was noticed in the other plots. One of the control measures recommended for BLB is spraying of cow dung extract (2%) (KAU, 2002). Probably, the lack of cow dung in these 2 nurseries might have favoured high incidence.

All the insect pests viz., thrips, GLH, rice bug and stem borer observed for its incidence did not show any discrimination between the plots receiving various treatments. The mean population of thrips per hill was 47 at 20 DAT and rice bug 1.9 at 69 DAT. The number of leafhopper per hill was 3.1 and 3.4 respectively at 22 and 54 DAT. The percentage of dead hearts due to stem borer was 1.9 and 2.9 per cent respectively at 70 and 85 DAT.

The above data indicated that the incidence of pest was bare minimum without causing damage to the productivity of the crop and without showing any discrimination, whether the crop was planted mechanically or manually. The general logic is that the mechanically planted crop due to its wider spacing provides more ventilation to the crop and hence, the pest and disease problem will be reduced, since the microclimate will not be congenial for the rapid multiplication and development of fungi or insect pests. This logic could not be established. Probably the high growth rate of the mechanically planted crop during its active vegetative growth phase might have provided an even microclimate environment as that of manually planted crop.

Among the three primary yield components, number of panicles m^{-2} and 1000 grain weight remained unaffected due to various treatments incorporating system and media of mat nursery, conventional nursery, manual or mechanical planting (Table 16). The treatments however variably influenced the number of filled grains $panicle^{-1}$ (Table 16). Ayyaswamy *et al.* (1991) observed that the yield attributes were not influenced by the different methods of nursery raising.

Total number of panicles m^{-2} under conventional nursery was 284 whereas it ranged from 220 to 309 in the mechanically transplanted crop using different types of nurseries (Fig.11). Thakur (1993) reported that the number of panicles m^{-2} was not influenced by the different establishment methods. Though the plant population was higher in manually planted crop (65 at harvest), it produced only 284 panicles, which meant that the number of panicles $hill^{-1}$ was on an average 4.4. When 309 panicles were formed in case of mechanically transplanted crop using soil + coir pith raw in the ratio 1:2 (T_6), it had a population of 29, indicating that nearly 10.7 panicles were formed per hill. In case of treatment T_9, which produced only 220 panicles m^{-2} for the mechanically transplanted crop using soil + cow dung in 2:1 ratio, produced on an average 7.9 panicles per hill. This indicated that mechanically transplanted crop though had a wider spacing and lesser population than conventional nursery, due to its physiological regulation of growth mechanism, produced more tillers and panicles than manually planted crop.

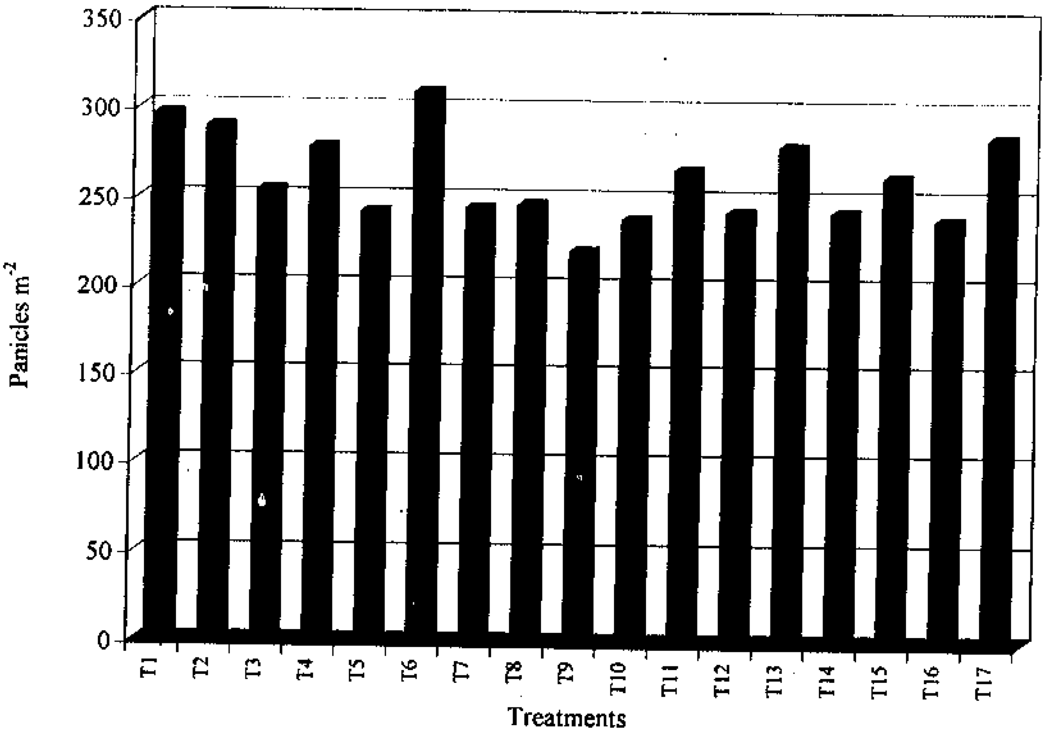


Fig. 11. Effect of treatments on no. of panicles m^{-2}(Experiment II)

Even though mechanically planted crop has produced a higher number of panicles per unit area or per plant one of the practical constraints observed was it also produced a high number of late formed panicles. In the manually planted crop using conventional nursery, out of the total 284 panicles formed, only 11.9 numbers were considered as late formed ones, which were still remaining greenish at the time of harvest. The mean number of panicles m^{-2} in case of the 16 mechanically planted crops was 260, in which 12.6 numbers were categorised as late formed.

Because of wider spacing available in mechanically planted crop more axillary buds were formed due to availability of more solar radiation. This is a phenomenon observed in rice where more tillers and panicles are formed with increasing spacing (Yoshida, 1981). This observation was particularly recorded again with the general apprehension by the farmers that in mechanically transplanted crop late formed panicles interfere with the synchronised maturity of the crop. This apprehension is not ruled out, as there are 3 treatments where the number of late formed panicles are significantly higher than the other treatments. These are the mechanically transplanted crop using the mat nursery with soil + coir pith raw in the ratio 1:2 (T_6) under dry system, and soil + coir pith compost in the ratio 1:2 (T_{11}) and soil + coir pith raw in the ratio 1:2 (T_{13}) under wet system. The number of late formed panicles are 29.7, 18.6 and 25.1 respectively in these treatments.

However the overall mean data on late formed panicles showed that it was only 12.5 out of the 261 total number of panicles m^{-2}, indicating that it is only 4.1 per cent of the total. This observation indicates that we need rice genotypes to be developed with more number of tillers $hill^{-1}$ as well as synchronised maturity within the hill so as to avoid any interference with maturity and harvest. It is noted that significantly more number of late formed panicles are seen in cases soil + coir pith raw in the ratio of 1:2 under dry system (T_6) and soil + coir pith raw in the ratio of 2:1 under wet system (T_{13}).

The crop had on an average 44 numbers of filled grains formed per panicle (Table 16). The panicles of the manually planted crop using conventional nursery had born 46 grains on each panicle. The number of filled grains panicle^{-1} varied from 24 to 61 in case of mechanically planted crop with treatments showing statistical difference (Fig 12). Most of the treatments had a statistically similar number of filled grains panicle^{-1} compared to the highest number of 61 produced by mechanically planted crop using dry mat nursery with soil + cow dung in the ratio 2:1. The lowest number of 24 grains panicle^{-1} was recorded in mechanically planted crop using wet mat nursery with soil + chaff in the ratio 1:2. A comparably low number was seen in T_2, T_5, T_{12}, T_{13} and T_{15}. The result did not show any clear trend, but gives an indication that soil + chaff in either of the ratios under wet system would reduce the number of filled grains panicle^{-1}. Such a situation was also seen in soil + coir pith compost in the ratio 1:2 and soil + coir pith raw in the ratio 2:1 under dry system. In rice, whenever the number of panicles increases, the number of filled grains panicle^{-1} shows a negative correlation (Matsushima, 1980).

Thousand grain weight of the crop and grain: chaff ratio remained unaffected due to the treatments (Table 16);(Fig.13). The overall mean test weight was 28.1 g and grain: chaff ratio was 14:1. According to Matsushima (1980), 1000 grain weight show the least variation compared to other components. This indicated that the physiological activity during the reproductive growth phase was not affected by the spatial changes brought about by the different treatments during the vegetative growth period. The translocation of the photosynthates from the source to sink and the after ripening process remained uniform due to various treatments. The number of panicles per hill as well as spikelets per panicle is the characters affected by the overall nutritional condition inside the plant and the external environmental conditions prevailing at the end of maximum tillering stage and at the start of panicle initiation stage. Probably this has changed the number of filled grains panicle^{-1}.

The grain: chaff ratio remained uniform for all the treatments which meant that the partitioning of the photosynthates was uniform and the translocation of the photosynthates was not affected by any of the extraneous or internal factors.

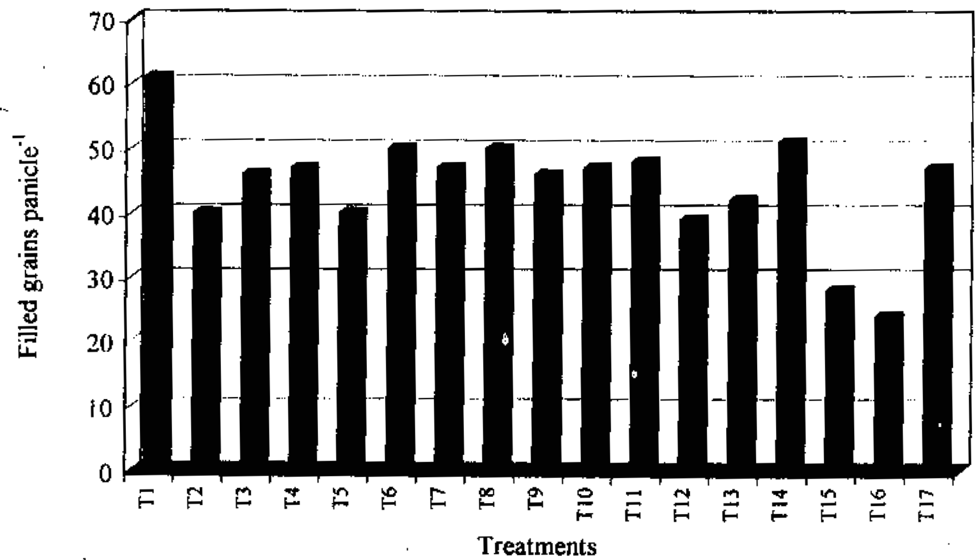


Fig. 12. Effect of treatments on filled grains panicle^{-1} (Experiment II)

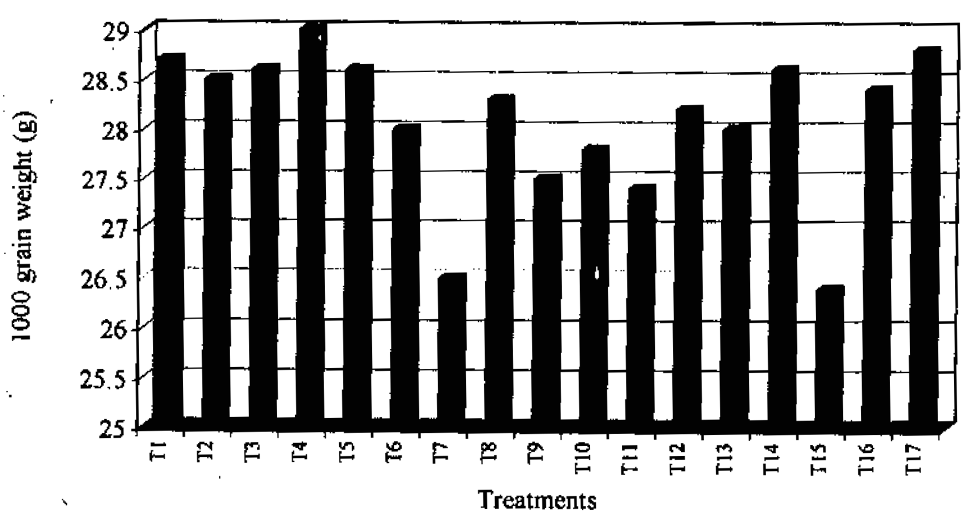


Fig. 13. Effect of treatments on 1000 grain weight (Experiment II)

Finally, when the biological yield of the crop was considered, the 17 treatments did not influence grain and straw yield of the crop, whether the crop was manually or mechanically planted; within the mechanically planted crop whether the mat nursery used was dry or wet, and within the nursery system, whether the media used were of different composition (Table 17); (Fig.14, 15). None could alter the grain and straw yield of the crop.

According to Rajendran (1991) the effect of nursery management did not reflect in increasing the grain yield of rice. Garg and Sharma (1984) also expressed no difference in yield between mechanically and manually transplanted crops. The crop produced on an average 4344 kg of grains and 7464 kg of straw ha^{-1}. The corresponding figure for the manually planted crop using conventional nursery was 4477 and 8178 kg ha^{-1}. The mean harvest index was 0.31 showing no discrimination between the treatments (Fig.16).

This investigation negates either arguments that mechanically planted crops have low yields due to low planting density or high yield due to high production of tillers and panicles. But this study affirms that a crop that is as good as that of manually planted crop with recommended population could be harvested by mechanical planting.

A high number of productive tillers, a good number of filled grains $panicle^{-1}$ varying with respect to tiller production, and a uniform test weight with effective partitioning of photosynthates considering the sink (uniform grain: chaff ratio) have altogether contributed to the same production level of both grain and straw in mechanically transplanted crop as that of manually planted crop using conventional nursery. The high growth rate operated initially in the mechanically transplanted crop has totally offset the effect of low population density in it. This has also smothered the effects of weed growth keeping it as a competitive crop with manually planted one. Hence the study clearly revealed that mechanically transplanted crop irrespective of the mat nursery used would produce as much grain and straw as that of a manually planted crop. The economics of production need to be the only criteria to distinguish between them.

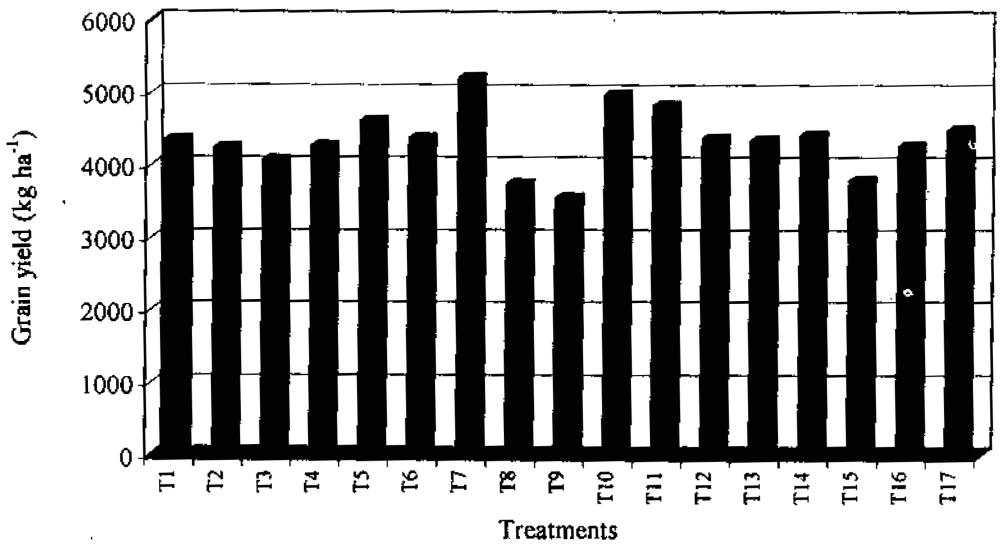


Fig. 14. Effect of treatments on grain yield (kg ha^{-1}) (Experiment II)

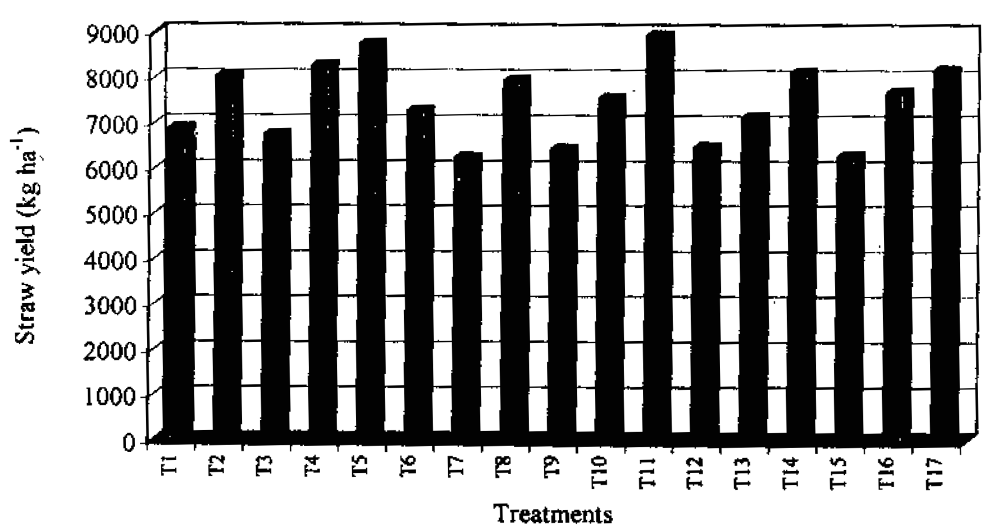


Fig. 15. Effect of treatments on straw yield (kg ha^{-1}) (Experiment II)

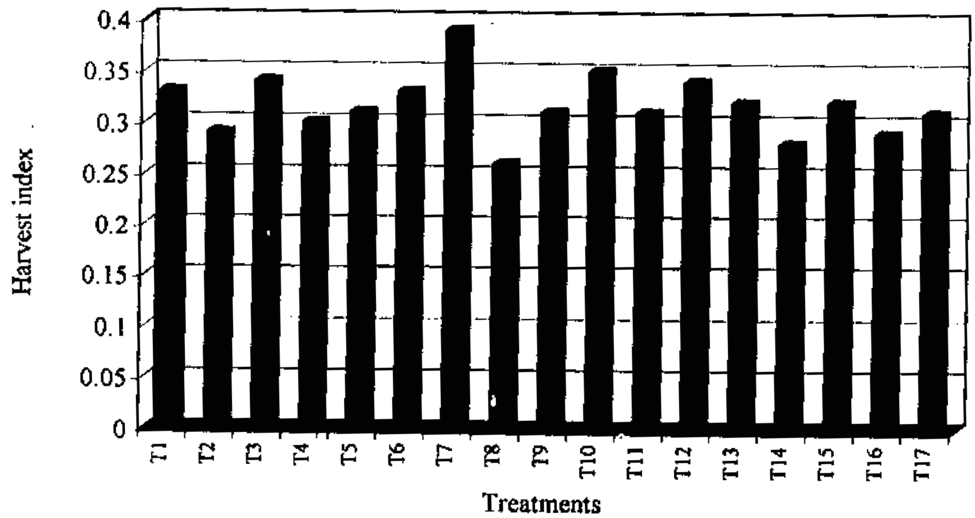


Fig. 16. Effect of treatments on harvest index (Experiment II)

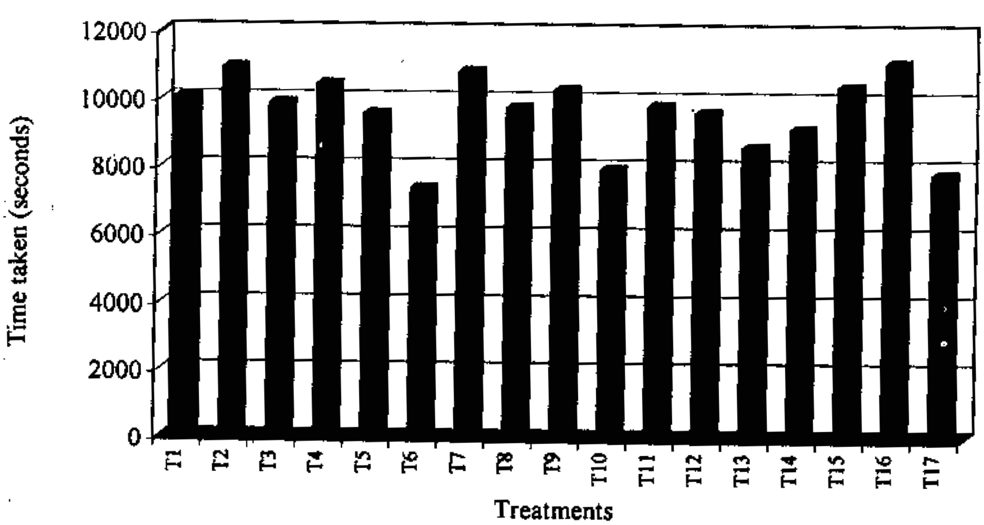


Fig. 17. Time taken (seconds) for planting 100 m^2 (Experiment III)

The nutrient content of the grain viz., N, P and K showed variations due to the different treatments (Table 18). The average N content of the grain was 0.34 per cent, ranging from 0.18 to 0.44 per cent. A close examination of N content of the grain revealed that the four treatments T_7, T_8, T_{12} and T_{14} had a low N content ranging from 0.18 to 0.25 compared to others.

P content of the grain also showed a varied concentration ranging between 0.18 and 0.3 with an average of 0.24 per cent. But the treatments T_1, T_2, T_4, T_5, T_8, T_{11}, T_{13} and T_{17} had a low P content ranging from 0.18 to 0.23 percent.

The average K content of the grain was 0.29 per cent showing significant variation due to treatments. The lowest content was 0.21 per cent was recorded in soil + coir pith compost in the ratio of 1:2 (T_4) and the highest content in soil + chaff in the ratio of 1:2 (T_{16}) with a value of 0.41per cent. The treatments T_5, T_9, T_{10}, T_{13} and T_{17} were similar in their grain K content as that of T_{16}. The nutrient content in the grain depends upon several factors like quantity of nutrient applied, the environmental conditions, the amount of sink produced, source-sink relations and the nutritional metabolism within the plant. The treatments incorporated did not have any variable nutrient levels and the crop had its over compensating mechanism to produce an equal biomass as discussed earlier. The grain number varied with respect to treatments and at the same time grain: chaff ratio remained even.

The NPK content of the straw (Table 19) revealed that there is no statistical variation in its contents between the treatments. Hence it is believed that there is no restriction towards nutrient availability for the plant due to treatments and translocation of photosynthates has taken place without limitation. Probably the number of active sink maintained by the crop caused the difference in the nutrient content of the grain. Several reports revealed that the nutrient content of the grain depended upon the number of filled grains maintained by the crop (De Datta, 1981).

The NPK content of the straw has not changed due to the treatments imparted. The average content of N, P, K of the straw was 0.22, 0.11 and 2.22 per cent respectively. We did not find any statistical difference in the straw yield

(Table 17). Moreover no treatment was there to influence the nutrient input and supply to the crop.

The uptake of nutrients N, P and K by the plant gave more substantial evidence to the above argument. The total N uptake remained the same with a mean of 32 kg ha^{-1}. This meant that the treatments did not influence the N nutrition of the plant.

The P uptake showed variation due to treatments. The overall mean uptake was 19 kg ha^{-1}. A low uptake was noticed in manually planted crop with conventional nursery with uptake of 10.2 kg probably due to a low content of P in the straw and the same time, high straw yield. A low P uptake was also noticed in T_1 probably because of its numerically low straw yield, in T_8 due to its numerically low grain yield, T_{11} due to low content of P in the grain and T_{16} low content of P in the straw.

Overall mean K uptake of the crop was 183 kg ha^{-1}. Most of the treatments had fairly high uptake ranging from 193 to 254 kg ha^{-1} as in case of T_1, T_2, T_6, T_7 and T_8 depending upon their K content in grain and straw as well as their corresponding yields. A very low uptake of K ha^{-1} was noticed in manually planted crop using conventional nursery and mechanically planted crop using wet mat nursery using soil + coir pith raw in the ratio of 2:1 (T_{13}). Potassium being a nutrient luxuriously consumed by the paddy crop, its variability with respect to treatments even if it does not incorporate K nutrition is a general phenomenon in rice crop.

The economics worked out as per the procedure suggested by Acharya (1997) is given in Table 27. B:C ratio was greater than 1.5,in all the treatments except in case of mechanically transplanted crop using wet mat nursery with soil + cow dung in the ratio 2:1(T_9). This exceptionally low B:C ratio is due to lower yield, compared to other treatments and not because of any cost difference between the other treatments. A similar situation is seen in case of mechanically transplanted crop using wet mat nursery with soil + chaff in the ratio 2:1 (T_{15}).

The manually planted crop using conventional nursery had a B:C ratio 1.58 and all the mechanically planted crops using different mat nurseries except T_3, T_8, T_9, T_{12} and T_{15} had a fairly higher ratio than this. B:C ratios above 1.8 is seen in case of mechanically transplanted crops using dry mat nursery with soil + coir pith raw in the ratio 2:1, soil + chaff in the ratio 2:1 and in wet nursery with soil + cow dung in the ratio 1:2 and soil + coir pith compost in the ratio 2:1. Mechanical transplanting with different aged seedlings had a cost benefit ratio in the range of 1.16 to 2.46 (Ravi *et al.*, 1994). According to Ahamed and Sivaswamy (1994) the medium and high mechanisation packages produced a higher B:C ratio. Similar results were obtained by James et *al.* (1996).

Since there is no yield advantage of manual planting over mechanical planting, selection of the mat nursery production system now depends upon the interaction between mat nursery and the machine. This result emphasises that mechanical transplanting using mat nursery is a viable economic option for the farmers and definitely manual planting can be replaced with mechanical transplanting without sacrificing any yield but definitely with a better economics. We have already seen that soil + cow dung in the ratio 2:1 provides a good mat both under dry and wet systems. The ratio 1:2 was also comparably good especially in producing healthy seedlings. Healthy mat is also seen in case of soil + coir pith compost in the ratio 2:1 under dry nursery system. Strong mats are seen when soil and chaff are used in the ratio of 2:1 under dry system and we get lesser number of missing hills with the same media under dry system. We also see strong mats with chaff soil media under dry system. Soil + cow dung provides strong mats in wet system. Hence it is suggested that we may use soil + chaff in the ratio 2:1 (T_7) or soil with coir pith raw in the ratio 2:1 (T_5) or soil + cow dung in either of the ratios (T_1 and T_2) to have economically viable mat production for mechanical transplanters. Under wet system soil + cow dung in 1:2 ratio (T_{10}), soil + coir pith compost in 2:1 ratio (T_{11}), soil + coir pith raw in either of the ratios (T_{13} and T_{14}) and soil + chaff in 1:2 ratio (T_{16}) can be a better option for the production of mat nursery for mechanical transplanting.

Table 26. Nursery cost (Experiment II)

COST	Norm	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
Input cost																		
General mat nursery	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	0
Specific mat nursery treatment		270	241	964	1617	229	158	213	128	270	241	964	1617	229	158	213	128	0
Specific Conventional nursery	1310																	1310
TOTAL INPUT COST		2004	1975	2698	3351	1963	1892	1947	1862	2004	1975	2698	3351	1963	1892	1947	1862	1310
Labour cost																		
General mat nursery	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	0
Specific Conventional nursery	1555	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1555
TOTAL LABOUR COST		1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1555
Total Nursery cost		3114	3085	3808	4461	3073	3002	3057	2972	3114	3085	3808	4461	3073	3002	3057	2972	2865
Advantage mat nursery		-249	-220	-943	-1596	-208	-137	-192	-107	-249	-220	-943	-1596	-208	-137	-192	-107	0

Table 27. Economics of cultivation (Experiment II)

COST	Norm	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
Input cost																		
General mat nursery	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	0
General main field	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460
Specific mat nursery treatment		270	241	964	1617	229	158	213	128	270	241	964	1617	229	158	213	128	0
Specific Conventional nursery	1310																	1310
Specific mechanical transplanting cost	VC	136	132	143	132	143	132	161	136	132	132	147	132	136	147	122	143	0
TOTAL INPUT COST		6600	6567	7301	7943	6566	6484	6568	6458	6596	6567	7305	7943	6559	6499	6529	6465	5770
Labour cost																		
General main field	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600
General mat nursery	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	0
General Mt cost	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	0
Specific Conventional nursery	1555	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1555
Specific manual planting	5000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5000
Specific mechanical transplanting cost as per treatment	VC	693	650	746	650	693	693	819	693	650	650	756	650	746	756	630	746	0
TOTAL LABOUR COST		20403	20360	20456	20360	20403	20403	20529	20403	20360	20360	20466	20360	20456	20466	20340	20456	24155
Grand total cost		27003	26927	27757	28303	26969	26887	27097	26861	26956	26927	27771	28303	27015	26965	26869	26921	29925
Depreciation		110	106.3	115	106.3	115	106.3	130	110	106.3	106.3	118.8	106.3	110	118.8	98.75	115	0
Working capital		27113	27033	27872	28409	27084	26993	27227	26971	27062	27033	27890	28409	27125	27084	26968	27036	29925
Interest on working capital		445.7	444.4	458.2	467	445.2	443.7	447.6	443.4	444.9	444.4	458.5	467	445.9	445.2	443.3	444.4	491.9
Cost A1		27559	27478	28330	28876	27529	27437	27675	27414	27507	27478	28348	28876	27571	27529	27411	27480	30417
Advantage		2922	2998	2168	1622	2956	3038	2828	3064	2969	2998	2154	1622	2910	2960	3056	3004	0
Grain		34784	33928	32544	34096	36856	34960	41672	29968	28416	39784	38576	34960	34784	35304	30312	34096	35816
Straw		10323	12044	10139	12399	13119	10914	9365	11915	9654	11334	13400	9720	10727	12173	9429	11528	12267
Gross income		45107	45972	42683	46495	49975	45874	51037	41883	38070	51118	51976	44680	45511	47477	39741	45624	48083
Net Income		17548	18494	14352	17619	22446	18437	23362	14468	10563	23640	23627	15804	17940	19948	12330	18143	17666
B;C ratio		1.64	1.67	1.51	1.61	1.82	1.67	1.84	1.53	1.38	1.86	1.83	1.55	1.65	1.72	1.45	1.66	1.58

5.4 Experiment III

The experiment III was designed to find out whether mat nursery can be used for manual planting, instead of conventional nursery. Conventional nursery requires $1/10^{th}$ of the main field area as the nursery area and needs pulling out of the seedlings, root washing and tying into bundles for manual planting. Mat nursery requires only 0.016 ha per ha of main field, can be raised anywhere, and needs only cutting into bits of convenient size to be held by the transplanting labour for transplanting. A comparison was made on the time taken to transplant conventional and mat nursery manually.

The result indicated that (Table 19) the mat nursery did not prolong the time taken for manual planting significantly, when compared to planting root washed seedlings. The time for planting on an average was 7800 seconds 100 m^{-2} for conventional nursery, indicating that 27 man days were required for transplanting 1 ha using it. The time required for manual planting of mat nursery varied between 7363 to 11110 seconds $100m^{-2}$ depending upon the media of the mat; however, not statistically differentiating between the mats (Fig 17). This indicated that 26 to 39 man days ha^{-1} was required for planting 1 ha using mat nursery. If the workers are getting enough experience in working with mat nursery, the speed of using it may improve and we expect further reduction in time for manual planting using mat nursery.

The planting done manually, in Experiment III was without instructing the workers for any specific plant population, but they were directed to perform as per their normal practice. The seventeen treatments did not show any meaningful variation, with regard to plant population at harvest (Table 20); (Fig.18). The overall mean population was 28 m^{-2} and conventional nursery plot had a population of 24 hills, whereas 19 to 37 hills m^{-2} was observed in case of manual planting using mat nursery. Since population was uniform without any statistical significance between the treatments, naturally, growth in terms of height of the plant remained unaffected due to the various treatments. The plants receiving different treatments had similar stature, with a mean height of 81 cm at harvest

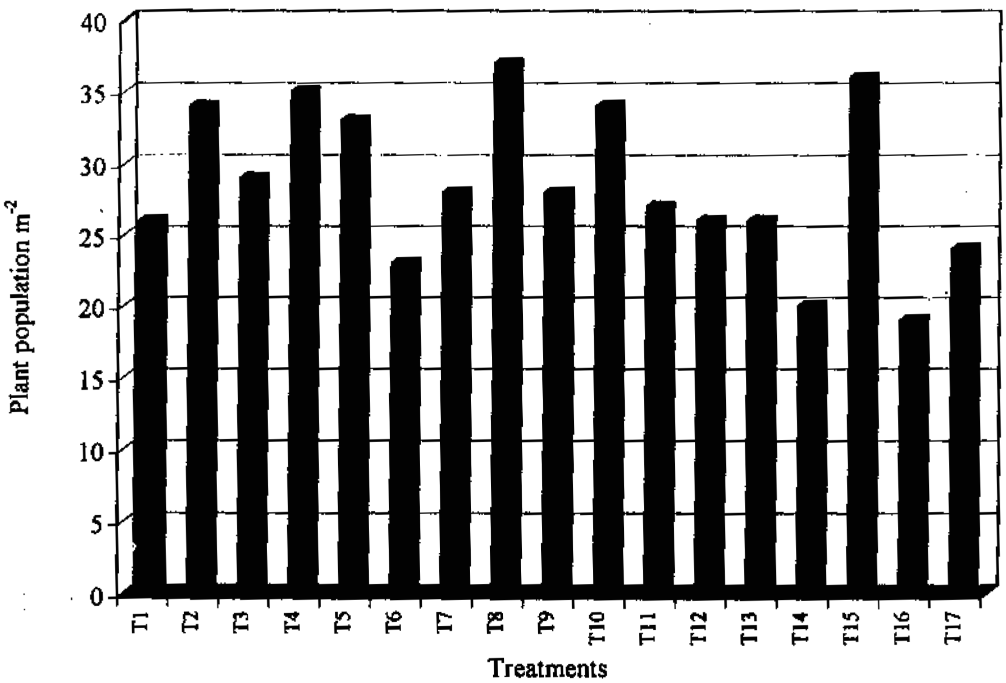


Fig. 18. Plant population at harvest (Experiment III)

(Table 21). This meant that, plants are not subject to any competition imposed by any restriction in the environment.

Tiller production, though remained unaffected in the earlier stages, was differentially influenced by the treatments towards the end (Table 22);(Fig.19). Chaff in the media in either proportions (2:1 or 1:2) as well as high content of coir pith raw (1:2 ratio) under wet system showed a deleterious effect in tiller production. We have already seen that, mat with chaff provided good strength to the mat (Table 8). The excess content of undecomposed organic matter in the root zone and its anaerobic decomposition under wet system might have influenced tiller production. A portion of undecomposed organic matter remains attached with the root when it was manually planted. Probably this might have affected tiller production in these treatments. Undecomposed organic matter affects tiller production (Prashant, 2002). Arunachalam *et al*, (1991) observed that had higher tiller number while using sathupai nursery compared to that using conventional nursery during summer and rabi seasons.

Reaction to pest and diseases by the crop was uniform (Table 23). The recording of BLB, thrips, GLH and stem borer revealed that the crop was uniformly affected by these pests/diseases. It is already seen that the population of the different treatments remained the same and the microenvironment available to the plant was also the same. Hence the pest and diseases remained uniform without variation. However, the population of bug was found varying. A fairly high (2.7 bugs $hill^{-1}$) bug population was seen in the plot using mat nursery raised under dry system with soil + chaff in the ratio 1:2.

Among the yield components panicles m^{-2} was significantly influenced by the nursery used for manual planting (Table 24); (Fig.20). A high number of panicles was produced by the crop planted using dry mat nursery with soil + coir pith raw in the ratio of 2:1 (T_5). An equal number of panicles was also produced by the crop planted using dry mat nursery with soil + chaff in the ratio 2:1 (T_7) or wet mat nursery with soil + coir pith raw in the ratio 2:1 (T_{13}). This indicated that a mat with $1/3^{rd}$ organic matter and $2/3^{rd}$ soil is good for having higher panicle number. The undecomposed organic matter may get decomposed by the time the

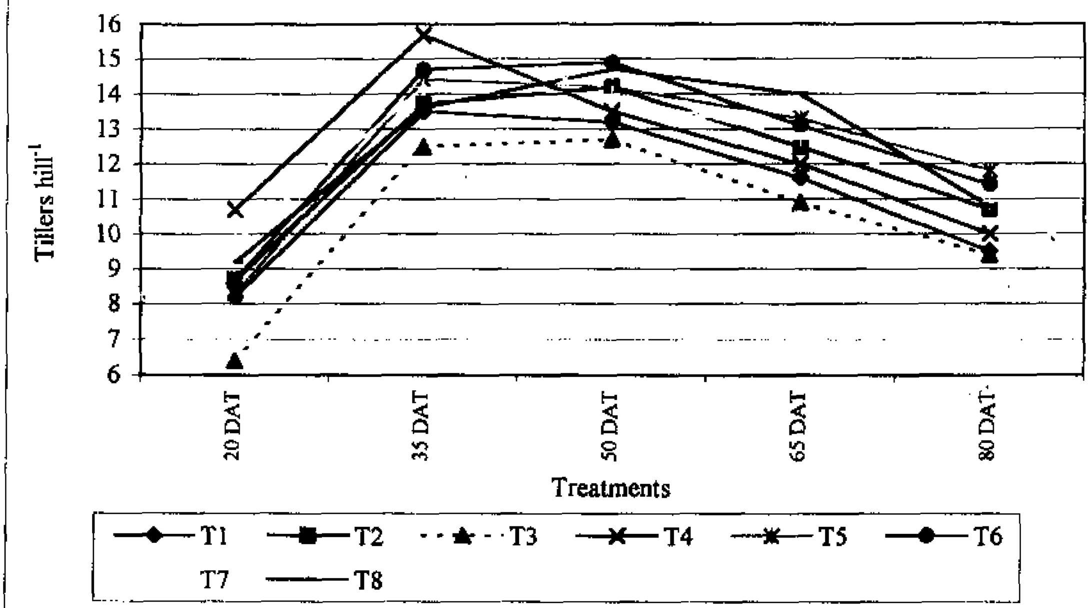


Fig. 19a. Effect of treatments on tiller production (Experiment III)

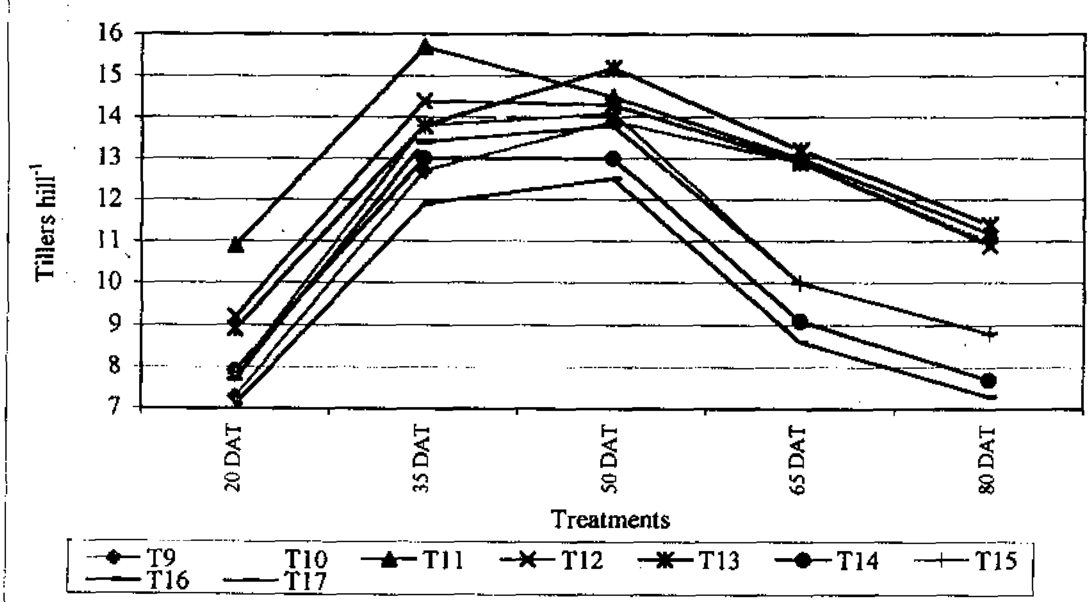


Fig. 19b. Effect of treatments on tiller production (Experiment III)

crop reaches its reproductive phase and would be useful for higher number of panicles. Supply of nutrients to the soil during vegetative growth phase always enhanced panicle production in rice (Murthy, 1980).

As the population was uniform, meaning that the plants got equal share of vertical and horizontal space, the formation, development and maturing of panicles were uniform and hence the number of late formed panicles was unaffected due to the various treatments. The overall mean number of late formed panicles were only 7 panicles m^{-2} (Table 24).

The number of filled grains per panicle was affected due to the treatments (Table-24). Crop raised using conventional nursery had a low number of filled grains per panicle (31). Such a lower number was also seen in case of soil + cow dung in the ratio of 1:2 (T_2), soil + coir pith raw in the ratio 2:1 (T_5) and soil + chaff in the ratio 2:1 (T_7), all under dry system (Fig. 21). Under dry system of nursery raising, organic matter is likely to be burned aerobically and inorganic nutrients released is likely to be leachable. Conventional root wash nursery did not carry along with it, the soil or organic matter attached to the roots. But when undecomposed organic matter is there in the soil in higher proportion, under aerobic or anaerobic system in a mat nursery, the decomposition is slower and a portion of the root zone material is also planted into the main field. This causes supply of gradually mineralising nutrients to the root zone. This might have resulted in highest number of filled grains per panicle in case of crop planted using mat nursery with soil + coir pith raw in 1:2 ratio in dry system or soil + coir pith compost in the ratio 1:2 under wet system. A good environment and translocation of nutrients improved number of filled grains per panicle in paddy (Vergara, 1980).

Test weight of the grain remained unaffected which indicated that this genetic character was almost maintained without environmental influence (Table 24); (Fig.22) The level of nutritional benefit due to mat nursery system has not influenced beyond filling of the grains to the level of grain size. This conclusion is substantiated by the observation that grain: chaff ratio also remained unaltered due to the various treatments (Table 24).

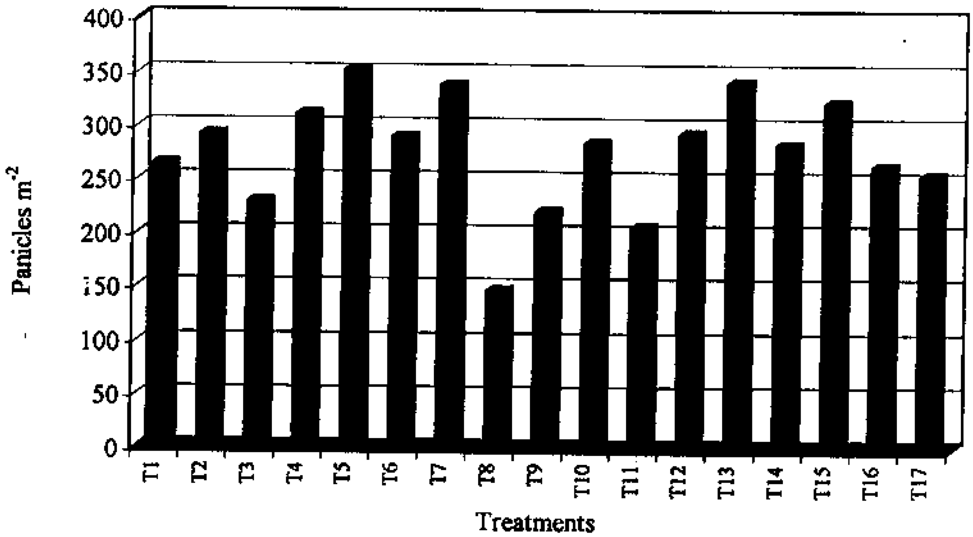


Fig. 20. Effect of treatments on no. of panicles m^{-2} (Experiment III)

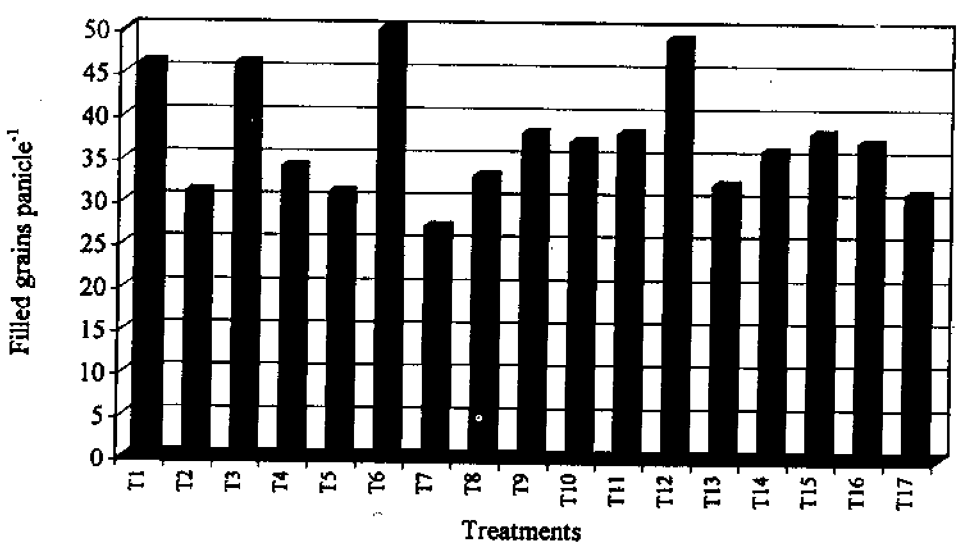


Fig. 21. Effect of treatments on filled grains panicle^{-1} (Experiment III)

Finally, nursery treatments did not influence the grain yield of the crop. We have already seen that the population remained unaffected and number of panicles m^{-2} was variably influenced by the treatments, T_5, T_7 and T_{13} having higher number of panicles m^{-2}. However, these treatments had a very low number of filled grains per panicle. Hence a balance has been created in the plant system to have an even level of productivity. This has resulted in a uniform level of grain yield in the crop. Hence it is definitely encouraging to observe that using mat nursery as on alternative to conventional root wash nursery for manual planting did not influence the performance and grain yield of the crop. The overall mean yield of the grain was 4441 kg ha^{-1} and the crop raised using conventional nursery had a grain yield of 2788 kg ha^{-1}.

The straw yield showed a different picture (Table 25); (Fig.24). Manually planted crop using conventional nursery had a very low level of straw yield of 6325 kg ha^{-1} (Table 25). All the crops raised using mat nursery had a higher level of straw production, when compared to the crop raised using conventional nursery except in case of soil + coir pith compost in the ratio of 2:1 under wet nursery (T_{11}). A low population as well as tiller number is associated with these 2 treatments and its cumulative effect has been reflected in the straw yield. This revealed that basically the system and media of mat nursery has not influenced the straw yield of the crop.

This observation is further substantiated by the fact that the harvest index of the crop remained unaffected due to various treatments (Table 25); (Fig.25). A very low value of harvest index of 0.3 indicates that straw production was favoured by the crop physiology than grain yield. This might be due to the fact that the population density, even though it was uniform, was low and more vegetative growth was favoured by the horizontal space available to the plant. At later stages of growth, translocation from source to the sink was not effective. However, yield of the crop was also substantially good. Stoskopf, (1985) observed that low harvest index indicated that vegetative growth was more favoured than grain production.

While studying the use of mat nursery for manual planting, the biggest concern is, whether the proposition of using mat nursery instead of conventional

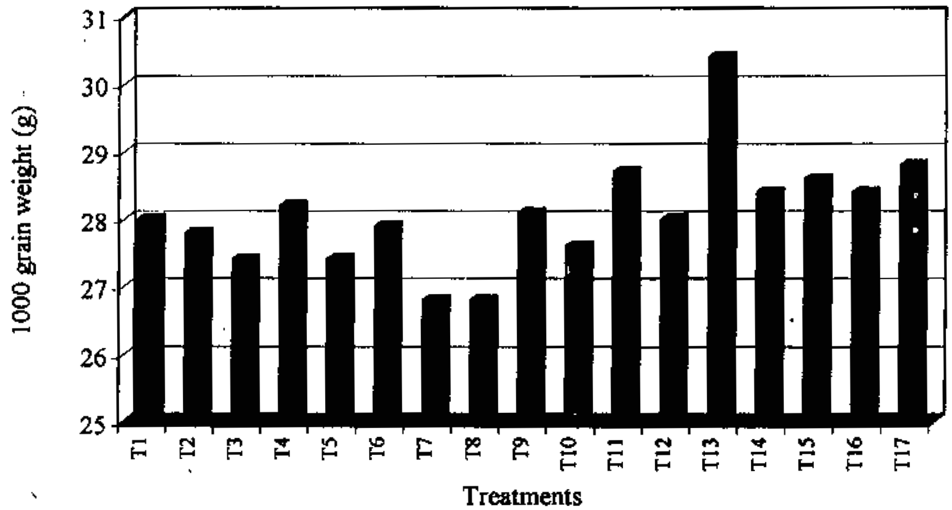


Fig. 22. Effect of treatments on 1000 grain weight (Experiment III)

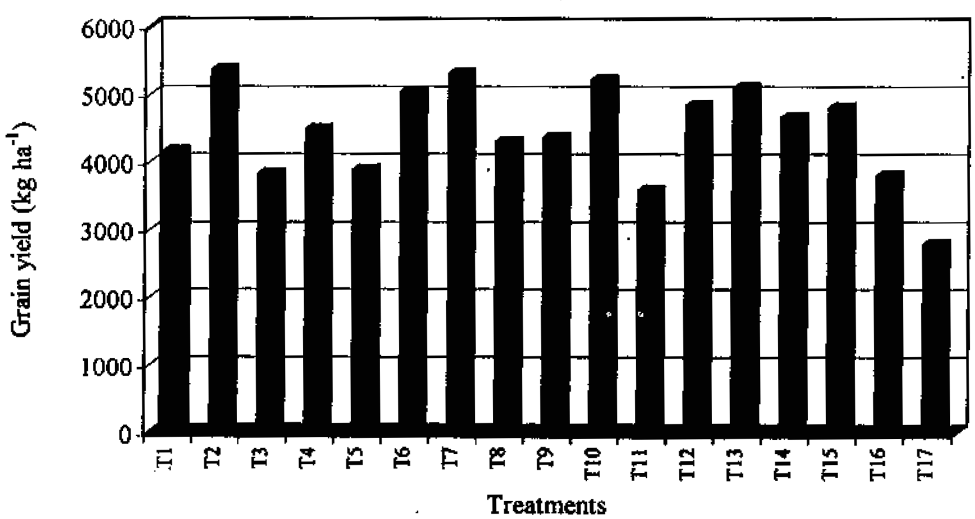


Fig. 23. Effect of treatments on grain yield (kg ha^{-1}) (Experiment III)

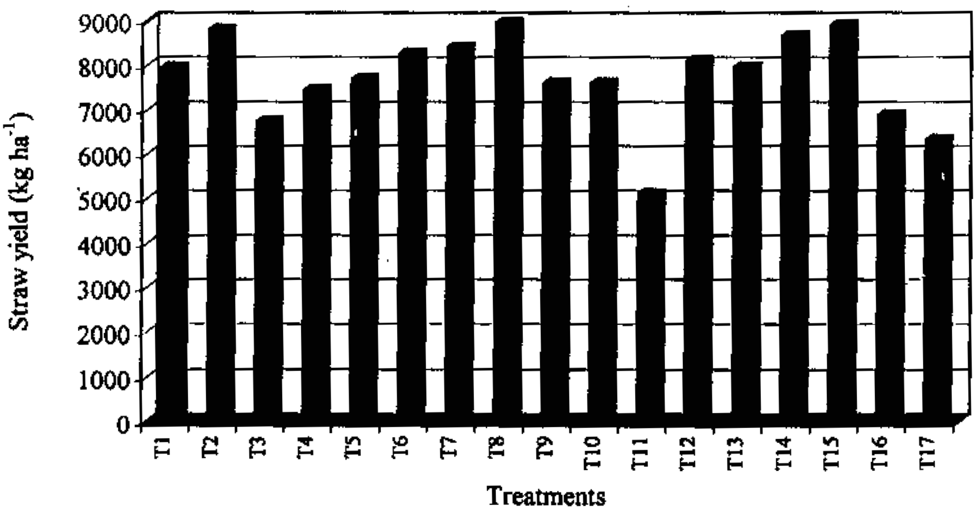


Fig. 24. Effect of treatments on straw yield (kg ha^{-1}) (Experiment III)

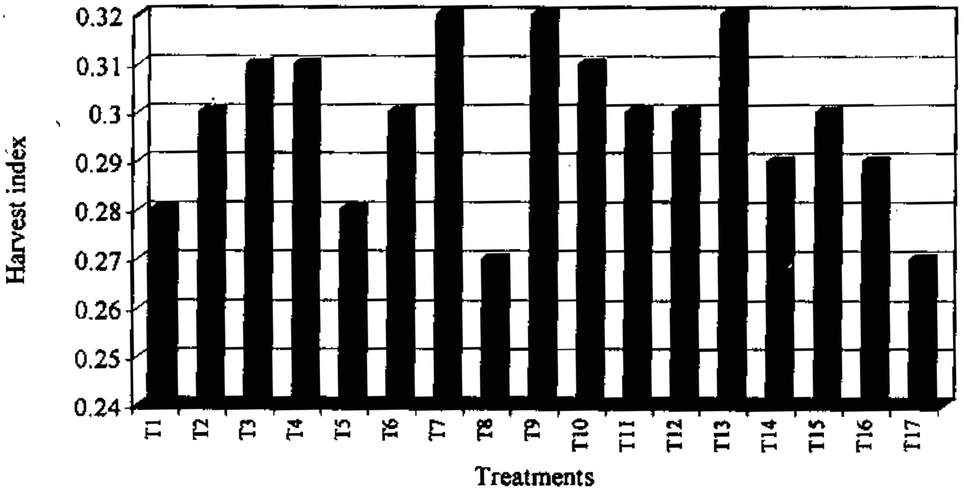


Fig. 25. Effect of treatments on harvest index (Experiment III)

nursery will be economical without yield reduction. We have already seen that the crop raised using conventional nursery or mat nursery are equally yielding. Further that the different systems of mat nursery have not contributed to a definite grain yield advantage. But in case of straw yield, there is a definite advantage of using mat nursery over conventional nursery. When the benefit: cost ratio is considered as per the procedure suggested by Acharya (1997), crop raised using conventional nursery had a benefit: cost ratio of 1.05 (Table 28). The treatment soil + coir pith compost in the ratio 2:1 under both systems (T_5 and T_{11}) and soil+ chaff in the ratio 1:2 under wet system (T_{16}) were obviously having B:C ratio below 1.5. So these mats are not to be considered economically feasible as an alternative to conventional nursery. All other crops raised using mat nursery, except T_5, T_{11} and T_{16} are showing high returns, with B: C ratio above 1.5. Crop raised specifically using the 6 types of mat nursery viz., T_2, T_6, T_7, T_{10}, T_{13} and T_{15} are having high B:C ratio equal to 1.8 or above it, which indicated their commercial preference for using as a substitute for conventional nursery.

When the nursery cost alone was considered (Table 29), the above 6 treatments, viz., T_2, T_{10}, T_6, T_{13} T_7, and T_{15} had a monetary advantage of Rs. 680, 1680, 1933, 1232, 608 and 908 respectively. This cost is inclusive of nursery raising and transplanting. The cost for the after care and management of the crop is almost the same, without distinguishing between the treatments. It is already seen that there is no definite yield advantage between the different mat nurseries. However, substantial increase in straw yield has been obtained in case of manual transplanting with mat nursery, in relation to conventional nursery.Considering all these factors, raising mat nursery using, soil+ coir pith raw in the ratio 1:2, (T_6) under dry nursery system which gives a mat nursery advantage of Rs. 1933/ha, will be more appropriate for field recommendation for commercial practice. Less input cost of the materials, viz., coir pith raw (T_6, T_{13}, T_{14}) and cow dung (T_{10}) combined with less labour requirement for manual planting of the mat strips raised under these treatments (Table 19) have made these treatments economically successful to replace conventional nursery for manual planting. Further, the less strength of the mats, under this system might have enabled (Table 8) the workers to easily separate the seedlings from the mat at the time of planting and transplanting operation became easier, even without pulling out seedlings before transplanting.

Table 28. Economics of cultivation (Experiment III)

COST	Norm	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
Input cost																		
General mat nursery	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	0
General main field	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460	4460
Specific mat nursery treatment		270	241	964	1617	229	158	213	128	270	241	964	1617	229	158	213	128	0
Specific Conventional nursery	1310																	1310
Specific mechanical transplanting cost	VC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INPUT COST		6464	6435	7158	7811	6423	6352	6407	6322	6464	6435	7158	7811	6423	6352	6407	6322	5770
Labour cost																		
General main field	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600	17600
General mat nursery	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	0
General MT cost	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Specific Conventional nursery	1555	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1555
Specific manual planting		3830	4100	3760	3900	3630	2930	4190	3730	3900	3100	3760	3600	3560	3560	3900	4260	5000
Specific mechanical transplanting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LABOUR COST		22540	22810	22470	22610	22340	21640	22900	22440	22610	21810	22470	22310	22270	22270	22610	22970	24155
Grand total cost/Total working capital		29004	29245	29628	30421	28763	27992	29307	28762	29074	28245	29628	30121	28693	28622	29017	29292	29925
Interest on Working capital		464.1	467.9	474	486.7	460.2	447.9	468.9	460.2	465.2	451.9	474	481.94	459.1	458	464.27	468.7	478.8
Cost A1		29468	29713	30102	30908	29223	28440	29776	29222	29539	28697	30102	30603	29152	29080	29481	29761	30404
Advantage		921	680	297	-496	1162	1933	618	1163	851	1680	297	-196	1232	1303	908	633	0
Grain		33216	42944	30608	35824	31080	40336	42472	34400	34880	41760	28704	38672	40800	37248	38432	30368	22304
Straw		11920	13204	10098	11166	11521	12394	12589	13434	11388	11401	7660	12144	11940	12990	13345	10320	9487
Gross income		45136	56148	40706	46990	42601	52730	55061	47834	46268	53161	36364	50816	52740	50238	51777	40688	31791
Net Income		15668	26435	10604	16082	13378	24290	25285	18612	16729	24464	6262	20213	23588	21158	22296	10927	1387
B;C ratio		1.53	1.89	1.35	1.52	1.46	1.85	1.85	1.64	1.57	1.85	1.21	1.66	1.81	1.73	1.76	1.37	1.05

Table 29. Nursery cost (Experiment III)

COST	Norm	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
Input cost																		
General mat nursery	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	1734	0
Specific mat nursery treatment		270	241	964	1617	229	158	213	128	270	241	964	1617	229	158	213	128	0
Specific Conventional nursery	1310																	1310
Specific Mechanical Transplanting cost	VC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INPUT COST		2004	1975	2698	3351	1963	1892	1947	1862	2004	1975	2698	3351	1963	1892	1947	1862	1310
Labour cost																		
General mat nursery	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	1110	0
Specific Conventional nursery	1555	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1555
Specific manual planting		3830	4100	3760	3900	3630	2930	4190	3730	3900	3100	3760	3600	3560	3560	3900	4260	5000
TOTAL LABOUR COST		4940	5210	4870	5010	4740	4040	5300	4840	5010	4210	4870	4710	4670	4670	5010	5370	6555
Total nursery cost + Planting		6944	7185	7568	8361	6703	5932	7247	6702	7014	6185	7568	8061	6633	6562	6957	7232	7865
Advantage mat nursery		921	680	297	-496	1162	1933	618	1163	851	1680	297	-196	1232	1303	908	633	0

Summary

6. SUMMARY

A field experiment on 'Standardisation of mat nursery for rice' was conducted at Agricultural Research Station, Mannuthy during May to September 2002, to provide package for the commercial production of paddy mat nursery, evaluate the mat nursery under mechanical transplanting and to provide information on the possibility of using mat nursery as an alternative to conventional root washed nursery

The study comprised of 3 experiments. Raising 16 types of mat nurseries in combination of 4 different media viz. cow dung, coir pith compost, coir pith raw and chaff in two ratios i.e.1: 2 or 2 : 1 (volume/volume) under wet and dry systems and its evaluation formed experiment I. CRD was the experimental design. For field evaluation of these 16 mat nurseries using 8-row Yanji Shakthi transplanter in comparison to manual planting using conventional nursery, RBD was the design with 2 replications. In experiment III, the design was RBD and the 16 types of mat nurseries were manually transplanted in comparison to manual planting using conventional nursery. The investigation led to the following findings:

Experiment I

1. Mat nursery seedling height was higher for soil +chaff in 2:1 ratio, under dry nursery at initial stages, and towards the end, soil cow dung mixture in 2: 1 ratio led to the maximum height. Under wet system at 15 DAS, soil with cow dung in the ratio 2:1 or 1:2 had the maximum height.

2. Scoring for pest and disease incidence (healthiness) based on leaf colour showed that presence of cow dung in the media helped the seedlings to have maximum green colour.

3. The thickness of root zone was not affected under dry system, due to the treatments, whereas in wet system, soil cow dung mixture in 2: 1 ratio (T_9) had the maximum thickness (24 mm).

4. The treatments soil and cow dung in 1: 2 ratio and soil + coir pith compost in 2: 1 ratio produced maximum number of healthy and minimum number of weak seedlings in dry nursery. Soil + cow dung in either of the ratios showed such a phenomenon in wet nursery

5. Heavier mats were produced with soil + cow dung or soil + chaff in 2: 1 ratio under wet system. The treatments showed no significant variation in dry system.

6. The root lengths were not at all influenced by the different treatments under both the systems.

7. Soil+ chaff in 2: 1 ratio produced stronger mats under dry system. Presence of cow dung irrespective of its proportion produced stronger mats under wet system.

Experiment II

8. Different media and the systems tried did not influence the forward speed of the transplanter and the area transplanted at the forward speed. The transplanting time ranged from 3.6 to 4.6 s m^{-1} run and the respective turnover for the machine varied from 1.104 to 1.44 ha day^{-1} (8hours). The area transplanted by the machine was between 23 m^2 $minute^{-1}$ to 30m^2 $minute^{-1}$.

9 Plant population of the mechanically planted crop remained uniform, without any statistical difference between the various treatments tried (23 to 32 hills m^{-2}). Similarly the number of missing hills was also found to be uniform (5 to 6 hills m^{-2}).

10. Number of seedlings $hill^{-1}$ and the number of floating seedlings did not show any difference among the treatments. The percentage of floating hills ranged between 43 and 50 percent.

11. Depth of planting, which is a fixed parameter for the machine remained unaltered, with a mean value of 49mm, ranging from 38 to 54mm.

12. The crop manually planted using conventional nursery with a spacing of 15 cm x 10 cm had the maximum plant population (65 hills m^{-2} at harvest) through out the growth period. The crops raised by mechanical transplanting with different mat nurseries had a mean population of 29 hills m^{-2}.

13. During the initial stages of growth i.e., up to 30 DAT there was some significant variation in the stature of the plant, which tend to disappear in the later stages. The crop had an average height of 89cm, at the time of harvest.

14. The mat raised with the media, soil + cow dung in the ratio 1: 2 under wet system put forth a significantly higher number of tillers $hill^{-1}$ throughout the growth and produced 17.5 tillers $hill^{-1}$ at harvest. Similarly the crop raised under conventional nursery with manual transplanting had a very low tiller production (9.5 tillers $hill^{-1}$).

15. The values of CGR, RGR and NAR showed significant variation up to active tillering stage and thereafter the trend diminished. The crop raised under manual planting using conventional nursery had comparable values with that of the mechanically planted crops. LAI and LAD were not at all influenced by the treatments during the growth period.

16. The overall mean weed no. m^{-2} at 20 and 40 DAT were 130 and 94, without showing any statistical difference between the treatments. The predominant weeds present in the area were *Cyperus iria., Isachne miliacea, Ludwigia parviflora, Echinochloa sp., Mollugo sp., Nymphaea stellata, Schoenoplectus lateriflorus and Sphenoclea zeylanica.*

17. The mean bacterial leaf blight incidence was 7.33 per cent and almost all other treatments did not show any difference, except T_3 and T_{13} .The insect pests i.e. thrips, GLH, rice bug and stem borer did not show any special preference for any treatment and their occurrence was uniform in all the plots.

18. Number of panicles m^{-2} was not significantly influenced by the various treatments and the crop raised under conventional nursery with manual

planting produced 284 panicles m^{-2}, while under mechanised planting the panicle production ranged from 220 to 304.

19. The treatments T_6, T_{11} and T_{13} had high number of late formed panicles $m^{-2}$and the respective numbers were 29.7, 18.6 and 25.1. The overall mean of late formed panicles m^{-2} were 12.5, which was only 4.8 per cent of the total number of panicles.

20. Number of filled grains panicle^{-1} varied between 24 and 61. Soil + cow dung in the ratio 2: 1 (T_1) produced the maximum number of filled grains panicle^{-1} (61), which was statistically comparable to almost all the other treatments except T_2, T_5, T_{12}, T_{13} T_{15} and T_{16}. Manually planted crop using conventional nursery produced 46 grains per panicle and the overall mean was 44.

21. The 1000 grain weight was not influenced by the different treatments and the test weight ranged from 26.5 to 29g, with a mean value of 28.1.

22. The grain: chaff ratio (weight/weight) remained unaltered by the treatment affects. The mean ratio of 14:1 indicated that there was 93% filling in the crop.

23. The grain and straw yield of the crop was also not influenced by the treatments tried. The overall mean grain yield was 4344 kg ha^{-1}, while that of straw was 7464 kg ha^{-1}. Crop raised under conventional nursery had comparable yield of 4477 kg grains ha^{-1} and 8178 kg straw ha^{-1}with that of mechanically planted crop. Similarly the harvest index was also unaffected, and the mean value was 0.31.

24. The nutrient content of the grain was significantly affected. The average values of N, P and K were 0.34, 0.22 and 0.29 percent respectively. But the N, P and K content of straw were unaltered with mean values of 0.22, 0.11 and 2.2 percent respectively. The total N uptake was not affected, while there was variable influence in the case of P and K. The overall mean uptake of N, P and K were 32, 19.6 and 183.1 kg ha^{-1} respectively.

25. Higher BC ratios above 1.8 was seen when the mat used for mechanical transplanting was soil + coir pith raw in the ratio of 2:1 and soil + chaff in the

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ratio 2:1 under dry system and soil + cow dung in the ratio 1:2 and soil + coir pith compost in the ratio 2:1 under wet system. Manually transplanted crop using conventional nursery had a low B: C ratio of 1.58.

Experiment III

26. The time taken for manual transplanting was unaffected by the type of nursery used. The man days ha^{-1}, for manual planting using conventional nursery was 27, where as that for mat nursery ranged from 26 to 39 man days ha^{-1}.

27. Plant population was almost uniform, whether it was mat nursery or the conventional root washed nursery used for manual planting. The mean population at the time of harvest was 28 hills m^{-2}.

28. The stature of the plants observed at 15 days interval did not show any significant difference with respect to the media and systems of nursery used. The mean height of the plant was 81 cm at harvest.

29. During the early stages of growth i.e., up to maximum tillering stage, the tiller production was unaltered due to the various treatments. Presence of chaff in both the ratios and coir pith raw in 1:2 ratio under wet system recorded a lower tiller production, comparable with that of conventional nursery.

30. The various pests and diseases observed did not show any variation on the performance of the crop except rice bug. The mean population of rice bug was 1.8, and treatment T_8^1 with it showing a higher number. (2.7 bugs $hill^{-1}$) The incidence of BLB, thrips, GLH and stem borer was almost uniform.

31. The system of nursery raising had influenced the number of panicles m^{-2}, with an overall mean of 275. Crop raised using conventional nursery had 254 panicles m^{-2}, whereas the crop raised using mat nursery had panicles ranging from 146 to 352.

32. Late formed panicles (those panicles that remained greenish at harvest) were not affected by the various treatments and on an average 7 panicles m^{-2} were formed late.

33. The highest no of 50 filled grains $panicle^{-1}$ was recorded in case of mat nursery raised with soil + coir pith raw in 1:2 ratio under dry system (T_6). The treatments T_2, T_5 and T_7 had a lower no of filled grains per panicle, statistically comparable with that of T_{17} (31).

34. Thousand grain weight was not affected by the treatments.

35. The overall mean grain: chaff ratio was 16:1 ranging between 7:1 to 24:1 and was also unaffected by the treatments.

36. The types of mat nursery used for manual planting did not influence grain yield of the crop. The average grain yield of the crop was 4441 kg $ha^{-1}$and the manually planted crop using conventional nursery produced 2788 kg grain ha^{-1}. The straw yield was significantly influenced, with a mean straw yield of 7726 kg ha^{-1}, while conventional nursery produced a low straw yield of 6325 kg ha^{-1}. The mean harvest index was 0.3, which remained unaltered due to the treatments tried.

37. A very low B: C ratio of 1.04 was recorded by the crop raised under conventional nursery while all the crops raised using mat nursery had a higher value than this. B: C ratios higher than 1.8 was obtained when the treatments were T_2, T_6, T_7, T_{10} and T_{13}.

Conclusion

The following conclusions can be made based on the present study:

1. Mechanical transplanting using 8-row paddy transplanted produces a crop as good as that of manually line planted crop with recommended population.
2. Mat nursery can be used instead of conventional nursery for manual planting.
3. Mechanical or manual transplanting with mat nursery provides better economics than manual planting.

4. Soil + cow dung in the ratio 1:2 in wet system (T_{10}) and soil + chaff in the ratio 2:1 in dry system (T_7) can be recommended for manual and mechanical planting.
5. For mechanical planting, soil + chaff in the ratio 2:1 in dry system (T_7) and soil + coir pith compost in the ratio 2:1 under wet system (T_{11}) can also be used for economically viable mat production.
6. Raising of mat nursery using soil + cow dung in the ratio 1:2 and soil + chaff in the ratio 2:1 under both systems and soil + coir pith raw in the ratio 1:2 under dry system (T_6) and soil + coir pith raw in the ratio 2:1 under wet system (T_{13}) can be recommended for manual planting based on economics.

Future line of work

Based on the results and observations made from the study, the following investigations are suggested for future.

1. Seeding density for mat preparation.
2. Mechanical devices for seeding in mat nursery.
3. Mechanical devices for mat seedling separation for manual planting.
4. Continuance of the present study for repeated confirmation.
5. Development of rice genotypes for mechanical planting.

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Appendices

APPENDIX - I

Weekly weather data for the cropping period averaged over twelve years (1991-2002)

Standard week No.	Temperature (°C)			Relative humidity (%)		Sunshine hours day^{-1}	Evaporation mm $week^{-1}$	Rainfall mm	No. of rainy days	Wind speed (km hr^{-1})
	Maximum	Minimum	Mean	Morning	Evening					
19	34.3	25.3	29.8	86	59	7.8	4.9	47.2	2	3.9
20	32.7	24.6	28.7	89	65	5.9	4.2	58.4	3	3.3
21	33.0	24.5	28.8	89	64	7.0	4.2	45.0	3	3.7
22	32.2	24.0	28.1	90	68	5.6	3.8	72.0	5	3.8
23	29.8	23.1	26.5	92	79	3.4	3.0	182.0	6	3.8
24	29.6	23.2	26.4	94	81	2.2	3.1	181.5	7	3.8
25	29.9	23.4	26.7	95	77	3.7	3.1	122.2	6	3.8
26	29.1	23.0	26.1	94	80	3.2	2.9	182.5	6	3.4
27	29.2	22.8	26.0	94	80	2.8	3.2	161.9	7	3.6
28	29.0	22.7	25.9	95	80	3.2	2.7	156.0	7	3.7
29	29.2	22.8	26.0	94	78	2.8	2.8	177.7	6	3.6
30	28.9	22.9	25.9	95	80	2.7	2.8	165.2	7	3.6
31	28.8	23.1	26.0	95	80	2.6	2.8	142.6	6	3.6
32	29.2	23.2	26.2	95	78	3.1	2.9	92.5	7	3.5
33	29.5	23.2	26.4	94	77	4.0	3.0	132.8	5	3.3
34	29.5	23.3	26.4	94	77	4.1	3.1	95.2	5	3.2
35	30.4	23.1	26.8	94	74	4.6	3.6	73.1	4	3.3
36	30.9	23.2	27.1	93	69	6.0	3.5	52.2	3	2.5
37	31.2	23.3	27.3	92	68	6.6	4.4	49.8	3	2.7
38	30.5	23.1	26.5	92	69	5.8	3.8	40.1	3	2.7

APPENDIX - II

Weekly weather data during crop season (2002)

Standard week No.	Temperature (°C)			Relative humidity (%)		Sunshine hours day^{-1}	Evaporation mm $week^{-1}$	Rainfall mm	No. of rainy days	Wind speed ($km\ hr^{-1}$)
	Maximum	Minimum	Mean	Morning	Evening					
19	33.7	25.3	29.5	84	60	7.7	4.8	44.2	2	4.9
20	30.8	24.0	27.4	93	76	3.1	2.7	173.2	5	3.3
21	32.2	24.2	28.2	87	67	6.9	3.7	4.0	0	3.6
22	30.8	24.0	27.4	89	73	3.5	4.2	119.0	2	4.2
23	30.7	23.4	27.1	94	73	5.0	3.5	64.2	4	4.0
24	28.9	22.5	25.7	94	93	0.6	2.5	219.1	5	3.7
25	29.5	23.3	26.4	93	81	1.8	2.8	109.8	6	4.5
26	30.5	23.7	27.1	94	75	3.5	3.1	74.6	5	3.7
27	30.3	23.6	26.9	94	72	5.2	3.4	57.0	4	3.7
28	29.4	23.1	26.3	94	77	3.0	3.1	126.0	4	4.0
29	29.7	22.7	26.2	95	73	2.7	3.1	58.0	5	3.8
30	29.9	22.9	26.4	93	73	3.8	2.9	70.4	5	3.7
31	28.1	22.5	25.3	95	86	0.7	2.4	83.5	7	4.0
32	28.6	22.2	25.4	95	79	0.9	2.8	94.0	6	3.8
33	27.9	22.8	25.4	94	83	2.6	2.1	337.0	7	3.7
34	30.1	25.4	27.8	93	72	5.4	3.8	13.8	2	3.7
35	30.9	24.1	27.5	93	65	7.3	4.3	3.8	1	3.8
36	29.8	25.4	26.5	94	71	5.5	3.4	98.7	3	3.2
37	30.7	25.0	26.8	92	63	8.7	4.4	8.0	1	3.3
38	31.3	24.8	27.1	91	59	8.3	4.3	0.0	0	3.7

STANDARDISATION OF MAT NURSERY FOR RICE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment was conducted during May to September 2002 at the Agricultural Research Station, Mannuthy, Thrissur to develop a suitable production package for rice mat nursery, evaluate it under mechanical transplanting and develop it as a substitute for conventional nursery for manual planting. The study consisted of three experiments. (I) Raising of sixteen types of mat nurseries using four different media in two ratios under two systems (dry and wet) and its evaluation. (II) Mechanical transplanting of these sixteen types of mat nurseries along with manual planting of conventional nursery and crop performance study. (III) Manual transplanting of sixteen types of mat nursery along with conventional nursery and crop evaluation. Experiment-I was designed in CRD, while experiment-II and experiment-III were laid out in Randomised Block Design, with two replications each. Rice variety Kanchana, was tried in the experiment.

Results revealed that soil+ cow dung in the ratio 2:1 in the mat produced taller seedlings and coir pith compost produced shorter seedlings. Presence of cow dung produced dark green seedlings with maximum number of healthy and minimum number of weak seedlings. Soil+ cow dung in the ratio 2:1 produced heavy mats under both systems. Presence of chaff in the media resulted in stronger mats. The performance of the transplanter, as it is a fixed parameter for the machine was unaltered by the different media and systems of nursery. But generally, the number of missing hills was lower under dry system, compared to wet system.

In case of experiment-II, a higher plant population of 65 hills m^{-2} was seen associated with the crop raised under manual planting using conventional nursery. But the same crop produced a significantly lower number of tillers $hill^{-1}$ throughout its growth period and the crop had 9.5 tillers $hill^{-1}$, at the time of harvest. The physiological growth attributes, observed through CGR, RGR and NAR was distinctively lower for the manually planted crop using conventional nursery in the initial stages of growth, but the trend disappeared in the later stages, indicating a uniform rate of growth. The insect pest attack was uniform without any variation due to treatments. Incidence of BLB was higher in case of mechanically planted crop using soil+ coir pith compost in 2:1 ratio under dry nursery and soil+ coir pith

raw in 2:1 ratio under wet nursery. Among the yield components, number of panicles m^{-2} and test weight were not altered by the treatments. The maximum number of filled grains $panicle^{-1}$ was seen in case of soil+ cow dung in the ratio 2:1 as the media under dry system (61). However, the final grain and straw yield remained unaffected due to the various treatments with a mean value of 4344 and 7464 kg ha^{-1} respectively. The NPK content of the grain and total uptake of P and K by the crop were influenced by the various treatments. Under dry system soil+ coir pith raw and soil+ chaff in the ratios 2:1 and in wet system soil+ cow dung in the ratio 1:2 and soil+ coir pith compost in the ratio 2:1 were economically superior and can be the mat nursery media for mechanical transplanting.

The use of mat nursery instead of conventional nursery did not prolong the time required for manual planting. Conventional nursery recorded a lower tiller production (8.8 at the time of harvest). Similar level of tiller production was seen in cases of soil+ chaff in either of the ratios and soil+ coir pith raw in the ratio 1:2. The pest and disease incidence, except rice bug, did not show any discrimination between the treatments. Soil+ chaff in the ratio 1:2 under dry system had a higher population of bugs (2.7 per hill). Soil+ coir pith raw in the ratio 2:1 under both the systems had the highest number of panicles m^{-2} i.e., 352 and 341, respectively. Conventional nursery had the lowest number of filled grains $panicle^{-1}$ (31). The grain yield was unaffected, due to treatments and the mean grain yield was 4441 kg ha^{-1}. Straw yield was influenced by the different treatments. A very low harvest index value of 0.3 was recorded for the crop. Crop raised using conventional nursery had a very low B:C ratio (1.05) and all mechanically planted crops had higher B:C ratio than this.

As the grain yield was not affected due to the various treatments, the selection of mat should be based basically on economic consideration. Soil+ coir pith raw as well as soil+ chaff in the ratio of 2:1 under dry system, and soil+ cow dung in the ratio 1:2 and soil+ coir pith compost in the ratio 2:1, under wet system could be a better option for mechanical transplanting based on the economics. Soil+ cow dung in 1:2 ratio and soil+ chaff in 2:1 ratio under both systems, and soil+ coir pith raw in 1:2 ratio under dry system and soil+ coir pith raw in 2:1 ratio under wet system were found economically suitable for manual planting.