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Development of nursery raising technique for "system of rice intensification" machine transplanting

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This study was aimed to develop the spaced mat nursery to suit the available transplanter for System of Rice Intensification (SRI) method of cultivation. To achieve 100% seed germination, enough root networks to provide enough rigidity for the mat and to offer conducive growth environment, the soil medium was optimized. Nine treatment media were prepared namely vermisoil (field soil+vermicompost-1:1, 2:1 and 3:1), soil+farm yard manure (FYM) soil (field soil+farm yard manure-1:1, 2:1 and 3:1), field soil+coirpith (1:1 and 2:1) and field soil alone. After 14 days of sowing, seedling height and root length were measured in all trays. Among the nine treatment media studied the maximum nursery height and root length of 17.06 and 10.75 cm was observed in FYM soil and vermisoil, respectively prepared in 1:1 ratio. For the same treatment media when ratio was changed to 2:1 it recorded 16.26 and 10.14 cm respectively. For the stiffness studies, field soil was mixed with decomposed sieved coirpith and fibrous coirpith each in the ratio of 1:1 and 2:1 and tested with and without base layer and measured the stiffness force. The mat stiffness was found to be maximum for a media mixture of field soil and coirpith at 1:1 and 2:1 ratios with a corrugated sheet base layer. From the results, the soil medium for growth and stiffness was optimized as field soil, FYM and fibrous coirpith in the ratio of 2:1:1.

Key words: System of rice intensification (SRI), mat nursery, rice transplanter, soil medium, mat stiffness.

INTRODUCTION

System of rice intensification (SRI) is being adopted in many states in India and the response from farmers has been overwhelming seeing the benefits of the method. Square planting method helps in operating weeders in check-rowed geometry to obtain maximum weeding efficiency and better soil aeration (Hameed and Jaber, 2007). In SRI, rice seedlings are transplanted by labourers. Square markings are made on the puddled fields either by ropes or by iron roller type marker. Each node of the square marking is transplanted with single rice seedling at precise spacing, usually 25 × 25 cm, about 16 plants per square meter. This method of planting requires careful planting on the grid which is difficult for the workers, who do not normally follow proper spacing in planting and maintain seedling population per hill. So this is the need of the hour for the transplanter to plant 14 days single seedling in a square planting. Instead of developing a new transplanter for this purpose the existing transplanter can be used with modification of existing mat nursery for planting in SRI method. These transplanters pick more than five seedlings per pick (Dewangan et al., 2005; Sahay et al., 2002). Study on various transplanters showed that Chinese make Yanji 8 row self propelled rice transplanter is most commonly

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used in India and the following parameters namely affordable for the majority of the farmers, simple mechanism, riding type, wider float, less weight and less cost given a way to this transplanter to suit SRI method. The main component in the development of SRI transplanter is suitable nursery raising method. The SRI transplanter will be successful only when the nursery raising method is modified to suit the SRI transplanter. Spaced mat nursery found to be suitable for SRI transplanter.

In SRI, single seedling is required to be planted per hill at spacing of 240 × 240 mm which would amount to 1,74,000 single seedlings per hectare. Therefore for planting one hectare, 345 trays of seedlings grown in the said configuration would be needed. Only 3.5 to 5 kg seed is required to plant one hectare as against 60 to 80 kg in conventional transplanting, assuming a 100% viable seeds. Hence, even in the absence of yield advantage, SRI is superior to conventional transplanted rice in terms of seed, labour and time required during transplanting (Sharma and Masand, 2008). When the seeds are sown at a sparse seed rate, with one seed placed at the each of the 504 nodes of the grid on the tray, the following points were of concern in implementing such a procedure; (i) The seed germination when not 100% would create lot of nodal voids after germination, (ii) The single seedling when grown for 14 days may not have enough root networks to provide enough rigidity for the mat to be handled by man and machine and (iii) The growth medium that is being extensively used for rice mat nursery production, may or may not provide conductive growth environment to the seeds to grow. Keeping these observations in mind the research was undertaken with the following objectives namely preliminary studies on transplanter for development of spaced mat nursery, optimization of soil medium for seedling health and mat stiffness.

MATERIALS AND METHODS

Laboratory experiment on Yanji 8 row self propelled rice transplanter

Determination of number of picks per row of mat

Since the width of the seedling box of the transplanter is 220 mm, a carton sheet of 220 × 440 mm size was used as a template. This template was kept inside the seedling box in the transplanter with seedling gate is kept in the starting position. When the engine crank was rotated manually the seedling box moved from one side to the other side by 220 mm and the transplanting needle made 14 marks on template. The distance between each marking was found to be 15.7 mm.

Determination of needle reaches into mat

The distance travelled by the separating needle to cut and pick from the nursery mat in seedling box through the seedling gate was found to vary between 7 and 20 mm by using the adjusting knob.

Development of spaced mat nursery

Since the requirement for the SRI transplanter is to pick and place single seedlings, it was planned to grow the seedlings themselves in a grid like sparse pattern on a typical transplanters' tray. Hence, it was contemplated that the tray surface area from which the transplanting finger picks the seedling need be divided into an imaginary grid in each of the nodes a single seedling is to be grown.

Based on the study with templates, the number of picks per row of seedling tray was determined as 14 and the reach length of picking into the tray as 7 to 20 mm. The typical seed tray width of 'Yanji' transplanter being 220 mm, the width from which one pick is drawn is hence 220/14=15.7 mm. The length of reach for the picker needle though adjustable between 7 and 20 mm, it was prefixed as 12 mm, since it is to be kept greater than the typical paddy seed length of 7 to 10 mm. Hence if the seedlings are grown in a grid pattern of 15.7 × 12 mm with one seedling occupying each node, the picking finger of that row would pick a single seedling to transplant. A typical transplanter tray of 440 × 220 mm size would then hold $\frac{432 \times 220}{15.7 \times 12} = 504$ grid nodes with one seedling in each node (Figure 1). Special nursery trays were developed to grow such sparsely sown mats. Stainless steel trays of 440 × 220 × 25 mm size were fabricated with the shutter to provide for easy removal of mat from tray. The side walls were provided with 5 mm beading bent outwards to avoid sharp edges as well to draw the mat out from tray.

Trials on development of sparsely sown seedling mats

Preliminary exploratory study on the sparse mat development

Field soil was sieved through 2 mm size sieve (BSS8) to remove stones, stubbles and lumps and was mixed with DAP powder at the rate of 15 g m^{-2} area. It was filled in the developed tray with an effective mat area of 432 × 220 mm to the brim with the shutter placed. Then water was sprinkled over the surface of the soil and leveled. The soil surface was brought to a wax like condition so that any marked line if made will not get erased. Then grid markings were formed using a foot rule (Figure 2).

Certified good quality seeds were selected and single seeds were sown in each node of the grid manually and covered using sieved field soil. Water was sprinkled using rose can. On the 5th day after sowing, germination was relatively less and on the 9th day the seedlings were observed to yellow and wither. To rectify this, 0.5% urea + 0.5% zinc sulphate were sprinkled, but no significant changes were noticed and the seedlings withered and did not survive (Figure 3). This preliminary trial was repeated twice and the results were similar. This proved that the methods of raising conventional mat nursery and raised bed nursery were not appropriate for spaced mat nursery.

Selection of suitable soil medium nursery

Selection of quality seed to ensure seedling count in sparse nursery experiment

Since SRI insists on single seedling per hill and young seedlings of 12 to 14 days old, obtaining healthy and robust seedlings from quality seeds is obligatory and thus every seed counts. Quality seeds ensure vigorous seedling growth, absolute establishment in the field, uniform plant population, accelerated growth rate, resistance against pest and diseases and uniform maturity at harvest. Most importantly a quality seed was selected to have above 90% germination rate.

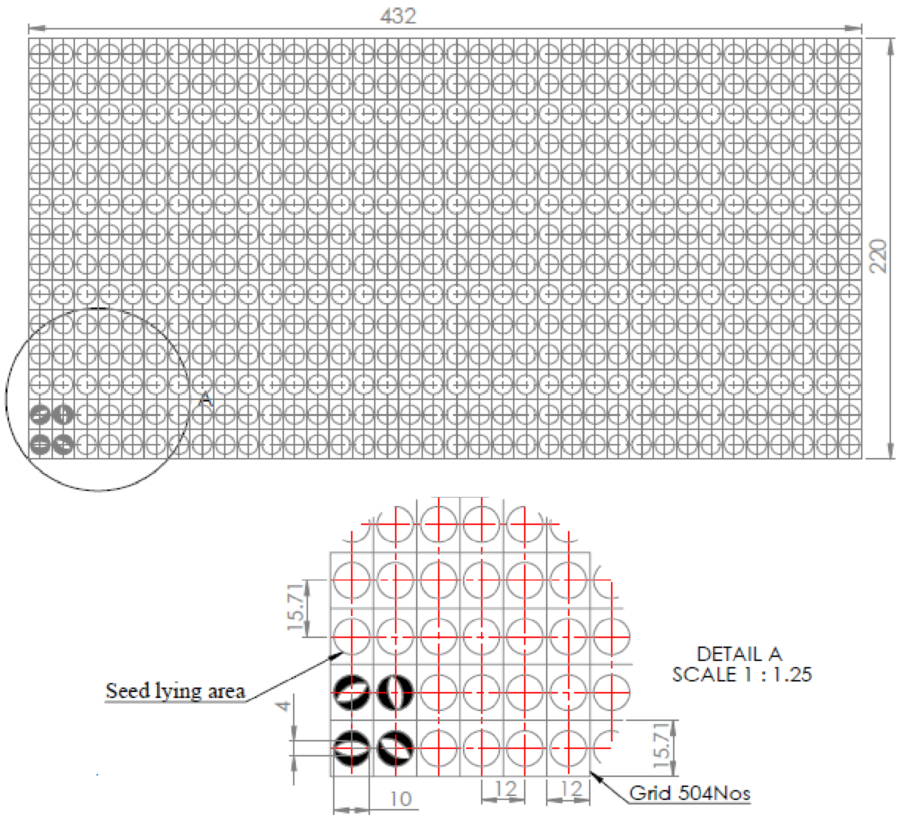

Figure 1. Imaginary grid on typical transplanter tray.

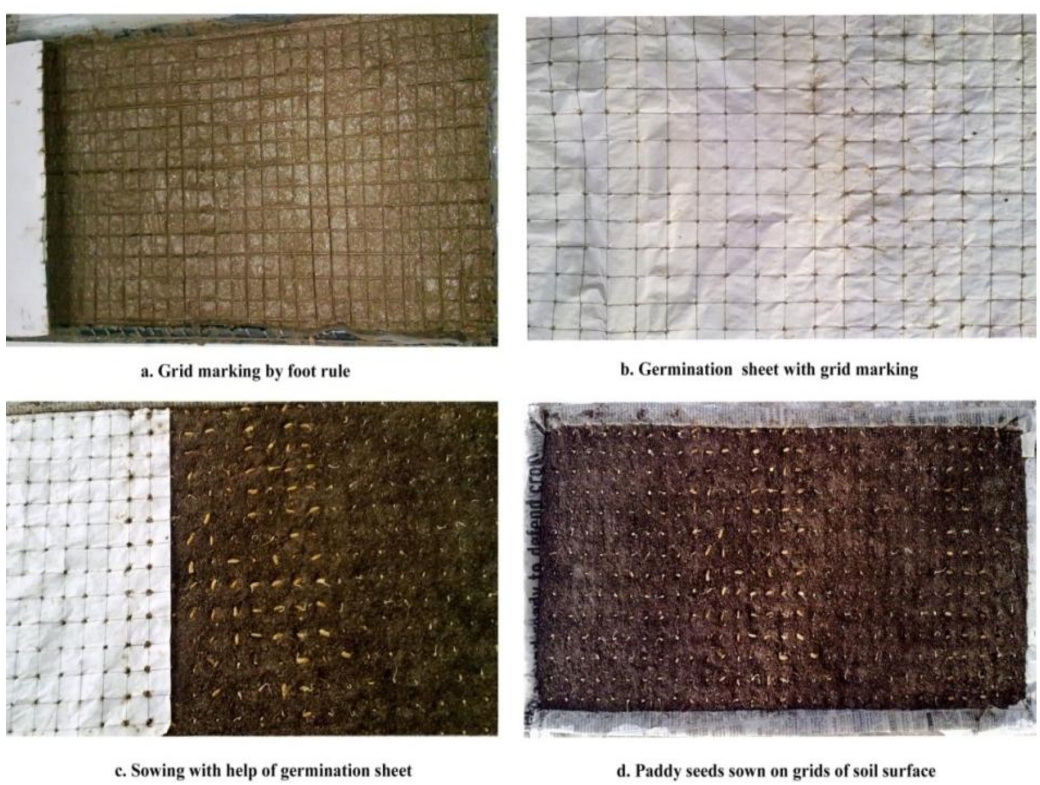

Figure 2. Manual sowing on mat

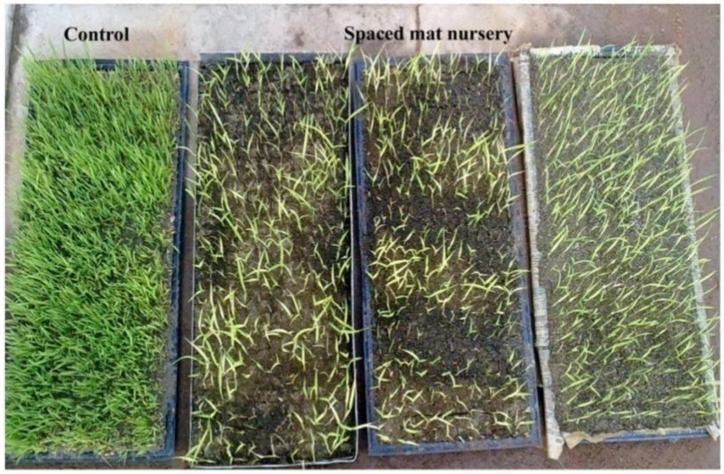

Figure 3. Poor growth of sparse nursery on conventional mat medium.

Table 1. Optimization of soil medium for better crop growth.

S/N	Medium	Mixing ratio
1	Field soil	-
2	Field soil + vermicompost	1:1
3	Field soil + vermicompost	2:1
4	Field soil + vermicompost	3:1
5	Field soil + FYM	1:1
6	Field soil + FYM	2:1
7	Field soil + FYM	3:1
8	Field soil + Coirpith	1:1
9	Field soil + Coirpith	2:1
10	Field soil	Control

Replication: 3.

Seed treatment: The certified paddy seeds with 90% germination rate were soaked in salt water (20%). Floating seeds over the water surface were removed and seeds that settled down at the bottom of the container were collected and washed thrice with fresh water. Then the seeds were treated in a mixture of *Pseudomonas, Azophos, Thirum 75 SD and Carbendazim* at 30, 400, 5 and 5 g, respectively for every 2 kg of seeds (Nghiep and Gaur, 2005). The seeds were soaked and treated thus for 12 h. Soaked seeds were transferred into a gunny bag and left for 24 h (Junsripibul, 1988). When white root or radicals emerge from the seeds, the seeds were used for sowing on the nursery bed.

Experiments on optimization of better soil medium

Nine treatment mediums were selected each with different combination of growth media as mentioned in Table 1, The media was added with DAP powder, *pseudomonas, VAM and Azophos* at the rate of 50, 6, 50 and 40 g m^{-2}, respectively in all the treatments (Ahamed and Ravi, 2006). The prepared soil media were separately filled in trays and leveled after sprinkling with water. Because of the tediousness involved in marking and dividing the soil surface into grids, grid pattern was drawn on 432 × 220 mm size germination sheet and kept on the wet soil in the tray, and the treated seed was sown in the grid one per node and covered with soil.

Conventional dense mat nursery was also prepared as a control treatment for the experiment. A seed rate of 160 g and 12 g per tray was used for conventional mat nursery and spaced nursery, respectively. Water was sprinkled twice (morning and evening) a day. After 14 days, seedling height, root length and germination percentage were measured in all trays. Statistical modeling (GNU 'R' statistical package) was done on this data to optimize the soil medium. Though the growth of the plant was good, the mats were not stiff enough to handle them while taken out from the tray. Insufficient root network was observed as the cause of such weak mat stiffness. Therefore the factors responsible for mat stiffness were studied next.

Method for assessment of mat stiffness

Before evolving the methods for improving the stiffness of the sparsely sown mats, it was necessary to develop a methodology for quantifying the stiffness of the mat. One easy and viable index indicative of the mat stiffness would be the rip or tear strength of the mat as measured by shearing the mat with a prong or claw. Rip force for separating a single seedling determines the stiffness of

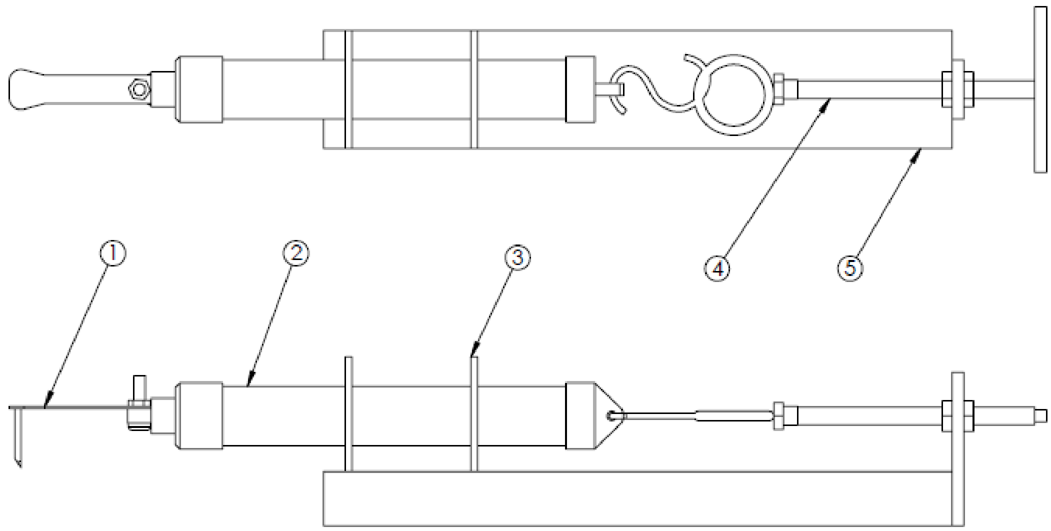

Figure 4. Test rig for rip force measurement.

nursery mat. A similar mechanism of transplanter picker was developed. A claw fitted with spring balance was used to find out the force required for separating seedlings from nursery mat made up of different soil mixture, different surfaces and different mat thicknesses. Rip strength was expressed in g cm^{-2}.

For finding ripping strength, a device was developed (Figure 4). The device contains a rectangle base (5), spring balance (2) (make: SALTER), a screw mechanism (4) and hollow rings (3) to support the spring balance. The spring end of the balance was fitted with a claw (1) and the other end was connected to the screw through a swivel. Minimum count of the spring balance was 5 g and maximum count was 1 kg. The manually driven screw mechanism is of 110 mm length and 6 mm diameter with the thread on the holding post. The base of device has two 2 mm thick hollow rings of 20 mm inner diameter to support the spring balance. Test rig and the nursery tray were kept on the same plane. The claw of the device was first made to pierce the mat from top at the required distances from edge of the mat and was kept aligned to facilitate pulling of single seedling along with medium. When the screw is manually tightened, the claw separates the seedling along with medium. The spring balance reading is read as the rip force in g. When divided by the ripping area (2 × thickness × length of rip) the rip strength in g cm^{-2} could be found.

Optimization of growth medium for better stiffness on spaced mat nursery

An experiment was carried out to test the stiffness of the mat composition devoid of any root network. To give the necessary stiffness to the medium, field soil was mixed with 4 year old decomposed coir pith in different ratios and filled in tray. Stiffness was measured at different settling time when it was taken out from the tray. This study was carried out in the soil medium without growing the seedling at all. The stiffness force was measured for the 8 types of soil medium with and without base layer of corrugated sheet at 4 different settling times.

Corrugated sheet was used as base layer as spread at the bottom of the tray and soil was filled after wetting. Two types of coirpith material namely sieved coirpith in 3 mm sieve and fibrous coirpith were added with soil. Fibrous coirpith was mixed with soil in the ratio of 1:1 and 2:1 by volume. The length of the fibre ranged between 10 and 35 mm. In this way the prepared soil media were filled in tray, made wet and for every 12, 24, 36 and 48 h the stiffness force was measured and analyzed for optimization of the medium devoid of root network. The GNU ‘R’ statistical package (The R foundation www.r-project.org) was used for the statistical modeling mentioned above.

The optimized soil medium for growth and that for stiffness were judiciously combined for this study. Composition of medium for nursery bed was varied in two different levels in the experiment. The two different compositions of media are namely, vermin soil and FYM soil. Vermi soil contains field soil, vermicompost and fibrous coirpith and FYM soil contains field soil, farm yard manure and fibrous coirpith.

Assessment of root length and plant height

After 14 days of growth, the plants in the nursery were measured for root length. A part of the mat was gently washed in water and each single plant was meticulously separated. The total root lengths and height of the plant were measured by foot rule. The influence of the soil medium of mat on the health of the nursery was also to be monitored and optimized.

RESULTS AND DISCUSSION

Optimization of soil medium for better crop growth on sparsely sown mat

Influence on nursery height

The experiment on optimization of better soil medium for growing sparse nursery was explained. Nine different

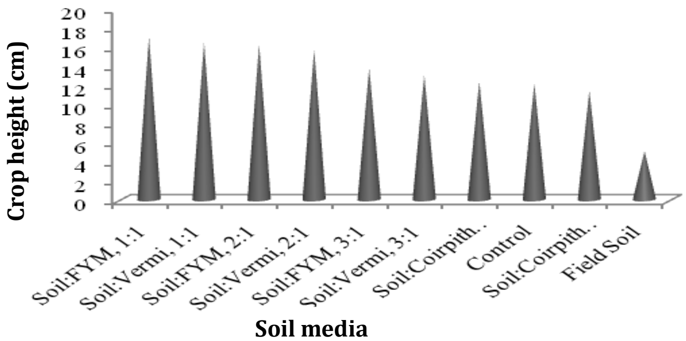

Figure 5. Effect of different soil media on nursery height.

combinations of growth medium were used to grow the selected/treated paddy seeds and on the 14th day, biometric observations on nursery height, root length and percentage germination were recorded. Single factor ANOVA was used to analyses the recorded data (**=P<0.01).

The treatment effect was found to be significant. The nursery height ranged from 15.69 to 17.06 cm. Ahmed et al. (2008) confirmed these results. The presence of vermicompost, FYM which were basically organic soil nutrients and coirpith an inert filler material mixed at different percentages had caused this difference in nursery height. The nursery height may be considered as an indicator of the health of the nursery that was grown. While comparing the treatment means by LSD (Least Significant Difference), it was found that a plain field soil reported the least effect on nursery height (5.07 cm), whereas the field soil mixture with organic composites such as vermicompost or FYM provided the best nursery growth (Figure 5). When the content of field soil was increased to a 3 parts in one ratio, the nursery growth drastically dropped to a lower level of about 13 cm. This fact provided further evidence that organic matter at an appropriate ratio is to be present in the medium for proper development of sparse nursery. The field soil/coirpith mixture was the next higher statistically on par group of nursery height levels (11 to 12 cm). Surprisingly, the control, namely the densely grown nursery on plain field soil was on par with this group in crop growth indicating that the medium selection is crucial for development of sparsely sown nursery. In the experiments on the suitability of soil medium for sparse nursery, the nursery heights observed in field soil with vermicompost soil medium were 16.49, 15.69 and 13.03 cm with respect to the ratio of 1:1, 2:1 and 3:1 and that observed in field soil with farm yard manure soil medium were 17.06, 16.26 and 13.8 cm with respect to the ratio of 1:1, 2:1 and 3:1.

Effect on root growth

The data on root length were analyzed using analysis of variance. Here also, the root length was significantly influenced by the treatment media (**=P<0.01). The reason for the above must be the same explained already for crop height. Since the root matrix development was anticipated to be the key component in forming the stiffness of the nursery, this factor was observed and analyzed separately. The mean comparison through LSD indicated that here again just similar to the ANOVA on nursery height, the presence of organic composites in the medium provided the best root growth of 10 cm which was higher than the values reported by Ahmed et al. (2008) and similar to the values reported by Vijayakumar et al. (2004). The observations clearly indicated a similar trend as in the case of nursery height. The only difference observed here was that the dense nursery in field soil (control) provided an on par root growth with that of the media with coirpith. Here also, the lowest root length of 4.69 cm was recorded on field soil with sparse sowing (Figure 6).

The sparse nursery root lengths observed in field soil with vermicompost based soil medium were 10.75, 10.14 and 9.02 cm with respect to the ratios of 1:1, 2:1 and 3:1 and that observed in field soil with farm yard manure based soil medium were 10.69, 10.47 and 8.49 cm for the ratios 1:1, 2:1 and 3:1 respectively. FYM soil and vermin soil at 2:1 ratio medium was chosen as the optimized medium for the production of sparse nursery with the lesser vermicompost content making it cheaper.

Optimization of soil medium for better stiffness of the sparsely sown mat

An experiment was carried out to assess the stiffness of medium devoid of any root network, as influenced by the ratio of mixtures, nature of medium, settling time after watering and provision of a base stiffening layer. A factorial analysis was attempted and a linear model was built on the mat stiffness. On analyzing the raw data of stiffness for normalcy, it was found that the distribution was not normal. But normalcy of data is mandatory for building a linear model. Various transformations such as square root and power transformations were tried on the

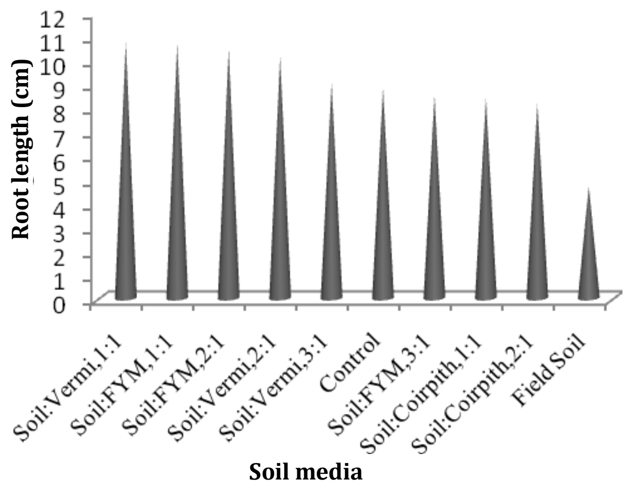

Figure 6. Effect of different soil media on root growth.

Table 2. Optimization of soil medium for better stiffness on spaced mat nursery.

S/N	Settling time (h)	With base layer		Without base layer	
		Soil : Sieved coirpith	Soil : Fibrous coirpith	Soil : Sieved coirpith	Soil : Fibrous coirpith
1	12	1:1 2:1	1:1 2:1	1:1 2:1	1:1 2:1
2	24	1:1 2:1	1:1 2:1	1:1 2:1	1:1 2:1
3	36	1:1 2:1	1:1 2:1	1:1 2:1	1:1 2:1
4	48	1:1 2:1	1:1 2:1	1:1 2:1	1:1 2:1

data with no avail (Table 2). Therefore a box-cox analysis was attempted on the model to find an appropriate transformation coefficient (λ). Figure 7 illustrate the log likely hood for different λ values for the full model being considered. The transformation coefficient was found to be -0.63, implying that the transformation necessitated on the stiffness (ripping strength, g cm^{-2}) is stiffness to the power of -0.63. Using the above transformation for the stiffness response, a full model involving the mixing ratio, type of soil medium, settling time after watering and the presence of stiffening base layer was built.

The linear model was stepped through by systematic removal of factors one by one based on AIC (Akaike Information Criteria) value and the minimal adequate model was searched through using the “step” function of the ‘R’ statistical tool. The best simple model was arrived as that with only layer, medium and mixing ratio in additive mode without any interaction. The AIC was -1294. The best model was put under diagnostics to find out whether the built linear model was adequate. Figure 8 illustrates the diagnostic plot, wherein no evidence was found on any trend in the distribution of residual against the fitted value. The Q-Q plot also proved that the response had a perfect normal distribution, which was quite anticipated because of the box-cox transformation. Table 3 shows the ANOVA on stiffness as influenced by the aforesaid factors. The settling time was found to be insignificantly influencing the stiffness of the mat. This was so because the medium having more of fibrous content was not affected by the settling time.

Figure 9a to c shows the Tukey plots relevant to the three influencing factors on the stiffness of the mat. It may be noted that none of the paired differences between treatments of each factor contains zero in its range and hence each pair statistically was proven to be significantly different. On analyzing the mean values of the stiffness as plotted between the ripping stress (mat stiffness) and the settling time (Figure 10a), the presence of base layer (corrugated sheet) improved the mat strength from about 115 to 155 g cm^{-2} proven to be

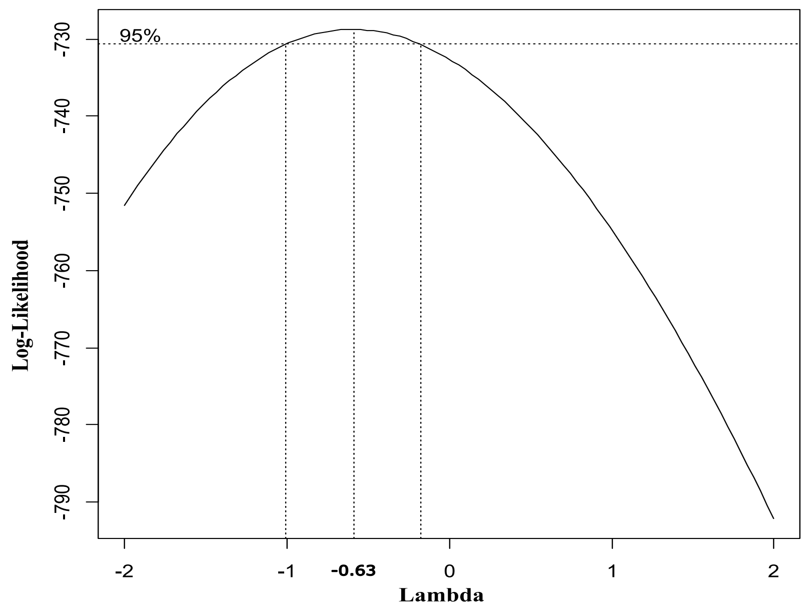

Figure 7. Determination of Box-Cox transformation parameter.

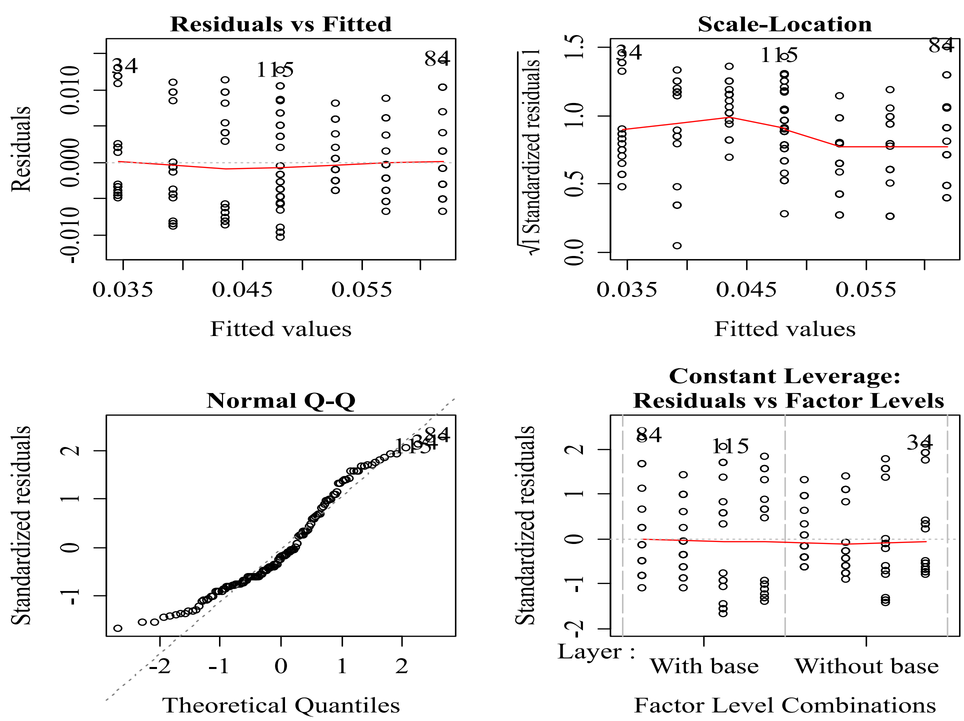

Figure 8. Diagnostics on model of mat stiffness affected by growth medium without nursery.

significant from the ANOVA. Though the corrugated sheet is thoroughly soaked for 14 days, the mat stiffness is higher.

Figure 10b depicts the influence of the mixing ratio on the stiffness. The equal proportion of soil and sieved/fibrous coirpith had caused an increase of mat strength by 20 g cm^{-2} over that of a 2:1 soil and sieved /fibrous coirpith (Table 3). This significantly higher mat strength was due to the presence of more organic matter by way of more soil in the medium causing better binding, thereby better stiffness. As for the influence of the type of medium, the fibrous coirpith media had about 170 g cm^{-2} of mat strength compared to 105 g cm^{-2} as exhibited by medium having sieved coirpith. The longer fibrous

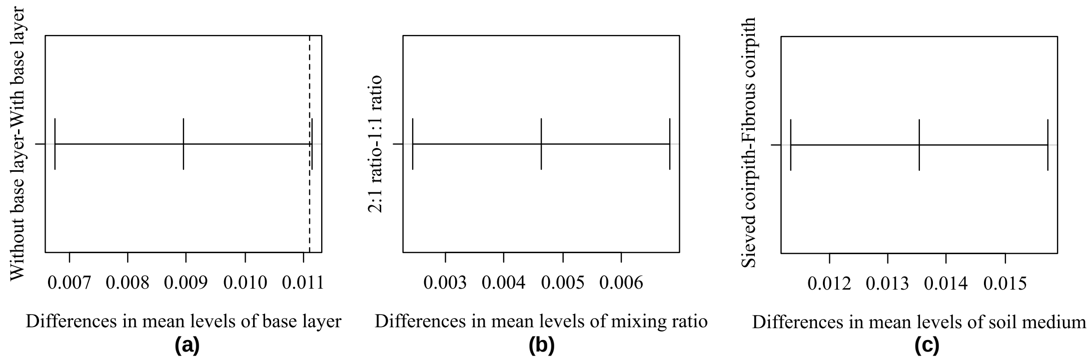

Figure 9. Tukey's mean comparison on effect of media characteristics on mat stiffness.*All differences at 95 % family-wise confidence level.

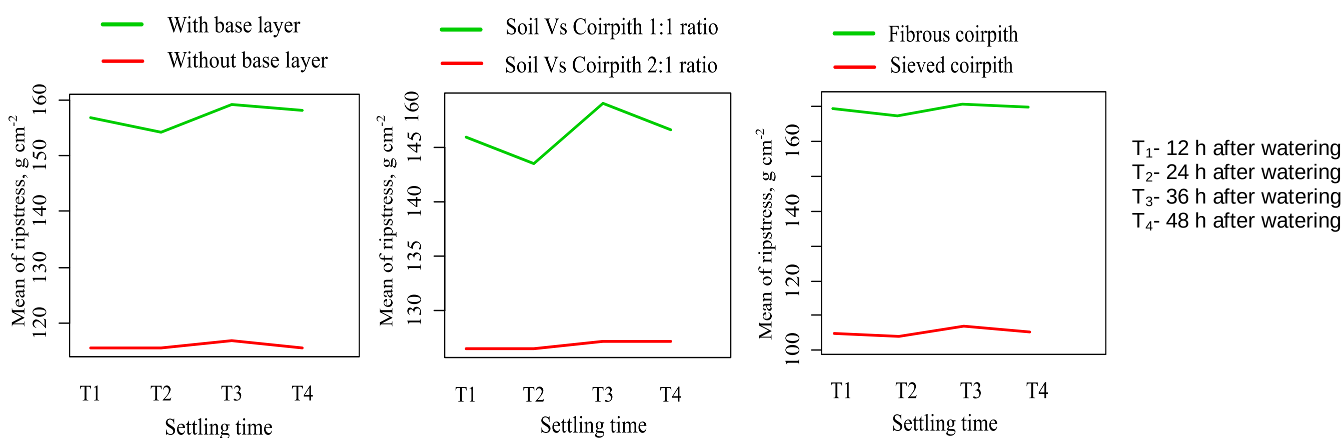

Figure 10. Influence of characteristics of growth media on mat stiffness.

Table 3. ANOVA on mat stiffness as influenced by media characteristics.

	Df	Sum squared	Mean Squared	F value	Pr(>F)
Layer	1	0.002563	0.002563	65.39	4.73e-13***
Medium	1	0.005861	0.005861	149.54	< 2e-16***
Mix ratio	1	0.000687	0.000687	17.52	5.34e-05***
Residuals	124	0.004860	0.000039		

Significance level: ***, 0; **, 0.001; *, 0.01.

content in the fibrous coirpith had interwining structure which had caused the significantly higher mat strength. The response curves in all the above graphs (Figure 10) happened to be flat exhibiting the fact that the settling time did have insignificance on the mat stiffness. A listing of model and the results obtained from factorial analysis is given subsequently as a sample factorial analysis.

From this analysis, it was concluded that the mat stiffness would be maximum for the media with fibrous coirpith, a media mixture of soil and coirpith at 1:1 ratio and with a corrugated sheet base layer followed by the same mixture at 2:1 ratio. The 2:1 ratio itself gave the sufficient mat stiffness suitable for SRI transplanter and hence optimized this ratio.

The optimized soil medium for growth and for stiffness were judiciously combined and studied. Vermi soil contains field soil, vermicompost and fibrous coirpith in the proportion of 2:1:1. FYM soil contains field soil, FYM and fibrous coirpith in the ratio of 2:1:1 and a base layer of corrugated sheet were incorporated in the above two soil media to stiffen the mat further. For these optimized soil mediums plant health and picking performance of transplanter were studied. There were no noticeable differences were observed between the vermin soil and FYM soil. Since

FYM soil is easily available as well as cheaper in cost, it was optimized for the SRI transplanter spaced mat nursery. This spaced mat nursery was suitable for loading into the seedling box of the transplanter for SRI method of transplanting.

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