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Research Article

Single Seedling Nursery Tray: An Innovative Breakthrough to Quality Seedling Raising Technique for SRI Transplanting Machine

[1]Zubairu Usman Bashar, [1, 2]Aimrun Wayayok, [1, 2]M.S.M. Amin and [1]Mohammad Razif Mahadi
[1]Department of Biological and Agricultural Engineering,
[2]Smart Farming Technology Research Centre, Faculty of Engineering, Universiti Putra Malaysia,
43400 Serdang, Selangor Darul Ehsan, Malaysia

Abstract: The main problem of adapting the SRI techniques is high labor requirements for manual and lacking of mechanized system for planting single seedling in the field. The existing seedling preparation methods remain challenging among SRI practitioners due to traumatic condition. This study was intended to create modern techniques for increasing the quality and transplanting potentials to improve seedling preparation and reduce transplanting shock. It involved development of rectangular tray having 924 square growing cavities with sliding base to facilitate seedling transfer. Seed selection was conducted and 100% germination was obtained from the sunken MR219 seeds collected in 80 g/L of NaCl solution. SRI-tray seeding was 100% placed into cavities with SRI-seed picker at 150 g/L of tapioca solution. Two different media (Soil + Burnt husk (1:1) as M_1 and Soil + Compost (1:1) as M_2) were used to evaluate the growth performances for 10 days. The measured parameters (Seedling Height (SH), Leaf Length (LL), Leaf Number (LN), Root Length (RL) and Loosening Index (LI)) were compared between SRI-tray and conventional ones. The SAS revealed that M_2 on SRI-tray had the highest significant values for SH, LL, RL and LI with the mean values of 155.6, 109.3, 89.3 and 75 sec when compared with conventional tray which had 125, 91 and 52 mm with no LI, respectively. The seed rate, nursery area and seedling age to support one hectare of planting area were found as 5.34 kg, 36 m^2 and 8-10 days on SRI-tray against 15-50 kg, 250-500 m^2 and 12-30 days on conventional practices.

Keywords: Compost, germination, growing cavities, loosening index, seedling height, vigor

INTRODUCTION

Rice (*Oryza sativa* in Asia or *Oryza glaberrima* in Africa), classified as a monocotyledon plant because of its behavior of producing one leaf per growth development. Rice is considered by cultural geographers as the staple food for a large part of the human population especially in Asia, Africa and some parts of Europe, America and West Indies upon which the latter were predominantly dependent on other cereals such as millet, wheat and maize. According to FAO (Farooq *et al*., 2006), rice stands as a grain with third-highest world production after wheat and maize. This tasty and versatile grain can also be grouped as the type of crops that can be grown substantially in almost every part of the world ranging from traditional to modern or integrated methods, depending upon the availability of water, soil texture and topography of the land by given an output as lowland (rain fed or irrigated) rice, deep water or floating rice, coastal wetland rice and upland rice. These bring to the existing number of over 40,000 varieties of rice worldwide (Farooq *et al*., 2009; Rajesh and Thanunathan, 2003).

The system of rice intensification popularly known as SRI is not only getting popularity and acceptance in Asia but also to the world at large where over 50 countries are now practicing. It is a system that requires transplanting of single seedling at a very young age of 8-10 days after seed germination in a nursery with a very proper lining of 25×25; 30×30 or even 50×50 cm, respectively spacing patterns depending on the fertility of the paddy field. It is also a system responding to some prevailing situations of climate change which are increasingly manifesting day by day leading to more insecurity in food supply resulting to higher food prices. Furthermore, it has been observed that by 2080, the 40 poorest countries, located in tropical Africa and Latin America, could lose 10 to 20% of their basic grain growing capacity due to drought (Kotschi, 2007), as result of climate change. Therefore, innovative contributions to sustainable agriculture become a global mandate in militating against the projected insecurity. Considering this unwanted circumstances, the System of Rice Intensification (SRI) opens a new window to improve agricultural practices. This system is aimed at

Corresponding Author: Zubairu Usman Bashar, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia, Tel.: +60389464823

primarily increasing the productivity of land and capital by offering double yields through the use of fewer seeds per hectare, low seedling density and wider spacing pattern (Noltze *et al*., 2012; Surya Prabha *et al*., 2011; Thomas and Ramzi, 2011; Uphoff *et al*., 2011). Several researchers also regarded it as a system that reduces the use of scarce resources such as water, chemical fertilizers and fuel as well as tolerating drought, wind and storms due to large and deep root system (Alagesan and Budhar, 2009; Anas *et al*., 2011; Uphoff *et al*., 2011). However, in SRI seedling quality and transplanting skills (single seedling per hill at wider spacing) play a vital role in getting an optimum yield. But the current seedling nursery management practices (mat, wet-bed, dry-bed or tray) in Malaysia and some parts of the world establish traumatic seedlings due to the broadcasting sowing technique and lack of separators between the individual growing seedlings. This results to roots interconnectivity as well as high inter-plant competition for nutrients, water, oxygen and sunlight; which eventually endangers the seedling quality and lower the production. This also makes the transplanting machines to place more than one seedling per hill at a time (Dewangan *et al*., 2005) as well as leaving some places unplanted in the field thereby making farmers paying for replanting leading to increased production cost. Furthermore, the current nursery practices brought major challenges in SRI farming as they could not soundly respond to SRI spacing and transplanting conditions due to these conventional seedling preparation techniques. Despite that several studies on seedling raising methods have been conducted by many researchers (Balasubramanian, 2009; Haytham *et al*., 2010; Rajendran, 1991; Rajesh and Thanunathan, 2003; Randall *et al*., 2004) but still the problem of multiple planting, roots cutting and slow establishment remain a malingering situation among SRI practitioners. Therefore, this tray opens a new window to SRI innovative approaches by providing new method of nursing individual, young, delicate but healthier and root separated rice seedling with low density and a sliding base to accurately transfer and release seedlings to the paddy field for single transplanting per hill.

MATERIALS AND METHODS

Single seedling nursery tray design considerations: This study involves developing a single seedling nursery rectangular tray of length, width and height of 635, 335 and 40 mm, respectively with open top and square growing cavities of 15×15 mm separated by a plate thickness of 1 mm with 30 mm height (Fig. 1 and 2). A sliding base plate serves as support in holding and releasing the seedling for dropping/planting into the

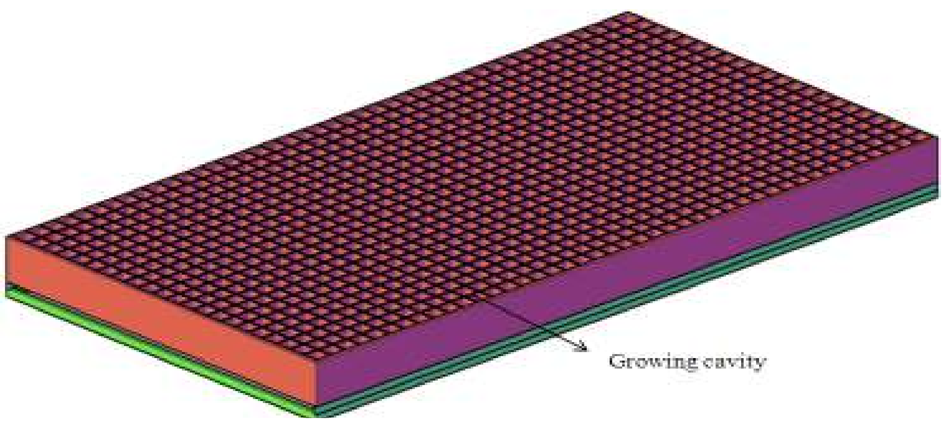


Fig. 1: Single seedling nursery tray

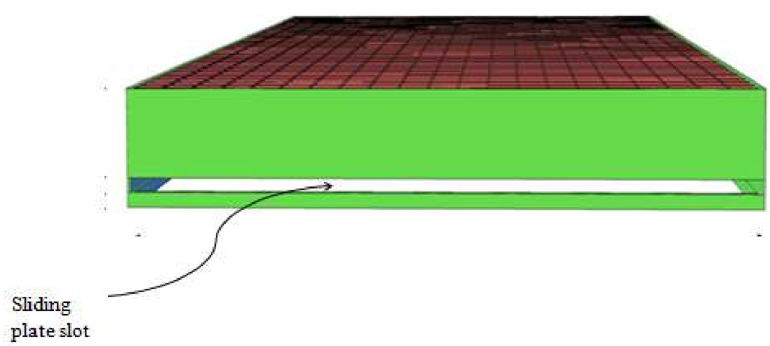
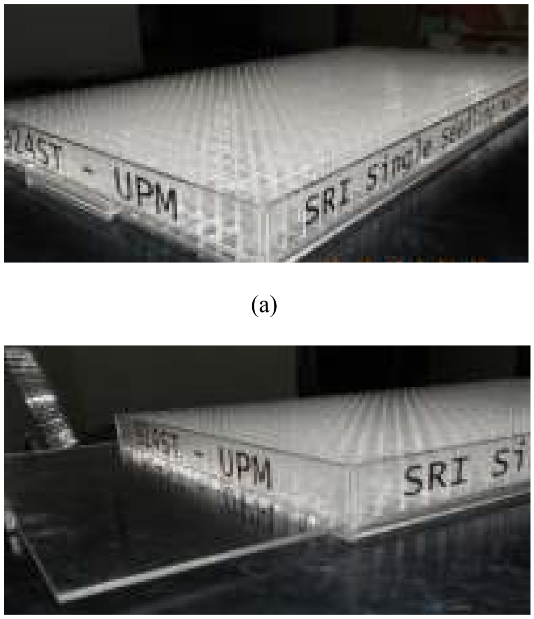


Fig. 2: Front view of the single seedling nursery tray



(a)

(b)

Fig. 3: A prototype SRI nursery tray developed using perspective PVC; (a): Arrangement of cavities; (b): Sliding base plate

field. This plate has length of 635 mm, width of 332 mm and thickness of 4 mm in order to allow resistance to the total load applied (Fig. 3). The tray is capable of producing 924 vigorous and viable independently separated seedlings for transplanting singly upon SRI Field spacing standards. These values were determined based on the following specifications: seedling number per tray, seedling number per planting area, number of trays per planting area, volume of preferred growing per planting area, sliding base plate and seedling's loosening index, respectively.

Seed sorting and priming techniques: Seeds selection was done through physical properties and germination test conducted in various laboratories of University Putra Malaysia during the period of the study prior to nursery setting to ensure a single and quality seed grows in the tray cavity. It involved the soaking of MR219 rice seeds in salty water thereby removing the floated as immature or an unfilled seeds with less endosperm and adapting/considering the sunken seeds as selected or best seeds. Different methods of seed sorting were reportedly used to select the best rice seeds for nursery purposes with water alone or mix with salt by Ella *et al*. (2011) and Farooq *et al*. (2009). These sorted seeds were later primed for 6 h prior to sowing in order to speed up the germination and quick establishment of the seedling. The theory of seed priming was first introduced by Heydecker and Coolbear (1977) as reported by Sun *et al*. (2010) proved to be among the major prime movers of seedling establishment as well as escalated bumper harvest in rice production.

Determination of the suitable growing media: Two different media were chosen (Soil + Burnt husk (M_1) and Soil + Compost (M_2)) and growth performance of the samples were monitored for 10 days on Seedling Height (SH), Leaf Length (LL), Leaf Number (LN), Root Length (RL) and Loosening Index (LI) on both SRI-tray and conventional tray. The loosening index has been considered here as the time taken for the seedling to drop from the SRI-tray after removing the sliding base plate. Three replicates from each media were statistically employed and the average was considered. Data from the readings were obtained through the Random Complete Block Design (RCBD) with three replications and computed with ANOVA using Statistical Analysis Software (SAS, 9.1). Other methods on growth performance were reportedly used by Aklibasinda *et al*. (2011) on Scotch pine with a mixture of rice husk and coir. They concluded that the growing media had significant effect on plant production parameters. They obtained the highest growth on rice hull. Similarly, Abirami *et al*. (2010) reported a highest seedling growth with sand, coir dust, compost and soil (1:1:1:1) combination on nutmeg (*Myristica fragrans* Houtt), respectively.

RESULTS

Placement of seeds into single seedling nursery tray: Seed placement into 924 SRI tray growing cavities manually proved to be tedious and time consuming and also affecting the young sprouting seed. Therefore, SRI-seed picker plate was developed with 924 picker tips for gluing and dropping the seeds into the tray. The time taken to place or sow the seeds per tray was observed and recorded. This was repeated five times and the average was considered on the stickiness and loosening of the sprouted seeds between the solution seeds and tray. Thus, a better gumming and dropping time were observed on solution mixture at 150 g of Tapioca (Starch) flour to 1 L of water at 100% efficiency with an average rate of 16 trays per man-hour. Moreover, with this practice, seed rate could practically be saved by more than 300% when compared to the conventional practice of seed spreading or broadcasting when sowing either on the beds and/or in the current tray and whether manual or mechanized methods. Results indicated that only 5.34 kg of seeds on SRI tray were required to plant on a hectare with 25×25 cm spacing pattern against the conventional practices of 50 kg on wet or dry beds nurseries (Table 1 and 2).

Table 1: SRI tray versus other nursery types

Nursery type	To plant one ha of main field: Nursery area, m^2	To plant one ha of main field: Seed rate, kg ha	Optimum seedling age, days (3 leaves)
Wet bed	400-500	50	20-25
Dry bed	500	50	25-30
Mat (dapog)	60-75	40-50	8-15
Modified mat	100	9-25	15
Conventional tray	250	15-20	12-15
SRI-tray*	36	4.27	8-10

*: The SRI single seedling nursery tray

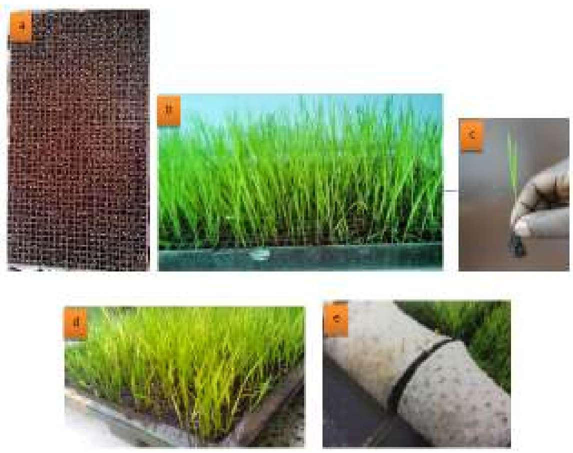


Fig. 4: Seeds sowing and establishment in SRI single seedling tray (a, b, c) versus conventional tray (d, e)

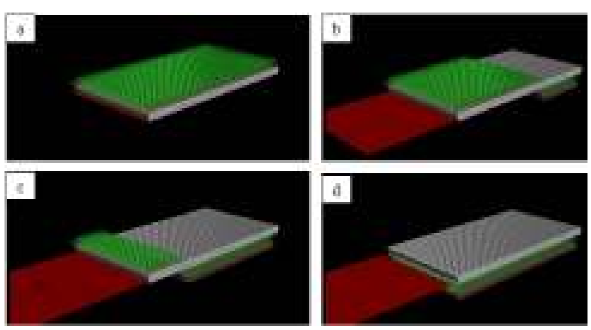


Fig. 5: Seedlings dropping stages by pulling of the sliding base plate

Effect of separated growing cavity on seedling age: The single seedling nursery tray was designed for the purpose of growing a healthier and viable seedling separately for transplanting into paddy field. Therefore, each seedling is grown in a separated area having a media storage capacity of 5.88 cm^3 with a total volume of 0.005 m^3 SRI tray (Fig. 4 and Table 2). The sliding base located at the bottom serves as retainer valve in holding and releasing the seedling to the planter board for transplanting into the field (Fig. 5).

Effect of growing media tray types: The average seedling heights in various growing media are presented in Table 3. It was observed that, three days after planting, the growing media has not shown much significant difference on SH in all the trays. Thereby M_1 indicated 52 mm while M_2 presented 53 mm on both SRI and conventional tray. But a significant influence was demonstrated on seedling height, where the highest recorded value of 155 mm obtained on SRI tray after 10 days of monitoring on M_2. While, the growth on conventional tray showed the lowest SH of 125 mm even on the same media. The effect of media was also recorded using Duncan's mean where these values significantly changed with the change in media composition. Table 4 indicated that M_2 responded well on all the parameters such as SH, LL, LN and LI but recorded lower reading on RL.

Influence of growing media on loosening index: Observations on the seedling loosening from the SRI tray for transplanting were recorded as the tray was developed with open top growing cavities having a sliding base to facilitate the release of seedlings to the field. Table 5 indicates the loosening data with respect to various growing media. Seedling established under a mixture of soil with compost was found to be the easiest media to remove the seedling from the SRI tray without any external force but just relying on gravitational force. It was found to be the fastest to fall down with a mean value of 74.3 sec (Table 4). Although ANOVA indicated that Soil with burnt husk is the best due to the highest recording value of 125.3 sec over Soil with compost (Table 4).

Comparison of seedlings root length: One of the basic requirements on SRI practice is root intensification. If the roots are deep and strong, this will enable the rice plant to stand against natural phenomena such as wind, storm and drought. The results revealed that growing value of 92 and 89 mm was recorded after ten days in M_2, respectively (Table 3). But a drastic decreased was observed on all the media when grown on conventional trays with M_1 (48 mm) and M_2 (52 mm) as presented in Table 4 and 6.

Table 2: Summary of basic output to nursery preparation per hectare

		Required germination (%)	Nursery area (m^2)	No. of seedling (nos.)	Seed weight (kg)	No. of tray (nos.)	Media volume (m^3)
SRI tray		100	0.21	924	0.024	1	0.005
Spacing pattern/ha	20×25	100	45.00	200,000	5.340	217	1.172
	25×25	100	36.00	160,000	4.272	174	0.940
	30*30	100	25.00	111,112	2.967	121	0.653

Table 3: SRI tray versus conventional tray on seedling height for 10 days

	Seedling height (mm)			
	M_1		M_2	
Day	SRI tray	Conv. tray	SRI tray	Conv. tray
1	0	0	0	0
2	0	0	0	0
3	52	52	53	53
4	66	67	59	63
5	94	98	85	77
6	107	113	103	104
7	116	118	114	116
8	125	121	132	119
9	134	124	148	121
10	146	126	155	125

M_1: Soil + burnt husk; M_2: Soil + compost

Table 4: Duncan's means grouping at 10 days for SRI tray

Treatment	Seedling height (mm)	Leaf length (mm)	Leaf number (No.)	Root length (mm)	Loosening index (sec)
M_1	145.3^b	100.3^b	3.0^a	92.3^a	125.3^a
M_2	155.7^a	109.3^a	3.0^a	89.3^b	74.3^b

Letter in the same column means significant at 0.05 level

Table 5: SRI tray versus conventional tray on root length for 10 days

	Root length (mm)			
	M_1		M_2	
Day	SRI tray	Conv. tray	SRI tray	Conv. tray
1	na	na	na	na
2	na	na	na	na
3	24	26	44	33
4	na	na	na	na
5	53	32	58	32
6	na	na	na	na
7	86	41	72	41
8	na	na	na	na
9	90	48	88	48
10	92	48	89	52

M_1: Soil + burnt husk; M_2: Soil + compost; na: Readings not applicable

Table 6: SRI tray versus conventional tray on leaf length for 10 day

	Leaf length (mm)			
	M_1		M_2	
Day	SRI tray	Conv. tray	SRI tray	Conv. tray
1	0	0	0	0
2	0	0	0	0
3	24	24	34	23
4	46	43	43	42
5	60	56	65	62
6	68	73	70	67
7	77	80	81	79
8	85	84	80	85
9	94	89	98	88
10	100	94	109	91

M_1: Soil + burnt husk; M_2: Soil + compost

Influence of growing media on leaf length and tray types: The data obtained indicated that leaf length was significantly affected by the growing media. Table 5 revealed that M_1 on both trays started with the common value on the first three days but a significant variation was recorded on M_2 on the same day with 34 mm on SRI tray and 23 mm on conventional trays. Furthermore, M_2 showed the maximum value of 109 mm at 10 days with seedling raised on SRI tray as against the 91 mm with the same media on conventional tray.

Seedling preparation per planting area: The transfer of seedlings to the field stands as yet another important aspect to nursery management. As the newly invented SRI tray was set to prepare seedling singly in a separated growing cavity, therefore seedling transfer to the field usually undergoes three stages namely: transporting of the whole tray to the planter board, whereby the sliding base plate will firstly be removed to allow the resting of seedlings to the board; this was followed by lifting of the main tray to facilitate fully seedlings release to the planter board for dropping into the field for manual or mechanized transplanting (Fig. 5a to d). Contrary to the conventional practice of rolling the root connected seedlings in form of a mat. The total nursery area required per one hectare with developed tray was estimated as 36 m^2 on transplanting spacing pattern of 25 by 25 cm. This indicated a remarkable decrease when compared with existing nursery practices of occupying 60-500 m^2 (Table 1) as reported (Balasubramanian, 2009; Noltze *et al*., 2012).

DISCUSSION

SRI- tray seeding: The seeding of single seedling tray with SRI-seed picker has indicated a significant success when compared with manual as the latter endangers the sprouted seeds as a result of brushing between fingers. Likewise, with this practice seed rate could practically be saved by more than 300% when compared to the conventional practice of spreading or broadcasting. Results indicated that only 5.34 kg of seeds on SRI tray were required to plant on hectare on 25×25 cm spacing pattern against the conventional practices of 50 kg on wet or dry beds nurseries (Table 1 and 2). Other research works (Balasubramanian, 2009; Dhananchezhiyan *et al*., 2013; Farooq *et al*., 2006) on seed sowing proved tedious and time consuming with high level likelihood of damaging the seed radical when placing manually or mechanically.

Seedling age: The research conducted revealed that seedlings prepared under SRI-tray were mostly ready for transplanting from a minimum age of 8 day and a maximum of 10 day old with respect to SRI standard of 2 to 3 leaves appearance (Jayakiran and Sajitha, 2010; Kassam *et al*., 2011; Khem and Khadka, 2012; Laulanié, 2003; Misha and Uphoff, 2011; Mishra and Salokhe, 2008; Noltze *et al*., 2012) before tillering initiation when compared with the conventional practice of 15 to 30 days. According to Laulanié (2003) tillering initiation begins in rice seedling after the appearance of 4th and 5th phyllochron. Therefore, if the seedling can be planted at younger age that will reduce the tillage shock as well as giving enabling environment. This change in aging was due to the fact that seedling raised from this tray appeared to be strong and healthier due to less competition in search of nutrients, water, aeration and sunlight. They were also grown with full chlorophyll potentiality and without weed disturbance. Similarly, the findings of Pasuquin *et al*. (2008) revealed that grain yield was found to be consistently higher when using younger seedlings contrary to older seedlings thus the latter provide low tiller number as well as delay in maturity time. With this it can be concluded that seedling age plays a significant role to high production.

Influence of growing media: The growing media showed significant influence between the SRI tray and conventional practice. The difference was attributed as a result of separated cavities which reduced the competition for nutrients and other growing conditions in Single seedling nursery tray. Likewise, the findings of Şeniz *et al*. (2011) on Scotch pine (*Pinus sylvestris*), Egharevba *et al*. (2005) on African walnut (*Plukenetia conophorum*) using amended topsoil, Abirami *et al*. (2010) on nutmeg also indicated relatively similar trends when seedlings were subjected to different growing media. Therefore, it is suggested that compost should be mixed in seedling media preparation when establishing seedling in a nursery in order to obtain vigorous and viable seedlings.

Influence of seedlings root length on tray types: Root proliferation stands as basic conditions to SRI adopting due to Alternate Wetting and Drying (AWD) policy. The results revealed that growing media as well as separated cavities have significant influence on the root length. The difference in RL between the SRI tray and the conventional practice was attributed to the conducive growing environment received by seedlings prepared in the SRI tray. These readings indicated that growing environmental condition plays a significant role on vigor and quality of rice seedling. It can therefore be concluded that such variation was due to the roots interconnectivity as well as high level of competition for nutrient, water, sunlight and aeration experienced by the establishing seedlings in the conventional practice. Likewise, seedlings produced from the Single seedling tray can be transplanted without any pulling stress when compared to the existing trays that create transplanting shock as well as delay the seedling re-establishment after transplanting.

Influence of growing media on leaf length: The data obtained indicated that leaf length was significantly affected by the growing media. Table 4 revealed that M_1 on both trays started with the common value on the first three days but a significant variation was recorded on M_2 on the same day with 34 mm on tray and 23 mm on conventional. Furthermore, M_2 (soil + compost) showed the maximum value of 109 mm 10 days with seedling raised on Single seedling tray as against the 91 mm with the same media on conventional tray.

Influence of growing media on loosening index: It was found to be the fastest to fall down with a mean value of 74.3 sec (Table 4). Although ANOVA indicated that Soil with burnt husk is the best due to the highest recording value of 125.3 sec over Soil with compost (Table 4). In contrast, it is shortest loosening time that is considered not the longest as loosening index was referred here as the time taken for the seedling to fall from the Single seedling nursery tray when the sliding base plate has been removed. Likewise, when transplanting seedling grown from Single seedling nursery tray, there will be less shock as each seedling can be planted freely with its growing media either manually or with transplanting machine.

Seedlings per planting area: The amount of seeds needed to plant one hectare ranged from 15 to 50 kg/ha when using the existing nursery methods. However, this brought a new figure of only 5.34 kg/ha which reflect about 10% of the total seeds used on conventional practices when using the currently designed Single seedling nursery tray at SRI spacing pattern of 25 by 25 cm. These values have proven a drastic reduction in seeds volume as the spacing pattern widened. Similarly, it also demonstrated a significant change on the seedling age before transplanting. This variation has been validated with a decrease on the age from 12 to 30 days (existing or conventional practices) to a minimal of 8 to 10 days (current SRI tray) as recommended by SRI practice that encouraged transplanting younger seedlings with appearance of 2 to 3 leaves (Anas *et al*., 2011; Ceesay, 2010; Kassam *et al*., 2011; Khem and Khadka, 2012). The growth performance evaluation revealed that seedlings raised under Single seedling nursery tray responded significantly well on all the tests when compared with existing seedling nursery practice. Other important advantages of Single seedling nursery tray over other nursery methods are capable of providing 924 viable seedlings with no competition on nutrient and other growing parameters, no weeding is required in the tray, less volume of qualitative growing media is used, facilitate seeds sowing and seedling transfer, reduce the seedling age, transplanting shock as well as encouraging single seedling planting per hill in the field. It can also be concluded that seed ratio per planting area was drastically reduced when using this newly tray when compared to the existing practices to about 80-90%. Likewise, age to transplanting was also reduced from 30 days to only 8 days.

ABBREVIATIONS

SRI = System of Rice Intensification
MR219 = Malaysian rice variety
M_1 = Soil with Burnt husk
M_2 = Soil with Compost
SH = Seedling Height
LL = Leaf Length
LN = Leaf Number
RL = Root Length
LI = Loosening Index
FAO = Food and Agricultural Organization
RCBD = Random Complete Block Design
ANOVA = Analysis of Variance
AWD = Alternate Wetting and Drying
NaCl = Sodium Chloride
SAS = Statistical Analysis Software

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