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Rice Straw-Seedbed for Producing Rice Seedling Mat

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Abstract: In this paper, new culture media from rice straw as a seedbed (RSS) for producing seedling mat (SM) for mechanical transplanter is discussed. Usually, a plastic box (58x28x3cm), called a nursery box, is used for raising rice seedlings which are then mechanically transplanted. This conventional soil seedbed (CSS) system has major problems for the following reasons: (1) a nursery box filled with soil weighs about 6 kg; (2) high cost of the nursery boxes; and (3) heavy and hard work. The SM (120x28x3cm) is established in a layer of treated rice straw arranged on a firm surface and has been developed in the Rice Research & Training Center, Egypt, to save the operation cost. The applicability of this technology appears high because there is enhancement of seedling growth in comparison with growth in the CSS. Sowing the rice seeds in the RSS improved the characteristics such as shoot length, root weight, shoot dry weight to shoot length (DW/L), nutrients content of seedling, and biomass and seedling vigour. The length of one SM is equivalent to that of two nursery boxes in the CSS halving the number of SM required. The SM technique is expected to reduce the working hours for transplanting by one-third of these for the CSS. The mat can be rolled up into a small diameter. The volume of the rolled seedlings is about one-fifth of that of the equivalent amount of seedlings in the CSS. A small pickup truck can carry seedlings for a rice field of 2ha at one time. Examination of the comparative cost-analysis reveals a strategy for substantially reducing the cost-benefit ratio for rice production with the using of SM technology. This study showed the potential of SM technology to stimulate agriculture in the region and consequently lead to productivity increases.

Key words: Rice straw % SM % CSS % Cost-benefit

INTRODUCTION

Straw is the only organic material available in significant quantities to most rice farmers. About 40 % of the nitrogen (N), 30-35% of the phosphorus (P), 80-85% of the potassium (K), and 40-50% of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity [1].

Rice transplanting was mechanized in the 1970s in Japan, and now more than 99% of paddy fields are cultivated by mechanized transplanting. In Egypt, about 600,000 ha are cultivated by rice every year, 70% of this area is manually transplanted, and 26% is planting by direct seeded rice and 3% is mechanically transplanted [2]. Mechanized transplanting is not popular because the high cost of plastic trays and preparation transportation the nursery boxes. Large-scale transplanters with higher efficiency and precision are becoming common, and mechanical transplanting is assumed to have reached its technical perfection with one problem remaining which is nursery boxes preparation.

Usually, a plastic box (60 × 28 × 3cm), called a nursery box is used for raising rice seedlings. Soil is packed into it, and seeds are sown. Nursery boxes are then arranged in vinyl houses and the seedlings are raised. When the seedlings are sufficiently grown, the nursery boxes are put on a truck and taken to the paddy fields. The seedlings are then transplanted by a transplanter. Recently, the long-mat Seedling Culture System' (Long-mat System (LS)), a new technique for raising rice seedlings hydroponically for modified machine

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qplanting was developed [3]. Both the hydroponic and CSS system have major problems for the following reasons: (1) a nursery box filled with soil weighs about 6 kg; (2) 200 nursery boxes are necessary for paddy fields of one ha [4], (3) it is necessary to carry nursery boxes many times from sowing to transplanting; (4) the plastic boxes are lost each season during the transplanting operation and adding to costs; (5) the farmer can not carry the nursery boxes because it is heavy; (6) it is very complicated to conduct the hydroponics culture successfully on farmer field in addition it is more sensitive and expensive technique; and (7) because the root-mat of the hydroponics system is softer and more flexible than that of the CSS, long-mat seedlings can be injured at the time of machine transplanting, and some seedlings die before rooting.

This paper discusses a new technique of SM production using RSS and compares this technique with the CSS method through the seedling growth characteristics, the cost-benefit evaluation. Establishing and popularizing the SM from the new RSS technology will be viewed.

MATERIALS AND METHODS

Plant and Growth Condition: Two experiments were conducted, experiment I in the second half of April and the experiment II on the beginning of May by using two nursery techniques at the Rice Research & Training Center (RRTC), Sakha, Kafr EL Sheikh, Egypt. Each experiment replicated six times. The RSS was characterized as follows: pH 7.5, EC 2.8 dSm^{-1}, carbon 24%, nitrogen 1.1%, K 1.5%, P 0.6% and organic matter 35%. CSS was characterized as follows: pH 7.2, EC 2.5 dSm^{-1}, nitrogen 0.7 %, K 0.7%, P 0.2% and physical properties were 18.2:27:54.8; sand, silt, clay respectively. SMes were established on a layer of RSS arranged on a firm surface. Six woody trays (120x 28 x 2.5cm) were filled by moistened RSS (750g) after covered the surface of the tray with reused polypropylene woven sheet (it was used before as a storage bags). RSS was prepared by soaking the rice straw compost (completely decomposition) for one week in fresh water then dry and grind before using. Seeds of rice (*Oryza sativa* L., var. Sakha 104; japonica type) were soaked for two days. The soaked seeds were sown uniformly (400g) to each tray and covered them with a thin layer of RSS then the nursery was covered with a black plastic sheet for incubation up to two days depending on the temperature. The bottom of the woody tray was not fixed for easy removing when the trays transfer to the nursery. All SMs transferred and arranged in the nursery area with polypropylene woven sheet only. Six conventional nursery boxes were prepared using ground soil as a culture media for rice seeds. Each box was sown with 200g of seeds. Nursery boxes were collected and covered with a plastic sheet and incubated for two days. Five days after sowing, commercial fertilizers (*Urea 46%*; 16gm^{-2} & *super phosphate 23%*; 66.5gm^{-2}) were applied for CSS. Sprinkler irrigation was used for the RSS technique and flooding irrigation for the CSS technique.

Measurement of Seedling Growth and Dry Matter Production: Seedlings were samples from six places (trays) in the nursery bed. Twenty seedlings of each place were selected randomly from each tray. The mean germination time (MGT) was calculated using the equation [5]. The different growth parameters including shoot dry weight (SDW), crop growth rate (CGR), leaf area, root dry weight and nutrients uptake were determined. Realizing the importance of dry matter accumulation in seedling health and shot dry weight – plant length ratio (DW/L) as well as low MGT as an indication of seed vigour and uniform seedling rate, the seedling vigour index (SVI) was determined as a percentage. Plant age in leaf number, shoot length, and SDW were measured of each sample. CGR at different seedling ages was also compared. CGR was computed for different growth intervals for each technique using the formula of Radford [6]. Leaf area was also measured for 20 seedlings at 20 DAS. Seedlings of the CSS and RSS were analyzed for NPK uptake at the end of the nursery period [7]. Samples were dried at 70°C for 24 hours and grinded to pass through a 20mm-mesh screen to estimate NPK uptake. A given amount of grinded samples were wet-digested with H_2SO_4/H_2O_2, and potassium concentrations in the digested solution were determined using a flame spectrophotometer. The P concentration was determined colorimetrically [8]. Total N was determined on composite plant samples by the Kjeldahl distillation method [9]. Heading time from seeding time, panicle number for meter square, filled grain percentage, 1000- grain weight and grain yield for hectare were measured during the economic study in this research.

Cost evaluation: Economic study and labour savings were calculated using Egyptian economic values. The ratio cost benefit was calculated on the basis of data from 10 ha (1380 roll of RSS and 3000 tray of CSS). The hiring costs and wage rates used for calculating cost benefit: cost ratio were as follows: cost of hiring a tractor = US$3.3 h-1;

season cost of one plastic try = US$0.25, cost of wood = US$59 m-3, paper cost = US$1.1 kg-1, plastic sheet cost= US$0.4 m-2, labour = US$4 labour-day-1. The currency conversion factor used was 1 US$ = 5 Egyptian pounds. Statistical differences in different traits between RSS and CSS were determined with Student's t-test using Microsoft Excel (Redmond, WA, USA).

RESULTS AND DISCUSSION

In figure 1&2, there was no effect of seedling media on the plant age given by leaf number at 10 DAS of RSS and CSS in both experiments. At both of 15 and 25 DAS, however, the plant age as given by leaf number with the CSS was lower than of these RSS. It was confirmed, therefore, that the development rate of plant age as given by leaf number in the RSS was faster than that in the CSS. The optimum plant age as given by leaf number was found at 20 DAS in the RSS and at 25 DAS in the CSS in experiment I &II. Kitagawa, *et al*. [10] found that the seedling age suitable for transplanting was 3.0 - 3.5. RSS grew rapidly, therefore, and the shoot and root become longer than those of CSS at transplanting time. The length of the shoot and the leaf number in RSS was higher than CSS during the nursery period, which is a good finding to transplant the RSS earlier than CSS (Fig. 1&2).

The difference in shoot dry weight between RSS and CSS became smaller at 20 DAS. The SDW in RSS was much lighter in comparison with that in CSS especially at 25 DAS in experiment I &II. The shoot dry weight mainly depends on the concentration of nutrients in the media (or substrate), and the physical, chemical and microbiological conditions for root activity and formation of new roots. In natural vegetation the shoot dry weight decreases as soil fertility decreases [11]. Seedlings grown in the RSS displayed better seedling quality in terms of seedling vigor and its characteristics and suitability for rice mechanical transplanting. This result is similar to that observed by Wang *et al*. [12].

The substitution of soil by the RSS in the nursery media affected the root dry weight, leaf area, CGR and nutrients uptake positively in both experiments (I&II) as shown in Tables 1&2. CGR of the variety tested was significantly affected by the growth media. During the nursery stage, the CGR of the RSS (40 mg day^{-1}) was much higher than that of the CSS (30 mg day^{-1}). Therefore, differences in the SDW resulted from differences in the CGR. Root dry weight of RSS was heaver than that of CSS in experiment I and II. The increase in root dry weight in RSS is important to improve the quality of seedling and for growth at the early stage of tillering. The high root dry weight in RSS

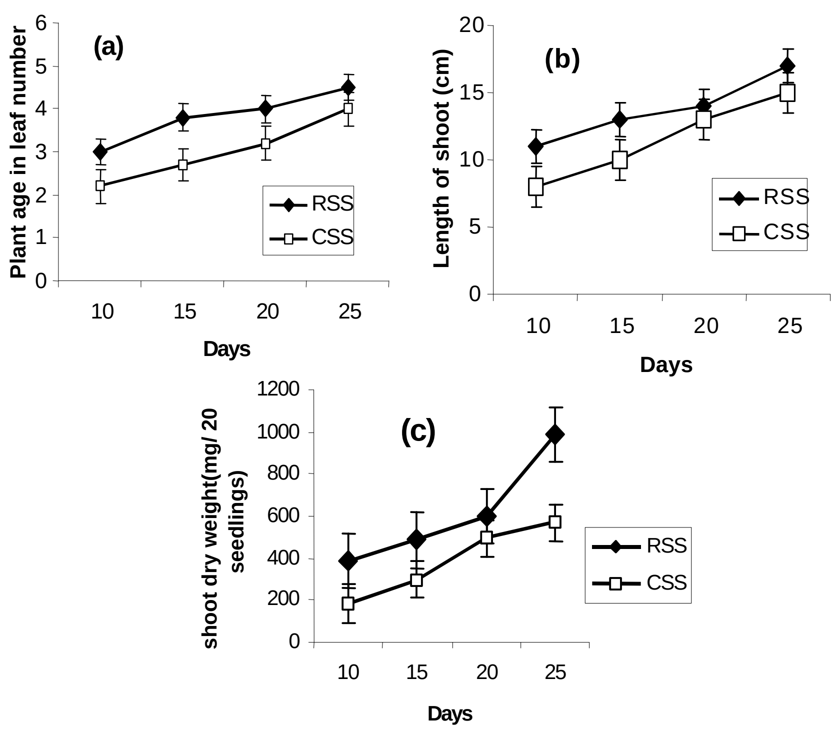

Fig. 1: Plant age in leaf number (a), Length of shoot (b) and Shoot dry weight (c) of RSS and CSS (Experiment I). Bars indicate stander error; n=5. * indicate significant differences at P<0.05

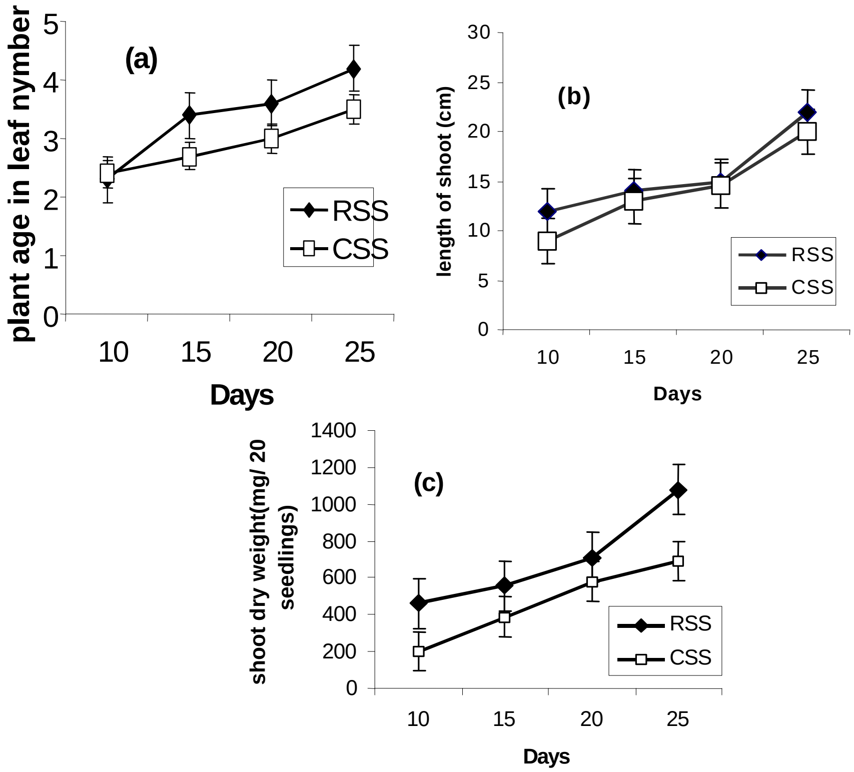

Fig. 2: Plant age in leaf number (a), Length of shoot (b) and Shoot dry weight (c) of RSS and CSS (Experiment II). Bars indicate Bars indicate stander error; n=5. * indicate significant differences at $P<0.05$

Table 1: Root dry weight, CGR, leaf area and nutrients uptake of RSS and CSS (experiment I)

				Nutrients uptake mg / 20 seedlings)		
Methods	Root dry weight (mg plant^{-1})	Crop growth rate (mg day^{1})	Leaf area (cm^2)	N	P	K
RSS	14*	40**	27.79*	15.3*	5.8*	9.8*
CSS	10	30	25.75	12.0	4.7	7.5

* and ** indicate significant differences at $P<0.05$, $P<0.01$, respectively, and ns indicate not significant differences at the $P<0.05$ level by Student's t-test (n=5).

Table 2: Root dry weight, CGR, leaf area and nutrients uptake of RSS and CSS (Experiment II)

				Nutrients uptake mg / 20 seedlings)		
Methods	Root dry weight (mg plant^{-1})	Crop growth rate (mg day^{1})	Leaf area (cm^2)	N	P	K
RSS	17**	44**	29.05*	18.0*	8.8*	12.2*
CSS	11	32	26.22	15.7	6.5	9.8

* and ** indicate significant differences at $P<0.05$, $P<0.01$, respectively, and ns indicate not significant differences at the $P<0.05$ level by Student's t-test (n=5)

may be attributed to the ideal characteristic of the growth media and high content of organic acids (such as humic and fulvic acids, etc.) in rice straw compost compared to in CSS media. The effect of RSS on plant nutrition was in general positive in relation to the CSS. The amount of N uptake in the shoot may derive from a dilution effect [13] caused by the more pronounced growth of the shoot in the RSS. The same pattern was observed for K for which, in general, accumulation in shoot tended to be greater in plants grown in the RSS than in plants grown in the CSS. In the case of K, the positive effect of the RSS was more pronounced as a synergistic effect could be present in most cases. This synergistic effect may derive from a greater N availability in the compost-based substrates than in the CSS. A pronounced synergistic effect could also exist for P (dry matter and P uptake increased in the RSS in relation to the CSS). Despite some conflicting results in literature about the effect of organic matter on P availability [14, 15], the positive effect of RSS on P uptake was evident. On the other hand, increases of P uptake in plants in response to N supply have also been reported in the literature [16]. In our case, the compost-based substrate had a notable N availability, which would cause a consistent N–P synergism on P uptake.

The SVI, the dry weigh of shoot divided by the shoot length, the germination percentage and the MGT were significantly increased in the plants grown in RSS except MGT compared with the plants grown in the CSS in both experiments (Tables 3&4). The low values of the germination percentage and high value of the MGT in both treatments may attributed to the low atmospheric temperature because the nursery was grown under open filed condition not under vinyl house, in addition to the high value of the pH of the growth media. It is probable that initial better SVI and MGT for the RSS was a consequence of reducing compaction, increasing gas exchange, increasing nutrient exchange capacity, and higher moisture retention in this medium compared with in CSS media. The differences between RSS and CSS in growth traits may be attributed to the presence of amino acids and important nutrients such as NPK in the RSS compared with the CSS which potentially enhance the initial radical growth; radical cell elongation depends on the accumulation of solutes such as potassium and nitrate [17]. The most important advantage of the RSS over the CSS is in releasing the macro and micro-nutrients slowly during the growth period [18]. Rice grown in the RSS was developed and healthier seedling compared with these grown using the CSS technique. The high temperatures generated in composting (above 55°C) during the decomposition period keep pathogen levels low and reduce the viability of weed seeds present in the compost material. Matsushima [16] reported that healthy seedling should be short and thick, and this characteristic of seedling could be expressed numerically as a ratio of shoot dry weight to the plant height (DW/L). The present study, the DW/L in RSS was significantly higher than in CSS in experiment I and II, indicating the qualities of RSS are superior to that of CSS. Matsushima [16] and Tasaka [19] and Wang [12] reported that the higher DW/L is indicator for the more active the tillering after transplanting.

Table 3: MGT, number of days taken for first seed germination, mean germination (%) and SVI of RSS and CSS (Experiment I)

Methods	Mean germination time (MGT)	Number of days taken for first seed germination	Germination (%)	DW/L (mg cm^{-1})	Seedling vigour index
RSS	15.0	2.1	68**	2.5*	3.3*
CSS	16.4*	3.7*	44	1.7	1.8

* and ** indicate significant differences at P<0.05, P<0.01, respectively, and ns indicate not significant differences at the P<0.05 level by Student's t-test (n=5)

Table 4: MGT, number of days taken for first seed germination, mean germination (%) and SVI of RSS and CSS (Experiment II)

Methods	Mean germination time (MGT)	Number of days taken for first seed germination	Germination (%)	DW/L (mg cm^{-1})	Seedling vigour index
RSS	12.2	1.5 ns	70 **	2.83^{ns}	4.9*
CSS	14.8*	2.0	51	2.1	2.6

* and ** indicate significant differences at P<0.05, P<0.01, respectively, and ns indicate not significant differences at the P<0.05 level by Student's t-test (n=5)

Table 5: Heading date, panical number, filled grain percentage, 1000-grain weight and grain yield of RSS and CSS (Experiment I)

Methods	Heading Date (day)	Panicle number (m^{-2})	Filled grain (%)	1000-grain weight (g)	Grain weight (t ha^{-1})
RSS	78 ^{ns}	562 *	76 ^{ns}	19 ^{ns}	9.6^{ns}
CSS	77	550	77	20	9.5

* and ** indicate significant differences at P<0.05, P<0.01, respectively, and ns indicate not significant differences at the P<0.05 level by Student's t-test (n=5)

Table 6: Heading date, panical number, filled grain percentage, 1000-grain weight and grain yield of of RSS and CSS (Experiment II)

Methods	Heading Date (day)	Panicle number (m^{-2})	Filled grain (%)	1000-grain weight (g)	Grain weight (t ha^{-1})
RSS	76 ^{ns}	571 *	75 ^{ns}	18 ^{ns}	9.5 ^{ns}
CSS	77	562	76	19	9.5

* and ** indicate significant differences at P<0.05, P<0.01, respectively, and ns indicate not significant differences at the P<0.05 level by Student's t-test (n=5)

Table 7: Management activities including inputs and costs (expressed on a 10 ha basis) used in (CSS) and (SM) rice nursery cultivation methods of the on-farm adaptive research trials under Egyptian condition as a mean of the experiment I and II

	Tractor & machine (h) (US$)		Labour (labour/day)		Total Cost for actual labour wage rate in US$		Amount of materials		Total cost of material inputs (plastic box, fertilizer etc.) in US$		Pickup truck (h)(US$) Distance from) Nursery to permanent field about 50 Km)	
Methods	CSS	SM	CSS	SM	CSS	SM	CSS	SM	CSS	SM	CSS	SM
Plastic box	-	-	-	-	-	-	2850	-	470	-	-	-
Paper (Kg)	-	-	-	-	-	-	22	-	25	-	-	-
Wood (m3)	-	-	-	-	-	-	-	2.4	-	142	-	-
Plastic sheet (m^2)	-	-	-	-	-	-	-	512	-	205	-	-
nursery box preparation	-	-	15	4	60	16	-	-	-	-	-	-
Culture material ($1m^3$)	(1h) (UZ10)	(0.5h) (2Z)	-	-	-	-	11	1	100	60	-	-
preparation of nursery site	(5h) (UZ50)	(1ha) (UZ10)	12	4	48	16	-	-	-	-	-	-
Fertilizer (Kg)	-	-	1	-	4	-	12	-	4.8	-	-	-
Irrigation	-	-	1	1	4	4	-	-	5	1.5	-	-
Transportation & loading	-	-	25	7	100	28	-	-	-	-	(8h) (UZ237.5)	(2.6) (UZ79)
Total	UZ60	UZ10.5	54	16	216	64			704.5	409.5	UZ 237.5	UZ79

Cost of hiring a tractor = US$3.3 hG^{1}; season cost of one plastic try = US$0.25, cost of wood = US$59 m^{-3}, paper cost = US$1.1 kgG^{1}, plastic sheet cost= US$0.4 mG^{2}, labour = US$4 labour-dayG^{1}

According to results reported by them the tillering in RSS after transplanting was higher active than that in CSS as shown in Tables 5&6 which shows the high panicle number in RSS compared with CSS in both experiments. There are no significant different between RSS and CSS in heading date, grain yield and 1000-grain weight except panicle number of experiment I and II as are shown in tables 5&6 the highest panicle number at maximum tillering stage in RSS may be attributed to the higher the root dry weight and DW/L compared with CSS. The ideal growth media of RSS also plays an important role for developing the panicle number compared to CSS which was normal clay soil. Since content of nutrients and organic acids in RSS were higher, the higher concentration of nutrients may be affecting the growth of seedlings in RSS [20]. It was suggested that there was less N in CSS than in RSS media at later growth stage of seedling in the present study because rice straw compost can be retained nutrients and supplied to the rice seedling during the nursery period. In addition the physical and chemical properties of the media are likely to affect the root development of rice seedlings [21].

Cost-Benefit Evaluation: The amount of labour required for nursery box preparation for the SM was reduced by two third, showed in table 7, due to the direct sowing on RSS in the field without loading or transferring any nursery boxes. Traditionally in Egypt, the CSS operation is done by labours except filling the plastic boxes with soil, water and seeds which are done by machine. Introduction of the RSS has lead to a shift from the use of CSS to SM with the modified rice nursery cultivation. The cost of labour is higher for the CSS: 54 labours as required for 10ha to prepare rice seedlings, load, and transfer the trays by pickup truck from the place of incubation to nursery. This was due to the extra care needed to young seeding extra care and more time is necessary to transfer the trays to the field. When the SM technique is introduced 16 persons for the equivalent 10ha area can easily complete the operation of the sowing to transplanting. The SM technique is expected to reduce the working hours for transplanting by one-third of these for the CSS because the driver will continue for translating without reloading and feeding the seedling for time longer than in CSS. Therefore, the SM is an excellent labour saving technology. The cost of materials was also higher for the CSS compared to the SM. This was due to the high price per plastic tray in addition to loss and damage of some trays during the transplanting operation. The volume of irrigation water required for the SM was very low. Spraying the nursery by water using a sprinkler irrigation system every three days was enough for seedling development during the nursery stage. The reduction percentage of number of labour, labour cost, tractor cost, material cost, and transportation cost of the SM technique were 70, 70, 82.5, 41.5, and 41.9%, respectively (Table 7). The labour intensity of SM technology is less than half of that in the CSS.

Fig. 3: Rolling up and standing of seedling mat at nursery site.

The typical working posture in the CSS, bending the waist to lift heavy nursery boxes, almost disappeared [22]. The posture used in the SM is much easier. It is estimated that the applicability of this technology is high because there will expected no inferiority with growth and yield in comparison with growth and yield in the CSS. The seedlings transported by a small pickup truck (150 cm X 220cmX 150cm) are sufficient for 1.6 ha, which is very cheap compared with a long pickup truck. The technology to roll up the SM in a compact form enables farmers to set seedlings on a truck for the rice transplanter in the usual position (Fig. 3).

In conclusion, this study is clearly that the SM system compared with the CSS system has no inferiority with the growth and quality of seedlings. Trails were conducted to develop an SM suitable for use with the RSS. The rice seedlings were grown in a newly developed nursery device for about 3 weeks, and the plant length reached 15.2 cm. The seedling mat was strong enough to be handled. Roll type seedlings were obtained more readily. Rice transplanter would not need to be remodeled in order to transplant SM. Water consumption was not recorded in this study, although consumption during seedling development was very low. The RSS expected to save irrigation water through use of sprinkler irrigation system. The CSS technique uses flood irrigation. Finally, the Rice Research & Training Centre has developed the basic technology of the SM, making the loading and transplanting of seedlings easier. Thus, it is effective both in large fields on plains and for small and scattered fields. Further research include the following: growth parameters and rice yield and its components after transplanting for both the RSS and CSS should be assessed and compared, as well as assessing the working accuracy of the rice transplanter.

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