CAFEi2016-106

Mechanization of transplanting and weeding for rice intensification (SRI) for improved paddy yield in Malaysia

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Abstract

The overall objective of this research was to develop a new approach to increase paddy production with the limited resources input through management practices that simultaneously provide better growth condition. The study evaluated the management practice method known as System of Rice Intensification (SRI) using a modified Kubota Transplanter for planting of paddy and a modified high clearance weeder for crop maintenance. Main SRI management practices such as planting depth, missing hill, hill population, number of seedling per hill, soil characteristics of the sites, and moisture content and the frequencies of weeding were evaluated. The effects of different hill-spacings on 14-days old seedlings of MR219 rice variety were studied using analysis of variances. The experiment was designed at three seeding rates (70g, 75g and 240g) per tray. The plant characteristics at transplanting time consisted of 2 to 3 number of leaves, 2 mm stem thickness, 19 mm stem length and 3.5 mm root length. The planting parameter showed that increase in spacing resulted in more tillers and more panicle per plant, while hill population and sterility ratio increases with decrease in spacing. The study also evaluated the effect of levels of mechanical weeding using four different locally fabricated rotary weeders on the yield and vegetative components of rice under the System of Rice Intensification at Tanjung Karang Irrigation Scheme of Malaysia. Results indicated that wedding levels had a significant effect on vegetative paddy height with 60.05cm as the highest average vegetative height obtained at three levels of rotavations (mechanical weeding). The analysis of variance of the yield indicates a significant difference in yield with increase in the levels of mechanical weeding with 13.1tons/Ha being the highest obtained 30DAT.

Keywords: young seedlings, transplanting, seed rates, system of rice intensification, mechanical weeding, and paddy yield.

INTRODUCTION

Rice (*Oriza sativa L.)* is one of the leading food crops of the world; it is a popular and staple food for nearly three quarter of the world population. The average global rice production is 466.47 million metric tons for the year 2014 with an average yield of 4.25 ton/ha (USDA, 2014). The ever-growing and global demand for rice can only be met by increasing its production through enhancing productivity and intensive cropping. The global increase in population and limitation in agricultural land demand efficiency and productivity in all stages of rice production. Manual paddy transplanting is tedious, laborious and time consuming operations requiring about 200 to 250 man hectare per hour, which is roughly 25 % of the total labor requirement of rice production (Mufti, 1995).

It was reported that a delay in transplanting by one month reduces the yield by 25 % and a delay of two months reduced the yield by 70 % (Rao, 1973). Increasing crop yield is the major concern for all stake holders (local paddy and government growers) through the

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introduction of new cultivars, changing of land preparation activities from manual labour to using tractors or machines in operations i.e. type and amount of fertilizer and pesticide usage, the cycle and the intensity and frequency of cycles (Malaysia Agriculture, 2010) . The system of rice intensification (SRI), a new and promising resource-saving method of growing rice under irrigated or rain-fed conditions, with an impressive yield at an average of 7 tons/ha (Uphoff Norman, 2006; Thakur et al., 2010; Stoop et al., 2011; Melati, 2012). However, the constraints to smooth adoption of SRI are the high labour demand in terms of manual transplanting and intensive weeding requirement.

Manual transplanting operation involved the holding of seedlings on one hand and using the other hand to remove the seedlings and fix to the soil in bending posture is a tedious operation and requires 200-250 man/hour/ha (Anoop et al., 2007). Recently, the solution is in changing to mechanization for mechanical transplanting. The main aim of the research was to develop a paddy transplanter to comply with SRI guidelines. The study is limited to modification of the paddy rice transplanting planting finger and the evaluation of its performance under the umbrella of system rice intensification (SRI) in Malaysia.

Weed control accounts for substantial cost in agricultural production and an important constraint to increasing yields wherever rice is grown. Weeding is one of the critical stages in rice cultivation and affects yield and quality of rice (Alizadeh, 2011). There is an increasing interest in the use of mechanical inter-row weeders because of concern over environmental degradation and a growing demand for organically produced food (Olaoye and Adekanye, 2012). The reported impressive yields of above 7tons /ha under SRI and its organic nature, the high labour demand especially its intensive mechanical weeding requirement has both stimulated the interest and concern of farmers. This research work was conducted to evaluate some of the locally fabricated rotavators with a view of establishing their performances, effect of weeding levels on vegetative components of rice, their ability to meet the intensive mechanical weeding up to 40DAT as required by SRI practice.

MATERIALS AND METHODS

Study Area

The experimental study plot was located at Sungai Burong, Tanjung Karang, Malaysia. The study area was a flat plain with the soil type predominantly silty clay, belonging to the Selangor soil series, with mechanical analysis of 1.1% sand (2000-50 μm), 45.4% silt (2-50μm), and 53.5% clay (< 2μm) (Abubakar et al., 2010). MR219 rice variety commonly cultivated by farmers in the study area was prepared and transplanted in an experimental plot on the 13th January, 2014. Selected and sorted seeds incubated in moist gunny material for a period of 2 days are uniformly scattered while some planted in rows in the nursery beds at different seed rates of 70 g, 75 g and 240 g. Seed invigoration technique as reported by Farooq et. al,2006 among others, are pre-germination operation involving the soaking of the seeds in water for 24 hours durations, then placing in-between two layers of saturated gunny bags to encourage the appearance radicles was adopted at different salt concentrations. The paddy field was cleared, harrowed, ploughed twice and puddled before transplanting of the 14 days old seedlings in the paddy field at different hill spacings of 14 cm x 30 cm, 16 cm x 30 cm, 18 cm x 30 cm, 21 cm x 30 cm and 24 cm x 30 cm. The transplanting was done with the use of Kubota SPU-68C transplanter running length wise of the prepared field, with the soil kept moist enough to prevent floating of the tiny friable seedlings. Alternate wetting and drying was maintained at the vegetative stage, while during the flowering up to 10 to 12 days prior to harvesting, a thin layer of water maintained through irrigation at frequent interval.

Rotary weeding was done during the entire crop growth period, based on the Bestari planting guide proposed by the Malaysian Agricultural Research and Development Institute (MARDI). However experiments to evaluate the effect of levels of mechanical weeding were carried out in an un-flooded nursery as required by SRI practices and transplanted manually at 25cm x 25cm row and intra-row spacing on the well levelled/puddled experimental plot. Experiments were carried out on the experimental plot of 6.85m x 28.14m each was set up in

a split plot design with five main plots, four sub plots treatment factors and four replication. The main plot treatments are: **A**: Three-row low clearance rotavator, **B**: one-row rotavator, **C**: Four-row low clearance rotavator, **D**: Five-row rotavator and **E:** No weeding (control). The sub plot factors are four (4) levels of weeding rotovation at 10, 20, 30 and 40 days after transplanting (DAT). None of the machines was able to weed at 40DAT, treatment D was able to weed at 30DAT while treatments A, B & C could only weed at 20DAT. Harvesting of the experimental plot was done on the 30th April, 2014 using Iseki 695 Combine. Observations on the planting depth, moisture content, bulk density, plant characteristics at transplanting time, number of seedlings, missing hills, tillers and panicles per meter square were recorded, while the yield per hectare from the field was asses to determine grain yield per hectare. Yield data was recorded accordingly and analysed as per procedure of analysis of variance and significance tested by "F" test.

RESULTS AND DISCUSSION

Transplanter

Throughout the experimental plots, the number of seedlings has a significant effect on seed rate in plots with one and three seedlings per hill. The grain yield was found to increase with increase in spacing in all the experimental plots. The 70 grams of seeds per tray recorded the least number at 14 cm x 30 cm spacing while spacing of 24 cm x 30 cm for 70 grams of seeds per tray has the maximum number of 28 grains per panicle. Tiller count clearly shown the differences in plants physiological and also the morphological features, with the highest average number tillers of 65 per hill at row and scattered planting of 70 g seeds for spacing of 24 cm x 30 cm, while the lowest recorded at 21 cm x 30 cm. Higher endosperm nutrient contents during 2nd and 3rd phyllochrons support faster recovery of younger seedlings, and when seedlings transplanted after 4th phyllochron stage take little longer time for recovery from the transplanting shock. Krishna and Biradarpatil 2009 found that rice plants experience shorter phyllochrons and increasing number of tillers when seedlings of less than 12 days are transplanted (two leaf stage). The highest and lowest yields were obtained from 75g seeds per tray scattered and 70g seeds per tray scattered treatment respectively, in all the spacings. The result clearly indicate increase in yield with increase spacing. Though the yield of 75g seeds per tray scattered treatment is higher than that of 240g seeds per tray scattered treatment but the difference was not statistically significant as shown in Table 1. The result based on analysis of variance (Table 2) indicated that 75g seeds per tray scattered had the highest number of single seedlings establishment per hill in all the spacings, except at 18cm x30cm spacing where 240g seeds per tray scattered had statistically higher number. The treatment 70g seeds per tray row and 70 g seeds scattered were statistically at par and recorded the least number of two seedlings per stand (Table 2).

Table 1. Rice Yield in Tons/ha

Block	Spacing treatment (m)			
	$d1 = 0.16$	$d2 = 0.18$	$d3 = 0.21$	$d4 = 0.24$
A	6.50	7.11	6.80	7.60
	6.30	7.09	6.10	7.70
	6.30	7.10	6.90	7.50
B	4.80	4.6	4.30	4.90
	4.70	4.4	4.50	5.00
	4.90	4.50	4.40	4.80
C	7.60	8.7	8.80	9.40
	7.70	8.5	8.90	9.20
	7.60	8.60	8.70	9.30
D	7.50	8.1	8.50	9.20
	7.70	7.9	8.40	9.30

	7.60	8.00	8.30	9.10

Block A : Scattered Planting Pattern, UPM
Block B: Row Planting Pattern, UPM
Block C : Scattered Pattern Spacings, Tanjung Karang
Block D: Scattered Pattern Spacings, Tanjung Karan

Table 2. Seedlings number per hill spacings

Seed (kg)	Spacing treatment (m)																			
	One seedling				Two seedling				Three seedling				Four seedling				Five seedling			
	d1	d2	d3	d4	d1	d2	d3	d4	d1	d2	d3	d4	d1	d2	d3	d4	d1	d2	d3	d4
	483	342	201	235	179	166	272	164	60	77	88	24	38	68	19	50	16	32	11	35
S1	485	346	200	240	182	164	270	166	63	75	86	27	39	70	16	50	15	36	13	37
	484	347	202	239	179	165	271	165	63	76	90	26	40	69	19	56	17	35	12	36
	285	233	138	180	230	140	238	108	211	220	154	160	113	87	36	40	44	10	23	19
S2	284	235	134	179	231	137	233	110	214	219	164	165	117	92	32	41	43	18	25	22
	283	234	135	183	229	137	237	109	214	221	159	170	115	91	37	42	45	14	24	22
	1200	591	722	810	1080	504	562	724	672	1040	423	455	270	530	516	180	133	298	303	90
S3	1210	594	719	809	1079	505	570	721	678	1039	424	445	272	538	515	182	136	297	310	90
	1205	597	719	811	1081	503	566	715	675	1038	421	450	268	354	511	178	136	296	311	90
	813	718	541	224	1354	512	824	134	910	901	464	270	2361	299	516	901	36	569	230	722
S4	809	719	539	226	1348	510	821	135	912	899	465	273	2360	289	514	900	34	571	231	718
	808	723	540	225	1348	508	824	136	911	900	460	267	2365	312	512	899	32	570	232	720

S1: 70g seeds/tray. Scattered Planting Pattern
S2: 70g seeds/tray. Row Planting Pattern
S3: 75g seeds/tray. Scattered Planting Pattern
S4: 240g seeds/tray. Scattered Planting Pattern

Mechanical weeding

The vegetative properties of rice at each level of weeding was recorded, the analysis of variance for the effects treatments are presented in Table 3. The analysis indicates that there is significant difference P (0.05) level in paddy height at 40DAT due to treatment effect. This result is similar to that reported by Cherati et al. (2012). They evaluated and compared engine powered and without engine powered weeders, and reported significant difference in paddy height at 30DAT. The mean comparison Table 4. indicates that the control plot E, had the least vegetative paddy height. This may be attributed to paddy competition with weeds for available nutrients and also lack of soil aeration due to absence of weeding on the plot. The highest vegetative height was on plot treatment D, which had three levels of weeding. The gains in vegetative was high in treatment D may be due to increase in weeding level and high aeration of the root zone. The means in treatments C and A had no difference in means and treatment B had the least among the treatment plots, this may be due to crop damage of the single row machine. Figure 1 shows the normal plot of residual errors for vegetative paddy heights at 30DAT.

Table 3. ANOVA: Vegetative height (cm) at 30DAT versus Treatments

Source	DF	SS	MS	F	P
Treatments	4	371.00	92.75	45.24	0.000
Error	15	30.75	2.05		
Total	19	401.75			

S = 1.432 R-Sq = 92.35% R-Sq(adj) = 90.30%

Table 4. Grouping Information (mean comparison) of Vegetative height Using Tukey Method

Treatments	N	Mean	Grouping
D	4	60.5	a
C	4	58.5	ab
A	4	58.5	ab
B	4	55.5	b
E	4	48.25	c

Means that do not share a letter are significantly different.

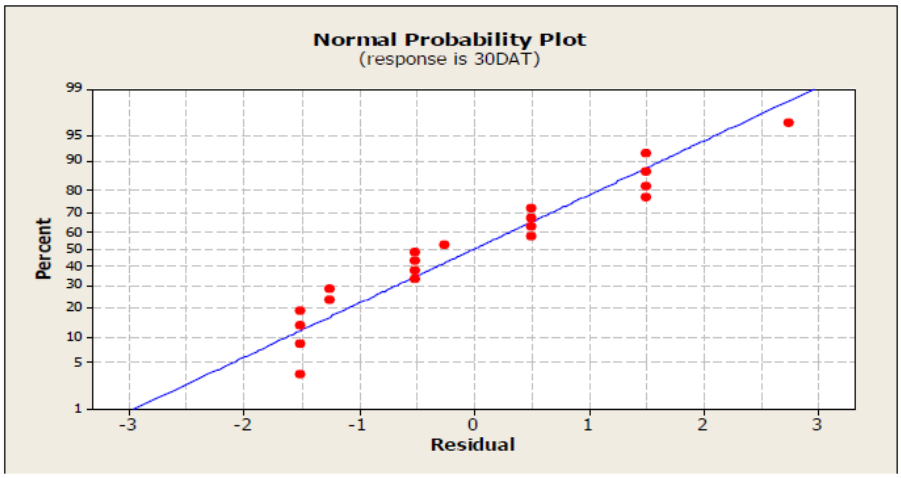

Figure 1. Normal plots of vegetative height residuals at 30DAT

The yield from the experimental plots were analysed to compare if variation exists between the mean of treatment plots. The analysis of variance as in Table 5 suggests that significant differences P (0.05) exist between the yields of at treatment plots. Mean comparison of the yield as in Table 6 suggest that treatment D, with three levels of weeding (30DAT) and average yield of 13.1tons/ha had the highest yield among the treatments. The high yield may be attributed to the high weeding level up to three times which result in greater aeration of the soil. The normal plotting of residuals is presented in Figure 2.

Table 5. ANOVA: Yield versus Machines (Treatments)

Source	DF	SS	MS	F	P
Treatments	4	90.44	22.61	18.01	0.000
Error	15	18.83	1.26		
Total	19	109.27			

S = 1.120
R-Sq = 82.77%
R-Sq(adj) = 78.17%

Table 6. Grouping Information (Mean comparison) of Yield and Treatments Using Tukey Method

Machines	N	Mean	Grouping
D	4	13.085	a
A	4	11.400	ab
B	4	10.258	b
C	4	9.672	b
E	4	6.655	c

Means that do not share a letter are significantly different.

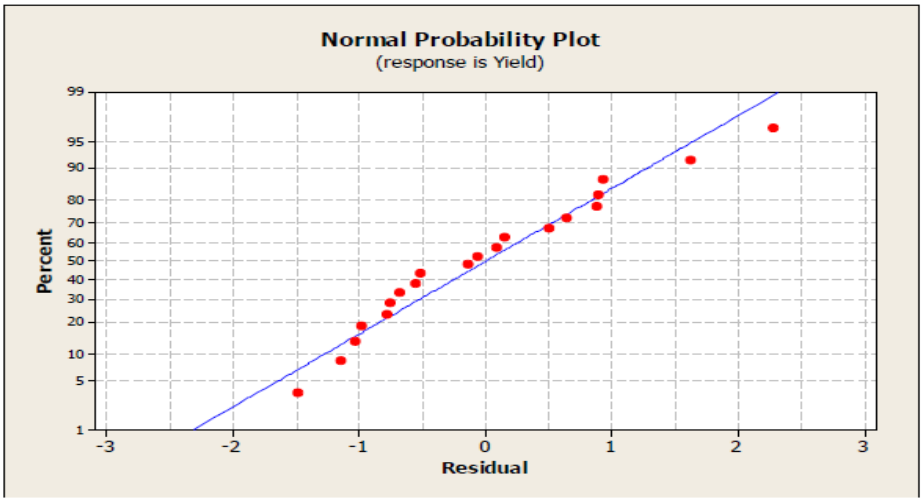

Figure 2. Normal plots of yield residuals

CONCLUSIONS

The following conclusions can be drawn from the study:

- There are visible evidence to say conclusively, that farmers can conveniently use the modified finger transplanter for their field work to boost their productivity up to 9.3tons per hectare at spacing of 24 cm x 30 cm, 75g of seeds per tray scattered pattern during the 2014 planting season. The crop establishment by machine was 7 tons per hectare using the Conventional claw, with least seeding rate of 75 g seeds per tray against the 240 g of seeds per tray.
- The results of this research confirm the performance of SRI practices in raising grain yield was achieved with reduced water, lower cost which offers greater benefits for the farmers and the country at large.
- In this study we evaluated and compared the effect of levels of mechanical weeding in paddy field under the system of rice intensification at Tajung Karang Scheme, Malaysia. The results suggest a significant increase in yield of paddy with increase in mechanical weeding levels.
- An average yield of 13.1tons/ha was recorded with three levels of mechanical weeding. The effect of mechanical weeding levels on the vegetative treats of paddy also indicated significant difference in paddy vegetative height, with the highest vegetative height of 60.05cm obtained at 30DAT and three levels of mechanical weeding.
- Due to lack of ground clearance of the evaluated mechanical weeding machines, the authors hereby recommend that further evaluation of yield and vegetative components of paddy at 40DAT or until canopy closure be carried out using a higher ground clearance mechanical weeder.

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