Research article

Comparison of Rice Plant Development with Different Transplanting Density under SRI Practices in the Lysimeter

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Abstract Transplanting a single young rice seedling is one of the common methods in SRI practices. However, farmers in some lowland areas hesitate to apply this method due to the threats such as seasonal floods, birds and pests. Most of the farmers are more comfortable with transplantation of two or more seedlings per hill. Thus, an experiment was conducted in the lysimeter at the rooftop of the University of Tokyo in 2015 to compare the rice plant development with different transplanting density. As an experimental design, two sets of single seedling transplantation were applied with alternative wetting and drying irrigation as replications; the same irrigation condition was applied to other transplantations with two, three and four seedlings per hill. The plant height, number of leaves and tillers, dry biomass, and grain yields were selected as the main factors for the comparison of rice plant development. As a result, no difference was observed for the development of height across all transplantation density treatments during the vegetative phase. However, during the reproductive and ripening phases, single-seedling transplantation reached greater height. For the development in number of tillers and leaves, three and four seedlings produced more tillers and leaves than one and two seedlings. We found that the grain yield is significantly higher in three and four seedlings rather than one seedling.

Keywords system of rice intensification, young seedling, transplanting density, plant development

INTRODUCTION

Rice is a major staple crop in the world. About 90% of all rice production and consumption takes place in Asian countries (FAO, 1998). Moreover, rice is also an important food in these areas, inter-connected with culture and eaten in festivals and other important events. While both the world population and the food demand is increasing, rice production is fluctuating due to the climate change and shifts in rice cultivation methods. Varieties of rice with high yield and climate tolerance have been discovered in recent years according to the International Rice Research Institute (IRRI, 1998). The varieties of rice and its cultivation differ by the climatic differences from region to region. The use of inorganic fertilizer in the paddy field is a common agricultural practice today in order to achieve high yields, but the excessive use of inorganic fertilizer have had negative impacts on the environment (Gimeno-Garcia et al., 1995). As a result, concerns with human health and interests in organic farming have risen. A new method of plant management, organic fertilizer application, water management, and resultant high yields in rice production was found in Madagascar in 1983 by Father Henri de Laulanı´e, a French Jesuit priest, and later disseminated worldwide by the Cornell International Institute for Food, Agriculture and Development. This method, called the system of rice intensification (SRI) today, is considered to save water yet achieves high-yield compared to the conventional method (Thakur et al., 2010; Chapagain and Yamaji, 2009). Stoop et al. (2002) reviewed the SRI method practiced around the world explaining how high yields are achieved through SRI's key principles through a range of environmental factors and agronomic management practices including variety selection.

There are several definitions of SRI based on the climatic features of the countries. We applied the irrigation management called alternative wetting and drying irrigation (AWDI), which is also known as the intermittent irrigation. SRI method is considered as a water-saving method with high yields. At the same time, water management by AWDI reduces the methane gas emission from rice cultivation (Pun and Yamaji, 2014), which is one of the major contributors to the potential global warming. With respect to the worldwide dissemination of SRI, there are nonetheless many issues with regards to its method of application. One such issue is the farmers' hesitation to transplant single rice seedling per hill, which is considered a key principle of SRI, due to the concerns over threats from floods, pests and birds to name a few. Instead, these farmers prefer to transplant two or more seedling per hill. Such tendency among the farmers and their challenges in protecting young seedlings in lowland areas is one of the reasons why the dissemination of SRI as a single-seedling transplantation method has been limited.

The experiment conducted in lysimeter 2014, transplanting single seedlings were cultivated under both AWDI and continuous flooding conditions. The plant development was significantly higher in non-SRI method than in SRI method. But there was no significant difference between the two methods in terms of grains produced. It is because of same transplanting density of rice seedling. In this study, we investigated the rice plant development with different transplanting density under SRI practices. The aim of this study is to find adequate recommendations to farmers who hesitates to transplant single seedling in lowland areas as well as some uplands.

MATERIALS AND METHODS

The lysimeter experiment was conducted in the University of Tokyo Kashiwa campus, Chiba Prefecture, Japan during the rice growing season in 2015. The study aimed to verify the difference in rice plant development by different transplanting density. The size of lysimeter was 495 cm in length and 158 cm in width. The lysimeter consists of a drainage valve on the right border and an irrigation facility from tap water on the left border (Fig. 1). The soil was puddled homogeneously for two weeks before transplanting. The organic fertilizer (2,200 gram) was also mixed homogeneously into the entire soil. The composition of organic fertilizer was 1.3% nitrogen 0.6% phosphorus, and 1.8% potassium, with C/N ratio of 22. We also installed a water tube with 13.5 cm diameter and 25 cm length to measure the ponding depth. Ponding depth was measured using data logger LR5042 (Hioki E.E. Corporation, Japan) over the course of the experiment. The water depth sensors inside the water tube were fixed at 15 cm deep from the soil surface. Data logger LR5042 measures water pressure in voltage ranging from -5.000 V to 5.000 V which is converted to the height of water in lysimeter with a calibrated equation. Water pressure data was collected every sixty minutes. The transplanted rice in the nursery was a 24-days old Japanese rice variety *koshihikari*. A total of 160 rice nurseries were transplanted on May 12, 2015. A single factor experiment method was utilized for this experiment, in which a single factor varied (density of rice seedlings while other factors remained constant (e.g. fertilizer, water management). The experiment followed the completely randomized design (CBD) with four treatments (number of rice seedlings per hill) with two replication. The randomization was done as shown in Fig. 1. The numbers indicated in Fig. 1 are a) SRI method with *one seedling per hill*, 2) SRI method with *two seedlings per hill,* 3) SRI method with *three seedlings per hill*, and *4*) SRI method with *four seedlings per hill*.

Rice plant height and the number of tillers and leaves were recorded once in a week during the vegetative phase. During the reproductive phase, the plants were covered with a net to protect from birds, and were measured twice a month. The water management applied was AWD (alternative wetting and drying) irrigation. Water was drained by using a hand pump when there was the excess rainfall.

The collected data was tested by ANOVA (Analysis of Variance) using R statistical software (R Core Team, 2014). Later, Tukey's HSD test was conducted to identify the differences in development among different treatments.

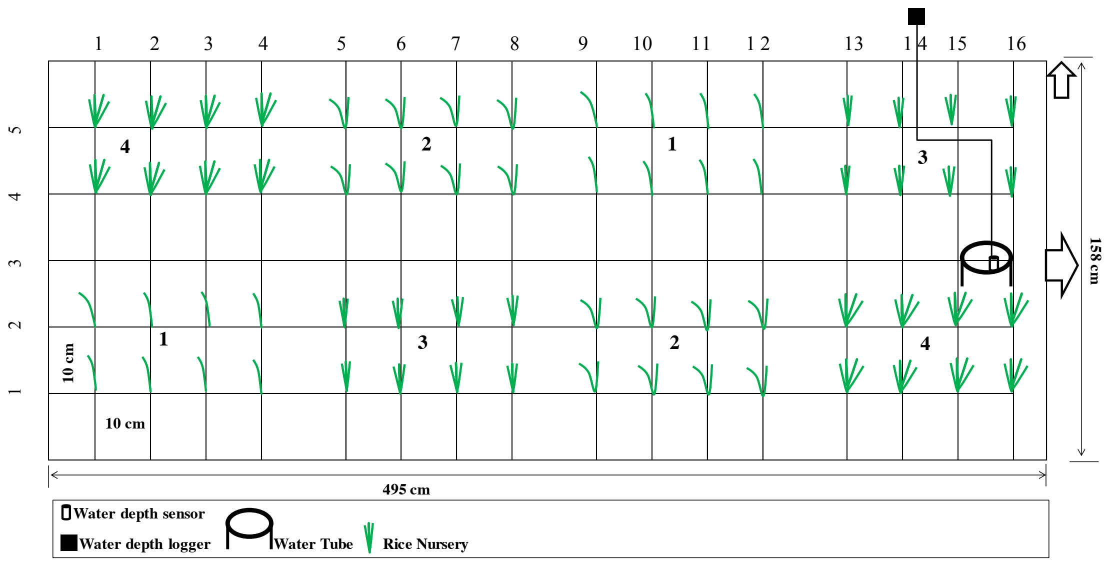

Fig. 1 Schematic diagram of the experimental setup

RESULTS AND DISCUSSION

Water Management and Climatic Condition

There are four seasons in a year in Japan. Paddy is cultivated only in summer seasons. Japanese rice farmers prepare the paddy field in late spring by flooding the field and applying fertilizers. Likewise, lysimeter was also prepared with flooding and fertilizer application at the end of April. The first rice was transplanted on the 12th of May. The method of water management was alternative wetting and drying irrigation (AWDI). We maintained the shallow ponding condition above the soil surface starting from the day of transplantation to 26th may until the rice plant became stronger. The maximum water level was 7.59 cm and minimum level was 0.24 cm from the soil surface (Fig. 2). The drainage valve was opened to reduce the water level in the lysimeter down to -13.10 cm from 27th May to 5th June. AWDI method was also applied based on the rainfall event in the study area (Fig. 2). The maximum rainfall in the study area occurred during the first 10 days of September at 249 mm (Japan Meteorological Agency, 2015). The comparison of rainfalls by 10-day intervals (start- first 10 days, mid-second 10 days, end-last ten days) during rice cultivation period revealed that the minimum rainfall (4 mm) was recorded at the start of August (10 days). Maximum temperature was also recorded during the cultivation period (36.7°C). If there was no rainfall event, tap water was used for irrigation. During the ripening phase, lysimeter was kept dry to prepare for the harvest.

Rice Plant Development

The rice plant height and the number of tillers and leaves were measured once in a week during the vegetative phase. However, measurements were taken only once a month during the reproductive phase, because the lysimeter was covered with a net to protect the rice plants from birds.

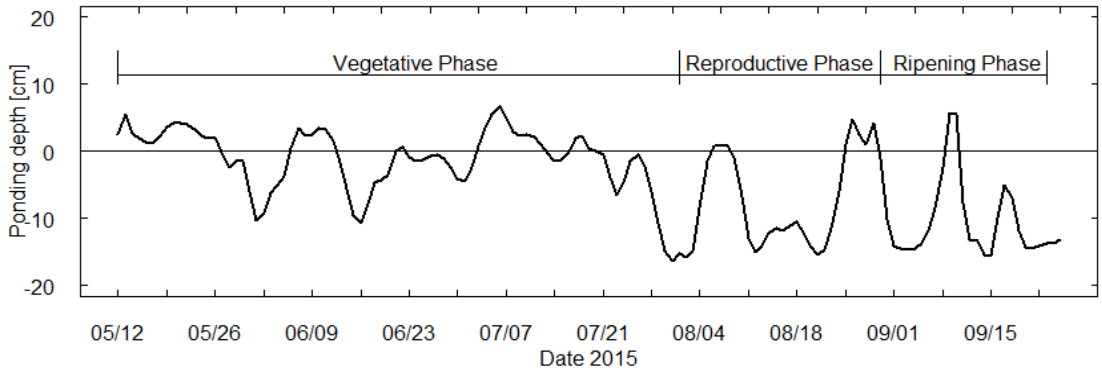

Fig. 2 Water management during the rice cultivation in the lysimeter

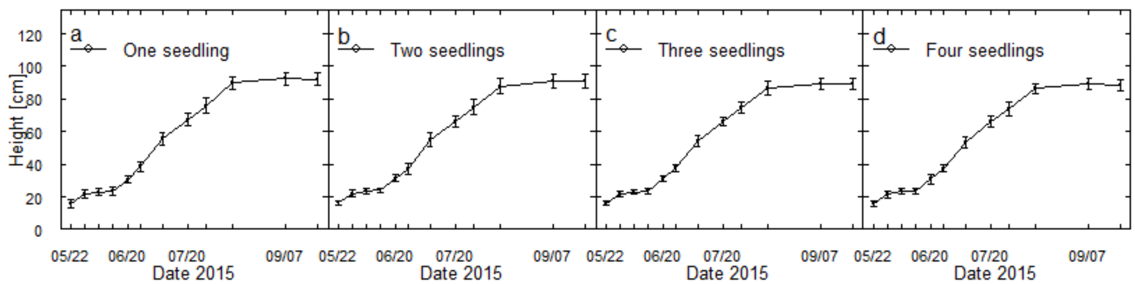

Fig. 3 Rice plant height development in all treatments

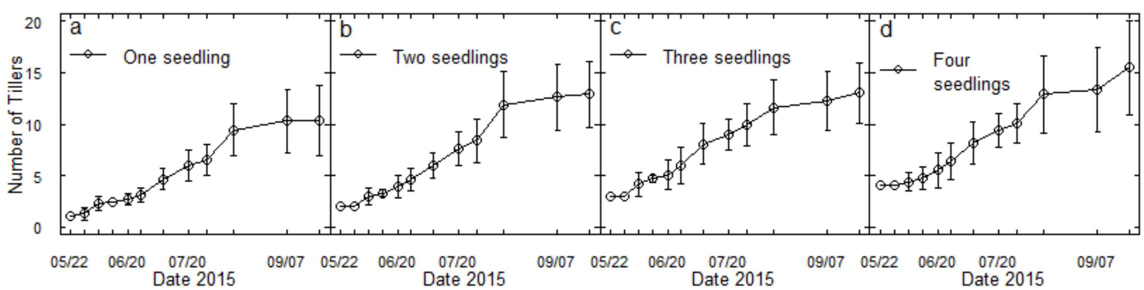

Fig. 4 Rice tillers development in all treatments

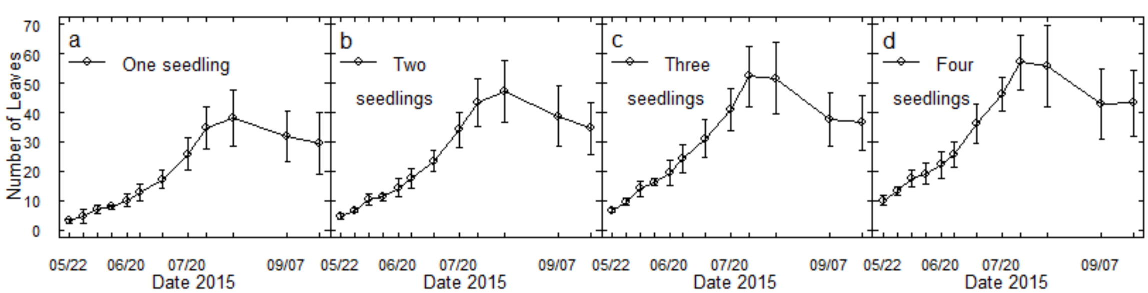

Fig. 5 Rice plant leaves development in all treatments

After the rice was transplanted on of May 12, the first height was measured on May 22, by a measuring tape. Fig. 3 shows that the average height in centimeters for two, three, and four seedlings per hill were 16.34 ± 1.21, 16.03 ± 1.34 and 16.03 ± 1.53, respectively, but the average height for one seedling per hill was only 15.69 ± 2.26. Fig. 4 shows the development of tillers, which was observed in every seedling density after the May 29. Fig. 5 shows the development of rice plant leaves counted altogether, where the maximum number of leaves was counted in four seedlings, followed by three, two, and one seedling. During the vegetative phase, numbers of leaves were similar in three and four seedlings. Number of tillers and leaves were also higher in three and four seedlings than one and two seedlings. The rice was harvested on September 23. Maximum height across all four treatments were observed in one and two seedlings, while the heights for three and four seedlings were similar to each other but less than that of the one and two seedling densities. The number of leaves decreased because lower leaves decayed. Some leaves decayed and dried but were not included in the count. The number of tillers increased at the end of the vegetative phase because of the emergence of small branches. However, formation of panicles was not observed for the small branches.

Table 1 Details of the rice plant development

Measured Variables	1 T (One Seedling)		2 T (Two Seedlings)		3T (Three Seedlings)		4 T (Four Seedlings)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Height (Centimter)	92.13	2.88	91.00	89.25	89.25	2.63	88.56	2.19
Stem (Number)	10.38	2.36	12.88	2.15	13.06	1.45	15.25	2.41
Green Leaves (Number)	29.69	7.21	34.63	6.44	36.50	4.64	43.25	6.69
Dead Leaves (Number)	13.44	2.26	19.56	2.99	20.13	3.52	20.81	3.40
Panicle (Number)	9.75	1.67	11.94	2.35	11.94	1.32	13.25	2.62
Dry Stem (Gram)	9.61	0.89	13.04	0.74	13.39	2.35	14.39	2.04
Dry Leaves (Gram)	4.14	0.41	5.55	0.51	5.76	0.86	5.84	0.73
Good Grain (Number)	647.75	162.97	798.00	64.39	752.88	85.18	681.13	75.21
Bad Grain (Number)	8.50	1.08	16.75	8.45	15.75	1.50	13.00	9.88
Dry Spikelet (Gram)	0.95	0.15	1.03	0.15	0.98	0.13	1.07	0.20
Grain Weight (Gram)	15.89	2.31	18.20	3.15	19.83	2.55	20.49	4.39

SD: Standard Deviation

Table 2 Comparison between indicators using T-test

1 T				1 T				1 T				1 T				1 T			
	2 T				2 T				2 T				2 T				2 T		
***		3 T		*		3 T		*		3 T				3 T		**		3 T	
****	**		4 T	**			4 T	**			4 T	*			4 T	***			4 T
Dead Leaves				Dry Stem				Dry Leaves				Dry Spikelet				Grain Weight			

T: Seedling, * Significant level at 0.1, ** Significant level at 0.05, *** Significant level at 0.01, **** Significant level at 0.001

Grain Yield and Biomass

The rice was harvested on September 23. To study the grain yields and total biomass development within four treatments, four rice plants were selected from the middle of each treatment. Height, the number of stems, green leaves, dead leaves, and panicles were measured for a total of 64 rice plants. Moreover, to study the details of rice plants, the number of grains (good and bad), dry stems and leaves, and spikelets were counted from selected 32 plants. The grain weight at 14% moisture level was measured from all rice plants (Table 1). The result of height among the treatments showed the mean difference is higher in one seedling but without significant difference. In case of stems, one seedling was lower than the two, three, and four seedlings. The number of green leaves at the time of the harvest were counted, but the number was lower for one seedling case.

The dead leaves were recorded just after the harvest. In comparison with other treatments, three seedlings showed a significantly higher level of dead leaves compared to one seedling treatment, as shown in Table 2 ($p < 0.05$). The four seedlings also had a greater number of dry leaves than one and two seedlings ($p < 0.001$ for comparison with one seedling treatment; $p < 0.01$ for comparison with two seedling treatment). The number of dry stems and leaves were higher for four seedling treatment than for one seedling treatment ($p < 0.05$). For other comparisons, differences in dry stems and leaves were not significant. The spikelets without grains were also higher for two, three, and four seedling treatments. The grain weight at 14% moisture level was measured. The grain weight (i.e. yield) was significantly higher for three and four seedlings compared to one seedling treatment ($p < 0.05$). However, there was no significant difference in grain weight (yield) among the two, three, and four seedling treatments.

CONCLUSION

We conducted the lysimeter experiment to clarify the difference in rice plant development by different transplanting density under the SRI practices. The common method of rice transplanting by SRI is single young rice seedling. However, famers in some lowland areas hesitate to transplant single seedlings by the SRI method because of the threats from birds, flood, and insects, causing a dilemma for the farmers over the implementation of the SRI method. We found that the grain yield is significantly higher for transplantation treatment with three and four seedlings rather than one seedling, validating the farmers' confidence in their way of applying the SRI method. This study thus suggests that farmers can transplant more than one seedling in lowland areas. The study used a Japanese koshihikari rice nursery. It is highly recommended to test with the local rice variety, climatic condition, and agronomical practices for a more precise confirmation of optimal seedling densities.

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