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Effect of seed rate on yield performance of dry direct seeded winter rice

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ABSTRACT

Seedling transplanting into the puddled soil is the conventional and most popular rice establishment method in Bangladesh but water scarcity is posing a serious threat to this system of rice cultivation especially in boro season. Dry direct seeding (DDS) is an alternative rice establishment technology which have potentiality to save irrigation water significantly. Seed is sown manually on dry cultivated land at 25 cm × 15 cm spacing but continuous line sowing can be done by power tiller operated seeder. Therefore, there is a need of evaluating the yield performance of line sown dry seeded rice at various seeding rates to standardize the seeding rate for further machine sowing recommendation. Two mega rice varieties for winter (boro) season *viz.* BRRI dhan28 and BRRI dhan29 were cultivated at five seeding rates (30, 40, 50, 60, and 70 kg ha^{-1}) in continuous line sowing and a spaced seeding (25 cm × 15 cm) using 30 kg seed ha^{-1} as a control treatment. The results reveals that the highest grain yield (6.73 and 7.13 t ha^{-1} in 2009–10 and 2010–11, respectively) was obtained from the seeding rate of 50 kg ha^{-1} for BRRI dhan29 but this yield was significantly lower than that obtained (7.07 and 7.46 t ha^{-1} in 2009–10 and 2010–11, respectively) in control. Although higher grain yield was obtained from the spaced seeding plots, this method is not economically viable as the machine seeding would save huge labour costs. Therefore, considering both yields and labour cost, dry direct seeding would be practiced with continuous seeding at 25 cm apart rows using 50 kg seed ha^{-1} for both the boro rice varieties.

Keywords: Water scarcity, puddle transplanting, winter rice, seed rate, yield

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1 Introduction

Transplanting of seedling by hand into the puddled soil is the conventional practice of rice (*Oryza sativa* L.) cultivation in most of the Asian countries including Bangladesh. Transplanting is a labour intensive practice requiring 30 man-days ha^{-1} and the land preparation by puddling for transplanted paddy consumes about 20∼40 per-cent of total water required for growing the crop (Bhuiyan et al., 1995; Chauhan and Opena, 2012). Traditionally farmers prefer puddled transplanted rice because weed control is very easy in this system. In traditional puddled transplanted rice where farmers mostly prefer to keep standing water in their field, around 1000∼5000 L of water is required to produce one kilogram of rice (Bouman and Tuong, 2001). The shortage of irrigation water both from surface and underground is posing a threat to the sustainability of rice production under conventional puddled transplanted system. In addition, the shortage of labour and increased wage rate is also posing a serious setback on conventional puddled transplanted system. Despite these problems, soil and environmental problems are also associated with the puddling system. Puddling destroys the soil structure and adversely affects the soil productivity (Gupta et al., 2003). Considering these problems, rice production could be sustained by adopting alternate production technology such as dry direct seeding (DDS) which can save up to 60% irrigation water (Rahman et al., 2012). Direct seeding of rice offers certain advantages such as low labour cost, low soil degradation, less drudgery, early crop maturity by 7–10 days, high tolerance to water deficit, saving water and energy (Datta, 1986; Gautam, 2008) and less methane emissions (Joshi et al., 2013). A physiological shock to the seedlings due to uprooting and harmonizing during re-establishment after transplanting is clearly avoided in direct seeded systems. Therefore, a shift of puddled transplanted rice to dry direct seeded rice, farmers may be more benifitted. The sowing is generally done by hand but mechanical seeding will make this alternate crop establishment technology more acceptable and popular.

The appropriate plant density is a decisive factor that affects crop microenvironment by influencing the degree of inter- and intra-row plant competition. Therefore, appropriate seed rates for direct seeded rice is an important consideration in getting the optimum plant population for maximum yield (Ahmed et al., 2014). Previous study suggests that hand sowing at 25 cm × 15 cm spacing provided the best yield of dry direct seeded boro rice (Sultana et al., 2012). This spacing is similar to the recommended practice for puddle transplanted boro rice in Bangladesh. At present sowing of dry direct seeded rice is done manually which is labour intensive but in many countries, including Bangladesh sowing is now done using mechanical seeders (Gathala et al., 2014) such as power tiller operated seeder (PTOS) and versatile multi-crop planter (VMP). The present study was therefore, undertaken with the view to find out the optimum seed rate for continuous line sowing rice seed by machine in dry direct seeded system towards reducing rice establishment cost.

2 Materials and Methods

2.1 Experiment site description

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh (24°43′8.3″N, 90°25′41.2″E) during December 2009 to May 2010 and December 2010 to May 2011. The experiment site was a well drained medium low land belonging to Non-calcareous Dark Grey soil under the Old Brahmaputra Floodplain Agro-ecological Zone (AEZ–9). The soil had pH of 6.85 and contained 1.50% organic matter, 0.074% total nitrogen, 11.85 ppm phosphorus, 0.18% potassium, 9.5 ppm sulphur and 0.43 ppm zinc. The study site experiences high rainfall, high relative humidity, high temperatures, and long days during the Kharif season (April–September) while scarce rainfall, low relative humidity, low temperatures, and short days in the rabi season (October-–March). During the experimental period, the average maximum temperatures were 29.0 and 28.2 °C in 2010 and 2011, and minimum temperatures were 18.0 and 22.9 °C, respectively. The relative humidity during the experimental period was 78.8∼80.2%. The total rainfall of 20.3 and 45.7 mm occurred during January to March in 2010 and 2011, respectively.

2.2 Treatments and design

Two rice varieties (*viz.*, BRRI dhan28 and BRRI dhan29) and six seed rates (*viz.* 30, 40, 50, 60 and 70 kg seed ha^{-1} sown continuously in 25 cm apart lines and a control seed rate of 30 kg ha^{-1} sown at 15 cm plant to plant distance) were used in a randomized complete block design (RCBD) with three replications. The unit plot size was 4.0 m × 2.5 m. The distances maintained between blocks and plots were 1.5 m and 0.5 m, respectively.

2.3 Crop management

The seeds were sown in dry cultivated well prepared soil on 25 December 2009 and 2010 as per experimental specifications. Before sowing, the seeds were primed by soaking into the water for 30 h followed by incubation for about 30 h or until the seed was about to sprout. The land was fertilized with cowdung, urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at the rate of 10 t, 260 kg, 70 kg, 100 kg, 100 kg, and 3 kg ha^{-1}, respectively. The whole amount of cowdung, triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in 4 equal splits such as at the final land preparation, at 45–50, 60–65 and 75–80 days after sowing (DAS). Weeds were controlled by doing hand weeding three times at 25, 45 and 60 DAS. Irrigation was given to the experimental plots (550–600 mm) in 8–10 occasions during the whole crop period.

2.4 Observations

The crop was harvested at full maturity (when about 80% of the seeds became golden yellow in colour) from central 2.1 m × 1.5 m area of each plot to record the yields of grain and straw. Five hills (excluding border hills) were randomly uprooted from each plot before harvest for recording the plant height, tiller production and yield contributing characters such as number of grains per panicle, 1000-grain weight. The harvested crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. The crop was threshed by a pedal thresher. Grain and straw were sun dried and cleaned. Finally, grain yield was adjusted at 14% moisture level.

2.5 Statistical analysis

The collected data were compiled and analyzed following Analysis of Variance (ANOVA) technique with the help of a computer based package programme MSTAT–C. The differences among the treatment means were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

3 Results

3.1 Plant height

BRRI dhan28 produced taller plants (102.9 cm and 104.5 cm) than BRRI dhan29 (98.4 cm and 100.0 cm) in both the cropping seasons. The interaction of variety and seeding rate effect on plant height differed significantly only in 2010–11 but not in 2009–10. BRRI dhan28 at control treatment gave the highest plant height (108.1 cm) which was statistically similar with that of BRRI dhan28 at 50 and 60 kg seed ha^{-1}. The lowest plant height (98.8 cm) was found with BRRI dhan29 at 50 kg seed ha^{-1} (Table 1).

3.2 Tiller density

Seeding rate had significant effect on total tillers, effective tillers of rice in both the seasons. The number of total tillers were higher at the highest seed rate of 70 kg ha^{-1} for BRRI dhan28 (313 and 316 tillers m^{-2}) and BRRI dhan29 (349 and 353 tillers m^{-2}). The lowest number of tillers were recorded from the lowest seeding rate of 30 kg ha^{-1}. The lowest tiller densities for BRRI dhan28 were 185 and 189 (tillers m^{-2}), respectively, in 2009–10 and 2010–11. Those values for BRRI dhan29 at 30 kg seed ha^{-1} were 205 and 209, respectively in 2009–10 and 2010–11 (Table 1). The number of effective tillers was the highest in BRRI dhan29 at the seeding rate of 70 kg ha^{-1} (297 and 301 m^{-2}) and the lowest for BRRI dhan28 at the seeding rate of 30 kg seed ha^{-1} (157 and 161 m^{-2}).

3.3 Panicle length

Panicle length affected significantly by the effect of varieties, seeding rates and their interaction. Panicle size was longer when seeding rate was lower while panicle size was shorter when seeding rate was higher. Considered with the varieties, the longer panicle was found in BRRI dhan29 (24.7 cm and 25.2 cm) than BRRI dhan28 (24.4 cm and 24.8 cm). The panicle length found in spaced seeded crop was similar to that obtained at the seeding rate of 50 kg ha^{-1} (Table 2). Seed rate higher than 50 kg reduced the panicle length in both the varieties.

3.4 Number of grains per panicle

Numbers of filled grains and unfilled spikelets per panicle were significantly affected by variety, seeding density and their interaction in both the seasons. The numbers of grains panicle^{-1} and unfilled spikelets panicle^{-1} was higher in BRRI dhan29 than the BRRI dhan28. The number of grains panicle decreased with increase in seeding rate from 30 to 70 kg ha^{-1}. The number of filled grain in BRRI dhan29 at 30 kg seed rate was 125 and 127 in 2009–10 and 2010–11, respectively, while those values were 81 and 83 panicle^{-1} in case of BRRI dhan28 with the highest seeding rate of 70 kg ha^{-1}. The grains panicle^{-1} was higher in control treatment (spaced planted crop) than the continuous seeding for both the varieties.

3.5 1000-grain weight

Seeding rate, variety and their interaction affected grain weight of rice significantly. The 1000-grain weight was always higher for lower seeding rate and it was true for both varieties. Grain weight decreased consistently with the seeding rate increased from 30 kg to 70 kg ha^{-1}. The 1000-grain weight for 40 kg ha^{-1} was similar to that for spaced planted crops. Between the two varieties, BRRI dhan29 had lower 1000-grain weight than the BRRI dhan28. The interaction showed that BRRI dhan28 sown at 30 kg continuous seeding gave the highest 1000-seed weight (23.99 g and 24.12 g) while the lowest 1000-grain weight was found with BRRI dhan29 at 70 kg ha^{-1} seed rate (19.72g and 19.86 g).

3.6 Grain and straw yield

Varieties, seeding rates and their interaction had significant effect on grain and straw yields. The control treatment produced the highest grain yield for BRRI dhan29 (7.07 and 7.46 t ha^{-1} in 2009–10 and 2010–11). Grain yields were lower for both the lowest and highest seeding rates in both the seasons. BRRI dhan29 produced higher grain yield by 21 and 20% in 2009–10 and 2010–11 than the BRRI dhan28. There was an interaction between variety and seeding rates and the highest grain yield was obtained from BRRI dhan29 sown at 25 cm × 15 cm spacing (7.07 t ha^{-1} and 7.46 t ha^{-1} in 2009–10 and 2010–11). The straw yield was higher for the highest seeding rate and the lower for the lowest seeding rate. The control (spaced planted crop) produced straw yield similar to those plots received seed rates of 50 and 60 kg ha^{-1}. Between the two varieties, BRRI dhan29 produced higher straw yield than the BRRI dhan28. The interaction between

Table 1. Plant height, tiller density, number of effective tillers hill^{-1} of two rice varieties under different seeding rates in dry direct seeded system

Varieties (V)	Seeding rate (kg ha^{-1})	Plant height (cm)		Tiller density (no. m^{-2})		Effective tillers (no. m^{-2})	
		2009–10	2010–11	2009–10	2010–11	2009–10	2010–11
BRRI dhan28	Control	106.5	108.11a	249.67e	253.33e	226.00e	230.00e
	30	100.77	102.38b	185.00h	188.66h	157.33h	161.33h
	40	100.63	102.25b	221.00f	224.66f	186.67g	190.66g
	50	105.23	106.85ab	249.67e	253.33e	217.33ef	221.33ef
	60	104.53	106.15ab	281.00d	284.66d	238.67d	242.66d
	70	99.67	101.28bc	313.00c	316.66c	260.33c	264.33c
BRRI dhan29	Control	98.37	99.98c	276.33d	280.00d	253.00c	257.00c
	30	98.63	100.25c	205.33g	209.00g	178.00g	182.00g
	40	100.23	101.85bc	256.67e	260.33e	215.00f	219.00f
	50	97.13	98.75c	317.33bc	321.00bc	273.33b	277.33b
	60	97.53	99.15c	328.67b	332.33b	282.33b	286.33b
	70	98.6	100.21c	349.33a	353.00a	297.00a	301.00a
SEM (±)		3.205	2.438	8.908	6.287	10.099	4.857
Variety (V)		**	**	**	**	**	**
Seeding rate (SR)		ns	ns	**	**	**	**
V × SR		ns	*	**	**	**	**
CV%		3.9	2.92	4.05	2.82	5.33	2.52

Table 2. Panicle length, filled grains and unfilled spikelets of two rice varieties under different seeding rates in dry direct seeded systems

Varieties	Seeding rate (kg ha^{-1})	Panicle length (cm)		No. of filled grains panicle^{-1}		No. of unfilled spikelets panicle^{-1}	
		2009–10	2010–11	2009–10	2010–11	2009–10	2010–11
BRRI dhan28	Control	24.27d	24.71d	111.50ef	113.67de	9.40f	10.33h
	30	26.13ab	26.58ab	117.87cd	119.67c	13.07e	14.00g
	40	25.37bc	25.81bc	107.77f	109.67e	16.40cd	17.33ef
	50	25.00cd	25.45cd	109.10f	111.00e	17.20c	18.33e
	60	23.40e	23.85e	89.90h	91.66g	21.13b	22.33cd
	70	22.17f	22.61f	80.67i	82.66h	24.60a	25.66a
BRRI dhan29	Control	25.77abc	26.21abc	125.37b	127.33b	14.43de	15.66fg
	30	26.48a	26.93a	134.20a	136.00a	14.97cde	16.00fg
	40	25.70abc	26.15abc	121.73bc	123.67b	19.60b	20.66d
	50	25.20c	25.65c	115.13de	117.00cd	21.63b	23.00bc
	60	22.77ef	23.21ef	101.50g	103.33f	21.40b	22.33cd
	70	22.30f	22.75f	91.37h	93.66g	24.10a	25.00ab
SEM (±)		0.421	0.389	3.217	1.854	0.927	0.727
Variety (V)		**	*	**	**	**	**
Seeding rate (SR)		**	**	**	**	**	**
V × SR		**	*	**	*	*	**
CV%		2.1	1.91	3.62	2.05	6.25	6.45

In a column, with same letter(s) or without letter(s) do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) at 5% level of probability; ns = Not significant, * = Significant at 5% level of probability, ** = Significant at 1% level of probability; Control: sowing of seeds at 25 cm × 15 cm spacing allocating 5 seeds hill^{-1}

Table 3. Effect of seeding rate, varieties and their interactions on 1000-grain weight, grain and straw yield of boro rice under dry direct seeded systems of cultivation

Varieties	Seeding rate (kg ha^{-1})	1000-grain wt. (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
		2009–10	2010–11	2009–10	2010–11	2009–10	2010–11
BRRI dhan28	Control	23.17b	23.30b	5.83c	6.23c	6.73c	7.18c
	30	23.99a	24.12a	4.43g	4.83e	5.17f	5.61f
	40	23.41b	23.54b	4.60fg	5.00e	5.57e	6.01e
	50	23.20b	23.34b	5.50de	5.90cd	6.60c	7.05c
	60	22.46c	22.59c	4.73f	5.13e	6.67c	7.11c
	70	22.07d	22.20d	4.47fg	4.86e	6.87c	7.31c
BRRI dhan29	Control	22.33c	22.47c	7.07a	7.46a	8.13b	8.58b
	30	22.40c	22.54c	5.33e	5.73d	6.20d	6.65d
	40	21.90d	22.04d	5.70cd	6.10c	6.83c	7.28c
	50	21.37e	21.51e	6.73b	7.13b	8.10b	8.55b
	60	20.04f	20.18f	5.70cd	6.10c	8.33b	8.78b
	70	19.72g	19.86g	5.30e	5.70d	8.67a	9.11a
SEM (±)		0.184	0.105	0.183	0.154	0.271	0.143
Variety (V)		**	**	**	**	**	**
Seeding rate (SR)		**	**	**	**	**	**
V × SR		**	**	*	*	**	*
CV%		1.02	0.67	4.12	3.23	4.75	2.36

In a column, with same letter(s) or without letter(s) do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) at 5% level of probability;
ns = Not significant, * = Significant at 5% level of probability, ** = Significant at 1% level of probability;
Control: sowing of seeds at 25 cm × 15 cm spacing allocating 5 seeds hill^{-1}

variety and seeding rate showed that BRRI dhan29 produced the highest straw yield when planted at the highest seeding rate of 70 kg ha^{-1}.

4 Discussion

Rice seed is sown by hand at 25 cm × 15 cm spacing in dry seeding system. Hand sowing is very tedious and labour intensive. On the other hand, seeding by machine could be a labour saving practice. The present study compares the performance of continuous line sowing at different seed rates with recommended spacing of 25 cm × 15 cm towards optimizing the seeding rate in boro season for machine sowing. The result showed that both the rice varieties (BRRI dhan28 and BRRI dhan29) produced the highest grain yield for sowing at 25 cm × 15 cm spacing (control). Sultana et al. (2012) reported that BRRI dhan45 gave the best yield at 25 cm × 15 cm spacing with four seeds per hill in dry seeded system in boro season. The present study confirms that 25 cm × 15 cm spacing is the best for dry direct seeding in boro season.

Dry direct seeding can be done by line sowing at 20 or 25 cm distance using continuous seeding or by spaced seeding with machine such as PTOS or VMP (Ahmed et al., 2015). The yield of BRRI dhan28 and BRRI dhan29 were 5.83 and 7.07 t ha^{-1} in spaced planted crop (25 cm × 15 cm) while none of the continuous seeding treatment attained the similar yield in both the seasons (Table 3). The highest grain yield with 25 cm × 15 cm spacing might be due to the longest panicle, highest filled grain panicle^{-1}, lower unfilled spikelet panicle^{-1} and the highest 1000-grain weight. The yield differences in different seeding rates could mostly be due to the variation in solar radiation interception.

Grain yield of rice differs significantly due to variable seed rates (Rangit et al., 2013). In a trial in Bangladesh, Ahmed et al. (2015) reported that the BRRI dhan49 gave the highest yield at a seed rate of 40 kg ha^{-1} in a seed rate trial from 20 to 100 kg ha^{-1}. Walia et al. (2011) found that the seed rate of 30 kg ha^{-1} recorded the highest grain yield which was significantly higher to plant density of 20 kg ha^{-1} and statistically at par with seeding rates of 40 and 50 kg ha^{-1}. In eastern IGP of India, Singh and Kumar (2009) reported that seed rate of 20–25 kg ha^{-1} was optimum for medium fine grain cultivars in dry seeded condition. They found that higher seed rate caused nitrogen deficiency, increased proportion of ineffective tillers, more lodging problems and attack of brown plant hoppers.

Yield of rice has a very strong positive correlation with total number of tillers and numbers of effective tillers (Ameen et al., 2014). The present study showed that the seeding rate of 70 kg ha^{-1} produced the highest total and effective tillers m^{-2} while 30 kg ha^{-1} (continuous seeding at 25 cm apart rows) produced the lowest total and effective tillers m^{-2} in both the cropping years. Ameen et al. (2014) found the maximum numbers of tillers (389) at the seeding density of 75 kg ha^{-1} and the minimum (245) for 30 kg ha^{-1}. Kehinde (2002) reported that seed rate of 150 kg ha^{-1} produced 577 tillers m^{-2} and it was at par with 125 kg ha^{-1} and these were significantly higher than the seeding rate of 100 kg ha^{-1}. Rice cultivars sown at high seeding rate ultimately resulted in higher number of tillers per unit area. These results are consistent with the Chauhan et al. (2011) who mentioned that increased seed rate caused an increase in number of tillers.

The highest number of sterile spikelets $panicle^{-1}$ was obtained from the combination BRRI dhan28 and 70 kg seed ha^{-1} (continuous seeding at 25 cm apart rows) and the lowest number of sterile spikelets $panicle^{-1}$ was observed from the combination BRRI dhan28 at 30 kg seed ha^{-1} (25 cm $\times$ 15 cm spacing with 4 seeds $hill^{-1}$) in both the years. Higher percentage of sterile spikelets at the higher seeding rate was attributed to dense population which exerted severe competition for photosynthates at reproductive stage and resulted in high sterility of spikelets particularly at lower part of panicle. The findings of the present study are in line with Akbar and Ehsanullah (2004) who reported that percentage of sterile spikelets increased by increasing the seeding density.

5 Conclusions

The highest yield of rice under dry direct seeding system was obtained at 25 cm $\times$ 15 cm spacing using five seeds $hill^{-1}$ for manual seeding. The next highest yield was obtained from line sowing at 25 cm apart rows with 50 kg ha^{-1} which yield was 5% lower than the spaced planting. Therefore, considering both the yield and labour cost, dry direct seeded rice would be practiced with continuous seeding at 25 cm apart rows using 50 kg seed ha^{-1}.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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