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Full Length Article

Improving the Performance of Direct Seeded System of Rice Intensification by Seed Priming

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Abstract

Water-wise crop production is gaining enormous attention due to looming water crises world. System of rice intensification (SRI) is a promising method for water-saving rice cultivation; however, it is more labor-intensive than the traditional method of rice production. Direct seeding (DSR) in SRI may be evaluated for potential benefits of both DSR and SRI. This study was conducted to evaluate the potential of rice seed priming in improving the performance of direct seeded SRI. Rice was direct seeded using primed seeds. For priming, seeds, of two rice cultivars Super Basmati and Shaheen Basmati, were overnight soaked in water (on-farm priming), soaked in aerated solution of $CaCl_2$ (osmopriming) or water (hydropriming) for 48 h. Direct seeding with dry seeds and conventional transplanting were taken as controls. Seed priming improved the seedling emergence, plant height, tillering, kernel weight and the paddy yield in DSR in both tested cultivars. However, paddy yield was higher from conventionally transplanting rice. Nonetheless, DSR in SRI using primed seeds had high benefit cost ratio than conventional transplanting or direct seeding using dry seeds. In conclusion, seed priming techniques may be employed to improve the performance of direct seeded SRI. © 2013 Friends Science Publishers

Keywords: Direct seeding; Fine rice; Seed priming, SRI; Yield

Introduction

Increasing food demand and declining water resources are becoming big challenges for food security (Kreye *et al*., 2009). With decreasing water availability, rice (*Oryza sativa* L.) cultivation may be switched towards water saving production systems. Traditionally rice is cultivated in standing water and thus requires huge inputs of irrigation water and extensive labor as well. System of rice intensification (SRI) is recently introduced water saving rice production system (Uphoff, 2002). Several reports indicate substantial yield increase in this system of rice production with significant decrease in water input (Uphoff, 2002, 2007). However, SRI requires more labor during transplanting in muddy fields (Moser and Barrett, 2003). High weed infestation in SRI, causing yield losses 30–100% is another challenge causing (Dobermann and Fairhurst, 2000).

Direct seeding of rice is an attractive alternative of the traditional transplanting system and SRI, which saves water and labor requirement (Pandey and Velasco, 2002; Farooq *et al*., 2011). Direct seeding in SRI seems a better option to harvest the benefits of both systems. However, stand establishment may be an issue in direct seeded rice in SRI.

We have optimized and developed several seed priming techniques to improve the performance of direct seeded (Farooq *et al*., 2006a–c) and transplanted rice (Farooq *et al*., 2007, 2010). However, potential of seed priming treatments in improving the performance of direct seeded rice in SRI has not been evaluated. This study was, therefore, conducted to evaluate the potential of seed priming in improving the performance of direct seeding in SRI.

Materials and Methods

General Experiment Detail

The study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (31°26' N, 73°06' E), during summer 2009. Two widely grown fine rice cultivars Super basmati and Shaheen basmati were obtained from Rice Research Institute, Kala Shah Kaku, Pakistan and Soil Salinity Research Institute, Pindi Bhatian, Hafizabad, Pakistan, respectively. Experimental soil was sandy loam with 0.8% organic matter; 0.043% N; 1.00 mg P kg^{-1}; 189 mg K kg^{-1}; 1.61 mg Zn kg^{-1} and 4.40 mg Fe kg^{-1}.

In conventional transplanting method, 30 days old nursery seedlings were transplanted manually using two seedlings per hill at 22.5 cm × 22.5 cm spacing, while in direct seeding, primed or untreated seeds were directly sown in 30 cm × 30 cm spaced in muddy seedbed following SRI

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principles. The experiment was laid out in split plot design, keeping rice production system in main and seed priming treatments in sub-plots, with three replicates.

Seed Priming Treatments

For seed priming, 500 g healthy seeds were soaked in aerated solution of $CaCl_2$ (ψ_s -1.25 MPa; osmopriming) or water (hydropriming) keeping seed to solution ratio of 1:5 (g mL^{-1}) for 48 h, seeds were rinsed thoroughly and were then re-dried near to original weight. For on-farm seed priming, rice seeds were soaked in water overnight and were surface dried before sowing.

Crop Husbandry

The experimental field was prepared by one deep ploughing followed by two cultivations and planking. The nursery of both cultivars was sown on 9^{th} July, 2009 while direct seeding was also done on the same date. Fertilizer NPK (150-90-75 kg ha^{-1}) was applied in the form of urea (46% N), di-ammonium phosphate (46% P_2O_5, 18% N) and potassium sulfate (50% K_2O) in both direct seeded and transplanted plots. Whole of P and K, and half of N was applied at the time of field preparation; while the second half of N was applied in two splits each at 40 and 68 days after seeding/transplanting. Zinc sulfate (35% Zn) was applied at the rate of 12 kg ha^{-1} 15 days after seeding/transplanting.

In transplanted rice, irrigation water was kept 7–10 cm at the time of transplanting and after a week it was maintained 5–6 inches to keep the field continuously flooded. While in SRI, the field was kept moist and muddy throughout the season. Irrigation was withheld about 2 weeks before harvesting when the signs of physiological maturity appeared. Weeds were controlled manually. All other agronomic practices were kept normal and uniform for all the treatments. Shaheen basmati and Super basmati were harvested on October 11 and November 05, 2010, respectively at harvest maturity.

Observations

Number of emerged seedlings was counted daily and data were used to calculate mean emergence time (MET) following Ellis and Roberts (1981), time 50% emergence (E_{50}) following Farooq *et al.* (2005). Number of seeds emerged was counted daily from three different places of an area of 100 cm × 100 cm in each treatment to calculate the average number of germinated seeds per unit area (m^2).

Days from emergence to heading by visual observation when 50% heading was complete, whereas days taken for 50% plants to reach maturity were considered as days from heading to maturity. Plant height was measured from base to flag leaf tip with the help of a meter rod. Panicle-bearing tillers were counted from a unit area (1 m × 1 m) at maturity. Panicle length (cm) was measured from base of the panicle to its tip with the help of a measuring rod. Ten panicles of primary tillers were randomly selected from each plot at harvest and saved in paper bags. Kernels were separated and counted, weight of 1000 kernels was recorded with an electric balance. After harvesting and threshing, the clean paddy was air-dried and weighed to record the grain yield.

Economic Analysis

Benefit-cost analysis was conducted to estimate the economic feasibility of experimental treatments. Net income was calculated by subtracting total expenditure from the gross income while benefit-cost ratio (BCR) was computed by dividing the gross income with total expenditure.

Statistical Analysis

The data obtained were statistically analyzed using MSTAT-C computer software and treatment means were compared by least significant difference (LSD) test at 5% probability level (Steel *et al*., 1997). Microsoft Excel was used for correlation coefficients and graphical presentation of the data.

Results

Seed priming significantly decreased the mean emergence time (MET) and time to 50% emergence (E_{50}) and increased the final emergence count (Table 1). However, there was no difference amongst the seed priming treatments for MET; whereas minimum E_{50} was noted from on-farm priming followed by osmopriming (Table 1). Maximum emergence count was noted from osmopriming (Table 1). Cultivar Super basmati had low MET and E_{50} and more emergence than cultivar Shaheen basmati (Table 1).

Direct seeded rice took less time for heading and maturity than the transplanted rice (Table 2). Osmopriming significantly decreased the time for heading in both rice cultivars. Likewise, osmopriming also reduced the time from heading to maturity; however, this was followed by hydropriming (Table 2). Although, direct seeding in SRI decreased the plant height than the transplanting, seed priming significantly increased the plant height in direct seeding with SRI with maximum value recorded from hydropriming in Super Basmati and osmopriming in Shaheen Basmati (Table 2). Similarly, maximum panicle bearing tillers were noted in transplanted rice; however, seed priming significantly increased the panicle bearing tillers in directed seed rice with maximum number from osmopriming in both tested cultivars (Table 2). Cultivar Super Basmati took more time for heading and maturity and had more plant height and panicle bearing tillers than cultivar Shaheen Basmati (Table 2).

Transplanted rice had more panicle length, kernels per panicle, kernel weight and kernel yield than direct seeded rice in SRI (Table 3). However, seed priming significantly

Table 1: Effect of seed priming on seedling emergence of direct seeded fine rice in SRI

Seed priming	Mean emergence time (days)			Time to 50% emergence (days)			Emergence count (m^{-2})		
	Super	Shaheen	Mean	Super	Shaheen	Mean	Super	Shaheen	Mean
Dry seeds	6.19	7.18	6.68A	5.58	6.83	6.21A	58.00cd	54.00d	56.00C
Osmopriming	5.19	6.13	5.66B	4.81	5.76	5.28BC	75.00a	60.00c	67.50A
Hydropriming	5.25	6.17	5.71B	4.88	5.85	5.36B	69.33b	56.67cd	63.00B
On-farm priming	5.27	6.15	5.71B	4.31	5.81	5.06C	69.00b	54.00d	61.50B
Mean	5.47B	6.41A		4.89B	6.06A		67.83A	56.17B	

Table 2: Effect of seed priming on phonology, plant height and panicle bearing tillers of direct seeded fine rice in SRI

Seed priming	Days to heading			Days from heading to maturity			Plant height (cm)			Panicle bearing tillers (m^{-2})		
	Super	Shaheen	Mean	Super	Shaheen	Mean	Super	Shaheen	Mean	Super	Shaheen	Mean
Transplanting	90.67a	80.00def	85.33A	39.33	34.33	36.83A	101.60a	96.37c	98.97A	354.00a	357.00a	355.50A
Dry seeds	82.33b	79.67ef	81.00B	37.67	34.67	36.17AB	81.96f	78.70g	80.33E	189.67g	168.33h	179.00C
Osmopriming	78.67fg	77.67g	78.17C	35.00	30.67	32.83C	98.07bc	97.13c	97.60B	340.67b	259.00d	299.80B
Hydropriming	81.33bcd	80.33cde	80.83B	35.67	31.00	33.33C	98.97b	93.60d	96.28C	332.67bc	246.33e	289.50B
On-farm priming	81.67bc	80.67cde	81.17B	36.33	32.33	34.33BC	96.76 c	90.90e	93.83D	326.00c	230.33f	278.20B
Mean	82.93A	79.67B		36.80A	32.60B		95.46A	91.34B		308.60A	252.20B	

Table 3: Effect of seed priming on kernel yield and related traits of direct seeded fine rice in SRI

Seed priming	Panicle length (cm)			Kernels per panicle			1000-kernel weight (g)			Kernel yield (t ha^{-1})		
	Super	Shaheen	Mean	Super	Shaheen	Mean	Super	Shaheen	Mean	Super	Shaheen	Mean
Transplanting	27.07a	26.80a	26.93A	81.50	81.27	81.38A	18.84	17.82	18.33A	2.83a	2.85a	2.84A
Dry seeds	18.87d	16.33e	17.60D	75.07	73.30	74.18C	14.67	14.47	14.57D	1.71g	1.57h	1.64D
Osmopriming	25.80ab	22.47c	24.13B	79.43	78.83	79.13B	16.64	16.03	16.34B	2.62b	2.18d	2.40B
Hydropriming	25.00b	21.37c	23.18B	79.50	77.20	78.35B	15.27	15.70	15.48C	2.44c	2.02e	2.23C
On-farm priming	24.43b	19.63d	22.03C	78.17	78.57	78.37B	15.90	15.57	15.73BC	2.45c	1.98f	2.21C
Mean	24.23A	21.32B		78.73	77.83		16.26A	15.92B		2.40A	2.11B	

Means sharing a letter in common do not differ significantly (p 0.05); SRI = System of rice intensification; Super = Super basmati; Shaheen = Shaheen basmati

Table 4: Economic analysis showing the effect of seed priming treatments

Seed priming	Kernel yield	Straw weight	Gross income	Variable cost	Fixed cost	Total expenditure	Net return	BCR
	t ha^{-1}		Rs. ha^{-1}					
Transplanting	2.84	9.55	91 885	8520	33 120	41 640	50245	2.21
Dry seeds	1.64	7.54	54 478	4920	25 390	30 310	24268	1.80
Osmopriming	2.40	10.93	79 651	8600	25 390	33 990	45 661	2.34
Hydropriming	2.23	9.95	73 865	6690	25 390	32 080	41 785	2.30
On-farm priming	2.21	9.56	72 092	6540	25 390	31 930	40 162	2.26

Market price of paddy = Rs. 30000 t^{-1}; Market price of paddy straw = Rs. 700 t^{-1}; BCR = Benefit – cost ratio

improved these traits in direct seeded rice with SRI, osmopriming was the best treatment in this regard with maximum panicle length, kernels per panicle, kernel weight and kernel yield (Table 3). Cultivar Super Basmati had more panicle length, 1000 kernel weight and kernel weight than cultivar Shaheen Basmati (Table 3).

Maximum net return was obtained from transplanted rice followed by osmopriming in direct seeded rice with SRI; however, minimum net return was harvested from untreated seeds in direct seeded rice with SRI (Table 4). While considering the BCR value, the highest BCR (2.34) was recorded from direct seeding in SRI with osmopriming and hydropriming (Table 4).

Discussion

The study has shown the possibility to improve the seedling establishment in direct seeded rice with SRI by employing different seed priming treatments. Seed priming significantly improved the seedling emergence and stand establishment. However, osmopriming was the most effective treatment in this regard (Table 1). As the food reserves are in readily available form in primed seeds (Farooq *et al*., 2006a,b), germination process is completed quickly in a short time resulting in more uniform and synchronized crop stand (Farooq *et al*., 2006a–c). This early and unformed stand establishment enables the crop to complete other phonological events in the crop ontogeny earlier than non-primed seeds (Table 2). Better and earlier seedling emergence resulted in more plant height and panicle bearing tillers (Table 2).

Seed priming also improved the panicle length; kernels per panicle, kernel weight and kernel yield (Table 3). Better and earlier stand establishment, from seed priming, enabled the plants to grow profusely and exploit the water and nutrient input in a better way, which caused longer panicle, more kernels in a panicle and higher kernel weight. Improvement in all these yield contributing traits resulted in better grain yield than harvested from direct seeding of dry seeds in SRI (Table 3). However, osmopriming (with $CaCl_2$) was the best treatment followed by hydropriming and on-farm priming (Tables 1–3). Osmotic advantage of Ca^{2+}, its role in signaling and activities of numerous enzymes (Taiz and Zeiger, 2010), most of which are active during reserve mobilization and radical protrusion (Farooq *et al.*, 2006c, 2010), are some of the reasons explaining better performance of osmopriming (with $CaCl_2$). Moreover, GA_3 *de novo* synthesis in the scutellum, release of hydrolases in the aleuronic layer, and its transport to the endosperm are also regulated by Ca^{2+} (Srivastava, 2002).

The effectiveness of any production system is ultimately evaluated on the basis of its economics and benefit:cost ratio (BCR). Although, maximum grain yield and net return were recorded from conventionally transplanted rice, seed priming improved the BCR in DSR with SRI (Table 4). Maximum BCR recorded from osmopriming seems the results of better grain yield with small additional cost incurred during priming. This indicates the practicability of employing seed priming for direct seeded rice with SRI. Thus, osmopriming may be employed to improve the performance of direct seeded rice with system of rice intensification.

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