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Research Article

Seed Priming Influence on High Temperature Tolerance and Weed Suppressive Ability of Late Sown Dry Direct Seeded Winter Rice

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Abstract

Seed priming is a pre-sowing hydration technique which leads to a physiological condition triggering germination and enhancing uniform seedling emergence. It is a promising tool for enhancing drought tolerance in plants which is essential for promoting economic development by coping up with the adverse effects of climate change on crop productivity. So, a better understanding of seed priming efficacy is required. Therefore, an experiment was conducted with a view to investigating the effect of seed priming agent on the weed growth and yield performance of high yielding rice variety BRRI dhan29 sown on different dates following dry direct seeded condition in *boro* season. Two sowing dates *viz*., 20th January (early or optimum sowing as control) and 20th February (late sowing as high temperature stress during reproductive stage) and seed priming agents included NaCl (20000 and 30000 ppm), KCl (20000 and 30000 ppm), $CaCl_2$ (20000 and 30000 ppm), $CuSO_4$ (50 and 75 ppm), $ZnSO_4$ (10000 and 15000 ppm), Na_2MoO_4 (2 and 3 ppm) and PEG (100 and 150 ppm) were used. Plant height and tillers of BRRI dhan29 were significantly enhanced when seeds were sown early (20th January) and due to seed priming at early stage and at harvest. Among the yield parameters grains panicle^{-1}, grain yield, and straw yield were produced more by early sowing (20th January). Grains panicle^{-1}, 1000-grain weight, and grain yield were positively influenced due to seed priming. Considering the growth and yield parameters and yield of rice, early sowing and seed priming with KCl or $CaCl_2$ were found as the best. Seed priming produced no significant effect on the weed growth. There was no significant effect of interaction between sowing date and priming agent on crop characters and yield parameters. Therefore, seed priming with 20000 ppm KCl or 20000 ppm $CaCl_2$ and early sowing is recommended for increasing the yield of dry direct seeded *boro* rice (BRRI dhan29). If somehow early sowing is not possible, seed priming with 20000 ppm KCl or 20000 ppm $CaCl_2$ is highly recommended or mitigating temperature stress during reproductive stage and enhancing yield of BRRI dhan29 under dry direct seeded, late sown condition.

Introduction

Rice (*Oryza sativa* L.), the staple food for more than half of the world's population, is grown in more than 100 countries across the globe (Fukagawa et al., 2019). According to the UN (2013), the world population is expected to reach 9.6 billion by 2050. As a result, in order to fulfil the fast-rising global population's food demands, worldwide grain output must be boosted by 70% by 2050 (FAO, 2013). Therefore, attempt should be made to increase the yield per unit area in Bangladesh.

In Bangladesh, rice is cultivated in three distinct seasons: *aus, aman,* and *boro.* Among the growing seasons, the *boro* season has the largest rice production, thus farmers are keen to cultivate *boro* rice. *Boro* rice accounts for around 56% of overall rice output in Bangladesh and is critical to the country's food security (Rahman et al., 2015). *Boro* rice is mostly grown through puddled transplantation, which requires constant water and depends on irrigation. However, water is becoming limited as a result of global climate change and competition from other sectors. Therefore, growing *boro* rice following puddled-transplanted system has been a huge challenge (Anwar et al., 2010).

In this context, dry direct seeded *boro* rice is considered to be a potential water-wise innovation which needs 50% less water compared to puddled transplanted system. The process of establishing the crop from seeds

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sown in the field rather than transplanting seedlings from a nursery is referred to as direct seeding of rice (Farooq et al., 2011). Direct seeding eliminates three essential operations: puddling (compacting soil to prevent water seepage), transplanting, and maintaining standing water. However, dry direct seeded rice is highly vulnerable to weeds because of lack of "head start" over weeds and standing water layer to suppress weeds. The risks of chemical control and the huge cost involvement in mechanical control demand an eco-friendly and cost-effective weed management (Rahman et al., 2017). Dry direct seeded rice cultivation has another problem with temperature. In our country, sometimes temperature remains below 20 °C during *boro* season. Therefore, very cold spell may induce seed germination failure if seeds are sown early (Biswas et al., 2011) reported that the optimum temperature range for rice seed germination is 20–35 °C and the International Seed Testing Association recommends 20 °C as the standard temperature for statutory germination tests (ISTA, 1999). The rice appeared to be the most sensitive to high temperatures at flowering. Therefore, if seeds are sown in late, terminal high temperatures during anthesis will be induced high percentage of spikelet sterility, which was attributed to disturbed pollen shedding and impaired pollen germination. Basak et al. (2013) reported that higher temperature reduced the yields in almost all locations in Bangladesh. The production of *boro* rice decreases 6% and 16% for temperature increases of 2 °C and 4 °C, respectively. In those cases, seed priming synchronized with sowing date may be a great solution.

Seed priming is a method of adding moisture to seeds, allowing them to be partially hydrated without radicle emergence (Farooq et al., 2007). It is an effective pre-germination physiological method that improves seed performance and results in faster and more synchronized seed germination (Matsushima and Sakagami, 2013) by exposing the seed to a stress situation prior to germination, allowing the plant to better withstand future stress imposition (Yadav et al., 2011; Anwar et al., 2021b). Different types of priming techniques include hydro-priming (soaking the seed in water), halo-priming (soaking the seed in inorganic salt solutions), osmo-priming (soaking the seed in organic osmotic solution), thermo-priming (treating the seed at low or high temperatures depending on species), solid matrix priming (treating the seed with solid matrices), and bio-priming (treating the seed with biological compounds) (Ashraf and Foolad, 2005).

Beneficial effects of seed priming include increased germination rate, synchronized germination and faster emergence of seedlings (Farooq et al., 2007; Anwar et al., 2012, 2021; Mim et al., 2021). The traits closely associated with weed competitiveness of rice include early height growth rate, early crop biomass (Ni et al., 2000) and early vigour (Zhao et al., 2006), which can be obtained through higher and faster germination of primed seeds. As a result, seed priming is thought to play an important role in weed control (Anwar et al., 2020).

Although seed priming techniques have been found to be effective for improved germination and seedling establishment in rice under controlled conditions (Basra et al., 2005, Farooq et al., 2006a), and although some success in improving the performance of direct-seeded rice has been reported (Du and Tuong, 2002), no comprehensive study has yet been conducted to evaluate the response to a wide range of seed invigorators. Furthermore, on-farm evaluation of these priming approaches has received little attention. With all these in mind, an experiment was carried out to examine the performance of different seed priming techniques in terms of growth, temperature stress tolerance and yield performance of dry direct seeded *boro* rice and to evaluate the seed priming as a tool for weed suppression in dry direct seeded *boro* rice.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory and Agro Innovation Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from January to June 2019 with a view to investigating the effect of seed priming agent on the weed suppressive ability and heat stress tolerance of BRRI dhan29 rice sown on different dates following dry direct seeded condition in *boro* season. The experimental area was situated at 23° 77' N latitude and 90° 33' E longitude at an altitude of 18.6 meter above sea level. The experimental site belongs to the Sonatala series of non-calcareous dark grey flood plain soil under the AEZ-9 (Old Brahmaputra Floodplain). The soil was silty loam, slightly acidic in nature and moderately fertile. The experimental area was located under the subtropical climate, which is specialized by moderately high temperature and heavy rainfall during April to September and low rainfall with moderately low temperature during October to March. The monthly values of maximum, minimum and average temperature (°C), relative humidity (%), monthly total rainfall (mm) and sunshine (hour) received at the experimental site during the study period are presented in Table 1.

Table 1. Weather data of experimental site during the experimental period

Year	Month	Air temperature (°C)			Total rainfall (mm)	Average relative humidity (%)	Total sunshine (hrs)
		Maximum	Minimum	Average			
2019	January	26.2	12.1	19.2	0.0	75.39	272.2
	February	27.0	15.5	21.3	33.00	75.86	164.8
	March	30.3	21.1	26.1	58.6	73.03	208.2
	April	31.7	22.3	27.0	66.8	78.5	193.2
	May	33.7	23.8	28.8	3318	80.53	179.8

Two different sowing dates viz., 20th January (early or optimum sowing as control) and 20th February (late sowing as high temperature stress during reproductive stage) and fifteen seed priming agents including NaCl (20000 and 30000 ppm), KCl (20000 and 30000 ppm), $CaCl_2$ (20000 and 30000 ppm), $CuSO_4$ (50 and 75 ppm), $ZnSO_4$ (10000 and 15000 ppm), Na_2MoO_4 (2 and 3 ppm) and PEG (100 and 150 ppm) and control were used. The experiment was laid out in a split-plot design with three replications. Date of sowing was assigned at in the main plot and priming agent in the sub-plot. The size of the unit plot was 2.5 m x 2.0 m. At first, land was prepared by dry ploughing and then levelled. Rice field was fertilized with 200, 60, 100 and 70 kg ha^{-1} of urea, triple superphosphate (TSP), muriate of potash (MoP), and gypsum, respectively. The full doses of TSP, MoP and gypsum were applied before sowing. Urea was applied at three equal splits. The first split was applied at 20 days after sowing (DAS), the second one at 40 DAS and the third one at 60 DAS. Priming was done by soaking seeds of BRRI dhan29 in different priming agent solutions (prepared using distilled water) as per treatments for 24 h at room temperature, (25 ± 2 °C). The ratio of seed weight to solution volume was 1:5 (g ml^{-1}). Then, seeds were removed from the priming agent solution followed by washing several times with distilled water to remove the traces of chemicals. Then, seeds were dried back to the original moisture content by forced air. Dried seeds were put in polythene bags and stored in a refrigerator at 5 ± 1 °C until used. Sprouted primed seeds were sown in rows in the main field on 20 January and then 20 February following the spacing 25 cm × 15 cm. Intensive care was taken during the growing period for proper growth and development of the crop. Intercultural operations such as weeding, irrigations and drainage were done during crop cultivation. Water was maintained around field capacity throughout the growing season.

At the vegetative stage plant height, number of tillers $hill^{-1}$, weed density, weed dry weight, weed species composition were observed. A quadrate of size 0.5 m x 0.5 m were placed randomly in two places of each weedy plots for collecting weed samples. Weed were clipped at ground level, identified and counted by species, and separately oven dried at 70 °C to constant weight. Weed density (WD) and weed dry weight (WDW) were expressed as no. m^{-2} and g m^{-2}, respectively. Dominant weed species were identified using the summed dominance ratio (SDR) computed as follows:

SDR of a weed species

$$= \frac{\text{Relative density (RD)} + \text{Relative dry weight (RDW)}}{2}$$

Where,

$$\text{RD\%} = \frac{\text{Density of a given wee species}}{\text{Total weed density}} \times 100$$

$$\text{RDW\%} = \frac{\text{Dry weight of a given weed species}}{\text{Total weed dry weight}} \times 100$$

Relative contribution of different weed groups (broad-leaved, grasses and sedges) to the weed vegetation in terms of RD and RDW were also calculated.

At harvesting stage plant height, total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, grains $panicle^{-1}$, sterility %, 1000-grain weight, grain yield, straw yield and harvest index were recorded. The crops were harvested at different dates when 90% grains became golden yellow in color. All the collected data were analyzed following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Rage Test (DMRT).

Results

Growth characters of dry direct seeded boro rice

Effect of sowing date

Plant height and number of total tillers $hill^{-1}$ of BRRI dhan29 in dry direct seeded condition was affected significantly by sowing dates. The crop sown on 20th January produced the tallest plants (27.21, 50.95, 77.75 cm at 40, 60 DAS and at harvest respectively) than 20th February seeding (26.05, 49.02, 76.12 cm at 40, 60 DAS and at harvest respectively) (Table 2). It is obvious that the reduction in plant height was attributed to the reason that late planting had shorter growing period due to photoperiodic response. The 20th January seeding produced higher number of tillers (4.08, 8.34 and 10.50) at 40, 60 DAS and at harvest respectively than 20th February seeding (Table 2). Late sowing shortened the growth period of the plant which might reduce the number total tillers $hill^{-1}$ at harvest than early sowing.

Table 2. Effect of sowing date on plant height and number of total tillers hill^{-1} at different days after sowing of dry direct seeded *boro* rice cv. BRRI dhan29

Sowing date	Plant height (cm) at different days after sowing (DAS)			No. of total tillers hill^{-1} at different days after sowing (DAS)		
	40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest
20 January	27.21a	50.95 a	77.75 a	4.08 a	8.34 a	10.50 a
20 February	26.05 b	49.02 b	76.12 b	3.71 b	7.87 b	10.33 b
$S\bar{x}$	0.1027	0.0844	0.102	0.0236	0.0624	0.0236
Level of significance	**	**	**	**	*	*
CV (%)	2.59	1.13	0.90	4.06	5.16	1.52

* = Significant at 5% level of probability, ** = Significant at 1% level of probability

Effect of priming agent

Seed priming agent significantly affected plant height of BRRI dhan29 at 40 DAS and at harvest, but not at 60 days after sowing (DAS) (Table 3). Although seed priming with PEG resulted in apparently shorter plants compared to control at 60 DAS. At 40 DAS and at harvest, all the seed priming agents except PEG produced statistically higher plant height than control and they are statistically similar. But PEG resulted in statistically similar plant height to control (Table 3).

Table 3. Effect of priming agent on plant height and number of total tillers hill^{-1} at different days after sowing of dry direct seeded *boro* rice cv. BRRI dhan29

Priming agent	Plant height (cm) at different days after sowing (DAS)			No. of total tillers hill^{-1} at different days after sowing (DAS)		
	40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest
20000 ppm NaCl	26.15 abcd	48.20	76.42 a	3.82	7.433 c	10.52
30000 ppm NaCl	25.92 abcd	48.10	77.08 a	3.82	7.900 bc	10.32
20000 ppm KCl	28.42 abc	53.27	78.95 a	4.28	9.200 ab	11.18
30000 ppm KCl	28.22 abcd	54.53	79.38 a	4.55	8.700 abc	11.25
20000 ppm $CaCl_2$	28.92 ab	52.87	79.58 a	4.08	9.533 a	11.12
30000 ppm $CaCl_2$	29.08 a	53.67	81.12 a	4.62	9.767 a	11.35
50 ppm $CuSO_4$	25.95 abcd	50.47	76.98 a	3.72	7.933 bc	10.12
75 ppm $CuSO_4$	25.92 abcd	49.93	77.85 a	3.78	8.300 abc	10.08
10000 ppm $ZnSO_4$	25.75 bcd	49.27	77.92 a	4.22	7.833 bc	10.08
15000 ppm $ZnSO_4$	26.12 abcd	49.03	78.52 a	3.95	7.833 bc	10.28
2 ppm Na_2MoO_4	26.72 abcd	48.97	77.52 a	3.72	7.633 bc	10.15
3 ppm Na_2MoO_4	26.25 abcd	48.07	77.92 a	3.82	7.900 bc	9.95
100 ppm PEG	25.25 cd	47.63	71.25 b	3.22	7.100 c	9.85
150 ppm PEG	25.02 d	47.33	71.28 b	3.38	7.267 c	9.82
Control	25.78 bcd	48.53	72.28 b	3.45	7.200 c	10.12
$S\bar{x}$	0.9497	1.831	1.399	0.3622	0.5022	0.5996
Level of significance	*	NS	**	NS	**	NS
CV (%)	8.74	8.97	4.46	22.78	15.18	14.11

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Seed priming agent failed to produce any significant effect on total tillers production of BRRI dhan29 at 40 DAS and at harvest but significantly affected tillering ability of BRRI dhan29 at 60 DAS (Table 3). Like plant height, PEG priming resulted in numerically lower number of tillers hill^{-1} as compared to control at 40 DAS and at harvest. At 60 DAS, seed priming with 30000 ppm $CaCl_2$ produced the highest number of tillers hill^{-1} (9.767) which was significantly similar to those obtained from seed priming with NaCl (20000 and 30000 ppm), KCl (20000 and 30000 ppm) and $CaCl_2$ (20000 ppm). Other seed priming agents performed better than no priming (Table 3).

Interaction effect of sowing date and priming agent

The interaction between sowing date and priming agent had no significant effect on plant height and total tillers production of BRRI dhan29 and all sampling DATs (Table 4). However, the interaction 20 February × 30000 ppm $CaCl_2$ produced the tallest plant at 40 DAS (29.08 cm), 60 DAS (53.67 cm) and at harvest (81.12 cm). And the shortest plant was obtained from the interaction 20 January × 150 ppm PEG at 40 DAS (25.02 cm), 60 DAS (47.33 cm) and at harvest (71.28 cm) (Table 4).

Table 4. Interaction effect of sowing date and priming agent on plant height and number of total tillers $hill^{-1}$ at different days after sowing of dry direct seeded *boro* rice cv. BRRI dhan29

Interaction (Sowing date × priming agent)		Plant height (cm) at different days after sowing (DAS)			No. of total tillers $hill^{-1}$ at different days after sowing (DAS)		
		40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest
20 January	20000 ppm NaCl	25.57	47.23	75.60	3.63	7.20	10.60
	30000 ppm NaCl	25.33	47.13	76.27	3.63	7.67	10.40
	20000 ppm KCl	27.83	52.30	78.13	4.10	8.97	11.27
	30000 ppm KCl	27.63	53.57	78.57	4.37	8.47	11.33
	20000 ppm $CaCl_2$	28.33	51.90	78.77	3.90	9.30	11.20
	30000 ppm $CaCl_2$	28.50	52.70	80.30	4.43	9.53	11.43
	50 ppm $CuSO_4$	25.37	49.50	76.17	3.53	7.70	10.20
	75 ppm $CuSO_4$	25.33	48.97	77.03	3.60	8.07	10.17
	10000 ppm $ZnSO_4$	25.17	48.30	77.10	4.03	7.60	10.17
	15000 ppm $ZnSO_4$	25.53	48.07	77.70	3.77	7.60	10.37
	2 ppm Na_2MoO_4	26.13	48.00	76.70	3.53	7.40	10.23
	3 ppm Na_2MoO_4	25.67	47.10	77.10	3.63	7.67	10.03
	100 ppm PEG	24.67	46.67	70.43	3.03	6.87	9.93
	150 ppm PEG	24.43	46.37	70.47	3.20	7.03	9.90
	Control	25.20	47.57	71.47	3.27	6.97	10.20
20 February	20000 ppm NaCl	26.73	49.16	77.23	4.00	7.67	10.43
	30000 ppm NaCl	26.50	49.06	77.90	4.00	8.13	10.23
	20000 ppm KCl	29.00	54.23	79.77	4.47	9.43	11.10
	30000 ppm KCl	28.80	55.50	80.20	4.73	8.93	11.17
	20000 ppm $CaCl_2$	29.50	53.83	80.40	4.27	9.77	11.03
	30000 ppm $CaCl_2$	29.67	54.63	81.93	4.80	10.00	11.27
	50 ppm $CuSO_4$	26.53	51.43	77.80	3.90	8.17	10.03
	75 ppm $CuSO_4$	26.50	50.90	78.67	3.97	8.53	10.00
	10000 ppm $ZnSO_4$	26.33	50.23	78.73	4.40	8.07	10.00
	15000 ppm $ZnSO_4$	26.70	50.00	79.33	4.13	8.07	10.20
	2 ppm Na_2MoO_4	27.30	49.93	78.33	3.90	7.87	10.07
	3 ppm Na_2MoO_4	26.83	49.03	78.73	4.00	8.13	9.87
	100 ppm PEG	25.83	48.60	72.07	3.40	7.33	9.77
	150 ppm PEG	25.60	48.30	72.10	3.57	7.50	9.73
	Control	26.37	49.50	73.10	3.63	7.43	10.03
$S\bar{x}$		1.343	2.590	1.979	0.5122	0.7102	0.848
Level of significance		NS	NS	NS	N S	NS	NS
CV (%)		8.74	8.97	4.46	22.78	15.18	14.11

NS = Not significant

Yield parameters and yield of dry direct seeded boro rice

Effect of sowing date

Number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield and straw yield of BRRI dhan29 was significantly influenced by sowing dates but sowing date had no significant effect on number of non-effective tillers $hill^{-1}$, sterility percentage, 1000-grain weight and harvest index (Table 5). The sowing date 20th January produced higher number of effective tillers $hill^{-1}$ (9.35) than sowing date 20th February (8.35) (Table 5). Among yield components, effective tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers (effective tillers) $hill^{-1}$. This increase of effective tillers $hill^{-1}$ at 20th January sowing was attributed to favourable environmental conditions which enabled the plant to improve its growth and development as compared to other sowing date. The 20th January seeding produced higher number of grains (50.57) while lower number of grains $panicle^{-1}$ (47.27) was produced by 20th February seeding (Table 5**)**. Late sowing, shortened the growth period of the plant which reduced the leaf area, length of panicle and number of grains $panicle^{-1}$ than early sowing. In case of 1000-grain weight, 22.02 g weight was produced by 20th January seeding and 20th February seeding produced 19.82 g.

Grain yield is a function of interplay of various yield components such as number of grains per panicle, effective tillers and 1000-grain weight. The 20th January sowing produced higher grain yield (3.66 t ha^{-1}) while lower grain yield (3.41 t ha^{-1}) was observed in 20th February sowing (Table 5). The higher grain yield was attributed to a greater number of effective tillers, a greater number of grains per panicle and increased 1000-grain weight. 20th January sowing produced more straw yield (3.97 t ha^{-1}) than that of 20th February seeding (3.71 t ha^{-1}) (Table 5).

Table 5. Effect of sowing date on yield contributing characters and yield of dry direct seeded *boro* rice cv. BRRI dhan29

Sowing date	Effective tillers hill^{-1} (No.)	Non effective tillers hill^{-1} (No.)	Grains Panicle^{-1} (No.)	Sterility (%)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
20 January	9.35 b	1.15	50.57 a	35.91	20.02	3.66 a	3.97 a	47.91
20 February	8.95 a	1.38	47.27 b	37.54	19.82	3.41 b	3.71 b	47.84
$S\bar{x}$	0.0408	0.0624	0.199	0.2867	0.0408	0.014	0.0131	0.2396
Level of significance	*	NS	**	NS	NS	**	**	NS
CV (%)	2.99	33.11	2.73	5.24	1.37	2.68	2.33	3.36

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Effect of priming agent

Number of grains panicle^{-1}, sterility percentage, 1000-grain weight and grain yield were significantly affected by seed priming agent. However, seed priming agent had no significant effect on effective tillers hill^{-1}, non-effective tillers hill^{-1}, straw yield and harvest index (Table 6). Number of effective tillers hill^{-1} narrowly ranged from 8.63 to 10.07 among different seed priming treatments. Number of non-effective tillers hill^{-1} narrowly ranges from 1.38 to 1.15 among different seed priming treatments. The highest number of grains panicle^{-1} (51.98) was produced by 30000 ppm $CaCl_2$ while the lowest (46.58) by 100 ppm PEG which is statistically similar to control (Table 6). The highest number of grains panicle^{-1} might be attributed due to vigorous growth of rice plant and more competitive with weed in this treatment. Significantly, more sterility was observed in control treatment (40.22 %) whereas other priming agents produced statistically similar sterility percentage (Table 5). Lower sterility (33.95 %) in 20000 ppm $CaCl_2$ treatment was due to optimum growth, development and starch filling in the grains.

The highest 1000- grain weight (20.87 g) was found in KCl (30000 ppm) treatment which was statistically similar with KCl (20000 ppm), $CaCl_2$ (20000 and 30000 ppm), $CuSO_4$ (30000 ppm) and $ZnSO_4$ (20000 ppm) and lowest one (19.4 g) was found in PEG (100 ppm) which was statistically similar with Na_2MoO_4 (2 ppm) and control (Table 6). The highest grain yield (3.87 t ha^{-1}) was produced by KCl (30000 ppm) which was statistically similar with KCl (20000 ppm) and CaCl2 (20000 and 30000 ppm) while the grain yield obtained from all other priming agents were similar to that which obtained from control (Table 6). Thus, the advantage of seed priming with only KCl or $CaCl_2$ in increasing yield of BRRI dhan29 under dry direct seeded condition was evident. The highest grain yield from KCl or $CaCl_2$ was mainly due to the favourable effect of higher number of grains panicle^{-1} and other yield attributes.

Table 6. Effect of priming agent on yield contributing characters and yield of dry direct seeded *boro* rice cv. BRRI dhan29

Priming agent	Effective tillers hill^{-1} (No.)	Non effective tillers hill^{-1} (No.)	Grains Panicle^{-1} (No.)	Sterility (%)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
20000 ppm NaCl	9.17	1.35	49.02 cdef	36.38 abcd	19.70 bcd	3.45 bcd	3.80	47.66
30000 ppm NaCl	8.93	1.38	49.45 cde	35.98 abcd	19.60 cd	3.48 bcd	3.74	48.24
20000 ppm KCl	9.97	1.22	50.48 bc	34.78 cd	20.67 ab	3.85 a	4.14	48.21
30000 ppm KCl	10.00	1.25	50.18 bcd	34.65 cd	20.87 a	3.87 a	4.16	48.18
20000 ppm $CaCl_2$	9.87	1.25	51.55 ab	33.95 d	20.63 ab	3.74 ab	4.07	47.83
30000 ppm $CaCl_2$	10.07	1.28	51.98 a	34.85 bcd	20.53 abc	3.74 ab	4.06	47.96
50 ppm $CuSO_4$	8.80	1.32	48.45 efgh	36.92 abcd	19.67 bcd	3.45 bcd	3.78	47.83
75 ppm $CuSO_4$	8.83	1.25	47.72 fghi	36.72 abcd	19.93 abcd	3.51 bcd	3.83	47.88
10000 ppm $ZnSO_4$	8.90	1.18	47.45 ghi	37.05 abcd	20.03 abcd	3.52 bcd	3.79	47.93
15000 ppm $ZnSO_4$	9.00	1.28	48.78 defg	37.75 abcd	19.60 cd	3.53 bc	3.85	47.80
2 ppm Na_2MoO_4	8.87	1.28	49.42 cde	36.78 abcd	19.47 d	3.50 bcd	3.76	48.26
3 ppm Na_2MoO_4	8.77	1.18	49.15 cdef	37.15 abcd	19.73 bcd	3.48 bcd	3.84	47.61
100 ppm PEG	8.70	1.15	46.58 i	38.62 abc	19.40 d	3.31 cd	3.64	47.54
150 ppm	8.63	1.18	47.08 hi	39.08 ab	19.53 cd	3.33 cd	3.67	47.63
Control	8.73	1.38	46.52 i	40.22 a	19.40 d	3.22 d	3.55	47.56
$S\bar{x}$	0.5549	0.1331	0.480	1.263	0.3123	0.091	0.1825	0.4297
Level of significance	NS	NS	**	*	**	**	NS	NS
CV (%)	14.86	25.77	2.40	8.43	3.84	6.26	11.64	2.20

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Interaction effect of sowing date and priming agent

There was no significant effect of interaction between sowing date and priming agent on any yield contributing characters and yield (data not shown).

Weed composition of the experimental field

Twelve weed species belonging to six different families were identified in experimental field of BRRI dhan29, among which four were broadleaves, six grasses and two sedges. Based on summed dominance ratio (SDR), the five most dominant weed species observed were *Paspalum commersonii*, *Echinochloa crusgalli, Polygonum hydropiper, Cyperus rotundus* and *Echinochloa colonum*. Grassy weeds contributed 61.8% of the total weed density and 64.1% of total weed dry matter, while broadleaf weeds respectively contributed 20.2 and 20.8% and sedges contributed 17.7 and 15.1% (Table 7).

Table 7. Dominant weed species with family name, type, relative density (RD), relative dry weight (RDW) and summed dominance ratio (SDR) (averaged of all plots)

Local name	Scientific name	Family	Group	RD (%)	RDW (%)	SDR (%)
Gaicha	*Paspalum commersonii*	Poaceae	Grass	24.2	24.3	24.25
Shama	*Echinochloa crusgalli*	Poaceae	Grass	19.7	25.4	22.55
Biskatali	*Polygonum hydropiper*	Polygonaceae	Broad leaf	15.4	15.7	15.55
Mutha	*Cyperus rotundus*	Cyperaceae	Sedge	11.7	8.8	10.25
Khude shama	*Echinochloa colonum*	Poaceae	Grass	9.5	7.4	8.45
Baro chocha	*Cyperus iria*	Cyperaceae	Sedge	6.3	6.3	6.3
Anguli ghas	*Digitaria sanguinalis*	Poaceae	Grass	4.2	3.5	3.85
Angta	*Panicum distichum*	Poaceae	Grass	3.1	2.9	3.0
Foska begun	*Physalis minima*	Solanaceae	Broad leaf	2.8	3.2	3.0
Bathua	*Chenopodium album*	Chenopodiaceae	Broadleaf	1.6	1.2	1.4
Durba	*Cynodon dactylon*	Poaceae	Grass	1.1	0.6	0.85
Keshuti	*Eclipta alba*	Compositae	Broadleaf	0.4	0.7	0.55

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Weed density and dry matter

Sowing date had significant effect on weed density and weed dry matter in dry direct seeded BRRI dhan29. More weed density and weed dry matter were found from early sowing 20th January compared to late sowing (Table 8). No significant effect of rice seed priming on weed density and weed dry matter was found (data not shown). Interaction effect of sowing date and priming agent failed to influence on weed density and weed dry matter content (data not shown).

Table 8. Effect of sowing date on weed density and weed dry matter at different days after sowing of dry direct seeded *boro* rice cv. BRRI dhan29

Sowing date	Weed density at different days after sowing (DAS)		Weed dry matter at different days after sowing (DAS)	
	30	60	30	60
20 January	147.28	130.95 a	59.33 b	44.42 a
20 February	153.94	121.95 b	61.69 a	40.95 b
$S\bar{x}$	1.8409	0.8165	0.2703	0.2978
Level of significance	NS	**	*	**
CV (%)	8.20	4.33	3.00	4.68

* = Significant at 5% level of probability, ** = Significant at 1% level of probability, NS = Not significant

Discussion

Dry direct seeded rice (DDSR) is grown in non-saturated and non-puddled soil (aerobic soil) with moisture content at around field capacity and thus resulted in twice the water productivity of conventional flood irrigated rice (Bouman et al., 2002). But so far, DDSR has not been gained much popularity among the rice farmers because of less emergence rate, poor crop establishment and high weed pressure (Mahajan et al., 2011). Seed germination may be affected by low temperature if seeds are sown early and it is also the fact that crop yield may be reduced due to terminal high temperature if seeds are sown in late. Therefore, seed sowing in right time is crucial. Keneda and Beachell (1974) studied that the common types of symptoms caused by low temperature are poor germination, slow growth and discoloration of seedlings, and stunted vegetative growth characterized by reduced height and tillering. Rosenzweig and Hillel (1995) reported that high temperature accelerated physiological development, resulting in hastened maturation and reduced yield. Dry tillage, aerobic soil condition along with lack of head start make this water-wise rice production system highly vulnerable to weeds, and therefore weed management is always a huge challenge in DDSR (Juraimi et al., 2013). Since primed seed exhibits increased, faster and synchronized germination along with better crop growth (Basra et al., 2005; Farooq et al., 2009), increased weed competitiveness (Anwar et al., 2012) and ultimately increased yield (Du and Tuong, 2002; Kaur et al., 2005), it was therefore hypothesized that seed priming may counteract those problems faced by DDSR.

In this study, rice plant growth was assessed in terms of plant stature and tillering ability at early, mid and late growth stages. The plant height and tillering ability were affected significantly by the sowing dates. Plant height decreased significantly when sowing date was delayed. These results are in line with (Akram et al., 2007) whom reported that plant height was significantly affected by sowing dates and early sowing dates of rice produce taller plants than late sowing. Although seed priming failed to boost plant height at mid-growth stages and tillering ability of BRRI dhan29 at early growth stages, but a clear advantages of seed priming was found at harvest. Anwar et al. (2012) also observed that plant height of direct seeded aerobic rice was enhanced due to seed priming but not the tillering ability. Mahajan et al. (2011), on the other hand found no significant influence of seed priming on the plant stature of rice grown under dry direct seeded condition.

Plant allometric attributes like leaf area index (LAI) and crop growth rate (CGR) are considered as the key indicators to judge changes in growth of plant over time. As reported by Farooq et al. (2009), increased efficiency of primed stand in resource capture and photosynthate assimilation might be resulted in increased LAI that ended in improved CGR; improved LAI and increased CGR resulted from seed priming might contribute to increased plant stature and tillering ability. Mahajan et al. (2011) opined that increased seedling length and dry weight caused by rapid cell division at the epical meristem due to seed priming might be the cause of increased plant growth. Better field performance of primed stand has also been reported by Basra et al. (2005).

Among the yield attributes, grains panicle^{-1}, grain yield and straw yield were produced more by early sowing than late sowing. These results are similar to that of Akbar et al. (2009), where they indicated that different sowing dates had a significant effect on the number of fertile tillers per meter square. These results are also in line with Rakesh and Sharma (2004) who reported that delaying in planting in rice resulted in significant decrease in a number of productive tillers per meter square and ultimately the paddy yield. Grains panicle^{-1} and 1000-grain weight were enhanced due to seed priming which eventually translated into increased grain yield. Among the priming agents, KCl and $CaCl_2$ resulted in the highest yield performance. A positive impact of pre-sowing seed treatment with priming agent on the productivity of direct seeded rice has been confirmed by many researchers, but which priming agent is the best is still not conclusive. Farooq et al. (2006b) confirmed that KCl and $CaCl_2$ priming appeared as the promising technique for increasing rice yield under dry direct seeded condition. Mahajan et al. (2011) on the other hand, revealed that hydro-priming was the best seed priming approach in improving yield attributes and yield performance of direct seeded rice. Anwar et al. (2012), also confirmed the advantages of seed priming with Zappa solution (peroxide-based seed priming material) over non-primed control to boost up rice yield grown under aerobic soil condition. Increased grain yield of primed rice stand might be the consequence of well-established vigorous seedlings resulting earlier and enhanced resource capture (Harris et al., 1999; Mahajan et al., 2011; Anwar et al., 2012). Farooq et al. (2009) on the other hand, opined that rapid and regulated production of emergent metabolites leading to more vigorous and healthier seedlings might lead to better growth and increased yield of rice stands obtained from primed seeds. In addition to successful hydration during priming, K and Ca salts performed the best in terms of rice growth and yield which might be due their role in enzyme activation, in particular, of hydrolases as mentioned by Farooq et al. (2006b).

In the present study, weed growth was monitored in terms of weed density and dry matter at 30 and 60 days after sowing (DAS) of rice seeds. But, seed priming failed to increase the competitiveness of rice cultivar BRRI dhan29 against weeds when grown under dry direct seeded condition. Zhao et al. (2007) also found no advantages of seed priming in terms of weed suppression by dry direct seeded rice. However, conflicting findings have also been reported by many others (Du and Tuong, 2002; Ghiyasi et al., 2008; Anwar et al., 2012) who confirmed that seed priming increased weed competitiveness of crops. As reported by Ghiyasi et al. (2008), seed priming resulted in robust seedling establishment which offered increased competitiveness against weeds resulting less weed growth. On the other hand, less vigorous and poor stands from unprimed seeds allow more vigorous weed growth (Guillermo et al., 2009). Clark et al. (2001) also revealed that faster and synchronized emergence along with increased vigour resulted from seed priming are the key factors for tolerating weeds. In this study, rice growth *i.e.* plant stature and tillering ability were enhanced due to seed priming only at later stage (at harvest), but not at early (40 DAS) or mid (60 DAS) growth stages which might be resulted in no reduction in weed density and dry matter, because early growth and vigour mostly contribute to weed competitiveness of dry direct seeded rice (Zhao et al., 2006; Anwar et al., 2010; Rahman et al., 2017; Arefin et al., 2018).

Conclusion

Seed priming appears as a vital tool for enhancing growth and improving yield of direct seeded rice grown under high temperature stress; but, advantages of seed priming in weed suppression is not evident. Considering the growth, yield parameters and yield sowing at around 20th January is better than late sowing at around 20 February. Therefore, seed priming with 20000 ppm KCl or 20000 ppm $CaCl_2$ is recommended for increasing the yield of dry direct seeded *boro* rice (BRRI dhan29) under early or optimum sown condition. If somehow early sowing is not possible, seed priming with 20000 ppm KCl or 20000 ppm $CaCl_2$ is highly recommended for enhancing yield of dry direct seeded rice (BRRI dhan29) grown in late season to mitigate high temperature stress.

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