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Seed Priming with $CaCl_2$ Improves the Stand Establishment, Yield and Quality Attributes in Direct Seeded Rice (*Oryza sativa*)

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ABSTRACT

Poor and erratic crop stand is one of the major constraints to the wider adoption of direct seeded rice at farmer's field. Seed priming is a doable technology to improve the performance of direct seeded rice. This study involved on-farm testing of seed priming techniques in direct seeded rice and priming tools used include on-farm priming, hydropriming, hardening and osmopriming with $CaCl_2$ followed by re-drying or surface drying. Non-primed seeds were taken as control. Osmopriming with re-drying effectively improved the crop stand, yield and quality attributes in direct seeded rice as compared to control and was followed by seed hardening and hydropriming for most of the traits. Improved crop stand was due to reduced emergence time and high seedling vigor and yield by osmopriming with $CaCl_2$ followed by re-drying was attributed to improved total and higher panicle bearing tillers, number of kernels per panicle, 1000-kernel weight, straw and kernel yield with high harvest index (HI). Reduced sterile spikelets and opaque kernels from $CaCl_2$ osmoprimed seeds with re-drying also resulted in increased kernel quality of the direct seeded rice. The results suggest successful employing of seed priming particularly osmopriming with $CaCl_2$ with re-drying for improved crop performance in direct seeded rice at farmer's field.

Key Words: Seed priming; Direct seeded rice; Stand establishment; Yield components; Quality

INTRODUCTION

Rice (*Oryza sativa* L.) is the important staple feeding the billions of the people in Asia where it is largely produced from irrigated system with conventionally transplanted flooded culture. But increasing water shortage is pressing the growers towards water saving rice cultivation particularly in countries like Pakistan where per capita water availability has decreased from 5260 m^3 in 1951 to 1050 m^3 in 2008 (Bhatti *et al.*, 2009) and traditional rice cultivation will face severe water scarcity by 2025 (IWMI, 2000).

Direct seeded rice (DSR) i.e., growing rice like other upland crops such as common wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) is a promising alternative with less labor and water requirement (Balasurbramanian & Hill, 2002; Farooq *et al.*, 2009, 2011). But uneven crop stand due to poor seed germination and seedling growth and high weed infestations are critical constraints affecting subsequent growth and yield and considered hindrance in its adoption at farmer's field (De Datta, 1986; Farooq *et al.*, 2009, 2011).

Seed priming is a simple and low cost solution to poor stand establishment in DSR (Farooq *et al.*, 2006a, 2009) and various priming techniques such as hydro-priming (Farooq *et al.*, 2006b), on-farm priming (Harris *et al.*, 2002), osmohardening (Farooq *et al.*, 2006a-c), hardening (Farooq *et al.*, 2004) and priming with growth promoters like growth regulators and vitamins (Basra *et al.*, 2006) have been successfully employed in rice for synchronized emergence, uniform stands and better yield and quality (Farooq *et al.*, 2006a, b).

Most of these priming techniques have been evaluated for their effects on germination and seedling emergence and involve physiological implication for improved growth and to some extent on yield and quality attributes of direct seeded rice. For example, seed priming with KCl or $CaCl_2$ have been reported to improve the seedling growth in nursery transplanted and stand establishment as well as yield performance in direct seeded rice (Farooq *et al.*, 2006b, c). In another study, Farooq *et al.* (2006a) reported that osmohardening with $CaCl_2$ resulted in enhanced and uniform seedling emergence and improved the kernel and straw yield than traditional soaking and other priming treatments. Likely, vigorous seedling growth, increased the emergence and yield performance by $CaCl_2$ priming has also been reported in rice under flooded (Zheng *et al.,* 2002) and in common wheat under late sown conditions (Farooq *et al.*, 2008). Nonetheless, Harris *et al.* (1999) concluded that primed crops emerge faster and more completely, produce more vigorous seedlings, flower and mature earlier and

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yield better than non-primed crops. Additionally, priming is a low risk technology, which can yield high returns when adopted at farmer' field.

Since many studies with improved performance of direct seeded rice by seed priming (Du & Tuong, 2002; Farooq *et al.*, 2006a,b,c, 2011) are available but most of these have only reported preliminary testing of seed priming using different osmotica and hardly ever describe their on-farm evaluation using optimized priming techniques with $CaCl_2$. Therefore, extensive investigation for more practical seed priming techniques is imperative (Farooq *et al.*, 2011). Moreover, during priming, seeds are usually re-dried near to their original weight to permit routine handling. Nonetheless, surface drying of seeds has been found effective for earlier and uniform emergence in rice (Farooq *et al.*, 2010) and yield advantages in many field crops are also reported, if seeds are just surface dried prior to sowing than re-drying (Chivasa *et al.*, 1999; Harris *et al.*, 2002).

This study was therefore conducted to appraise the potential seed priming techniques and to know either re-drying is essential after seed priming with $CaCl_2$ or not and to find out its feasibility for on-farm adoption in direct seeded rice.

MATERIALS AND METHODS

Seed source and experimental details: Seeds of widely grown fine rice cultivar Super Basmati (*Oryza sativa* L.) obtained from the Rice Research Institute, Kalashah Kakoo, Sheikhupura, Pakistan were used. The initial seed moisture contents were approximately 6.59% on dry weight basis. The experiment was conducted at farmer's field in the rice growing belt (31°30'N, 73°05'E & 214 m MSL) during the summer season 2006. The experimental soil was light textured sandy with pH 7.8, total exchangeable salts 0.27 dS m^{-1}, 0.77% of organic matter, total nitrogen 0.048%, available phosphorus 17 mg kg^{-1}, exchangeable potassium 100 mg kg^{-1} and exchangeable sodium 0.7 me 100 g^{-1}. The experiment was laid out in randomized complete block design (RCBD) using three replications. The net plot size was of 3.3 m x 6 m.

Seed priming treatments: For priming, healthy rice seeds were used with seed weight to solution volume ratio of 1:5 (g mL^{-1}) (Farooq *et al.*, 2006a). For on-farm priming, seeds were soaked in tap water for 12 h. Hydropriming was carried out by soaking seeds in aerated distilled water for 48 h and for hardening, seeds were soaked in tap water for 24 h, dried back and cycle was repeated. While in case of osmopriming, seeds were soaked in $CaCl_2$ solutions having ψs of -1.25 MPa (Farooq *et al.*, 2006a). Except for on-farm priming and osmopriming followed by surface drying, in which seeds were rinsed only, while for other priming treatments, after rinsing three times, seeds were also re-dried near to original moisture contents under shade with forced air at 27±3°C for 48-72 h (Basra *et al.*, 2006). Afterwards seeds were sealed in polythene bags and stored in a refrigerator at 5°C until used.

Crop husbandry: After pre-saturation irrigation, when the moisture conditions reached at field capacity level, the required seed bed for rice direct seeding, was achieved by applying five plowings each followed by leveling with tractor drawn implements. Previous crop was common wheat. Primed and non-primed control seeds were drilled in 22 cm spaced rows at 75 kg ha^{-1} with a single row hand drill on July, 3, 2006 at field capacity level. After soil analysis report, 150, 90, 70 and 10 kg ha^{-1} N, P_2O_5, K_2O and Zn were applied using urea (46% N), di-ammonium phosphate (18% N, P 46%), sulphate of potash (50% K_2O) and zinc sulphate (35% Zn) as fertilizer source, respectively. The whole quantity of P_2O_5, K_2O and Zn, and half of the N was applied prior to seeding as basal dose, while remaining N was applied in two equal splits each at tillering i.e. 30 days after sowing and at panicle initiation.

The irrigation was applied to keep the soil moisture at field capacity level with 7-10 days interval depending on the crop requirement. Irrigation was withheld about one week before harvesting on physiological maturity. During crop growth period in all 12 irrigations were applied. Weeds were controlled manually; however as precautionary measures to avoid from paddy blast and bacterial blight, the crop was sprayed twice with Rabcide 30 WP with dose of 617.5 g 100 L^{-1} ha^{-1} and Copper Oxychloride 50% WP with dose of 2.5 kg ha^{-1}, respectively.

Stand establishment, agronomic traits and yield components: For recording observations regarding seedling establishment, field was visited daily according to the seedling evaluation handbook of Association of Official Seed Analysts (1990). Time to 50% emergence (E_{50}) was calculated following the formulae of Coolbear *et al.* (1984) modified by Farooq *et al.* (2005). Mean emergence time (MET) was calculated according to the equation of Ellis and Roberts (1981), and emergence index (El) was determined following the Association of Official Seed Analysts (1983). Data on agronomic and yield related traits was recorded at harvest maturity following the standard procedures. For plant height, twenty primary tillers were selected at randomly in each plot and measurement was taken from base to the leaf tip. Total number of tillers was counted from an area of 100 x 100 cm^2 from three different places and was averaged for per unit area (m^{-2}). Later on, panicle bearing tillers was separated manually from each plot. Number of branches and kernels per panicle were counted from twenty primary tillers harvested randomly from each plot and was averaged separately. Data regarding 1000-kernal weight from each replication was recorded in grams. For kernel yield, crop from an area of 4 m^2 was harvested and threshed manually, and then clean rough rice was air dried, bulked, weighed and adjusted to 14% moisture contents, while straw yield from each plot was determined from sundried samples and expressed in t ha^{-1}. HI (%) was expressed as the ratio of grain yield to total above ground biomass and multiplied with hundred.

Kernel quality attributes: Quality characteristics represent different stages of kernel development and a panicle was positioned in front of electric lamp to differentiate between sterile and opaque kernels from normal kernels and expressed in percentage (Nagato & Chaudhry, 1969).

Weather data and statistical analysis: Meteorological data for temperature, relative humidity, rainfall and pan evaporation for the whole crop season was collected from nearby meteorological station located at 5 km from the experimental site. The weekly mean values have been presented in the Fig. 1. Data was analyzed statistically using software MSTAT-C. Analysis of variance was used to test the significance of variance sources, while the difference among treatment means were compared using LSD test (p=0.05) (Steel *et al*., 1996).

RESULTS

Seedling establishment: All the priming treatments effectively reduced the mean emergence time (MET) as indicated from lower values for the MET observed for osmopriming with re-drying and maximum MET for hydropriming and osmopriming with surface drying as compared to control. While no significant difference was found for time to 50% emergence (E_{50}) among seed priming techniques. Nonetheless the emergence index (EI) was improved by seed priming treatments over non-primed seeds. Highest EI was recorded for hardening, which behaved similar to osmopriming with re-drying or surface drying (Table I).

Table I: Effect of seed priming on the seedling establishment in direct seeded rice

Treatments	MET (days)	E_{50} (days)	EI
Control	8.621 b	5.217	338.2 c
On-farm priming	8.602 b	5.289	503.8 b
Hydropriming	9.040 a	5.318	403.3 c
Hardening	8.494 b	4.955	607.8 a
Osmopriming ($CaCl_2$) with surface drying	8.913 a	5.268	544.0 ab
Osmopriming ($CaCl_2$) with re-drying	8.263 c	4.861	548.2 ab
LSD at 0.05	0.1627	ns	96.51

Means sharing the same letters in a column do not differ significantly at p 0.05;
MET=Mean emergence time, E_{50}=Time to 50% emergence time, EI=Emergence index,
ns = Non significant

Agronomic, yield and kernel quality related traits: Seed priming treatments response to agronomic and yield related traits of harvested paddy in direct seeded rice was also remarkable (Table II). Improved plant height, panicle bearing tillers, number of kernels per panicle, 1000- kernel weight, straw and kernel yield and harvest index (HI) were recorded for osmopriming with $CaCl_2$ followed by re-drying as compared to non-primed control and other priming techniques. Nonetheless, no significant difference was found for plant height, total tillers and number of branches per panicle to hydropriming and seed hardening (Table II). Increased number of kernels per panicle was also recorded for osmopriming with no remarkable difference with hardening and hydropriming treatments. Similarly, improved straw and kernel yield and harvest index (HI) was also recorded for $CaCl_2$ osmopriming with re-drying and were statistically similar to hydropriming for straw and kernel yield, while hydropriming and seed hardening treatments for HI than control with lower poor performance (Table II).

Priming response for kernel quality characteristics was also significant. Reduced spikelet sterility percentage was observed for osmopriming with re-drying or surface drying and hardening followed by hydropriming than control and on-farm priming with higher sterile spikelets. While reduced number of opaque kernels was recorded for hardening and on-farm priming followed by osmopriming with re-drying as compared to control with increased percentage (Fig. 2 & 3).

DISCUSSION

On-farm assessment of seed priming techniques in direct seeded rice was done in terms of seedling establishment, kernel yield and quality characteristics. Seed priming techniques improved the crop stand and seedling vigor and osmopriming with $CaCl_2$ by re-drying was the most effective to improve the seedling establishment as evident from reduced values for the MET and higher EI; however it was similar with hydropriming for the MET and hardening for the EI (Table I). Ruan *et al.* (2002b) also reported higher EI rates in rice seeds primed with $CaCl_2$. Similarly improved EI and reduced seedling emergence time has been reported in seeds primed with $CaCl_2$ (Farooq *et al*., 2006a, b) but instead of osmopriming, they employed

Table II: Effect of seed priming on the some yield components in direct seeded rice

Treatments	Plant height (cm)	Total tillers (m^2)	No. of fertile tillers (m^2)	No. of branches per panicle	No. of kernels per panicle	1000 kernel weight (g)	Straw yield (t ha^{-1})	Kernel yield (t ha^{-1})	Harvest index (%)
Control	67.21 c	479.7 b	435.0 b	7.733 a	66.23 c	17.61c	14.05 bc	1.003 c	7.133 c
On-farm priming	63.37 d	407.3 c	367.3 c	6.400 b	49.73 d	18.28 bc	10.17 e	0.9533 c	9.410 b
Hydropriming	71.33 a	506.7 a	443.0 b	8.033 a	69.60 ab	18.36 b	15.00 ab	1.667 ab	11.12 ab
Hardening	70.81 ab	513.0 a	456.0 b	6.833 b	68.67 abc	19.13 a	13.81 c	1.483 b	10.70 ab
Osmopriming ($CaCl_2$) with surface drying	68.04 bc	410.3 c	380.3 c	6.733 b	66.90 bc	18.78 ab	11.62 d	1.183 c	10.19 ab
Osmopriming ($CaCl_2$) with re-drying	71.89 a	512.7 a	508.0 a	7.833 a	69.87 a	18.97 ab	15.49 a	1.813 a	11.74 a
LSD at (0.05)	**3.030**	**14.17**	**26.70**	**0.6223**	**2.713**	**0.7022**	**0.9998**	**0.2301**	**1.581**

Mean sharing the same letter in a column do not differ significantly at p = 0.05

Fig. 1: Meteorological conditions of the paddy; RF; Rainfall (mm day^{-1}), PE; Pan evaporation (mm day^{-1}), Temp; Temperature (°C), RH; Relative humidity (%) during whole crop season from sowing up to harvesting

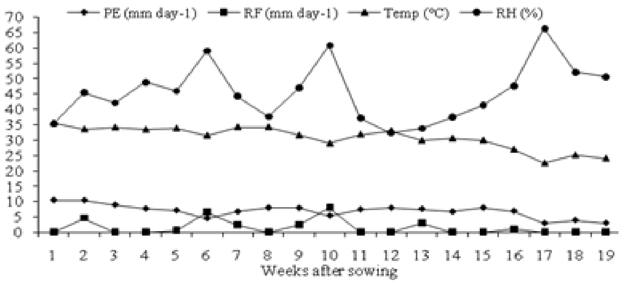


Fig. 2: Effect of seed priming techniques on the spikelet sterility (%) in direct seeded rice

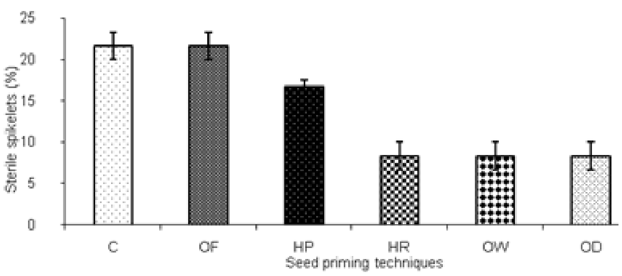
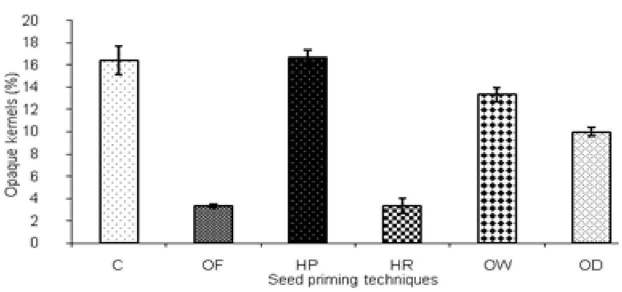


Fig. 3: Effect of seed priming techniques on the opaque kernels (%) in direct seeded rice; C=Untreated control, OF=On-farm priming; HP=Hydropriming; HR=Hardening; OW=Osmopriming with $CaCl_2$ with surface drying; OD=Osmopriming with $CaCl_2$ followed by re-drying



the seed osmohardening with integration of hardening and osmopriming and seeds were hydrated in low osmotic potential (ψ_s= -1.25 MPa) solution of $CaCl_2$ than osmopriming of same osmotic potential as used in this study (Farooq *et al.*, 2006a, b, 2007). Although statistically high values for time to 50% emergence (E_{50}) are not according to Farooq *et al.* (2006a, b) in which they reported reduced time to 50% emergence by $CaCl_2$ osmohardening or hardening but comparatively lower mean values were found for hardened or $CaCl_2$ osmoprimed seeds in this study as reported earlier (Table I).

Improved plant height in osmopriming with $CaCl_2$ and hydropriming seems to be the result of vigorous seedlings growth, which gave an energetic start and also evident from uniformity of seedlings stand indicated from reduced MET and higher El values (Table I). Primed seeds often had high vigor levels, which results in earlier and uniform emergence (Harris *et al.*, 2002; Ruan *et al.*, 2002a) and positive correlation also has been found between seed vigor and field performance in rice (Yamauchi & Winn, 1996). Higher total and fertile tillers number from primed seeds in direct seeded rice is probably the result of better emergence in direct seeded rice (Table I). Improved number of tillers from seeds osmoprimed with $CaCl_2$ and hardening in direct seeded rice (Ruan *et al.*, 2002a; Mohanasarida & Mathew, 2005b; Farooq *et al.*, 2006a, b) supports our findings in which they reported increased number of total and fertile tillers by seed osmohardening with $CaCl_2$. Increased number of branches and per panicle kernel number were recorded for $CaCl_2$ osmopriming with no significant difference for hydropriming, while 1000-kernel weight for seed hardening was statistically similar to $CaCl_2$ osmopriming with re-drying or surface drying. The number of branches per panicle and 1000-kernel weight are important yield contributing traits but very little effect or no response of seed priming on these traits have been reported (Farooq *et al.*, 2006a, b). Improved straw and kernel yield was also recorded for the osmopriming with $CaCl_2$ that was statistically similar to hydropriming. Improved kernel yield by priming treatment as compared to non-primed control is the result of improved number of fertile tillers and increased kernels per panicle. Panicle sterility was also much higher in control treatment (data not shown), which resulted in lower harvest index in it, while seed priming treatments improved the panicle fertility leading to better higher harvest index (Table II).

Increased final emergence and improved kernel yield and HI have been reported in direct seeded rice by seed priming with the $CaCl_2$ and KCl (Du & Tuong, 2002; Farooq *et al.,* 2006a). Similarly Kurdikeri *et al.* (1995) also reported improved field emergence and kernel yield in maize seeds planted after soaking in water and with the 0.5% $CaCl_2$ than dry seeds, which resulted in erratic crop emergence and yield. These findings illuminate that seed priming enhanced yield performance in direct seeded rice with improved seedling emergence and vigor. However, poor performance from $CaCl_2$ osmoprimed seeds with surface drying might be the result of slow starch hydrolysis due to non-availability of water and curtailed emergence seems to be related to in-efficient mobilization and utilization of seed reserves (Lee & Kim, 2000).

Among priming treatments except hydropriming and on-farm priming including non-primed control, all other treatments reduced the sterile spikelets, which might be the possible result of increased nutrient and moisture supply (Fig. 1, 2). The improved mobilization of nutrient and moisture supply from primed seeds might have resulted in enhanced fertilization, which ended in lower number of sterile spikelets as reported by Thakuria and Choudhary (1995) for direct seeded rice primed with potassium salts as compared to non-primed control with higher sterile spikelets. This mobilization of nutrients towards the panicles might have resulted in lower opaque kernels. Improved kernel quality has been observed in direct seeded rice seeds osmoprimed with the KC1 and $CaCl_2$ under flooded (Zheng *et al.*, 2002) and similarly $CaCl_2$ and KC1 osmohardened seeds under dry direct seeded conditions in fine and coarse rice cultivars (Farooq *et al.*, 2006a, b). They also reported that osmopriming with $CaCl_2$ followed by hardening were the most effective priming technique for improved quality in fine rice cultivars in direct seeded culture.

The study suggests that seed priming improves the performance of direct seeded rice; osmopriming with $CaCl_2$ being the most pragmatic technique in this regard. In addition the re-drying not only add into the benefits of seed priming but also permit routine handling including drilling and safe storage. Nonetheless participatory evaluation of seed priming for its adoption in direct seeded rice must be done at large scale.

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