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Seed priming improves stand establishment and productivity of no till wheat grown after direct seeded aerobic and transplanted flooded rice

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ABSTRACT

No tillage (NT) in wheat (*Triticum aestivum* L.) offers a pragmatic option for resolving the time and edaphic conflicts in rice (*Oryza sativa* L.)–wheat cropping system (RWS). However, poor stand establishment is an issue in NT wheat, which adversely affects crop growth, grain yield, and profitability. Therefore, a 2-year field study was conducted to assess the potential role of seed priming in improving the stand establishment, grain yield, water productivity and profitability of NT and plough till (PT) wheat grown after direct seeded aerobic (conservation) and puddled transplanted flooded (conventional) rice-based systems. For seed priming, wheat seeds were soaked in aerated water (hydropriming) or solution of $CaCl_2$ (ψs −1.25 MPa; osmopriming) for 12 h, and non-primed seeds were used as control. After harvest of rice, grown as direct seeded aerobic and puddled transplanted flooded crop, primed and non-primed wheat seeds were sown following NT and PT. In both years, stand establishment of NT wheat after direct seeded aerobic and puddled transplanted flooded rice was impeded. Nonetheless, seed priming improved the stand establishment which was visible through earliness and better uniformity of seedling emergence. Overall, primed seeds completed 50% emergence in 6.4 days, against 7.8 days taken by non-primed seeds in NT wheat. The highest emergence index (41.7) was recorded in primed seeds versus 32.0 for non-primed seeds. Improved stand establishment enhanced growth, grain yield, water productivity and profitability in NT wheat. In this regard, osmopriming was the most effective, and produced grain yield of 4.5 Mg ha^{-1} against 3.8 Mg ha^{-1} for non-primed seeds in NT wheat. Water productivity of the NT wheat grown from osmoprimed seeds was 8.72 kg ha^{-1} mm^{-1} while that from non-primed seeds was 7.21 kg ha^{-1} mm^{-1}. Among the RWSs, the maximum wheat biomass was produced with PT after direct seeded aerobic rice. However, grain yield, water productivity, and profitability were the highest in NT wheat following direct seeded aerobic rice. Wheat yields grown after direct seeded aerobic rice and transplanted flooded rice were 4.4 and 4.2 Mg ha^{-1} respectively. Planting NT wheat after direct seeded aerobic rice provided the highest system productivity (1.80) than other RWSs. Thus, seed priming is a viable option to improve the stand establishment, grain yield, water productivity and profitability of NT wheat in the RWS. Nonetheless, osmopriming was a better option than hydropriming in this regard.

Abbreviations: a.i., active ingredient; CA, conservation agriculture; Ca^{2+}, calcium; CIMMYT, International Maize and Wheat Improvement Center; NT, no till; DNA, deoxyribonucleic acid; dS m^{-1}, desi siemen per meter; DSAR, direct seeded aerobic rice; E, East; EI, emergence index; FAO, Food and Agriculture Organization; g, gram; h, hours; HP, hydropriming; kg ha^{-1}, kilogram per hectare; m, meter; m^3, cubic meter; masl, meter above sea level; MET, mean emergence time; Mha, million hectares; mm, millimeter; MPa, mega pascal; N, nitrogen; N, north; °C, centigrade; OP, osmopriming; P, phosphorous; ppm, parts per million; PT, plough till; PudTR, puddled transplanted flooded rice; RNA, ribonucleic acid; RWS, rice–wheat cropping systems; SP, seed priming; T_{50}, time to 50% emergence; USDA, United States Department of Agriculture; w/v, weight/volume; WP, water productivity; Ψs, solute potential.

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1. Introduction

Wheat (*Triticum aestivum* L.) is a staple food of billions across the globe. In south Asia, wheat is grown in diverse cropping systems among which rice (*Oryza sativa* L.)–wheat system (RWS) is the most prominent and practiced on 13.5 million hectares (Mha); of which 2.2 Mha is in Pakistan (Surendra et al., 2001; Ahmad and Iram, 2006). In conventional RWS, rice is grown by transplanting the nursery seedling into a puddled field; however, the following wheat crop is sown in ploughed and pulverized soil. However, puddling in rice deteriorates soil physical quality (Farooq and Nawaz, 2014), which adversely impacts root and shoot growth of the following winter crops (McDonald et al., 2006), by reducing nutrient and water availability (Ishaq et al., 2001). Indeed, puddling results in the formation of a strong crust (Kirchhof and So, 1996), which inhibits wheat seedling emergence (Mohanty et al., 2006). Moreover, late maturity and harvest of basmati rice further delays wheat planting in this system (Farooq et al., 2008a), which drastically reduces yield and profitability.

Conservation agriculture (CA); which involves least soil disturbance, retains residue cover and diversified crop rotation; offers a pragmatic option to resolve the edaphic and time conflicts in the conventional RWS (Farooq and Nawaz, 2014; Lal, 2015). Water-saving rice production systems, including direct seeded aerobic rice (DSAR) culture, may resolve the edaphic constraints while also reducing water and energy input (Oliver et al., 2008; Farooq et al., 2009, 2011). Direct seeded aerobic rice also matures earlier than puddled flooded transplanted rice (PudTR), thus allowing the timely sowing of the following crop (Farooq et al., 2008a). Direct seeding in aerobic environment also improves soil physical quality for post rice winter cereals (Farooq and Nawaz, 2014) by enhancing deeper root penetration and improving water and nutrients uptake. Moreover, no tillage (NT) facilitates early wheat sowing, and reduces the production cost (Farooq and Nawaz, 2014). In contrast, plough tillage (PT) often degrades the soil structure (Qureshi et al., 2003), and depletes soil organic matter (SOM) content (Lal, 2015).

Although, NT allows earlier sowing of wheat in the RWS; poor stand establishment remains an issue (Farooq et al., 2008a; Farooq and Basra, 2008), which must be addressed. In this regard, seed priming is a promising technique for rapid and uniform emergence of seedlings, increased vigor and enhanced yields (Murungu et al., 2004; Kaur et al., 2005; Farooq et al., 2006, 2007, 2008b; Harris, 2006; Harris et al., 1999, 2001, 2005, 2007a,b). Seed priming involves a partial hydration of seeds, which initiates germination metabolism without actual germination. Effectiveness of seed priming techniques in improving stand establishment and productivity of rice (Farooq et al., 2007) and of subsequent wheat have been reported (Farooq et al., 2008b).

In hydropriming, seeds are soaked in water. However, osmopriming includes soaking seeds in low water potential solutions (Farooq et al., 2008b). Different inorganic salts and organic acids had been used as priming agent; nonetheless osmopriming with calcium salts has been the most effective option (Farooq et al., 2008b; Jafar et al., 2012; Hussain et al., 2013). Seed priming helps achieving uniform and early crop stand (Farooq et al., 2006) through increase in the germination metabolism (Farooq et al., 2010) and quick expansion of seed embryo (Corbineau et al., 2000; Pandita et al., 2007). Seed priming also triggers metabolic and structural repair (Bray et al., 1989; Basra et al., 2005), and widens the temperature range for germination (Farooq et al., 2009).

However, research data on the potential of seed priming in improving stand establishment, productivity and profitability of NT wheat are scanty. Therefore, this study was conducted to test the hypothesis that seed priming improves stand establishment, grain yield, water productivity and profitability of NT wheat sown after DSAR and PudTR. The specific objective of this study was to evaluate the effect of seed priming on the earliness and uniformity of seedling emergence in NT wheat and the possible impact of improved stand establishment on growth, productivity and profitability of wheat.

2. Materials and methods

2.1. Site and soil

This two-year study was conducted at Agronomic Research Area, Department of Agronomy, University of Agriculture, Faisalabad (longitude 73.8 E, latitude 31.8 N, and altitude 184.4 masl), Pakistan during the winter season of 2012–2013 and 2013–2014. The experimental soil was sandy loam having pH of 6.9–7.2, SOM contents of 0.88–0.91%, electrical conductivity of 3.61–3.71 dS m^{-1}, total nitrogen (N) concentration of 0.08–0.07%, exchangeable potassium (K) of 176–178 ppm, and available phosphorous (P) of 4.45–4.61 ppm. Soil is classified as Lyallpur soil series (aridisol-fine-silty, mixed, hyperthermic Ustalfic, Haplarged) in USDA classification (USDA, 2014), and Haplic Yermosols in FAO classification (FAO, 2014).

2.2. Climate

The climate of the study site is semi-arid sub-tropical. The mean maximum and minimum temperature in summer are 39 °C and 27 °C, respectively. During winter, the mean maximum and minimum temperatures are 21 °C and 6 °C, respectively. May, June and July are the hottest while December, January and February are the coldest months. The winter season starts from November and continues till March. The average yearly rainfall is about 300 mm, and is highly seasonal with approximately 50% falling in July and August. The weather data on temperature, rainfall, relative humidity and sunshine hours during the experimental period are given in Table 1.

2.3. Plant material

Seeds of wheat cultivar 'Punjab-2011' were obtained from the Punjab Seed Corporation, Faisalabad, Pakistan. Seed moisture contents and germination potential were 9.1% and 95%, respectively.

2.4. Experimental details

The experiment was laid out in randomized complete block design in split-plot arrangement with four blocks. There were four rice–wheat cropping systems: (1) DSAR–NT wheat, (2) DSAR–PT wheat, (3) PudTR–NT wheat, (4) PudTR–PT wheat. There were three seed priming treatments: (1) hydropriming, (2) osmopriming, and (3) non-primed seeds. The RWSs were laid out as the main plots and priming treatments as the sub plot. The size of main plot and sub-plot was 8 × 9.7 m and 1.8 × 7 m, respectively. For direct seeding, rice was drilled into well-pulverized soil after four cultivations (up to 30 cm depth) and leveling at field moisture capacity on June 26 and June 28 during 2012 and 2013, respectively. Aerobic conditions were maintained throughout the whole rice season in DSAR system and water was applied on crop need base. Nursery for transplanting in flooded rice system was sown on June 26 and June 28 during 2012 and 2013, respectively. It was transplanted in puddled flooded field [four cultivations (upto 30 cm depth) following by leveling, and puddling] on July 27 and July 28 during 2012 and 2013, respectively. In this system, rice was flooded until physiological maturity. After the harvest of rice in both production systems, plots for wheat were prepared as stipulated by the treatment. For priming, wheat seeds were soaked in aerated solution of calcium chloride (ψs −1.25 MPa; osmopriming) and distilled water (hydropriming) for 12 h with