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Full Length Article

Effect of Seed Size and Seed Priming on Stand Establishment, Wheat Productivity and Profitability under Different Tillage Systems

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Abstract

No-tillage (NT) offers pragmatic option to address the time and edaphic conflicts in rice-wheat system. However, stand establishment is poor in NT systems due to less seed-soil contact. In this scenario, seed priming might be useful to improve the stand establishment, productivity and profitability in rice-wheat system. In this 2-year study, we evaluated the role of seed priming in improving the stand establishment and productivity of wheat grown from different seed size under different tillage systems. The experiment consisted of three seed priming treatments (unprimed seeds, hydroprimed seeds and osmoprimed seeds), three seed size (bold, medium and small) and two tillage systems (NT and conventional tillage). In both years, seed priming improved the stand establishment of wheat as indicated by reduction in time to start emergence, time to 50% emergence, mean emergence time, and improvement in final emergence. In this regard, osmopriming remained better than the hydropriming. Improvement in stand establishment due to seed priming improved the morphological and yield parameters of wheat. Osmopriming produced a highest grain yield of 4.70 Mg ha^{-1} against the unprimed seeds where it was 4.36 Mg ha^{-1}. The highest net benefits were recorded with osmoprimed bold seeds; while benefit cost ratio was the highest in hydroprimed bold seeds in both tillage systems with either seed size. Overall, bold seeds produced more vigorous stand than the medium and small sized-seed sown crop. In conclusion, seed priming in NT and conventional tillage systems is a pragmatic option to improve the stand establishment, productivity and profitability of wheat with either seed size.

Keywords: Bread wheat; Seed priming; No-tillage; Seed size; Osmopriming; Stand establishment; Profitability

Introduction

In rice-wheat and cotton-wheat cropping systems, the delayed maturity of the kharif crops *viz*. rice (*Oryza sativa* L.) and cotton (*Gossypium hirsutum* L.) and poor residue management practices hinders the timely sowing of the following wheat crop (Khan, 2002; Tahir *et al*., 2009). In this scenario, no tillage (NT) facilitates the timely sowing of wheat (Hobbs and Gupta, 2002; Erenstein and Laxmi, 2008). Moreover, NT reduces the production cost (Laxmi *et al.,* 2007; Singh *et al.,* 2011; Farooq and Nawaz, 2014; Rehman *et al.,* 2014; Nawaz *et al.,* 2017a; Shahzad *et al.,* 2017), improves the soil properties (Shahzad *et al.,* 2016a; Nawaz *et al.,* 2017a, b) and maintains the soil productivity on long term basis (Lal, 1999). However, weed management and poor stand establishment remains an issue in NT systems due to poor seed-soil contact (Nawaz and Farooq, 2016; Nawaz *et al.,* 2016; Shahzad *et al*., 2016b, c).

To improve the crop stand in NT systems, seed priming seems to be a promising technique, which ensures rapid and uniform seedling emergence (Farooq *et al.,* 2008a; Hussain *et al.,* 2017a). Seed priming is the controlled hydration of seeds that triggers the enzymatic activities to initiate the metabolic cascades within embryo through mobilization of pre-germination reserves (Pandita *et al.,* 2007; Asal and Taheri, 2012). Seed priming has also been reported to improve the performance of small-sized or shriveled seeds in wheat (Haider *et al.,* 2016). Seed priming ensures uniform and vigorous seedling emergence which ultimately improves the crop growth (Ashraf and Foolad, 2005; Hussain *et al*., 2017a, b) and yield. Various studies have reported that seed priming improved the allometric and yield-related traits in cereals (Harris *et al.,* 2001; Harris, 2006; Hussain *et al*., 2017a).

Seed vigor is an important physiological traits which triggers the crop emergence under diverse soil and climate types (Fujikura *et al.,* 1993; Farooq *et al.,* 2008b). As the bold-sized seeds have more food reserves due to large embryo size (Lima *et al*., 2005), they are believed to have more seed vigor than the small-sized seeds. Thus, seed vigor

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empowers the seedlings with the competitive ability to perform better under diverse crop systems (Kaur *et al*., 2005; Ahirwar, 2012). In a previous study, seed priming of small-sized seeds improved the stand establishment and productivity of wheat in different tillage systems (Haider *et al.,* 2016).

To the best of our knowledge, no study has been carried out to evaluate the role of seed priming in improving the stand establishment, productivity and profitability of wheat grown from different sized seeds under NT and conventional tillage (CT) systems. Thus, this 2-year study was planned to evaluate the role of seed priming of various sized seeds of wheat in improving the productivity and profitability under different tillage systems.

Materials and Methods

Experimental Site, Soil and Climate

This 2-year field study was conducted at the Agronomic Research Area, University of Agriculture, Faisalabad (31°N latitude, 73°E longitude and 184.4 masl altitude) Pakistan during 2012–2013 and 2013–2014. Soil sampling was done from 0–20 cm depth with the help of an auger. The air dried composite samples were passed through 2 mm sieve. The soil analysis revealed that the soil was sandy loam with pH 8.2, electrical conductivity 0.31 dS m^{-1}, organic matter 0.81%, total nitrogen 0.06%, available phosphorous 5 ppm and exchangeable potassium 166 ppm. The soil of the experimental location is classified as aridisol-fine-silty from Lyallpur soil series according to USDA classification (USDA, 2014).

The climate of Faisalabad is semi-arid with December and January as the coldest month and June, July as the hottest months. The wheat crop season starts from November and ends in May. The cumulative rainfall received during the study period was 101.2 mm in 2012–13 and 125.9 mm in 2013–14. However, the average monthly temperature varied from lowest of 11ºC in January to the highest of 32ºC in May. The relative humidity varied from 74% in January to the 29% in May. The monthly sunshine hours received were the lowest (5.5 h) in January and highest in May (10.4 h).

Experimental Design, Treatments

The experiment was conducted in randomized complete block design under split-split plot arrangement with three replications. The net plot size was kept 6 m × 1.8 m. Two tillage systems (NT and CT) were assigned to main plots, three seed size treatments (bold, medium and small) were maintained in sub-plots, and three seed priming treatments (control, osmopriming and hydropriming) were kept in sub-subplots.

The seeds of wheat cultivar "Punjab-2011" were collected from the Directorate of Farms, University of Agriculture, Faisalabad, Pakistan. Seed grading was done into three different sizes i.e., large, medium and small categories with sieve grader using the USA standard testing sieves with No. 8 (2.36 mm) and No.10 (2.00 mm) to separate medium and small-sized seeds from the seed lot, respectively. The seeds that were not passed through the No. 8 (2.36 mm) were graded as large sized while those unable to pass through No. 10 were medium sized and small size was considered for those seeds that were passed from mesh No. 10 (2.00 mm). After grading, hydropriming and osmopriming were done using distilled water and 1.2% calcium chloride ($CaCl_2$) solution, respectively. For osmopriming, the seeds were soaked in aerated solution of $CaCl_2$ (1.2%) for 10 h at 25±2°C. The ratio of seeds to solution was 1:5 (w/v). After priming, the seeds were re-dried under shade up to their original weight and stored in a refrigerator. The unprimed seeds were used as control treatment.

Crop Husbandry

After pre-sowing irrigation, wheat sowing was done in two tillage systems i.e., CT and NT. In NT, the seeds were planted directly into the stubbles without any land preparation. For CT, the field was cultivated twice with cultivator followed by planking. To ensure the fine tilth of the soil, rotavator was also operated once.

The graded and primed seeds of wheat were sown on November 24, 2012, and November 27, 2013 using seed rate of 125 kg ha^{-1}. Single row manual hand drill with 22.5 cm row spacing was used for sowing.

A fertilizer dose of 140-100 kg NP ha^{-1} was applied on the basis of soil analysis. Whole phosphorous and half dose of nitrogen was applied as basal dose, while remaining nitrogen was applied at tillering with first irrigation. For weed management, manual hoeing was done to eradicate the weeds. First irrigation was applied at 23 days after sowing and supplementary irrigations were given according to the crop requirement. In total, four irrigations were applied to wheat crop throughout its growing period. Crop was harvested manually, on April 25, and April 27, in 2013 and 2014, respectively. After harvesting the crop, the plants were tied in small bundles and were left in the plots for sun drying.

Observations

The observation regarding stand establishment were recorded on the daily basis. The emerged seedlings were counted from an area of 1 m × 1 m daily until the constant count was achieved (Association of Official Seed Analysts, 1990). Time to start emergence was recorded as the day first seed was emerged. The mean emergence time was recorded as described by Ellis and Roberts (1981). Time taken to 50% emergence was recorded as described by Farooq *et al*. (2005). To measure the plant height and spike length with the help of measuring scale, twenty plants were randomly selected before the crop harvest from each plot and then average was calculated. The total number of tillers and productive tillers were counted from a unit area (1 m × 1 m) from each plot at harvest. The grains per spike were counted from twenty randomly selected spikes and averaged. The harvesting of each plot was done separately. The whole plants biomass (straw + grain) from each plot was weighed separately to determine the total biological yield per plot, which was later converted to Mg ha^{-1}. Each plot was threshed separately by using mini thresher and grain yield was recorded using the electrical balance.

Grain yield was recorded in kilograms and was later expressed as Mg ha^{-1}. The harvest index (HI) was calculated as the ratio of grain yield to the biological yield. 1000 grain weight was recorded from threshed grains of each subplot after counting the 1000 seeds from seed lot of each plot. Quality attributes of wheat i.e., grain starch and protein contents (%) were measured using near infrared technology (NIR). Wheat grain samples, 500 g from each subplot, were collected and inserted in NIR, and the reflectance value from each sample was noted (Moroi *et al*., 2011).

Statistical and Economic Analyses

Benefit-cost ratio was calculated by subtracting the total cost from the gross income of each treatment combination (CIMMYT, 1998). The total cost, gross income and net benefits were recorded as detailed in Farooq and Nawaz (2014).

The data were analyzed using Statistix 9 (Analytical software, Statistix; 9.1 Tallahassee, FL, USA, 2008) software and the treatment means were compared with Least Significance Difference (LSD) test at 5% probability level (Steel *at al.,* 1997).

Results

Stand Establishment

Tillage systems had no impact on time to start emergence and time to 50% emergence during both years. However, the lowest mean emergence time and highest final emergence count was recorded with CT than the NT (Table 1). Seed priming significantly improved the wheat stand establishment. During both years, the minimum days to start emergence, time to 50% emergence, mean emergence time, and the highest final emergence count was recorded with osmopriming which was statistically similar with hydropriming for time to 50% emergence during first year, and time to start emergence and mean emergence time during the second year of experimentation (Table 1). Among, seed size treatments, bold-sized seeds showed the highest emergence count and took less time to start emergence, to complete 50% emergence and mean emergence during the both years (Table 1). The interactive effects of tillage systems, seed size and seed priming treatments for stand establishment traits were non-significant for both years.

Morphological and Yield Parameters

Tillage systems, seed size, and seed priming treatments had a significant influence on plant height, number of grains per spike, 1000 grain weight, productive tillers, straw yield, biological yield and grain yield during both years (Table 2 and 3). However, tillage systems had no effect on straw yield during second year and harvest index during both years; seed size and seed priming has no effect on harvest index during both years (Table 2 and 3).

The wheat crop under CT produced significantly higher plant height, number of grains per spike, 1000 grain weight, productive tillers, biological yield, straw yield and grain yield during both years (Table 2 and 3). Among the seed size treatments, the highest plant height, number of grains per spike, 1000 grain weight, productive tillers, biological yield, straw yield and grain yield was recorded from bold seeds during both years which was statistically similar with medium sized seeds for plant height, productive tillers, biological yield and straw yield during first year of experimentation (Table 2 and 3). The poor morphological and yield parameters were recorded in small sized seeds in both years (Table 2 and 3).

Among the seed priming treatments, osmopriming produced the highest plant height, number of grains per spike, 1000 grain weight, productive tillers, biological yield, straw yield and grain yield, and that was statistically similar with hydropriming for numbers of grains per spike during both years, 1000 grain weight during first year and plant height, biological yield, straw yield and grain yield during the second year of experimentation (Table 2 and 3). The interactive effects of tillage systems, seed size and seed priming treatments on morphological and yield parameters of wheat were non-significant during both the years.

Seed Quality Traits

Seed size, and seed priming treatments had a significant influence on grain protein and grain starch contents (Table 3). However, tillage systems had no significant effect on grain protein and grain starch contents (Table 3). Among seed size treatments, the maximum grain protein and starch contents were observed in the bold-sized seed followed by medium sized seeds during both years. Among the seed priming treatments, the highest grain protein and starch contents were recorded with osmopriming which was statistically similar with hydropriming during both years (Table 3). The interactive effects of tillage systems, seed size and seed priming were non-significant during both years.

Table 1: Influence of seed size and seed priming on stand establishment of wheat under different tillage systems

Treatments	Days to start emergence (days)		Time to 50% emergence (days)		Mean emergence time (days)		Final emergence count (m^2)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Tillage systems								
Conventional tillage	5.40	5.45	7.53	6.94b	7.98	7.21 b	353	341 a
No-tillage	5.41	5.33	7.56	6.97a	7.95	7.26 a	340	333 b
LSD ($p \leq 0.05$)	NS	NS	NS	0.03	NS	0.05	NS	6.89
Seed Size								
Bold Seed	5.70 a	5.55 a	7.10 a	7.11 a	8.10 a	7.31 a	323 c	315 c
Medium Seed	5.32 b	5.38 ab	7.09 a	6.94 b	8.01 a	7.21 b	349 b	344 b
Small Seed	5.14 b	5.22 b	6.94 b	6.92 c	7.71 b	7.10 c	360 a	352 a
LSD ($p \leq 0.05$)	0.31	0.25	0.15	0.03	0.14	0.01	9.33	5.18
Seed Priming								
Unprimed seed	5.83 a	5.61 a	7.43 a	7.81 a	8.08 a	7.94 a	327 c	305 c
Hydropriming	5.31 b	5.33 ab	7.08 b	7.14 ab	7.93 b	7.20 b	352 b	346 b
Osmopriming	5.12 c	5.22 b	6.94 c	6.39 b	7.89 b	7.14 c	370 a	360 a
LSD ($p \leq 0.05$)	0.22	0.19	0.14	0.85	0.04	0.01	5.28	3.45

Mean sharing the same letter for main effects, do not differ significantly ($p \leq 0.05$) by the least significant difference test; NS = Non-significant

Table 2: Influence of seed size and seed priming on morphological and yield related parameters, biological yield of wheat under different tillage systems

Treatments	Plant height (cm)		Number of grains per spike		Productive tiller (m^2)		1000-grains weight (g)		Biological yield (Mg ha^{-1})	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Tillage systems										
Conventional tillage	98 a	98 a	49.5 a	49.5 a	391 a	397 a	40.4 a	40.0 a	13.4 a	13.7 a
No-tillage	97 b	97 b	48.8 b	48.1 b	382 b	385 b	39.3 b	39.4 b	12.8 b	12.4 b
LSD ($p \leq 0.05$)	1.14	2.08	0.67	1.25	6.43	3.55	0.88	0.43	0.25	1.26
Seed size										
Bold Seed	99 a	99 a	50.7 a	50.8 a	393 a	408 a	41.2 a	41.0 a	13.8 a	14.3 a
Medium Seed	98 a	97 b	49.6 b	48.1 b	387 ab	387 b	39.8 b	39.4 b	13.5 a	13.1 b
Small Seed	95 b	95 c	47.2 c	47.8 b	381 b	376 c	38.6 c	38.9 b	11.9 b	11.9 c
LSD ($p \leq 0.05$)	0.78	1.07	0.65	1.08	8.1	8.6	1.02	0.54	0.57	0.51
Seed priming										
Unprimed seed	97 b	96 b	48.3 b	48.1 b	376 c	378 c	39.1 b	39.2 c	12.4 c	12.6 b
Hydropriming	98 b	97 a	49.3 a	49.0 a	389 b	390 b	39.9 a	39.7 b	13.2 b	13.2 a
Osmopriming	99 a	98 a	49.8 a	49.4 a	397 a	403 a	40.5 a	40.4 a	13.6 a	13.5 a
LSD ($p \leq 0.05$)	0.79	0.63	0.57	0.51	4.41	7.78	0.69	0.33	0.19	0.46

Mean sharing the same letter for main effects, do not differ significantly ($p \leq 0.05$) by the least significant difference test; NS = Non-significant

Table 3: Influence of seed size and seed priming on straw yield, grain yield, harvest index and grain quality of wheat under different tillage systems

Treatments	Straw yield (Mg ha^{-1})		Grain yield (Mg ha^{-1})		Harvest index (%)		Grain starch content (%)		Grain protein content (%)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Tillage systems										
Conventional tillage	8.64 a	8.99	4.67 a	4.74 a	35.1	34.6	64.4	64.1	10.9	11.5
No-tillage	8.33 b	8.18	4.50 b	4.25 b	35	34.1	63.7	63.5	10.9	11.4
LSD ($p \leq 0.05$)	0.29	NS	0.05	0.27	NS	NS	NS	NS	NS	NS
Seed Size										
Bold Seed	8.93 a	9.31 a	4.85 a	4.98 a	35.2	34.8	65.8 a	65.5 a	11.2 a	11.7 a
Medium Seed	8.75 a	8.68 b	4.75 b	4.40 b	35.1	34.7	64.9 b	64.9 a	11.2 a	11.7 a
Small Seed	7.78 b	7.75 c	4.12 c	4.11 b	34.8	33.6	61.4 c	61.0 b	10.4 b	10.9 b
LSD ($p \leq 0.05$)	0.57	0.62	0.06	0.31	NS	NS	0.78	0.81	0.4	0.59
Seed Priming										
Unprimed seed	7.98 c	8.25 b	4.42 c	4.30 b	35.6	34.5	63.4 b	63.4 b	10.6 b	11.3 b
Hydropriming	8.63 b	8.62 ab	4.59 b	4.53 a	34.8	34.4	64.4 a	63.9 ab	11.1 a	11.5 ab
Osmopriming	8.85 a	8.87 a	4.73 a	4.66 a	34.7	34.4	64.3 a	64.1 a	11.1 a	11.6 a
LSD ($p \leq 0.05$)	0.18	0.62	0.09	0.19	NS	NS	0.8	0.61	0.19	0.31

Mean sharing the same letter for main effects, do not differ significantly ($p \leq 0.05$) by the least significant difference test; NS = Non-significant

Economic Analysis

The economic analysis revealed that the highest net benefits were recorded from osmopriming in both tillage systems from all the seed size.

However, the benefit cost ratio was the highest in hydropriming in both tillage systems from all the seed sizes (Table 4). The variable cost was the highest in osmopriming than hydropriming. Among the wheat tillage systems, the variable cost was the lowest in NT system (Table 4).

Table 4: Influence of seed size and seed priming on the economics of wheat under different tillage systems

Treatments		Bold Seed			Medium Seed			Small Seed			
		Control	HP	OP	Control	HP	OP	Control	HP	OP	Remarks
Conventional tillage	Grain yield	4.88	5.08	5.31	4.54	4.79	4.99	4.07	4.24	4.48	Mg ha^{-1}
	Adjusted grain yield	4.40	4.57	4.78	4.09	4.31	4.49	3.66	3.81	4.03	Mg ha^{-1}
	Grain yield value	1427.0	1484.2	1552.7	1328.9	1401.6	1458.4	1188.4	1239.5	1310.3	$ 13/40 kg
	Straw yield	8.87	9.45	9.69	8.57	9.08	9.73	7.75	8.10	8.17	Mg ha^{-1}
	Adjusted straw yield	7.98	8.50	8.72	7.71	8.18	8.76	6.98	7.29	7.35	Mg ha^{-1}
	Straw yield value	498.8	531.4	544.8	481.9	510.8	547.1	435.9	455.5	459.3	$ 2.5/40 kg
	Gross income	1925.8	2015.6	2097.4	1810.7	1912.4	2005.5	1624.3	1695.1	1769.6	$ ha^{-1}
	Variable cost	191.1	203.3	260.7	191.1	203.3	260.7	191.1	203.3	260.7	$ ha^{-1}
	Permanent cost	593.3	593.3	593.3	593.3	593.3	593.3	593.3	593.3	593.3	$ ha^{-1}
	Total cost	784.4	796.6	854.0	784.4	796.6	854.0	784.4	796.6	854.0	$ ha^{-1}
	Net benefits	1141.4	1219.0	1243.5	1026.4	1115.8	1151.5	839.9	898.5	915.6	$ ha^{-1}
	Benefit cost ratio	1.46	1.53	1.46	1.31	1.40	1.35	1.07	1.13	1.07	
No tillage	Grain yield	4.57	4.70	4.94	4.22	4.42	4.51	3.89	4.02	4.12	Mg ha^{-1}
	Adjusted grain yield	4.11	4.23	4.44	3.80	3.97	4.06	3.50	3.62	3.71	Mg ha^{-1}
	Grain yield value	1336.3	1375.9	1444.5	1234.6	1291.7	1318.5	1136.7	1175.2	1204.1	$ 13/40 kg
	Straw yield	8.25	9.21	9.28	7.90	8.49	8.58	7.37	7.48	7.76	Mg ha^{-1}
	Adjusted straw yield	7.43	8.29	8.35	7.11	7.64	7.72	6.64	6.73	6.98	Mg ha^{-1}
	Straw yield value	464.1	518.1	522.1	444.4	477.3	482.4	414.7	420.5	436.5	Rs. 2.5/40 kg
	Gross income	1800.4	1894.0	1966.5	1679.0	1769.0	1800.8	1551.4	1595.7	1640.6	$ ha^{-1}
	Variable cost	128.0	139.6	201.5	128.0	139.6	201.5	128.0	139.6	201.5	$ ha^{-1}
	Permanent cost	593.3	593.3	593.3	593.3	593.3	593.3	593.3	593.3	593.3	$ ha^{-1}
	Total cost	721.2	732.8	794.8	721.2	732.8	794.8	721.2	732.8	794.8	$ ha^{-1}
	Net benefits	1079.2	1161.2	1171.7	957.7	1036.2	1006.0	830.2	862.9	845.8	$ ha^{-1}
	Benefit cost ratio	1.50	1.58	1.47	1.33	1.41	1.27	1.15	1.18	1.06	1$= 100 Pak rupees

HP = Hydropriming; OP = Osmopriming

Discussion

This study indicated that tillage systems have no impact on time to start emergence and time taken to 50% emergence. However, final emergence was the lowest in NT system (Table 1). This lowest seed emergence in NT might be attributed to low seed-soil contact due to which the seed imbibition was inhibited in wheat seeds sown in NT. The final emergence was the highest in CT which was due to better seed-soil contact in well-pulverized moist soil due to tillage operations prior to seed sowing (Hobbs and Gupta, 2002; Tripathi *et al.,* 2005; Haider *et al.,* 2016).

Among the seed priming treatments, osmopriming was the most beneficial for improvement in stand establishment, morphological and yield parameters, grain yield and grain quality of wheat in NT and CT systems which was followed by hydropriming. Indeed, seed priming reduces the time period for lag phase and activates the hydrolytic enzymes which rapidly metabolize the seed reserves (Hisashi and Francisco, 2005; Arif *et al.,* 2014). Moreover, better performance of osmoprimed seeds than hydroprimed seeds was attributed to the role of calcium in the activity of α-amylase and metabolism of carbohydrates during the seed germination (Farooq *et al.,* 2006). Some other studies have reported that seed priming improved the stand establishment than un-primed seeds (Ghiyasi *et al.,* 2008; Farooq *et al.,* 2015; Nawaz *et al.,* 2016). Moreover, better crop stand in NT due to seed priming was attributed to the presence of sufficient seed moisture in seeds which caused the radical protrusion with less dependence on soil moisture.

Among the seed size treatments, the highest grain yield was recorded in bold size seeds which were attributed to increased grain weight and grain number in this treatment. Moreover, bold sized seeds have more food reserves thus facilitating the germination process than the small sized seeds. Previously, Meyer and Carlson (2001) also observed that the germination rate and seedling vigor was increased with the increasing seed size. Indeed, stored seed reserves (as in bold seeds) are the only source of food unless the seedling starts to produce food through photosynthesis (Kaya and Day, 2008). Moreover, bold seeds develop better root systems which facilitate the uptake of water and nutrients from deep soil layers (Guillen-Portal *et al.,* 2006) thus improving the crop performance. Thus, the more food reserves and large embryo size in bold seed size favored the seed germination and might have improved root growth in both tillage systems. As the seed size increases, the seed protein and starch contents also increases, and the same was observed in this study. Some earlier studies reported faster growth and more grain protein contents from the plants grown from the bold-sized seeds (Choudhry and Imtiaz, 2001; Anuradha *et al*., 2009).

Overall, wheat yield was the highest in CT due to expansion of yield parameters owing to improvement in soil structure, improved water infiltration and enhanced soil aeration (Lio, 2006). The economic analysis revealed that the highest net benefits were recorded from osmopriming in both tillage systems from all the seed sizes which was attributed to highest grain yield in this treatment. However, the benefit cost ratio was the highest in hydropriming in both tillage systems from all the seed sizes. Indeed, the variable cost was the highest in osmopriming than hydropriming which enhanced the input cost in osmopriming. Among the wheat tillage systems, profitability was more in NT system which was attributed to no cost of seedbed preparation in NT system.

Conclusion

Seed priming improved the stand establishment, morphological/yield parameters, grain yield, grain quality and net benefits of wheat in NT and CT systems; osmopriming being more superior to hydropriming. Thus, seed priming in NT and CT systems is a pragmatic option to improve the stand establishment, productivity and profitability of wheat with either seed size. Long-term studies should be conducted to evaluate the role of seed size and seed priming with different osmotica for improving the productivity of different wheat varieties under diverse soil and climate types.

References

Ahirwar, J.R., 2012. Effect of seed size and weight on seed germination of *Alangium lamarckii,* Aloka. *Ind. Res. J. Rec. Sci*., 1: 320–322

Anuradha, R., P. Balamurugan, P. Srimathi and S. Sumathi, 2009. Influence of seed size on seed quality of chick pea (*Cicer arietinum* L.). *Legume Res. Int. J.,* 32: 133–135

Arif, M., M.T. Jan, I.A. Mian, S.A. Khan, P. Hollington and D. Harris, 2014. Evaluating the impact of osmopriming varying with polyethylene glycol concentrations and durations on soybean. *Int. J. Agric. Biol.,* 16: 359–364

Asal, M.B.A. and G. Taheri, 2012. Survey the effect of seed priming on germination and physiological indices of cotton khordad cultivar. *Ann. Biol. Res.,* 3: 1003–1009

Ashraf, M. and M.R. Foolad, 2005. Presowing seed treatment – A shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Adv. Agron.,* 88: 223–265

Association of Official Seed Analysts (AOSA), 1990. Rules for testing seeds. *J. Seed Technol*., 12: 1–112

Choudhry, A.U. and H. Imtiaz, 2001. Influence of seed size and seed rate on the phenology, yield and quality of wheat. *Pak. J. Biol. Sci.,* 4: 414–416

CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo), 1998. *From Agronomic Data to Farmers Recommendations: An Economics Training Manual*, pp: 31–33. CIMMYT, Mexico

Ellis, R.H. and E.H. Roberts, 1981. The quantification of ageing and survival in orthodox seeds. *Seed Sci. Technol.,* 9: 373–409

Erenstein, O. and V. Laxmi, 2008. Zero tillage impacts in India's rice–wheat systems: a review. *Soil Till. Res.,* 100: 1–14

Farooq, M. and A. Nawaz, 2014. Weed dynamics and productivity of wheat in conventional and conservation rice-based cropping systems. *Soil Till. Res.,* 141: 1–9

Farooq, M., S.M.A. Basra and S.A. Asad, 2008a. Comparison of conventional puddling and dry tillage in rice–wheat system. *Paddy Water Environ.,* 6: 397–404

Farooq, M., S.M.A. Basra, H. Rehman and B.A. Saleem, 2008b. Seed priming enhances the performance of late sown wheat (*Triticum aestivum* L.) by improving chilling tolerance. *J. Agron. Crop Sci.,* 194: 55–60

Farooq, M., S.M.A. Basra and K. Hafeez, 2006. Rice seed invigoration by osmohardening. *Seed Sci. Technol*., 34: 181–186

Farooq, M., S.M.A. Basra, K. Hafeez and N. Ahmad, 2005. Thermal hardening: a new seed vigor enhancement tool in rice. *J. Integr. Plant Biol.,* 47: 187–193

Farooq, S., M. Shahid, M.B. Khan, M. Hussain and M. Farooq, 2015. Improving the productivity of bread wheat by good management practices under terminal drought. *J. Agron. Crop Sci*., 201: 173–188

Fujikura, Y., H.L. Kraak, A.S. Basra and C.M. Karssen, 1993. Hydropriming, a simple and inexpensive priming method. *Seed Sci. Technol.,* 21: 639–642

Ghiyasi, M., A.A. Seyahjan, M. Tajbakhsh, R. Amirnia and H. Salehzade, 2008. Effect of osmopriming with polyethylene glycol-8000 ongermination and seedling growth of wheat (*Triticum aestivum* L.) seeds under salt stress. *Res. J. Biol. Sci*., 3: 1249–1251

Guillen-Portal, F.R., R.N. Stougaaard, Q. Xue and K.M. Eskridge, 2006. Compensatory mechanism associated with the effect of spring wheat seed size on wild oat competition. *Crop Sci*., 46: 935–945

Haider, M.U., M. Hussain, M.B. Khan, M. Ijaz, A. Sattar, M. Akram and W. Hassan, 2016. Influence of seed priming and seed size on wheat performance under different tillage systems. *Int. J. Agric. Biol*., 18: 858–864

Harris, D., 2006. Development and testing of "On-Farm" seed priming. *Adv. Agron.,* 90: 129–178

Harris, D., B.S. Raghuwanshi, J.S. Gangwar, S.C. Singh, K.D. Joshi, A. Rashid and P.A. Hollington, 2001. Participatory evaluation by farmers of on farm seed priming in wheat in India, Nepal, and Pakistan. *Exp. Agric.,* 37: 403–415

Hisashi, K.N. and A.M. Francisco, 2005. Effects of 6-methoxy-2-benzoxazolinone on the germination and α-amylase activity in lettuce seeds. *J. Plant Physiol*., 162: 1304–1307

Hobbs, P.R. and R.K. Gupta, 2002. Resource conserving technologies for wheat in rice-wheat systems. *In: Improving the Productivity and Sustainability of Rice-wheat Systems: Issues and Impact.* Ladha, J.K., E.H. James, J.D. Duxbury, R.K. Gupta and R.J. Buresh (Eds.). ASA Special Publication, ASA, Madison, Wisconsin, USA

Hussain, M., M.B. Khan, M. Shahzad, A. Ullah, A. Sher and A. Sattar, 2017a. Influence of priming on emergence, weed infestation, growth and yield of wheat sown under different tillage practices. *Int. J. Agric. Biol*., 19: 367–373

Hussain, M., M. Farooq and D.J. Lee, 2017b. Evaluating the role of seed priming in improving drought tolerance of pigmented and non-pigmented rice. *J. Agron. Crop Sci*., 203: 269–276

Kaur, S., A.K. Gupta and N. Kaur, 2005. Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *J. Agron. Crop Sci.,* 191: 81–87

Kaya, M.D. and S. Day, 2008. Relationship between seed size and NaCl on germination, seed vigor and early seedling growth of sunflower (*Helianthus annuus* L.). *Afr. J. Agric. Res.,* 3: 787–791

Khan, M., 2002. Effect of planting date, chlortoluran + MCPA and wheat varieties on weed control and wheat yield. *Sarhad J. Agric.,* 18: 443–447

Lal, R., 1999. Tillage and agricultural sustainability. *Soil Till. Res.,* 20: 133–146

Laxmi, V., O. Erenstein and R.K. Gupta, 2007. *Impact of Zero Tillage in India's Rice-wheat Systems*. CIMMYT and RWC Research Report, CIMMYT and the Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi

Lima, E.R., A.S. Santiago, A.P. Araujo and M.G. Teixeira, 2005. Effects of the size of sown seed on growth and yield of common bean cultivars of different seed sizes. *Brazil. J. Plant Physiol.,* 17: 273–281

Lio, F.S., 2006. The influence of tillage practices on the performances of cereals and roots and tubers crops. *J. Sustain. Agric. Environ. Stud.,* 3: 101–105

Meyer, S.E. and S.L. Carlson, 2001. Achene mass variation in *Ericameria nauseosus* (Asteraceae) in relation to dispersal ability and seedling fitness. *Funct. Ecol.,* 15: 274–281

Moroi, A., V. Nicoleta, V.A. Alisa, D.N. Ilena and M.A. Iuliana, 2011. Prediction of the ash content of wheat flours using spectral and chemometric methods. *Ann. Univ. Dunarea de Jos Galati Fascicle VI Food Technol.,* 35: 33–45

Nawaz, A. and M. Farooq, 2016. Weed management in resource conservation production systems in Pakistan. *Crop Prot.,* 85: 89–103

Nawaz, A., M. Farooq, R. Lal, A. Rehman, T. Hussain and A. Nadeem, 2017a. Influence of sesbania brown manuring and rice residue mulch on soil health, weeds and system productivity of conservation rice–wheat systems. *Land Degrad. Dev.,* 28: 1078–1090

Nawaz, A., R. Lal, R.K. Shrestha and M. Farooq, 2017b. Mulching affects soil properties and greenhouse gases emissions under long term no-till and plough till systems in Alfisol of central Ohio. *Land Degrad. Dev.*, 28: 673–681

Nawaz, A., M. Farooq, R. Ahmad, S.M.A. Basra and R. Lal, 2016. Seed priming improves stand establishment and productivity of no till wheat grown after direct seeded aerobic and transplanted flooded rice. *Eur. J. Agron.*, 76: 130–137

Pandita, V.K., A. Anand and S. Nagarajan, 2007. Enhancement of seed germination in hot pepper following presowing treatments. *Seed Sci. Technol.*, 35: 282–290

Rehman, H., A. Nawaz, A. Wakeel, Y.S. Saharawat and M. Farooq, 2014. Conservation agriculture in South Asia. *In: Conservation Agriculture*, pp: 249–283. Farooq, M. and K.H. Siddique (Eds.). Springer, Dordrecht 3300 AA, the Netherlands

Shahzad, M., M. Hussain, M. Farooq, S. Farooq, K. Jabran and A. Nawaz, 2017. Economic assessment of conventional and conservation tillage practices in different wheat-based cropping systems of Punjab, Pakistan. *Environ. Sci. Pollut. Res.*, 24: 24634–24643

Shahzad, M., M. Farooq, K. Jabran, T.A. Yasir and M. Hussain, 2016a. Influence of various tillage practices on soil physical properties and wheat performance in different wheat-based cropping systems. *Int. J. Agric. Biol.*, 18: 821–829

Shahzad, M., M. Farooq, K. Jabran and M. Hussain, 2016b. Impact of different crop rotations and tillage systems on weed infestation and productivity of bread wheat. *Crop Prot*., 89: 161–169

Shahzad, M., M. Farooq and M. Hussain, 2016c. Weed spectrum in different wheat-based cropping systems under conservation and conventional tillage practices in Punjab, Pakistan. *Soil Till. Res.*, 163: 71–79

Singh, B., E. Humphreys, P.L. Eberbach, A. Katupitiya, Y. Singh and S.S. Kukal, 2011. Growth: yield and water productivity of zero till wheat as affected by rice straw mulch and irrigation schedule. *Field Crops Res.*, 121: 209–225

Steel, R.G.D., J.H. Torrie and D.A. Dicky, 1997. *Principals and Procedures of Statistics, A Biochemical Approach*, 3rd edition, pp: 352–358. McGraw Hill, Inc. Book Co. New York, USA

Tahir, M., A. Tanveer, T.H. Shah, N. Fiaz and A. Wasaya, 2009. Yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. *Pak. J. Life Soc. Sci.*, 7: 39–42

Tripathi, R.P., P. Sharma and S. Singh, 2005. Tilth index: an approach for optimizing tillage in rice- wheat system. *Soil Till. Res.*, 80: 125–137

USDA, 2014. *Keys to Soil Taxonomy*, 12th edition. Natural Resources Conservation Service, Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2 053580 (Accessed: 04 March 2018)

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