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Full Length Article

Influence of Seed Priming and Seed Size on Wheat Performance under Different Tillage Systems

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Abstract

This field study was conducted to assess the effect of seed priming and seed size on emergence, growth and productivity of wheat under conventional and conservation tillage during winter season 2012–2013. Seeds of wheat cultivar Punjab-2011 were separated into small sized (1000 grain weight = 22.5 g) and bold sized (1000 grain weight = 44.4 g) seeds by winnowing. Both bold and small sized seeds were soaked in aerated solution of $CaCl_2$ (ψs -1.25 MPa; osmopriming) for 24 h while untreated (dry) seeds were taken as control. Osmoprimed and dry seeds of both sizes were sown under conventional and conservation (zero tillage) tillage practices. Results indicated that wheat sown under conventional tillage observed quick, uniform and better early stand establishment compared with zero tilled wheat. However, seed primed with $CaCl_2$ significantly lowered the days to start emergence, mean emergence time and improved final emergence count compared with dry seeds sown, particularly of zero tilled wheat. Zero tilled crop observed a significant cut in leaf area index (LAI), crop growth rate (CGR) and net assimilation (NAR), while bold seed size and osmopriming improved the LAI, CGR and NAR under both tillage practices, zero tilled wheat in particular. Moreover, zero tilled wheat observed a significant yield penalty due to significant increase in yield related traits; however, osmopriming and bold seed size improved wheat productivity due to substantial expansion in yield related traits under conventional and zero tillage, zero tillage in particular, practices. In conclusion, bold sized seed osmoprimed with $CaCl_2$ was better able to produce higher yield of conventionally tilled and zero tilled wheat.

Keywords: Seed size; MET; Priming techniques; NAR; Zero tillage

Introduction

In rice-wheat and cotton-wheat cropping systems, wheat (*Triticum aestivum* L.) is typically sown by tilling fields with conventional tillage practice in South Asia. This practice increases production cost, delays wheat planting, and also results in losses of residual soil moisture which could have been used for establishment of succeeding wheat crop. On the other hand, zero tillage saves planting time, fuel and water, and also improves the efficiency of applied fertilizers (Singh *et al*., 2007). In addition, soil microbial activity is increased in zero tillage system due the less oxidation of soil organic matter which enhanced the sustainability and productivity of soil (Mitchell *et al*., 2004). Zero tillage is better than conventional tillage because of high yield and profit recorded by the farmers in addition to its eco-friendly impact (Nagarajan *et al*., 2002). Bharadwaj *et al*. (2004) reported about 8% higher wheat output under zero tillage compared with conventional tillage. This elevation in wheat yield under zero tillage might be correlated with early wheat planting; as zero tillage saves planting time of wheat (Singh *et al*., 2007). Late sowing of wheat is one the major yield constraints, planting of wheat after 21 Nov reduces the yield of the wheat crop (Govt. of Punjab, 2015–2016). For instance, wheat planted on 25th Dec exhibited about 23% yield reduction compared with 25th Nov sown crop (Hussain *et al*., 2012a, b).

However, occasionally poor and erratic early stand establishment in zero tilled wheat is a serious issue in its wider adoption (Mann *et al*., 2008). Thus, it is direly needed to attain quick and uniform stand establishment for efficient utilization of natural resources and harvesting the target yield of wheat under zero till systems.

Seed priming techniques often seemed beneficial to improve seed emergence and early stand establishment of wheat (Khan *et al*., 2010; Farooq *et al*., 2015; Mahboob *et*

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al., 2015). Efficacy to seed priming techniques to advance the seedling germination rate, speed and uniformity of emergence even under less than normal field situation is well established (Lee *et al*., 1998; Kant *et al*., 2006; Farooq *et al*., 2008). During seed priming process, seeds are soaked in distilled water or solutions of low water potential, which allows pre-germination metabolic activities without actual germination, and seeds are then put out from the solution, rinsed and dried close to original weight to sanction routine handling (Bradford, 1986). Several osmotica, including polyethylene glycol (PEG), KNO_3, K_3PO_4, $MgSO_4$, NaCl, KCl and $CaCl_2$ etc. are being used as seed priming agent with known osmotic potential (Hussain *et al*., 2006; Farooq *et al*., Farooq *et al*., 2015). In primed seeds, metabolic reactions are activated which speed up the germination and reduced the natural heterogeneity in germination (Rowse, 1995).

Likewise, bold seed also plays a vital role in improving germination, better stand establishment, growth and productivity of wheat (Lafond and Baker, 1986; Aprico *et al*., 2002; Royo *et al*., 2006). Ali Abadi *et al*. (2011) reported improved germination, higher dry weight, vigor, and length of seedling by using bold sized seeds while under stress condition, speedy germination was obtained when small seed of wheat were sown (Lafond and Baker, 1986). Moreover, large sized seeds develop better root system and thus enable the seedlings to get soil moisture efficiency from deeper layers (Leishman and Westoby, 1994). Some early researchers concluded that seed size notably affected the yield and yield component of wheat (Stougaard and Xue, 2004; Royo *et al*., 2006). However, some controversial findings about the role of seed size in improving wheat output are available. For instance, wheat planted with bold sized seeds give higher yields than smaller seeds under late-sown conditions (Singh and Kailasanathan, 1976), but not under favorable management conditions (Kalita and Choudhury, 1984).

Although, many studies have been conducted to evaluate the role of seed size and priming techniques in improving wheat production; however, to best of our knowledge, no inclusive study has been conducted to evaluate the role of interactive effects of seed size and priming techniques on wheat production grown under conventional and zero till systems. Therefore this field study was designed to explore the role of interactive effect of seed size and priming techniques on wheat output grown under conventional and zero till systems.

Materials and Methods

This field study was conducted at Agronomic Experimental Area, Bahauddin Zakariya University, Multan, Pakistan (71.43º E, 30.2º N and altitude 122 m) during Rabi season, 2012-2013 to find out role of seed size and priming techniques on wheat performance sown under conservation and conventional tillage practices. The climatic of this region is semi-arid and subtropical. Experimental field was homogeneous and characteristics of soil were silty clay in behavior. Before wheat sowing, soil analysis was performed to verify the fertility status and other physico-chemical properties of soil (Table 1).

Experimental Details

Seeds of wheat cultivar Punjab-2011 were obtained from Ayub Agricultural Research Institute Faisalabad, Pakistan. Seeds were divided into two categories i.e. small sized (1000 grain weight = 22.5 g) and bold sized (1000 grain weight = 44.4 g) by winnowing. Seeds of both categories (bold and small sized) were put in aerated solution of $CaCl_2$ (osmopriming; ψs -1.25 MPa) for 18 h at room temperature (25±5ºC) with 1:5 (w/v) seeds to solution ratio (Hussain *et al*., 2016). After 24 h, seeds were removed from priming media, washed three times with ordinary tap water and then dried under shade near to their original weights using enforced air at 27±3ºC, while dry (un-hydrated) seeds were used as control. Primed seeds were put in sealed ploythene bags and were kept in refrigerator at 5ºC till sowing. Osmoprimed and dry seeds of both categories were sown with conventional and conservation (zero tillage) tillage practices.

The trial was laid out in randomized complete block design with split-split plot arrangement by randomizing tillage practices, seed size and priming techniques respectively in main, sub and sub-sub plots. The whole experiment was replicated four times and net plot size of 5 m × 2.5 m was used.

Crop Husbandry

Before sowing, field was irrigated to make conditions favorable for seedbed preparation. When soil arrived at workable condition, two cultivations were given followed by planking to prepare seedbed for conventional system while the land was kept un-disturbed for zero tillage system. Wheat was sown on December 4, 2012 manually with hand drill in 25 cm spaced rows with uniform seed rate of 125 kg ha^{-1}. Crop was fertilized with 150 kg ha^{-1} nitrogen (N) and 100 kg ha^{-1} phosphorus (P) by using urea and nitrophos. Half of N and total amount of P were applied at sowing by drill and rest of N was side dressed at 1st irrigation. Overall three irrigations were given to avoid moisture stress. Weeds were controlled manually. Mature crop was harvested on April 14, 2013.

Observations Recorded

Stand establishment: After sowing, the experiment was visited daily to count the number of emerged seedlings until the constant emergence count by following the method expressed in seedling evaluation Handbook of Association of Official Seed Analysts (1990). The day on which 1st seedling got emerged in any plot was taken as time to start emergence. Time to complete 50% emergence (E_{50}) was determined as described by Farooq *et al*. (2005), while mean emergence time (MET) was derived following Ellis and Roberts (1981). Total number of emerged seedling on last day of emergence was measured from one m^{-2} areas and nominated as final emergence count.

Crop Allometry

Leaf area was calculated with leaf area meter at 25 days interval. After that, LAI was extracted with the formula given by Madison and Watson (1947). Sampling to calculate leaf area was started from 45 days after sowing (DAS) and finished before crop maturity i.e. from stage 7 to 10.4 according to Feekes scale (Large, 1954). Procedures described by Hunt (1978) were used to calculate crop growth rate (CGR).

Yield Related Traits

Total numbers of productive tillers were counted from three different sites of 1 m^{-2} areas from each plot and averaged. Twenty random selected plants at maturity were used to record average plant height. Length of 20 randomly chosen spikes from each plot was measured with ruler and averaged. These above mentioned spikes were used to note number of spikelets and number of grains per spike. From each seed lot, three samples (each of 1000 grains) were taken, weighed and averaged to note 1000-grain weight. At harvest maturity, two central rows were harvested manually and put in the field for sun drying for four days. After drying, tied into bundles and weighed by using spring balance to calculate biological yield. Then these bundles were threshed manually to separate the grains from straw and separated grains were weighed to compute grain yield. The difference between biological and grain yield was expressed as straw yield. The calculated grain, straw and biological yields were then changed into t ha^{-1}. After that grain yield was adjusted at 10% moisture contents.

Statistical Analysis

The calculated data was statistically analyzed with the help of Fisher's analysis of variance procedure and least significant test (LSD) test at 5% probability was utilized to evaluate the diversity amid treatments means (Steel *et al.*, 1997). Similarly Microsoft Excel Program along with ± S.E. was used for graphical presentation of data.

Results

Wheat sown under conventional tillage observed quick and more synchronized emergence {evident from lowers values of time to start emergence, mean emergence time (MET) and time taken to complete 50% emergence (E_{50})} compared with zero tillage (Table 2). Nonetheless, osmopriming with $CaCl_2$ substantially lowered the time to start emergence, MET and E_{50} compared with dry seeds both under conventional and zero till systems (Table 2). However, the small and bold sized seeds behaved similarly under both tillage systems in this regard (Table 2). The final emergence count of zero tilled wheat was considerably lesser than the wheat sown under conventional system; however osmopriming markedly improved the final emergence count of wheat sown under both tillage systems, and zero till system in particular (Table 2).

Table 1: Physio-chemical properties of the soil

Determination	Unit	Value	Status
Physical Analysis			
Sand	%	27.8	
Silt	%	52.5	
Clay	%	19.7	
Saturation percentage	%	38	
Textural class	Silty clay loam		
Chemical Analysis			
pH		8.4	
EC	dS m^{-1}	3.42	
Organic matter	%	0.85	Very low
Total nitrogen	%	0.03	Very low
Available phosphorus	ppm	7.40	Low
Available potassium	ppm	125.00	Medium
Total soluble salts	%	0.96	

Periodic data indicated that leaf area index (LAI) progressively increased with growth period while crop growth rate (CGR) increased up to 70 days after sowing (DAS) and then start declining (Fig. 1 and 2). Wheat sown under zero tillage observed a notable reduction in LAI and CGR at 45, 70 and 95 DAS (Fig. 1 and 2). Nonetheless, bold seed size and osmopriming substantially improved the LAI and CGR of wheat sown under conventional and zero till systems at 45, 70 and 95 DAS (Fig. 1 and 2). Wheat sown under conventional tillage observed higher net assimilation rate (NAR) than wheat sown under zero tillage either sown by bold or small seeds; however, crop sown with bold seeds recorded higher NAR than small seeded crop under conservative or conventional tillage practices (Fig. 3). However, osmopriming improved the NAR of wheat sown under conventional and zero tillage practices by using bold sized seeds only (Fig. 3).

Wheat sown under zero till systems with small sized seeds recorded the minimum plant height compared with rest of the combinations while osmopriming improved the plant height under conventional tillage compared with the rest of combinations (Table 3). Population of productive tillers and spike length was significantly decreased by growing wheat under zero tillage compared with conventional tillage (Table 3). Moreover, bold sized wheat seeds notable improved the number of productive tillers and spike length of zero tilled wheat (Table 3). However the osmoprimed and dry seeds behaved similarly under zero and conventional tillage system in this regard (Table 3).

Table 2: Effect of priming techniques and seed size on early stand establishment of wheat sown under various tillage systems

Treatments	Time to start emergence (days)		MET (days)		E_{50} (days)		Final emergence count (m^{-2})	
	ZT	CT	ZT	CT	ZT	CT	ZT	CT
Seed size								
Bold seed	7.37 A	5.75 B	12.22 A	10.34 B	8.09 A	6.07 B	364.50 B	529.50 A
Small seed	7.00 A	5.75 B	12.03 A	10.28 B	7.62 A	6.32 B	468.00 AB	589.50 A
LSD <0.05	0.74		1.22		0.70		155.90	
Priming								
Dry seed	7.75 A	6.25 C	12.28 A	10.65 B	8.40 A	6.64 C	396.00 B	506.50 AB
Osmoprimed seed	6.62 B	5.25 D	11.97 A	9.96 C	7.32 B	5.75 D	436.50 B	612.50 A
LSD <0.05	0.37		0.65		0.29		118.90	

Means not sharing the same letter within a column or row differ significantly from each other at $p \leq 0.05$

ZT = Zero tillage, CT = Conventional tillage, MET = Mean mergence time, E_{50} = Time to complete 50% emergence

Table 3: Effect of priming techniques and seed size on plant height, productive tillers and spike length of wheat sown under various tillage systems

Treatments	Plant height (cm)		Productive tillers (m^{-2})		Spike length (cm)	
	ZT	CT	ZT	CT	ZT	CT
Seed size						
Bold seed	100.82 A	101.41 A	138.60 B	150.10 A	10.43 C	11.17 A
Small seed	99.66 B	101.52 A	117.70 C	150.10 A	10.18 D	10.92 B
LSD <0.05	0.70		2.50		0.25	
Priming						
Dry seed	100.40 B	101.00 B	126.10 B	149.70 A	10.23 B	10.94 A
Osmo-primed seed	100.10 B	102.00 A	130.20 B	150.50 A	10.38 B	11.14 A
LSD <0.05	0.90		4.51		0.22	

Means not sharing the same letter within a column or row differ significantly from each other at p 5%

ZT = Zero tillage, CT = Conventional tillage

Table 4: Effect of priming techniques and seed size on yield components of wheat sown under various tillage practices

Treatments	Spikelets per spike		Grains per spike		1000- grain weight (g)	
	ZT	CT	ZT	CT	ZT	CT
Seed size						
Bold seed	17.61 B	18.47 A	49.12 C	53.76 A	37.38 C	40.00 A
Small seed	17.00 C	18.15 A	45.23 D	51.79 B	37.38 C	38.94 B
LSD <0.05	0.39		1.05		0.92	
Priming						
Dry seed	17.08 B	18.26 A	45.74 D	51.50 B	37.50 C	39.00 B
Osmoprimed seed	17.54 B	18.36 A	48.61 C	54.05 A	37.25 C	39.94 A
LSD <0.05	0.72		0.72		0.64	

Means not sharing the same letter within a column or row differ significantly from each other at p 5%

ZT = Zero tillage, CT = Conventional tillage

Wheat sown with zero tillage observed a significant cut in number of spikelets and grains per spike, and 1000-grain weight than wheat sown under conventional tillage system (Table 4). However, bold sized seeds compared with small sized seeds improved number of spikelets and grains per spike, and 1000-grain weight of wheat particularly sown under zero tillage (Table 4). Nonetheless, osmopriming with $CaCl_2$ improved number of grains per spike under conventional and zero till systems while 1000-grain weight was improved only under conventional tillage system (Table 4).

Wheat sown under zero tillage system observed a significant decrease in grain, straw and biological yields compared with wheat sown under conventional tillage system (Table 5). Wheat sown by using bold sized seeds not only compensated the yield losses largely under zero tillage system but improved the grain, straw and biological yields of wheat sown under conventional tillage system as well (Table 5). Moreover, osmopriming with $CaCl_2$ significantly improved the grain yield of wheat under conventional and zero tillage while improved the straw and grain yield only under conventional tillage system (Table 5).

Discussion

Findings of this field study elaborated that zero tilled wheat observed delayed and poor emergence, growth and productivity compared with the conventionally tilled wheat. However, bold sized seed osmoprimed with $CaCl_2$ was better able to produce higher wheat output sown under conventional and zero tillage systems (Tables 2–5).

Table 5: Effect of priming techniques and seed size on yield of wheat sown under various tillage systems

Treatments	Grain yield (t ha^{-1})		Biological yield (t ha^{-1})		Straw yield (t ha^{-1})	
	ZT	CT	ZT	CT	ZT	CT
Seed size						
Bold seed	3.44 C	3.73 A	12.89 B	13.85 A	9.45 AB	10.11 A
Small seed	3.29 D	3.51 B	11.63 C	12.70 B	8.33 C	9.18 B
LSD <0.05	0.28		0.72		0.74	
Priming						
Dry seed	3.27 D	3.54 B	12.18 C	13.40 B	8.91 C	9.48 B
Osmoprimed seed	3.46 C	3.69 A	12.34 C	13.51 A	8.87 C	9.81 A
LSD <0.05	0.65		0.28		0.26	

Means not sharing the same letter within a column or row differ significantly from each other at P ≤ 5%
ZT = Zero tillage, CT = Conventional tillage

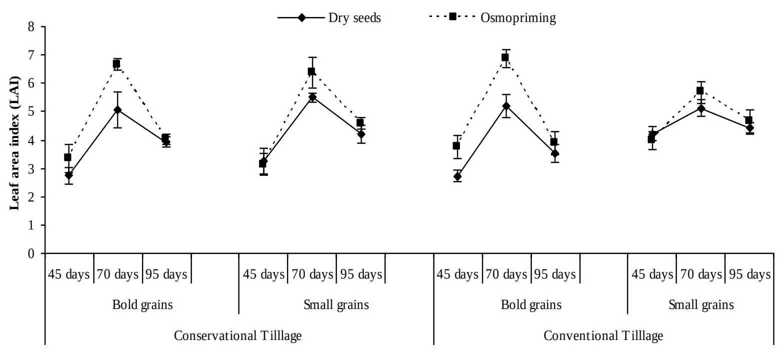

Fig. 1: Effect of priming techniques and seed size on leaf area index of wheat sown under conventional and conservation tillage practices

Well prepared seedbed in conventional tillage might be provided the better contact of seed with well pulverized moist soil and thus more moisture supply might resulted in early and better stand establishment compared with zero tilled wheat. Osmopriming resulted in quick and better early stand establishment under conventional and zero tillage system (Table 2). This might be due to the shortening of lag phase and quick metabolism of seed reserves with the activation of hydrolytic enzymes during priming process (Hisashi and Francisco, 2005; Farooq *et al*., 2009; Arif *et al*., 2014). Several earlier reports highlighted the supremacy of seed priming in improving the emergence count against non-primed seeds, and osmopriming with $CaCl_2$ seemed highly suitable especially for wheat even under less than optimal conditions (Ghiyasi *et al*., 2008; Farooq *et al*., 2015). In this study, quick and synchronized emergence was observed in wheat seeds osmoprimed with $CaCl_2$ might be due to involvement of Ca salts in carbohydrate metabolism and improving α-amylase activity during the germination (Farooq *et al*., 2006).

Wheat sown under conventional tillage observed higher LAI, CGR, and NAR than wheat sown under zero tillage; however, crop sown with bold seeds recorded higher LAI, CGR, and NAR than small seeded crop under zero tillage or conventional tillage practices. Osmopriming improved the LAI, CGR, and NAR of wheat sown under conventional and zero tillage practices by using bold sized seeds only (Fig. 3). High allometric attributes from osmoprimed seeds might be the result of healthy and vigorous seedlings. Improved CGR is possible due to strong and energetic start from vigorous seedling attained from osmoprimed with $CaCl_2$ under both tillage systems which resulted in improved LAI and NAR. Osmopriming with $CaCl_2$ resulted in vigor enhancement and better growth in crops (Farooq *et al*., 2008).

Conventionally tilled wheat recorded higher yield due to significant expansion in yield related traits like number of productive tillers, grains per spike and 1000-grain weight etc. (Tables 3–5). Results of several studies highlighted that conventional tillage is one of the most indispensable operation carried out to improve soil structure, increase infiltration capacity, and aeration (Lio, 2006); which in turn increases plant height, productive tillers, spike length, grains per spike and grain size due to better growth (Khurshid *et al*., 2006; Rashidi and Keshavarzpour, 2007, 2008; Rashidi *et al*., 2008). Zero tilled wheat recorded lesser population of productive tillers due to erratic and poor emergence (Table 2) and higher weeds pressure (data not given). Lesser accrual of photo-assimilates due to less CGR (Fig. 2) and small LAI might be responsible of declined 1000-grain weight in zero tilled wheat ultimately ending with yield penalty (Tables 3 and 4).

Nonetheless, bold sized wheat seeds notably improved plant height, number of productive tillers and spike length of zero tilled wheat. Results of some researchers delicate that seed size notably affected plant

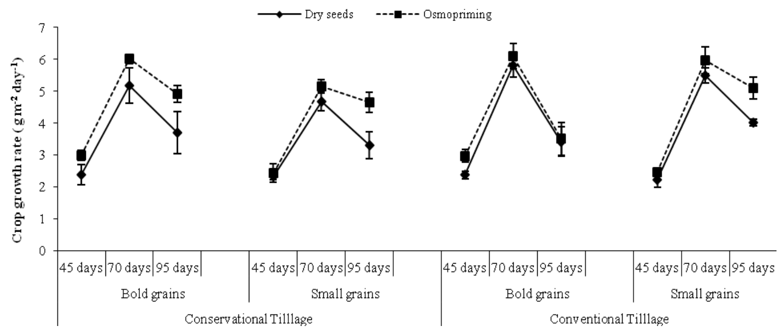

Fig. 2: Effect of priming techniques and seed size on crop growth rate of wheat sown under conventional and conservation tillage practices

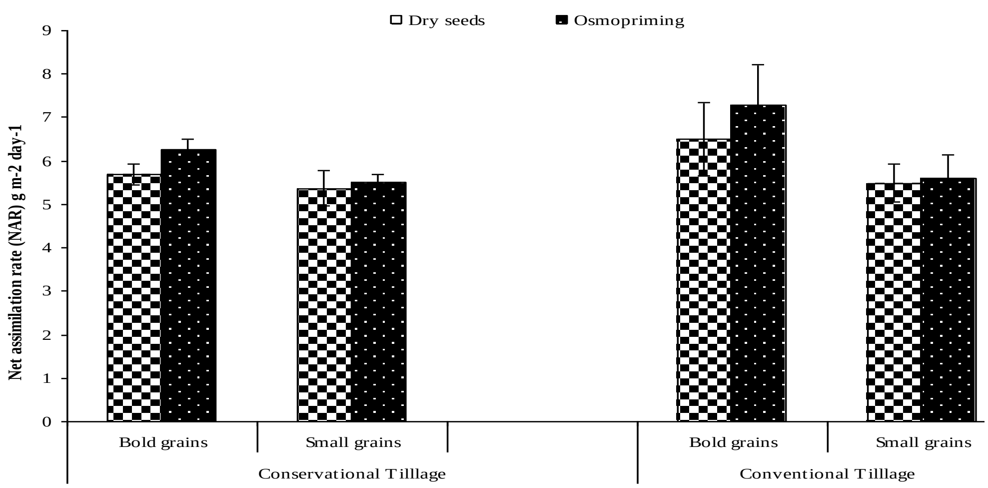

Fig. 3: Effect of priming techniques and seed sizes on net assimilation rate of wheat sown under conventional and conservation tillage practices

height, productive tillers, and number of seeds per spike (Stougaard and Xue, 2004; Royo *et al*., 2006). Ali Abadi *et al*. (2011) reported that germination, seedling dry weight, seedling vigor and seedling length increased by increasing in seed size. Larger seeds develop better root system of seedling and advantage of deep root is to get soil moisture efficiency from deeper layers of soil (Guillen-Portal *et al*., 2006). Moreover, osmopriming with $CaCl_2$ significantly improved the grain yield of wheat under conventional and zero tillage while improved the straw and grain yield only under conventional tillage system. Earlier and more uniform stand establishment, and higher LAI and CGR of osmoprimed seeds compared with dry seeds might be responsible of notable improvement of zero tilled wheat. It is well established that wheat seed priming with $CaCl_2$ not only improved the early stand establishment but also improved wheat productivity even less than optimal conditions (Farooq *et al*., 2008, 2015).

Conclusion

Conventionally tilled wheat observed quick, uniform and better early stand establishment compared with zero tilled wheat. However, seed primed with $CaCl_2$ significantly lowered the days to start emergence, mean emergence time and improved final emergence count compared with dry seeds sown, particularly of zero tilled wheat. Moreover, zero tilled wheat observed a significant yield penalty due to decease in yield related traits; however, osmopriming and bold seed size improved wheat productivity due to increase in yield related traits of conventional and zero tilled wheat, zero tilled wheat in particular.

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