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Research Article

Seed priming improves yield and nitrogen uptake in wheat under varying nitrogen and moisture regimes

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Abstract

A field experiment was conducted to investigate the effect of seed priming (dry seed, water soaked and 0.2 % P solution) and nitrogen (N) levels (0, 50 and 100 kg N ha^{-1}) on wheat growth and N uptake under two different irrigation regimes (3 and 5 times irrigation). The results indicated that priming, N levels and soil moisture regimes significantly affected yield and N content of wheat. The higher moisture level produced significantly higher grain yield (3666.5 kg ha^{-1}), biological yield (1042.6 kg ha^{-1}), harvest index (35.2%), soil (0.036%), straw (0.36%) and grain nitrogen (1.49%) compared to low moisture level. Similarly, 100 kg N ha^{-1} resulted maximum grain yield (4173.7 kg ha^{-1}), biological yield (11355.4 kg ha^{-1}), harvest index (36.8%), soil nitrogen (0.038%), straw nitrogen (0.39%) and grain nitrogen (1.52%) in wheat. Likewise, among various seed priming methods, 0.2% P seed priming produced significantly greater grain yield (3665.4 kg ha^{-1}), biological yield (10760.8 kg ha^{-1}), harvest index (34.8%), soil (0.038%), straw (0.39%) and grain nitrogen (1.51%) over un-primed seed. Hence seed priming (0.2% P) and N application (100 kg N ha^{-1}) both under high and low moisture regime is recommended for farmers on the basis of good crop yield in Peshawar region.

Keywords: Grain yield; Nitrogen; Priming; Soil moisture; Wheat

Introduction

Wheat (*Triticum aestivum* L.) is used as a major source of food all over the world. It is also the staple food of Pakistan and meets the major dietary requirements; supplies about 73% of the calories and protein of the average diet [1]. In Pakistan wheat is cultivated both in irrigated and rain fed areas. The total area occupied by wheat during 2015-16 in Pakistan was 9.25 million hectares, which produced 25.45 millon tons food grain while in Khyber Pakhtunkhwa (KP) the total area occupied by wheat was 0.78 million hectare which produced 1.35 million tons [2]. Punjab is the leading producer of wheat. In KP more wheat is grown in barani than in irrigated area. Besides grain, wheat straw (bhossa) is also used as roughage for livestock.

Seed priming comprises of the soaking of seed in water or any chemical or nutrient solution and drying back to the storage moisture until use. The seed priming induces a range of biochemical changes in the seed that are required to start the germination process such as breaking of dormancy, hydrolysis or metabolization of inhibitors and enzyme activation. Some or all of these processes that precede the germination are triggered by priming and persist following the re-desiccation of the seeds [3]. Primed seed of wheat with P increase emergence m^{-2}, tiller m^{-2}, grains $spike^{-1}$, thousand grain weight and grain yield as compared to dry seed [4]. Seed priming with P improve emergence and seedling fresh and dry weight as compared to dry seed and showed that water and nutrient priming can be used as tool to accelerate and improve emergence and early growth of maize [5].

Nitrogen plays an important role in crop life. It is one of the most important nutrients needed by plants in large quantities. Adequate nitrogen promotes vigorous vegetative growth and deep green color. Nitrogen has been recognized as one of the most limiting nutrient. Its use and demand is continuously increasing day by day [6]. Izaurralde *et al*. [7] evaluated the response of three cultivars of durum wheat to four irrigation regimes [no irrigation or irrigation applied at three growth stages (sowing, jointing, and anthesis)]. Thousand-kernel weight and test weight increased with irrigation at all three stages whereas irrigation at sowing and jointing resulted in high pigmentation and protein values. When irrigation was applied at sowing and jointing, but not at anthesis, with water stress occurring only at grain filling, the quality of grain was positively affected.

Globally, fertilizer nitrogen (N) applications are approximately 80 million tones, with half being applied in developing countries and the other half in developed countries [8]. It has been estimated that by the year 2025 the consumption of nitrogen fertilizer will increase 60 to 90 percent, with two-third of this being applied in the developing world [9]. This trend in fertilizer use is mostly driven by the need of developing countries to keep food supply up with population growth. It has been projected that by year 2020 world population will be more than 8 billion people, with more than 90 percent of this additional growth concentrated in developing countries [10]. However, the efficiency of N fertilizer use tends to be low in this system [11].

Besides other factors, time and amount of irrigation are two important factors upon which production of a bumper crop depend in irrigated areas. Irrigation is needed in many areas of the country for good crop growth and proper grain development as rainfall is inadequate and erratic throughout the country. For temperate cereals there are two critical periods during which water stress greatly reduce yield, i.e the period from anthesis to the milk stage. Wheat usually needs four to six irrigation depending upon latitude, soil type, cultivar, rainfall and other factors affecting evapotranspiration. Priority in watering should be assigned as follows: adventitious roots development, anthesis, milk stage. tillering, spike emergence and subsequent irrigation should be given accordingly to the need of the crop and availability of water [12]. In this experiment we had investigated the effect of seed priming on the emergence, plant growth and yield of wheat at two contrasting seedbed moisture condition.

Materials and methods

Experimental site

This experiment was conducted at New Developmental Farm, Khyber Pakhtunkhwa Agricultural University Peshawar during winter 2015-16. The soil of experimented site was silt loam, with pH 7.81, EC 0.25 dS m^{-1} and deficient in N and P (Table 1).

Table 1. Physio-chemical properties of experimental field

Property	Units	Value
Silt	%	64.5
Sand	%	29.6
Clay	%	5.4
Textural Class	-	Silt loam
EC(e)	dSm^{-1}	0.25
pH	-	7.81
Soil total N	%	0.12
AB-DTPA extractable P content	$mg\ kg^{-1}$	3.26

Experimental procedure

To study the effect of seed priming, nitrogen and soil moisture regimes on yield and yield nitrogen uptake of wheat). Rendomized complete block design (RCBD) split plot arrangement was used. The experiment was consisted of three factors i.e. moisture regimes; one under high moisture seedbed condition (optimum irrigation; 5 times) and other under low moisture seedbed condition (reduced irrigation; 3 times), seed priming (dry seed, water soaked, seed primed with 0.2% P solution) and nitrogen levels (0, 50, 100 kg ha^{-1}).Moisture level served as main plot while **t**reatment combination of seed priming and N levels were kept in subplot with three replications. Low moisture plots were irrigated two weeks before sowing while high moisture plots were irrigated a week before sowing. Both low and high moisture plots were not irrigated till 40^{th} day after sowing. Soil moisture of both low and high moisture regimes were 23 and 30 %, respectively at the time of sowing of the crop. Wheat variety Saleem-2000 was sown at the rate of 120 kg ha^{-1} in a subplot size of 5 m by 5 m having 16 rows 5 meter long and 30 cm apart. Dry plots were flood irrigated during first week of November and wet plots a week later (to manufacture a slightly drier seedbed as a result of seven days extra drying).

Nitrogen was applied in three split doses, one third each at sowing, tillering and boot stages. Seed priming was consisted of dry seed, water soaked seed and seed primed in 0.2% P solution. KH_2PO_4 was used as source of P. For primed seeds, 180 g of seed per plot was sealed in perforated plastic bags and the bags were soaked for 12 hours in either distilled water or in a 0.2% aqueous solution of P. After soaking, bags were removed, drained and then surface dried in shade for around half an hour to facilitate clump-free sowing. Phosphorous at the rate of 90 kg ha^{-1} was applied at sowing time. Sources of phosphorous and N were SSP and urea, respectively. All the standard agronomic practices were uniformly adopted for the experiment. The wet plots were irrigated after emergence was complete (i.e. about 21 days after sowing, DAS) and once in a month later on. The dry plots were not irrigated again until 40 DAS.

Wheat growth parameter

Four central rows were harvested in each subplot and sun dried and bundles were weighed and its biological yield was converted into kg ha^{-1}. Small wheat thresher was used for threshing the biological yield taken from four central rows in each sub plot. After threshing the grains were weighed by balance and were converted to kg ha^{-1}, Harvest index was calculated as the ratio of grain yield to the total biological yield.

Soil and plant analysis

Soil nitrogen was estimated by [13] method. 0.2 g soil sample and 1.1 g digestion mixture was taken in flask; conc.H2SO4 (3-4ml) was added to it. Keep this flask on hot plate under flame hood for digestion until the mixtures turned in to greenish. Distilled water was added to make volume up to mark. 10ML of digest was taken in the tube along with 4 ml of 40% NaOH for distillation. 5ml boric acid solution and few drop of indicator were added to it. Then titrate against o.oo5N HCl till pink color appeared.Grain and straw nitrogen were also estimated by same procedure as for soil nitrogen. The difference was that we used 0.5 g of both grain and straw samples instead of 0.2 g.

Statistical analysis

The data were statistically analyzed using the procedure appropriate for RCB design with split plot arrangement upon obtaining significant F-values. The least significant difference (LSD) test was applied for the comparison of treatment means at 5% level of probability [14].

Results and discussion

Grain yield (kg ha^{-1})

Data regarding grain yield of wheat is given in (Table 2). Analysis of the data revealed that moisture levels (M), nitrogen levels (N) and seed priming (P) significantly affected grain yield of wheat. Higher grain yield was obtained at 100 kg N ha^{-1} (4173.7 kg ha^{-1}) followed by N level of 50 kg N ha^{-1} (3316.2 kg ha^{-1}). Minimum grain yield (3036.7 kg ha^{-1}) was obtained at 0 kg N ha^{-1}. Seed priming improved grain yield. Higher grain yield of 3665.4 and 3457.2 kg ha^{-1} were recorded for P primed and water soaked seed respectively. Lower grain yield was recorded for not primed seed (3403.9 kg ha^{-1}). The interaction of all the factor were non-significant in grain yield of wheat.

These results are in disagreement with Pandey *et al.* [15] who found linear response between number of irrigations and grain yield. These results are in agreement with Ortiz Monasterio *et al.* [16] who reported that N application increased biomass and grain yield of the crop. Ghosh *et al.* [17] reported higher grain yield for priming as compared to control. Seed priming with water alone is also effective in substantially increasing yields of maize [18].

Table 2. Grain yield (kg ha^{-1}) of wheat as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture		N x P
		Low	High	
		N x P x M		
	Un-primed	3174.9	2974.9	3074.9
0	Water Primed	2825.0	2825.0	2825.0
	0.2 P% Primed	2985.1	3435.2	3210.1
	Un-primed	3493.7	3707.1	3600.4
50	Water Primed	3337.7	3174.9	3256.3
	0.2 P% Primed	3358.8	2825.0	3091.9
	Un-primed	3111.1	3961.5	3536.3
100	Water Primed	3970.6	4610.1	4290.3
	0.2 P% Primed	3903.6	5485.1	4694.3
		N x M		N
0		2995.0	3078.3	3036.7 c
50	------	3396.7	3235.7	3316.2 b
100		3661.8	4685.6	4173.7 a
		P x M		P
	Un-primed	3259.9	3547.8	3403.9 c
------	Water Primed	3377.8	3536.6	3457.2 b
	0.2 P% Primed	3415.8	3915.1	3665.4 a
Mean		3351.2 b	3666.5 a	

LSD for N at $P \leq 0.05$ = 215.23
LSD for P at $P \leq 0.05$ =215.23
LSD for M at $P \leq 0.05$ = 29.76
LSD for N x P at $P \leq 0.05$ = NS
LSD for M x N at $P \leq 0.05$ = NS
LSD for M x P at $P \leq 0.05$ = NS
LSD for M x N x P at $P \leq 0.05$ = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Biological yield (kg ha^{-1})

Data regarding biological yield of wheat are given in (Table 3). Analysis of the data revealed that nitrogen levels and seed priming significantly affected biological yield of wheat. The effect of moisture was not significant. Biological yield increased with increasing level of N. Higher biological yield was obtained at 100 kg N ha^{-1} (11355.4 kg ha^{-1}) followed by N level of 50 kg N ha^{-1} (10363.3 kg ha^{-1}). Minimum biological yield (9558.8 kg ha^{-1}) was obtained at 0 kg N ha^{-1}. Seed priming improved biological yield. Higher biological yield of 10760.8 kg ha^{-1} was recorded for 0.2% P primed seed followed by water primed seed which gave biological yield of 10352 kg ha^{-1} while not primed seed resulted in lower biological yield (10160.2 kg ha^{-1}).

These results are dissimilar with Tahmasabi *et al*. [19] who reported that biological yield increased as number of irrigations increased. The results are similar with Zubair *et al*. [20] who stated that higher N levels increased vegetative growth which enhanced biological yield. These results endorse the findings of Basra *et al*. [21] and Rashid *et al*. [22] who reported that primed seed significantly increased total biomass and dry weight as compared to control line.

Table 3. Biological yield (kg ha^{-1}) of wheat as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture: Low	Moisture: High	N x P
		N x P x M		
	Un-primed	8633.9	10599.0	9616.4
0	Water Primed	10942.2	8889.1	9915.6
	0.2 P% Primed	11259.3	6996.4	9127.8
	Un-primed	11796.4	10276.0	11036.2
50	Water Primed	10215.8	9433.8	9824.8
	0.2 P% Primed	10115.7	10347.9	10231.8
	Un-primed	8633.9	11022.3	9828.1
100	Water Primed	10942.2	11688.8	11315.5
	0.2 P% Primed	11259.3	14586.0	12922.7
		N x M		N
0		10278.4	8828.2	9553.3 c
50	------	10709.3	10019.2	10364.3 b
100		10278.4	12432.4	11355.4 a
		P x M		P
	Un-primed	9688.0	10632.4	10160.2 c
------	Water Primed	10700.1	10003.9	10352.0 b
	0.2 P% Primed	10878.1	10643.4	10760.8 a
Mean		10422.1	10426.6	

LSD for N at $P \leq 0.05$ = 745.67
LSD for P at $P \leq 0.05$ = 745.67
LSD for M at $P \leq 0.05$ = 338.77
LSD for N x P at $P \leq 0.05$ = NS
LSD for M x N at $P \leq 0.05$ = NS
LSD for M x P at $P \leq 0.05$ = NS
LSD for M x N x P at $P \leq 0.05$ = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Harvest index (%)

Data regarding harvest index of wheat are given in (Table 4). Analysis of the data showed that the effects of moisture and nitrogen levels were significant. While effects of priming and all the interactions were not significant. Among moisture levels maximum harvest index (35.2 %) was recorded at high moisture level as compared to low level of moisture. Higher harvest index was recorded for 100 kg N ha^{-1} (36.8%) which was statistically similar with 50 kg N ha^{-1} (35.1%) whereas minimum harvest index was calculated for 0 kg N ha^{-1} (29.4%).

These results are dissimilar with Ahmad *et al*. [23] who stated that number of irrigations increased harvest index. These results are also in disagreement with Akhtar [24] who stated that harvest index was significantly affected by nitrogen levels. Likewise, Shatab and Shad [25] also reported that harvest index increased with P priming.

Table 4. Harvest index (%) of wheat as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture		N x P
		Low	High	
		N x P x M		
	Un-primed	27.0	29.0	28.0
0	Water Primed	27.7	30.0	28.8
	0.2 P% Primed	29.7	33.3	31.5
	Un-primed	33.3	35.0	34.2
50	Water Primed	33.7	35.7	34.7
	0.2 P% Primed	32.3	40.3	36.3
	Un-primed	36.0	36.0	36.0
100	Water Primed	36.3	39.4	37.9
	0.2 P% Primed	35.3	37.7	36.5
		N x M		N
0		28.1	30.8	29.4 c
50	------	33.1	37.0	35.1 b
100		35.9	37.7	36.8 a
		P x M		P
	Un-primed	32.1	33.3	32.7
------	Water Primed	32.6	35.0	33.8
	0.2 P% Primed	32.4	37.1	34.8
Mean		32.4 b	35.2 a	

LSD for N at $P \leq 0.05$ = 1.79
LSD for P at $P \leq 0.05$ =NS
LSD for M at $P \leq 0.05$ = 3.20
LSD for N x P at $P \leq 0.05$ = NS
LSD for M x N at $P \leq 0.05$ = NS
LSD for M x P at $P \leq 0.05$ = NS
LSD for M x N x P at $P \leq 0.05$ = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Soil nitrogen (%)

Data regarding soil nitrogen of wheat are given in (Table 5). Analysis of the data showed that the effects of moisture, nitrogen and seed priming were significant while all the interactions were not significant. Maximum soil nitrogen was recorded for high moisture plots (0.036%) as compared to low moisture plots (0.033%). Nitrogen level increased number of soil nitrogen. Higher soil nitrogen was recorded for 100 kg N ha^{-1} (0.038%) followed by 50 kg N ha^{-1} (0.034) and 0 kg N ha^{-1} (0.030%). Higher soil nitrogen were recorded for 0.2% P primed seed (0.038%) followed by water soaked seed (0.035%) and dry seed (0.030%).

These result are similar with [26] who reported that priming affects in soil rich C and N are larger than those in poor soil.

Straw nitrogen (%)

Data regarding number of straw of wheat are given in (Table 6). Analysis of the data showed that nitrogen level and seed priming significantly affected the straw nitrogen while moisture level and all interactions were found non-significant. Straw nitrogen increased with increasing level of nitrogen. Maximum straw nitrogen was recorded for 100 kg N ha^{-1} (0.39%) followed by 50 (0.35%) and 0 kg N ha^{-1} (0.33%). Seed priming improved straw nitrogen. Higher straw nitrogen was recorded for 0.2% P primed seed (0.39%) which was statistically similar with water soaked seed treated plots (0.36%) while minimum straw nitrogen was noted in dry seeded plots (0.32%).

These results were similar to Khan [27] who concluded that increasing rates of nitrogen (0 to 143.4 kg ha^{-1}) increased straw yield and plant height but delayed maturity.

Grain nitrogen (%)

Data regarding grain nitrogen of wheat are given in (Table 7). Analysis of the data revealed that moisture, nitrogen and seed priming significantly affected grain nitrogen while the interaction were found non-significant. Maximum grain nitrogen was produced by high moisture plots (1.49%) as compared to low moisture plots (1.45%). Grain nitrogen increased with increasing level of nitrogen. Maximum grain nitrogen was recorded for 100 kg N ha^{-1} (1.52%) followed by 50 (1.47%) and 0 kg N ha^{-1} (1.42%). Seed priming also improved grain nitrogen. Higher grain nitrogen was recorded for 0.2% P primed seed (1.51%) which was statistically similar with water soaked seed (1.49%) while less grain nitrogen was documented in dry seeded plots which gave (1.41%) grain nitrogen.

These results were similar to Awasthi and Bhan [28] who concluded that the application of the highest N rate of 60 kg ha^{-1} gave maximum grain nitrogen, net returns and nitrogen use efficiency. Brain et al. [29] also reported an increase in grain protein with N level

Table 5. Post-harvest soil nitrogen (%) as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture		N x P
		Low	High	
		N x P x M		
	Un-primed	0.021	0.035	0.028
0	Water Primed	0.026	0.037	0.032
	0.2 P% Primed	0.029	0.033	0.031
	Un-primed	0.032	0.030	0.031
50	Water Primed	0.033	0.032	0.033
	0.2 P% Primed	0.044	0.036	0.040
	Un-primed	0.031	0.033	0.032
100	Water Primed	0.043	0.039	0.041
	0.2 P% Primed	0.041	0.044	0.042
		N x M		N
0		0.025	0.035	0.030 c
50	------	0.036	0.033	0.034 b
100		0.038	0.039	0.038 a
		P x M		P
	Un-primed	0.028	0.033	0.030 c
------	Water Primed	0.034	0.036	0.035 b
	0.2 P% Primed	0.038	0.038	0.038 a
Mean		0.033 b	0.036 a	

LSD for N at $P \leq 0.05 = 0.0035$
LSD for P at $P \leq 0.05 = 0.0035$
LSD for M at $P \leq 0.05 = 0.002$
LSD for N x P at $P \leq 0.05$ = NS
LSD for M x N at $P \leq 0.05$ = NS
LSD for M x P at $P \leq 0.05$ = NS
LSD for M x N x P at $P \leq 0.05$ = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Table 6. Straw nitrogen (%) of wheat as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture		N x P
		Low	High	
		N x P x M		
	Un-primed	0.28	0.36	0.32
0	Water Primed	0.30	0.38	0.34
	0.2 P% Primed	0.29	0.33	0.31
	Un-primed	0.32	0.30	0.31
50	Water Primed	0.34	0.33	0.33
	0.2 P% Primed	0.45	0.37	0.41
	Un-primed	0.31	0.34	0.33
100	Water Primed	0.44	0.40	0.42
	0.2 P% Primed	0.42	0.45	0.44
		N x M		N
0		0.29	0.36	0.33 b
50	------	0.37	0.34	0.35 b
100		0.39	0.40	0.39 a
		P x M		P
	Un-primed	0.31	0.33	0.32 b
------	Water Primed	0.36	0.37	0.36 a
	0.2 P% Primed	0.39	0.39	0.39 a
Mean		0.35	0.36	

LSD for N at P ≤ 0.05 = 0.032
LSD for P at P ≤ 0.05 = 0.032
LSD for M at P ≤ 0.05 = NS
LSD for N x P at P ≤ 0.05 = NS
LSD for M x N at P ≤ 0.05 = NS
LSD for M x P at P ≤ 0.05 = NS
LSD for M x N x P at P ≤ 0.05 = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Table 7. Grain nitrogen (%) of wheat as influenced by moisture, N levels and seed priming

Nitrogen (kg ha^{-1})	Priming	Moisture		N x P
		Low	High	
		N x P x M		
	Un-primed	1.24	1.49	1.36
0	Water Primed	1.42	1.51	1.47
	0.2 P% Primed	1.42	1.46	1.44
	Un-primed	1.38	1.43	1.41
50	Water Primed	1.46	1.46	1.46
	0.2 P% Primed	1.58	1.50	1.54
	Un-primed	1.44	1.47	1.45
100	Water Primed	1.56	1.53	1.55
	0.2 P% Primed	1.54	1.58	1.56
		N x M		N
0		1.36	1.48	1.42 c
50	------	1.47	1.46	1.47 b

100		1.51	1.52	1.52 a
		P x M		P
	Un-primed	1.35	1.46	1.41 b
------	Water Primed	1.48	1.50	1.49 a
	0.2 P% Primed	1.51	1.51	1.51 a
Mean		1.45 b	1.49 a	

LSD for N at P ≤ 0.05 = 0.036
LSD for P at P ≤ 0.05 = 0.036
LSD for M at P ≤ 0.05 = 0.042
LSD for N x P at P ≤ 0.05 = NS
LSD for M x N at P ≤ 0.05 = NS
LSD for M x P at P ≤ 0.05 = NS
LSD for M x N x P at P ≤ 0.05 = NS

Mean values followed by different letters in each category are significantly different at 5% level of probability using LSD test

Conclusion and recommendations

It was evident from our findings that high moisture (seedbed), N application at the rate of 100 kg N ha^{-1} and 0.2% P primed seed improved wheat yield and nitrogen uptake as compared to the rest of treatments combinations. That's why, N application at the rate of 100 kg ha^{-1} and 0.2% P seed priming at high moisture is strongly recommended for improving productivity and nitrogen content of wheat in Peshawar region.

Authors' contributions

Conceived and designed the experiments: IA Mian, MW Muhammad, S Fahad & M Adnan, Performed the experiments: M Abbas, B Muhammad, M Romman, S Iqbal, B Khan & Hajira, Analyzed the data: F Wahid, F Subhan & M Noor, Contributed materials/ analysis/ tools: B Saeed, K Rehman, M Arshad, R Perveez & S Andaleeb, Wrote the paper: IA Mian, M Adnan & M Abbas.

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