Response of wheat to application methods of nitrogen, seed priming and irrigation under saline conditions

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Flood irrigation and broadcast application of nitrogenous fertilizers for wheat is wastage of precious inputs, promoter of weed infestations and major causes of low yields in Pakistan. For this hypothesis, controlled irrigation (60, 70 and 80% MAD-Management Allowed Depletion), nitrogen applications (broadcast and placement with 60, 90 and 120 kg urea ha^{-1}), and seed priming (control, hydro priming and seed priming with 100 g Poly Ethylene Glycol per liter of water) were tested on wheat variety Pir-Sabak 2015 at Charsadda, Swabi and Kohat of Khyber Pakhtunkhwa-Pakistan during 2017-19. Wheat yield parameters were positively correlated with controlled irrigation, placement nitrogen application and seed priming. Emergence, grains per spike, grains weight, spikes per m^2, grain yield, leaf area, specific leaf area, leaf area ratio and crop growth rate were highest for.70% MAD irrigation, placement application of 90 kg urea per hectare and seed priming (hydro and osmo priming). Yield parameters of wheat were declined with either 60 and 80% MAD, broadcast urea application and null seed priming.

Keywords: Irrigation, fertilizer methods, soil types, seed treatment, cereals

INTRODUCTION

Water application through flood irrigation system results in far more available water than optimum which enhances vegetative growth and controversially decreases duration for grain filling and maturity. In addition it favors environment for weeds, crop diseases and insect/pests attacks. Excess water may also function to leaching out of nitrogen from root zones. Flood irrigation system for wheat crop caused water logging and salinity (Jamali and Laghari, 2019). Bed planting of wheat saved significant amount of irrigation water and also increased wheat yield as compared with conventional irrigation method (Hussain et al., 2017). Higher crop productivity (24.95%) and irrigation water productivity (19.5%) achieved with subsurface drip irrigation contrast to flooding (Umair et al., 2019). Literature across the world suggested that there should be a strategic water application method for wheat crop to gain maximum yield and profit. The aim of these strategies could be achieved with controlled application of irrigation water. Management allowed depletion (MAD) is one of them as this technique does not require installations of expensive hardware but does need some skills.

Nitrogen application with proper methods at right growth stage of wheat play vital role. In Pakistan most farmers practice broadcast instead placement method. A primary defective method of fertilizer application that promotes weed infestation and associated insects, pests, and diseases. In addition, seed priming enhances emergence and stand establishment. Seed priming allow deoxyribonucleic acid mitosis (Bray et al., 1989), increase protein formation (Ibrahim et al., 1983; Fu et al., 1988), adenosine triphosphate availability (Mazor et al., 1984), seed coat rupture (Dahal et al., 1990), minimized seed deterioration (Saha et al., 1990), waste of food reserves (Styer and Cantliffe, 1983) and successful in wheat yield (Harris et al., 2001). The objectives of our research are to optimize the application method of irrigation water and Nitrogen based fertilizer through MAD and placement method with aspects of seed priming.

MATERIAL AND METHODS

Experiments were conducted at three zones of Khyber Pakhtunkhwa, Pakistan as given in the given below with location coordinates, mean annual rainfall, high/low temperature during summer/winter and soil type.

Table 1 Illustration of experimental sites.

Location	North latitudes	East longitudes	rainfall	Summer High/Low Temperature (°C)	Winter High/Low Temperature (°C)	Sand	Silt	Clay	Soil Type
Charsadda	34-03' and 34-38'	71-28' and 71-53'	132 mm	41/ 26	19/ 5	52.4	43	4.6	Sandy loam
Swabi	34° 7′ 0	72° 28′ 0	639 mm	39.5/27.5	18/5	30.31	43.93	26.22	loam
Kohat	32° 47' and 33° 53'	70° 34' and 72° 17'	303 mm	38.1/28.7	15.6/7.4	29.58	37.42	33	Clay loam

Land Preparation: The field was thoroughly prepared with mould board plough and soil cutter to loosen hard debris with special emphasis on field leveling.

Treatment Application: For the experimental purpose wheat variety Pirsabak 2015 studied during 2017-19. Experiments were planted according to Randomized Complete Block Design having three replications to evaluate seed priming [Control, Hydro priming (HP) and Poly ethylene Glycol with 100 gm L^{-1} of water (PEG)], nitrogen managements [60, 90, 120 Kg urea ha^{-1} as broadcast (BC) and placement method (PM)] and water quantity through irrigation with 60, 70 and 80% management allowed depletion technique (MAD).

***Seed Priming*:** Priming was achieved either with tape water and 100 g Poly Ethylene Glycol (PEG) per liter of water for 24 hours at room temperature. Seeds were then placed under shade to firmly dry out before sowing.

***Urea application*:** Urea is a nitrogenous fertilizer and contains 46% nitrogen. It was applied both as broadcast (BC) and placement method (PM). PM was applied in rows during sowing and at first irrigation in two split dozes. In BC the urea was applied to the entire field as broadcast in two split dozes at sowing and at first irrigation.

***Irrigation Application*:** Irrigation was applied with management allowed depletion (MAD) technique at tillers (jointing), head and milky stages with field depths of 30, 70 and 100 cm respectively. Flume was used to measure discharge of water with stopwatch to determine time of irrigation with the given formula.

$$\text{Time (sec)} = \frac{\text{Area of the field (A)} \times \text{Depth of root zone (d)}}{\text{Discharge of water (Q)}}$$

Management allowed depletion (MAD) was implemented according to soil type, discharge of water and stage of crop. Soil moisture content measured before application of irrigation for irrigation adjustments. The field area was thoroughly leveled for smooth irrigation.

Yield Parameters: Wheat attributes contributing to yield were recorded as follow methods.

$$\text{Emergence/Spikes m}^{-2} = \frac{\text{Number of Plant counted}}{\text{R-R distance (m)} \times \text{row length (m)} \times \text{No. of rows}}$$

Grains Spike^{-1} (GS): Grains from ten mature spikes were counted and averaged.

Grain Weight (GW): Thousand grains were weighed by electronic balance in grams.

Leaf Area (LA): Leaf area from five tillers measured with leaf area meter and averaged.

$$\text{Leaf Area Ratio (LAR)} = \frac{\text{Average leaf area (cm}^2\text{)}}{\text{Average tiller dry weight (g)}}$$

$$\text{Specific Leaf Area (SLA)} = \frac{\text{Average leaf area (cm}^2\text{)}}{\text{Average leaf dry weight (g)}}$$

$$\text{Crop Growth Rate (CGR)} = \frac{W2-W1}{T2-T1} \times \frac{1}{G.A}$$

W1 = Plants dry weight (g) at tillering/heading

W2 = Plants dry weight (g) at heading/maturity

T1 = Days to tillering/heading

T2 = Days to heading/maturity

$$\text{Grain yield (GY)} = \frac{\text{Grain yield (kg)} \times 10{,}000 \text{ m}^2}{\text{Row length (m)} \times \text{R-R distance (m)} \times \text{No. of rows}}$$

***Statistical Analysis*:** Data was statistically analyzed using Pearson computer software MStatc Test and means were compared using LSD test at 5% level of probability.

RESULTS

Wheat Yield Parameters**:** Highest emergence (80 seedlings m^{-2}), GS (56), GW of 35.91 g, spikes m^{-2} (286) and GY (3203 kg ha^{-1}) obtained for 90 kg urea ha^{-1} as PM. Lowest emergence of 70 seedlings m^{-2}, number of 46 GS, GW (30.03 g), number of 258 Spikes m^{-2} and GY (2649 kg ha^{-1}) was recorded for 60 kg urea ha^{-1} as BC. For irrigation maximum GS (55), 1000 GW (34.51 g), spikes m^{-2} (278) and GY (7179 kg ha^{-1}) recorded for 70% MAD. However minimum number of 49 GS^1 and GW (31.9 g) obtained for 60% MAD. And for 80% MAD lowest number of 267 spikes m^{-2} and GY of 2757 kg ha^{-1}. For seed priming maximum emergence (79 seedlings m^{-2}), GS (52), GW of 33.43 g and GY (3021 kg ha^{-1}) obtained for PEG seed priming. However, maximum 276 spikes m^{-2} recorded for hydro priming (Figure 1-3). For irrigation x seed priming, highest GS (57 and 56), GW (35.55 g and 35.19 g), spikes m^{-2} (284 and 283) noted respectively for PEG and hydro priming and maximum GY (3347 kg ha^{-1}) recorded for PEG seed priming under 70% MAD. Lowest GS (46), GW (31.53 g) obtained for the control under 60% MAD. While minimum spikes m^{-2} (263) GY (2688 kg ha^{-1}) noted for control under 80% MAD. For interaction irrigation x nitrogen management, highest GS (61), spikes m^{-2} (295) and GY (3574 kg ha^{-1}) recorded for 90 kg urea ha^{-1} with placement under 70% MAD. Lowest GS (45), spikes m^{-2} (255) and GY (2531 kg ha^{-1}) obtained for 60 kg urea ha^{-1} with broadcast under 80% MAD.

Leaf parameters**:** Maximum LA (79.57 cm^2) and SLA (308.48 cm^2 g^{-1}) attained for placement application of 90 kg urea ha^{-1} as compared to minimum LA (65.87 cm^2) and SLA (287.04 cm^2 g^{-1}) recorded for broadcast application of 60 kg urea ha^{-1}. Mean data concerning to irrigation proposed that highest LA of 76.27 $cm^{2,}$ LAR (22.87 cm^2 g^{-1}) and SLA (310.58 cm^2 g^{-1}) acquired with 70% MAD and lowest LA (71.06 cm^2), LAR (21.25 cm^2 g^{-1}), and SLA (286.94 cm^2 g^{-1}) noted for 80% MAD. With reference to seed priming maximal LA (74.9 cm^2), LAR (22.29 cm^2 g^{-1}) and SLA (301.68 cm^2 g^{-1}) attained with PEG seed priming as compared to minimal LA (69.4 cm^2), LAR (21.39 cm^2 g^{-1}) and SLA (293.37 cm^2 g^{-1}) attained for the control. Interaction of irrigation x seed priming proposed that highest LA (77.8 cm^2) for hydro priming while highest LAR (23.4 cm^2 g^{-1}) and SLA (314.7 cm^2 g^{-1}) obtained for PEG seed priming with 70% MAD. However lowest LA (65.5 cm^2) noted for 60% MAD, and LAR (20.8 cm^2 g^{-1}), SLA (283.9 cm^2 g^{-1}) for control plots under 80% MAD (Figure 1-4 and Table 2).

***Crop growth rate (g m^{-2} d^{-1})*:** Maximum crop growth rate from tillering-heading (CGR1) (13.34 g m^{-2} d^{-1}) and crop growth rate from heading-maturity (CGR2) (9.50 g m^{-2} d^{-1}) recorded for 90 kg urea ha^{-1} as placement. However minimum CGR1 (11.30 g m^{-2} d^{-1}) and CGR2 (8.08 g m^{-2} d^{-1}) noted for 60 kg urea ha^{-1} as broadcast. Irrigation managements revealed highest CGR1 (13.55 g m^{-2} d^{-1}) and CGR2 (9.32 g m^{-2} d^{-1}) obtained for 70% MAD while least CGR1 (11.13 g m^{-2} d^{-1}) and CGR2 (8.49 g m^{-2} d^{-1}) attained for 80% MAD. Seed priming maximal CGR1 (12.66 g m^{-2} d^{-1}) and CGR2 (9.00 g m^{-2} d^{-1}) obtained for PEG seed priming and minimal CGR1 (11.86 g m^{-2} d^{-1}) and CGR2 (8.65 g m^{-2} d^{-1}) attained for control. Interaction of irrigation managements x seed priming revealed that highest CGR1 of 13.8 g m^{-2} d^{-1} and CGR2 of 9.4 g m^{-2} d^{-1} recorded both for PEG priming under 70% MAD. In contrast lowest CGR1 of 10.70 g m^{-2} d^{-1} and CGR2 of 8.2 g m^{-2} d^{-1} noted for control under 80% MAD. Interaction of irrigation management x nitrogen managements revealed highest CGR1 (14.9 g m^{-2} d^{-1}) and CGR2 (10.1 g m^{-2} d^{-1}) produced by the application of 90 kg urea ha^{-1} with placement under 70% MAD. However least CGR1 (10.01 g m^{-2} d^{-1}) and CGR2 of 7.8 g m^{-2} d^{-1} observed for 60 kg urea ha^{-1} with broadcast under 80% MAD (Figure 1-5).

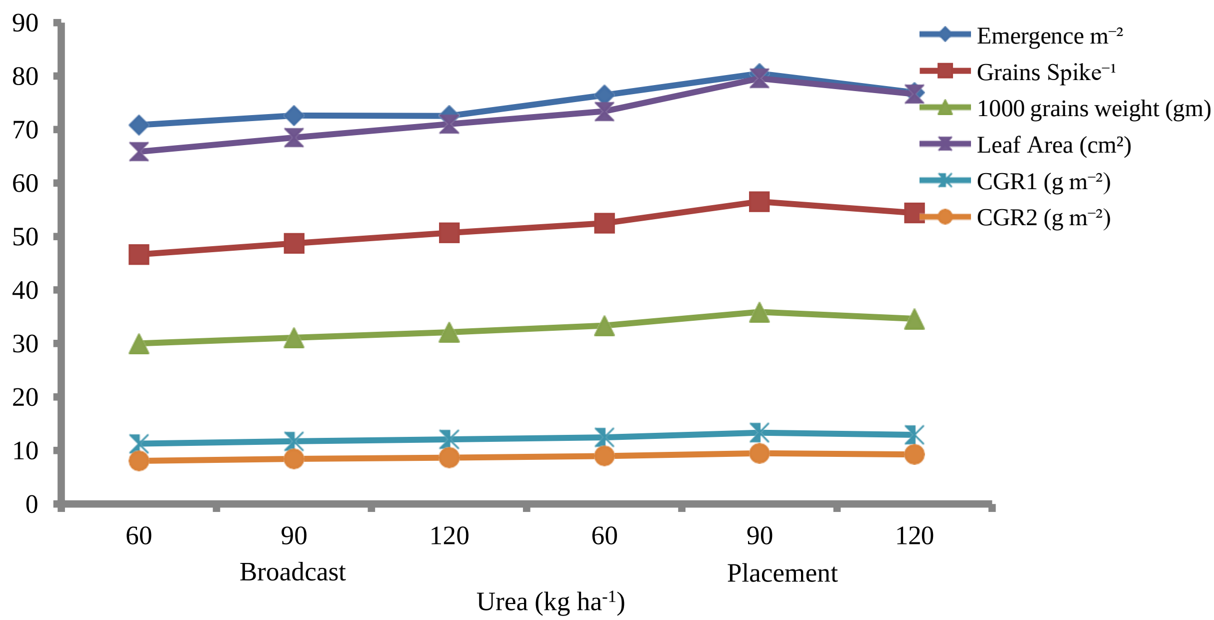

Figure 1 Effect of nitrogen managements on emergence m^{-2}, Grains Spike^{-1}, 1000 grains weight (gm), Leaf Area (cm^2), CGR1 (g m^{-2}) and CGR2 (g m^{-2}) of wheat.

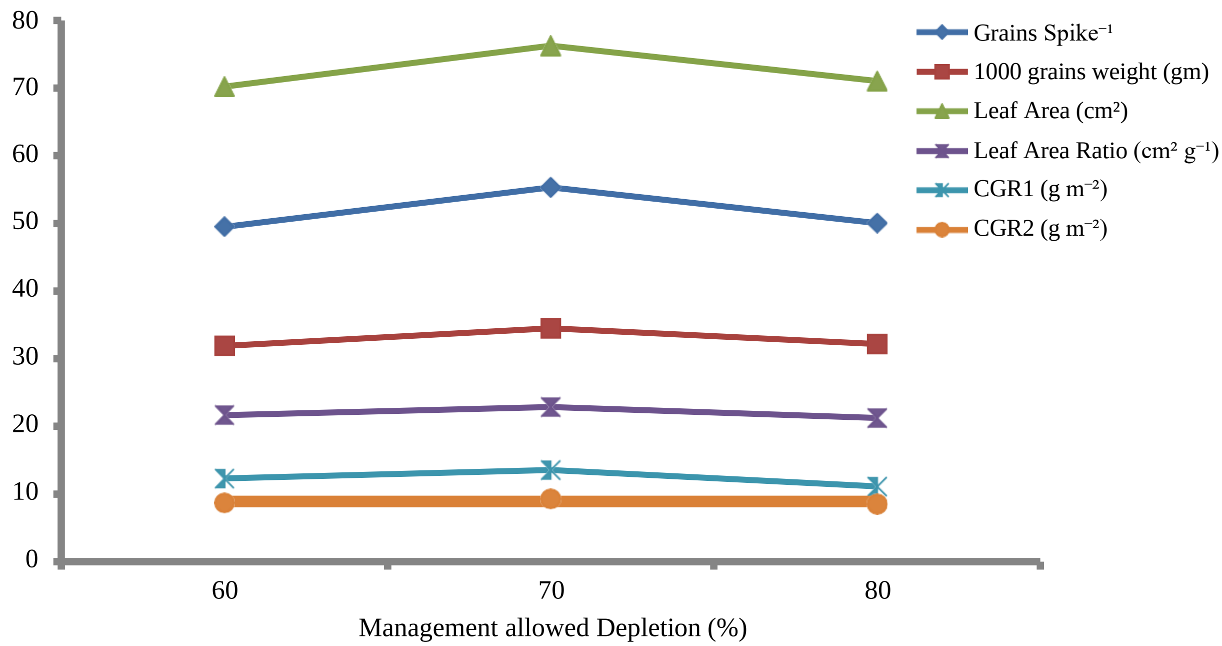

Figure 2 Effect of irrigation managements on Grains Spike^{-1}, 1000 grains weight (gm), Leaf Area (cm^2), Leaf Area Ratio (cm^2 g^{-1}), CGR1 (g m^{-2}) and CGR2 (g m^{-2}) of wheat.

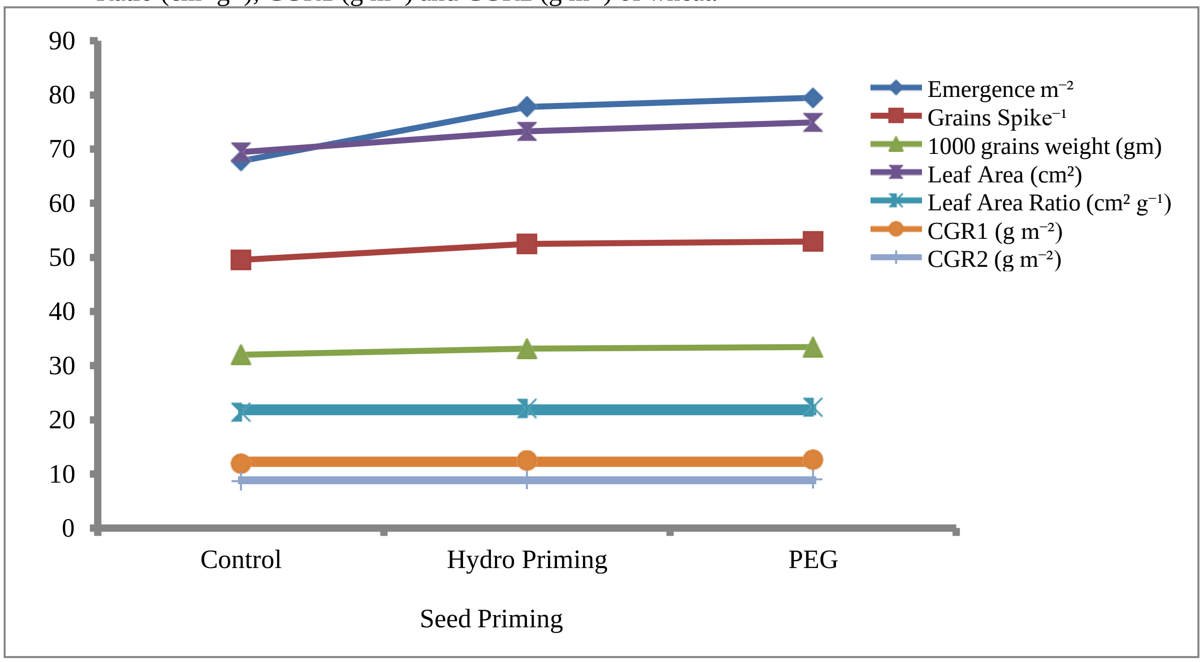

Figure 3 Effect of seed priming on Emergence m^{-2}, Grains Spike^{-1}, 1000 grains weight (gm), Leaf Area (cm^2), Leaf Area Ratio (cm^2 g^{-1}), CGR1 (g m^{-2}) and CGR2 (g m^{-2}) of wheat.

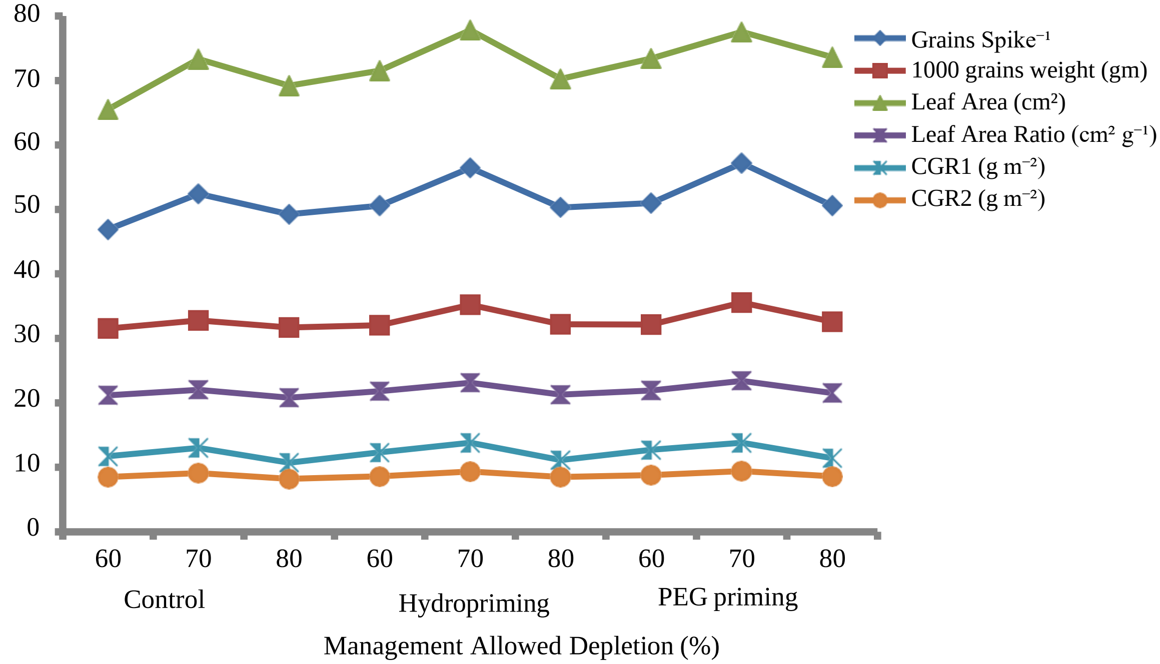

Figure 4 Interaction effects of seed priming and irrigation managements on Grains Spike^{-1}, 1000 grains weight (gm), Leaf Area (cm^2), Leaf Area Ratio (cm^2 g^{-1}), CGR1 (g m^{-2}) and CGR2 (g m^{-2}) of wheat.

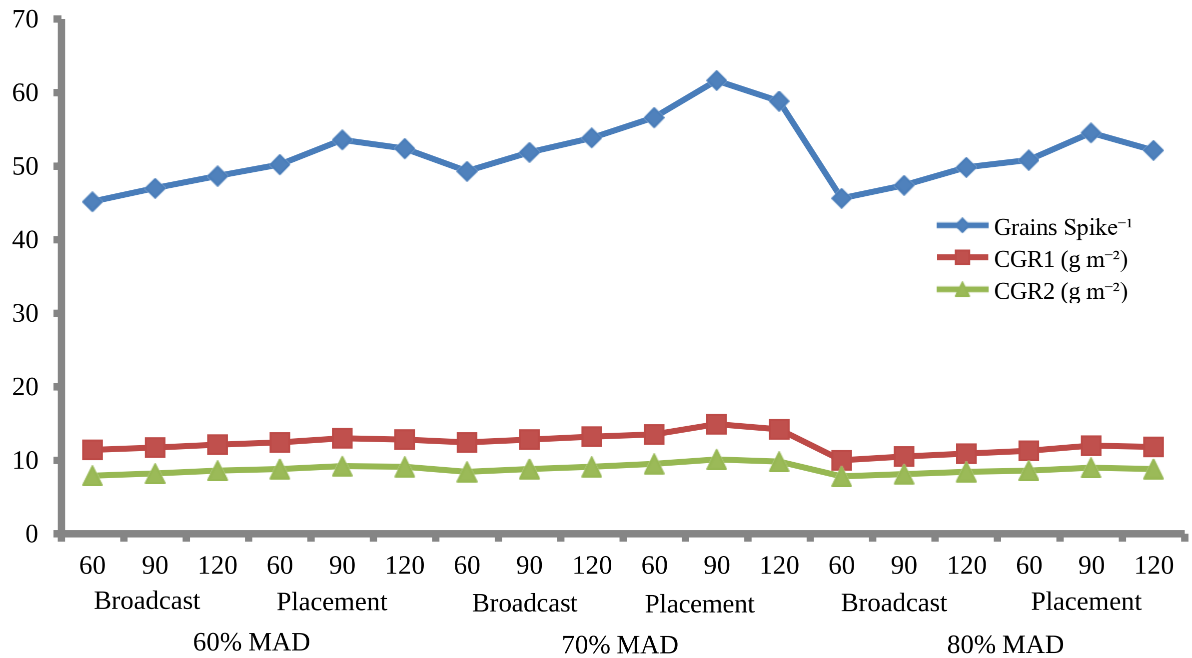

Figure 5 Interaction effects of nitrogen and irrigation managements on Grains Spike^{-1}, CGR1 (g m^{-2}) and CGR2 (g m^{-2}) of wheat.

Table 2 Effect of nitrogen managements, irrigation and seed priming on wheat parameters under saline conditions.

Parameters	Nitrogen Managements (urea kg ha⁻¹) Broadcast 60	Broadcast 90	Broadcast 120	Placement 60	Placement 90	Placement 120	LSD value at P<0.05
Spikes m⁻²	258.36	263.81	269.25	275.20	286.17	280.28	2.035
Specific Leaf Area (cm² g⁻¹)	287.04 f	291.47 e	295.41 d	300.07 c	308.48 a	304.49 b	2.00
Grain Yield (kg ha⁻¹)	2649 f	2756 e	2848 d	2963 c	3203 a	3087 b	32.65

Parameters	MAD% 60	MAD% 70	MAD% 80	LSD value at P<0.05
Spikes m⁻²	270.56	278.08	267.89	1.439
Specific Leaf Area (cm² g⁻¹)	295.96	310.58	286.94	1.418
Grain Yield (kg ha⁻¹)	2816.00	3179.00	2757.00	23.09

Parameters	Seed Priming Control	Hydro Priming	PEG	LSD value at P<0.05
Spikes m⁻²	264.78	276.54	275.22	1.439
Specific Leaf Area (cm² g⁻¹)	293.37	298.44	301.68	1.418
Grain Yield (kg ha⁻¹)	2761.00	2971.00	3021.00	23.09

Parameters	Control MAD% 60	Control MAD% 70	Control MAD% 80	Hydro priming MAD% 60	Hydro priming MAD% 70	Hydro priming MAD% 80	PEG MAD% 60	PEG MAD% 70	PEG MAD% 80
Spikes m⁻²	264.25	266.66	263.43	273.99	283.11	272.52	273.44	284.48	267.73
Specific Leaf Area (cm² g⁻¹)	290.90	305.20	283.90	296.00	311.70	287.50	300.90	314.70	289.30
Grain Yield (kg ha⁻¹)	2704	2890	2688	2838	3302	2774	2907	3347	2808

LSD value at P<0.05	
Spikes m⁻²	2.492
Specific Leaf Area (cm² g⁻¹)	2.456
Grain Yield (kg ha⁻¹)	39.99

DISCUSSIONS

Flood irrigation and broadcast application of fertilizers are the main methods amongst farmers of Pakistan. These primitive methods lead to leaching, erosion and weed infestations. Excess water and supplemental fertilizers application benefit weeds more as compared to main crop (Muhammadi et al., 2012).

Emergence, grains spike^{-1}, 1000 grains weight, spikes m^{-2} and grains yield were highest for 70% MAD, 90 kg placement nitrogen and seed priming with either tape water or PEG. These yield parameters of wheat were lowest for broadcast nitrogen application, 60 and 80% MAD and trials of no seed priming (Hassan et al., 2010; Ajirloo et al., 2013; Abbasdokht, 2010). In fact dried seeds (no priming) pass through imbibitions to start germination and will take couple of days.

Excess or deficient available water affects wheat crop simultaneously growth stages. Irrigation application at different management allowed depletion significantly affected wheat yield parameters (Keyvan and Kobraee, 2011).

Nitrogen management improved grains weight with placement method compared with the broadcast. With wheat breeding and weed infestation it becomes mandatory to control irrigation and nutrition in the cropping systems (Ali et al., 2011). Healthy shoot and root establishment help the plant to get high nutrition and photosynthetic efficiencies (Farooq et al., 2008).

Cultural practices of wheat are depended on controlled irrigations and fertilizer application methods. Flood irrigation and broadcast fertilizers would only be effective if the wheat crop grown for vegetative purpose. As flood irrigation prolong vegetative stage and time for grain filling and squeezed seed size obtained due to light and temperature signals.

In our trials broadcast was less effective compared with placement nitrogen method (Yousfi et al., 2019). Similarly seed priming had detrimental effect on grain yield of wheat in contrast to no seed priming (Jafar et al., 2016). It was evident from the results that flood irrigation retarded potential growth of wheat.

Placement nitrogen application and controlled irrigation through MAD enhanced LA, LAR and SLA. Seed priming minimized abiotic stresses on leaf area (Mirza et al., 2016; Razzaq et al., 2013). As early reported that SLA increased by different water application in wheat (Ahmad et al., 2005). Seed priming increased leaf protein and improved growth of wheat (Afzal et al., 2006).

Placement nitrogen proved best for gaining higher CGR of wheat (Bakhtiari et al., 2014). Efficient CGR between different growth stages is detrimental for gaining higher yields. The growth rate is directly depended on soil fertility and controlled irrigation. High quantity of irrigation water lowered water use efficiency and economic benefit (Sun et al., 2006).

***Conclusion*:** It could be concluded that hydro and osmopriming (PEG @100 g liter^{-1} of water) promoted yield attributes of wheat. As PEG is costly therefore, hydropriming may be preferred to lower inputs costs. Placement application of urea fertilizer @90 kg per hectare in two splits should be applied. Irrigation with 70% MAD (Management Allowable Depletion) should be applied at all critical growth stages of wheat for maximum yield attributes. As 60% MAD proved to be wastage of water and time. 80% MAD is shortage of irrigation to wheat crop. Control irrigation was found better strategy in terms of saving precious irrigation water. Broadcast application of urea fertilizer was found wastage of time, money, labor, promotion of weeds infestations followed by insects and pests as compared to placement method of urea fertilizer.

***Conflict of Interest*:** The Authors declare that there is no conflict of interest.

***Authors' Contribution Statements*:** Roohul Amin, Zahid Hussain, Shah Nawaz Khan and Rani Gul prepared hypothesis and performed actual field research. Ikramullah, Muhammad Ali, Wajid Ali Shah and Manzoor Ahmad worked on data compilation, analysis, tables and graphs.

Acknowledgement

The project was supported by Pakistan Agricultural Research Council, Islamabad, Pakistan under Agricultural Innovation Program (AIP) of CIMMYT funded by USAID during 2017-19. Field and experimental facilities were provided by the Bacha Khan University, Charsadda, Pakistan.

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