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SEED PRIMING: A POTENTIAL STRATAGEM FOR AMELIORATING SOIL WATER DEFICIT IN WHEAT

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Drought is one of the primary cause of reduced agricultural growth and yield in the world today. Therefore, present study was conducted to evaluate the potential of synthetic and natural priming agents in improving performance of drought sensitive (Millat-11) and tolerant (AARI-11) wheat cultivars under various irrigation deficit regimes. Seeds of both cultivars were primed with water (hydro), moringa leaf extract (MLE30), KCl (2%) and benzyl amino purine (BAP) (50 mg L^{-1}) along with on farm priming. Hydro-priming was kept as control. Irrigation soil water deficit regimes were comprised of without soil water deficit at crown root initiation (CRI), tillering (T), booting (B), and heading (H) stages (control) {CRI+T+B+H} and soil water deficits applied at {H}, {T+H}, {CRI+H}, {CRI+B}, {T+B} growth stages. Seeds primed with MLE30 and BAP significantly improved the grain yield. MLE30-priming showed maximum increase in the concentrations of antioxidant enzymes (SOD, POD, and CAT) and non-enzymes (AsA and TPC) under irrigation deficit imposed at (CRI+H) stage. Nevertheless, benefit cost ratio (BCR) also showed that the seed priming with MLE30 is an efficient and economical technique as compared to BAP, KCl, on farm and hydro priming in improving the productivity of wheat cultivar AARI-11 under all observed soil water deficit regimes. Ultimately, it is concluded that MLE30 is a natural and cost effective priming tool for maximizing wheat yield owing to its stress ameliorating potential.

Keywords: Priming agents, *Moringa* leaf extract, antioxidant, irrigation deficit, critical growth stages.

Abbreviations: MLE, *Moringa* leaf extract; BAP, benzyl amino purine; CRI, crown root initiation; T, tillering; B, booting; H, heading; LAI, leaf area index; SLAD, seasonal leaf area duration; CGR, crop growth rate; NAR, net assimilation rate; ROS, reactive oxygen species; SOD, super oxide dismutase; POD, peroxidase; CAT, catalase; AsA, ascorbic acid; TPC, total phenolic contents; chl., chlorophyll; BCR, benefit cost ratio.

INTRODUCTION

Wheat is an important cereal crop serving as staple food for more than 1/3rd of the world's population. But global climate change events have increased the frequency of drought spells leading to less harvest of the crop (Richards *et al.*, 2001). The soil water deficit conditions resulted in reduced chlorophyll contents, leaf area, number and weight of grains with poor grain set and development in wheat (Farooq *et al*., 2014). The extent of yield loss is directly related to the duration of water stress as well as crop growth stages. The soil water deficit at crown root initiation to milking growth stage caused 30-37% yield reduction in wheat as compared to normal irrigation at the said growth stages (Kahlown *et al*., 2003). Similarly, yield reduction of wheat in relation to mild to severe soil water deficit stress has been recorded up to 37% at booting to maturity (Shamsi *et al*., 2010), , 57% at heading (Balla *et al*., 2011), 18–53% at pre-anthesis (Majid *et al*., 2007), 11–39% at anthesis (Jatoi *et al*., 2011), 1–30 % at post-anthesis (Eskandari and Kazemi, 2010) and 9–78% at grain filling (Guoth *et al*., 2009) stages. However, it is a dire need to identify comparatively more critical pre and post anthesis growth stages of wheat for irrigation requirements under field conditions. The main aim of current study was to minimize yield reduction under limited supply of water with improved management practices.

Application of various agronomic and management strategies including increased seed rates (Coventry *et al*., 1993), screening of drought tolerant wheat varieties (Abdolshahi *et al*., 2012), change in planting time (Yan *et al*., 2008) and judicious management of available water resource by using modern technologies (Hussain and Shah, 2002) have been practiced to mitigate the adverse effects of soil water deficit . In recent years, adaptation of seed priming by farming community is one other major agronomic practice. Other advantages include environment friendly, time and cost efficient and more practicable approach. It is a pre-sowing treatment of seeds in which they are exposed to some chemical compounds (priming agent) and induce tolerance in plants against upcoming stress events during its growth and development (Beckers *et al*., 2006). Seed priming with polyethylene glycol (PEG), $CaCl_2$, KCl, NaCl and growth regulators such as salicylic acid, cytokinin, gibberellic acid (GA), and benzyl amino purine (BAP) has been proved to be a simplest and effective technology to improve wheat tolerance under stressed environments by modulating its antioxidant defense system (Farooq *et al*., 2014). This technique can further be improved with the application of a more cost effective priming agent natural in origin like *Moringa oleifera* leaf extract (MLE). Moringa leaf extract is an emerging natural plant growth promoter, having a rich reserve of zeatin (Makkar *et al*., 2007), cytokinin (Zhang and Ervin, 2008), total soluble protein, enzymatic and non-enzymatic antioxidants (Yasmeen *et al*., 2013). These antioxidants slow down the formation of highly toxic hydroxyl radicals, one of the reactive oxygen species (ROS), thereby improve the water use efficiency and protect wheat plants from cellular damage (Huseynova *et al*., 2010).

The present study was designed to unveil the effects of soil water deficit stress at pre and post-anthesis growth stages of wheat and ameliorating stress impact through different seed priming agents with increased economic returns.

MATERIALS AND METHODS

***Plant material*:** In a preliminary experiment, AARI-11 and Millat-11 proved to be tolerant and sensitive to drought, respectively (Nawaz *et al*., 2015). Therefore, in present study the potential of priming for invigoration of both varieties was tested under soil water deficit regimes in field conditions.

***Experimental layout* :** The experiment was conducted at the Experimental Area, Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan (71.43°E, 30.2°N and 122 m), Pakistan for two consecutive years (winter 2013-2014 and 2014-2015). Weather data for the both growing seasons was recorded (Fig. 1). The soil of experimental field was clay loam with EC_e, pH, organic matter, total nitrogen, available phosphorus, potassium and zinc (2.42 dS m^{-1}, 8.7, 0.85%, 0.055%, 5.52, 01.5 and 0.37 mg kg^{-1}), respectively, during both growing seasons. The experiment was laid out in randomized complete block design in factorial arrangement comprising of priming agents, wheat varieties and irrigation deficit regimes with a net plot size of 3 × 5 m^2 and replicated thrice. The crop was sown with single row hand drill during second fortnight of November during both years of the trial by using seed rate at 125 kg ha^{-1}. Fertilizers were applied at 120-100-62.5 kg NPK ha^{-1} using urea, single super phosphate and potassium sulfate, respectively. Whole of the phosphorus, potash and half nitrogen dose was incorporated in soil prior to sowing. Remaining half nitrogen was applied in 2 equal splits, each at first and second irrigation. Weeds were controlled through hand weeding.

***Seed priming*:** The priming techniques were detailed as hydro-priming (control), moringa leaf extract (MLE30-priming), KCl (2%) (osmo-priming), benzyl amino purine (50 mg L^{-1}) (BAP-priming), and overnight soaking (on farm priming). The seeds were soaked for priming treatments with seed: primer ratio (1:5) for 12 hours and dried at laboratory temperature for 6 hours (Nawaz *et al*., 2016).

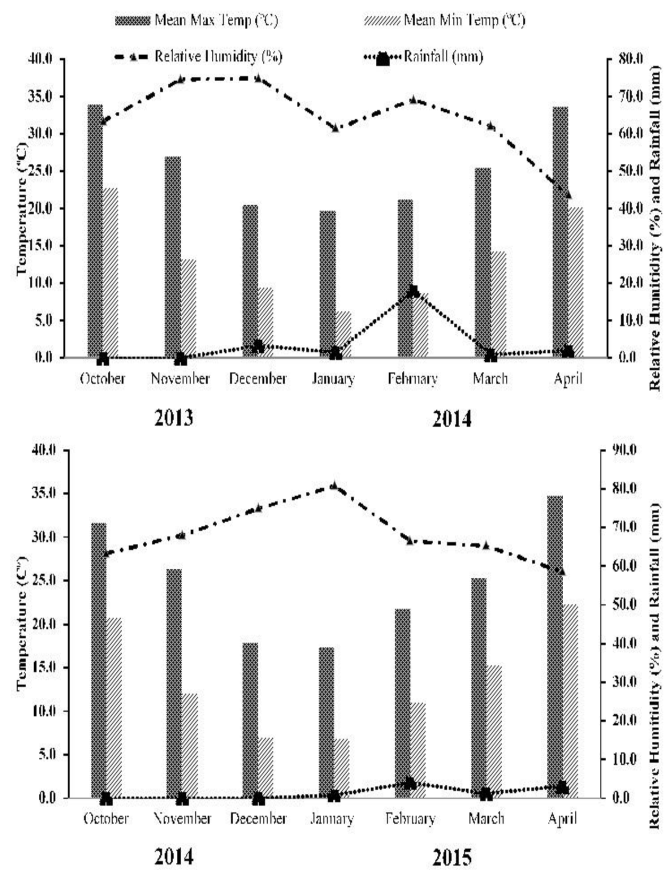

Figure 1. Meteorological data for growing period of crops during the year 2013-2014 and 2014-2015.

***Irrigation deficit regimes*:** The irrigation deficit regimes were designed based upon critical growth stages of wheat. These were comprised of no irrigation deficit at crown root initiation (CRI), tillering (T), booting (B), and heading (H) stages (control) and irrigation deficit at {H}, {T+H}, {T+B}, {CRI+H} and {CRI+B}.

***Enzymatic and non-enzymatic antioxidants*:** The sampling for biochemical attributes was done one week after the establishment of irrigation deficit. Sampled flag leaves were analyzed for antioxidant status. Total soluble proteins were quantified by following the protocol devised by Bradford (1976). For the determination of antioxidants, sample extraction in buffer followed by spectrophotometric estimation was performed. Phosphate buffer (pH 7) was used for extraction of leaf samples. Referred protocols were followed to determine peroxidase (POD), catalase (CAT), superoxide dismutase (SOD) (Giannopolitis and Ries, 1977), ascorbic acid (AsA) (Ainsworth and Gillespie, 2007) and total phenolic contents (TPC) (Waterhouse, 2001).

***Chlorophyll contents and mineral nutrients*:** Leaf chlorophyll "*a*" and "*b*" (Nagata and Yamashta, 1992) and potassium (K^+) contents (Rashid, 1986) were estimated using standard procedures.

***Plant stand establishment*:** Leaf area per plant (cm^2) was measured at 30, 40, 55, 75 days-after sowing (DAS) during the crop growth and development by using leaf area meter (CI-203, CID Inc., USA). Seasonal leaf area duration (SLAD), crop growth rate (CGR) and net assimilation rate (NAR) was determined following the procedure described by Hunt (1978). Formulas used are given below as:

Seasonal leaf area duration (SLAD) days:

$$SLAD = (LAI_1 + LAI_2) \times (T_2 - T_1) / 2$$

(Yasmeen *et al.*, 2012)

LAI_1= Leaf area index at first time in the crop growing season
LAI_2= Leaf area index at last time at crop maturity
Crop growth rate (CGR) ($g\ m^{-2}\ day^{-1}$)

$$CGR = (W_2 - W_1) / (T_2 - T_1)$$

(Yasmeen *et al.*, 2012)

W_1 = oven dried weight at first sampling
W_2 = oven dried weight at second sampling
T_1 = time of first sampling
T_2 = time of second sampling
Net assimilation rate (NAR) ($g\ m^{-2}\ day^{-1}$)

$$NAR = TDM/LAD$$

Where
TDM = Total dry matter accumulated (W_2 - W_1)

$$LAD = (LAI_1 + LAI_2) \times (T_2 - T_1) / 2)$$

(Yasmeen *et al.*, 2012)

***Yield and yield components*:** At maturity, the one square meter (1 m^2) area from each experimental unit was harvested manually during second fortnight of April. The plants were tied into bundles and weighed to record biological yield. These bundles were threshed manually to determine grain yield, number of grains per spike, 1000-grain weight and straw yield.

***Benefit cost ratio*:** To check and compare the economics for most cost effective priming technique the total expenditures including land rent, seedbed preparation, seed, sowing labor, fertilizers, irrigations, weeds control measures and harvesting charges of the crop were calculated. Gross income was calculated from the present market prices of wheat grains and straw in Pakistan. Net income was obtained by subtracting the total expenditure from gross income. Benefit to cost-ratio was estimated as a ratio of gross income to total expenditure.

***Statistical analysis*:** Data were computed and analyzed using Fisher's analysis of variance technique. The differences between mean values were compared following least significance difference at 5% probability level (Steel *et al.*, 1997).

RESULTS

Irrigation deficit regimes showed significant differences between the wheat cultivars (drought tolerant-AARI-11 and drought sensitive-Millat-11). Whereas, the exogenous application of different priming agents significantly improved the leaf area index (LAI) of wheat at these stressful conditions. The maximum LAI at 55 DAS was observed in AARI-11 with MLE30 application under control and {CRI+H} soil water deficit stress condition, during both years of the trial (Fig. 2). Likewise, seed priming in both cultivars under soil water deficit stress conditions at {CRI+H} and {CRI+B} stages improved SLAD as compared to control during both years of the study. AARI-11 cultivar with MLE30 priming treatment showed significantly higher values of SLAD under different irrigation deficit regimes (Fig. 3). Results showed linear increase in CGR till 75 DAS by the exogenous application of MLE30 in AARI-11 under soil water deficit condition at {CRI+H} during both years of the trial (Fig. 4). However, statistically similar results were observed for CGR between wheat cultivars and priming agents during both experimental years under all irrigation regimes (Fig. 4). Results depicted that seed priming agents positively promoted NAR of both wheat cultivars. Among various priming treatments, MLE30 and BAP performed better in increasing NAR of AARI-11 under control conditions, followed by soil water deficit levels i.e. at {H} and {CRI+H}during both years of the trial (Fig. 5).

The maximum TSP was obtained in MLE30 followed BAP-primed leaves of AARI-11 under irrigation deficit at

{CRI+H}, as compared to control during 2nd year of trial (Table 1). Exogenously applied priming agents also mitigated the water-deficit stress at the critical growth stages of wheat through the activation of enzymatic and non-enzymatic anti-oxidants. The greater amount of enzymatic antioxidants as SOD, POD, and CAT in AARI-11 were found under irrigation deficit treatment{CRI+H}by the application of MLE30 priming during the both years of trial. However, priming with H_2O, and KCl produced lowest activities of SOD, POD and CAT under control and soil water deficit at H stage during both years of study (Table 1-2). Drought-induced stress at {CRI+H} stages showed the maximum value of AsA and TPC, compared with other treatments (Table 2). Millat-11 showed the maximum AsA contents, owing to priming treatment with MLE30, BAP and KCl, under soil water deficit condition at {CRI+H} stages during first year of the trial (Table 2). However, higher values of TPC appeared in AARI-11 under water-stress level at {CRI+H} stages by the exogenous application of MLE30 and BAP during the year-II (Table 2).

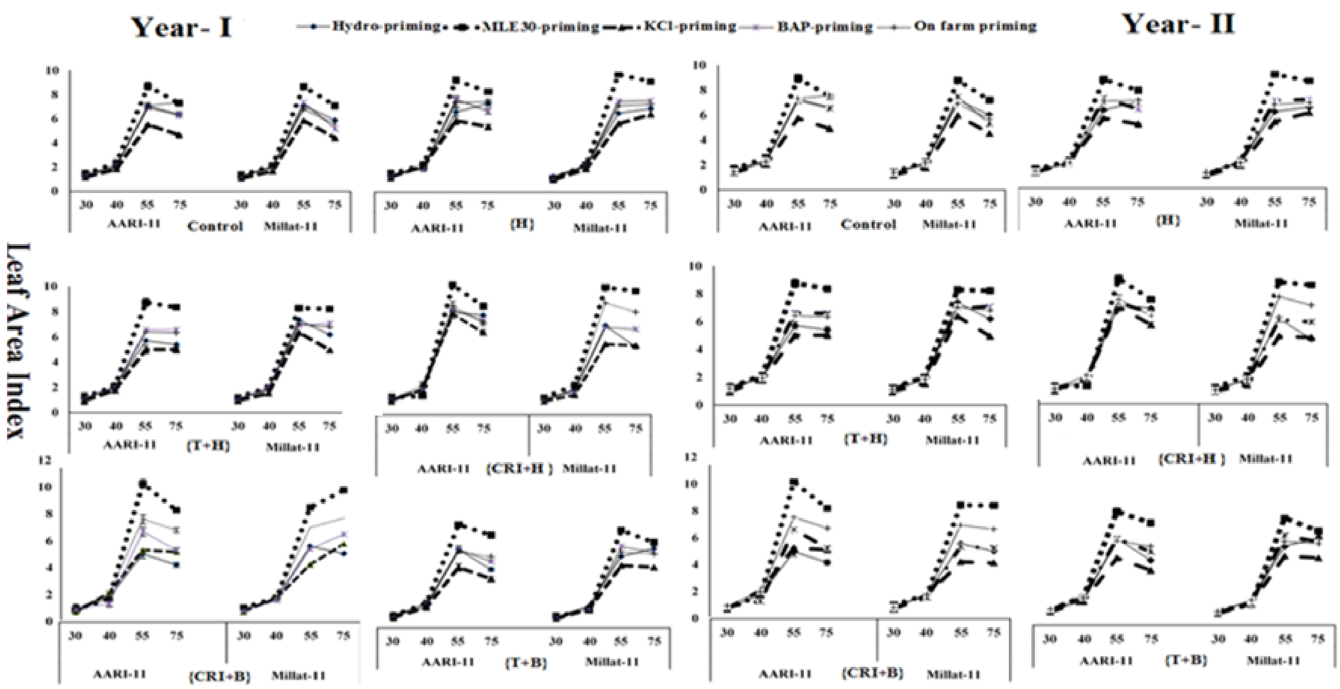

Figure 2. Influence of different seed priming agents on leaf area index (LAI) of wheat cultivars under applied irrigation soil water deficit conditions ±S.E during 2013-2014 (Year-I), 2014-2015 (Year-II) {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}.

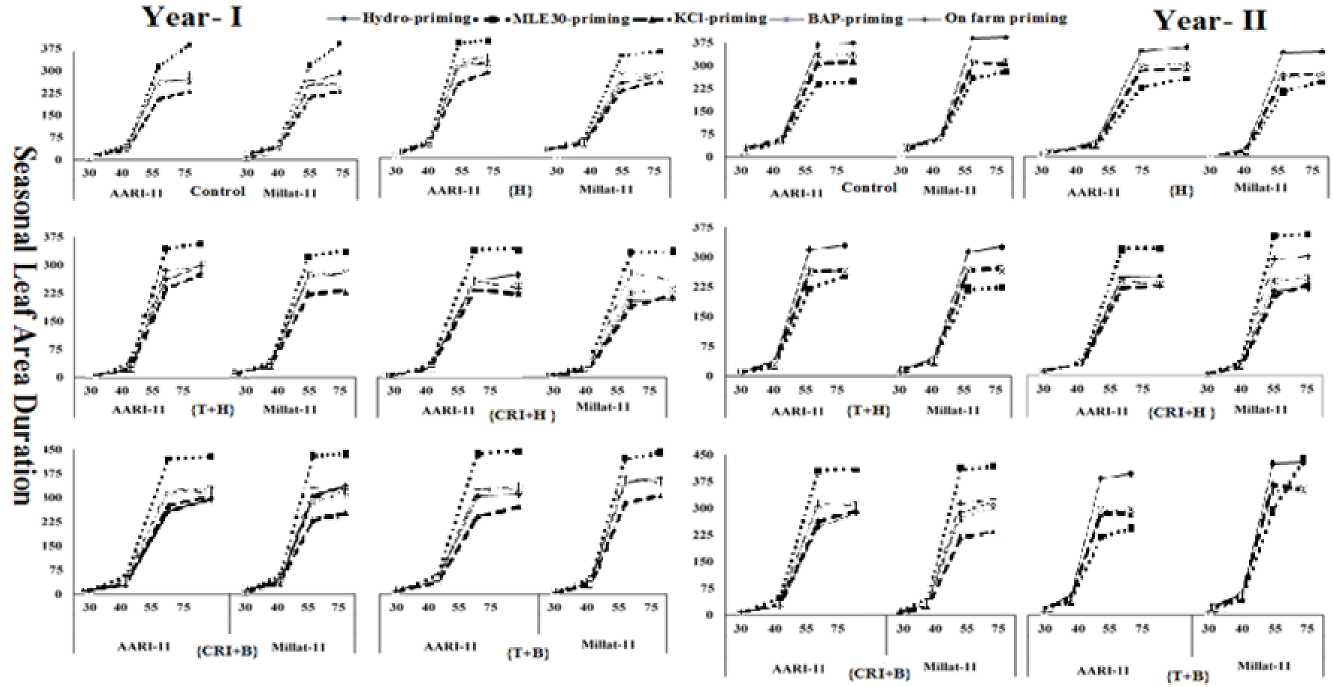

Figure 3. **Influence of different seed priming agents on seasonal leaf area duration (SLAD) (days) of wheat cultivars under irrigation soil water deficit conditions ±S.E during 2013-2014 (Year-I), 2014-2015 (Year-II) {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}.**

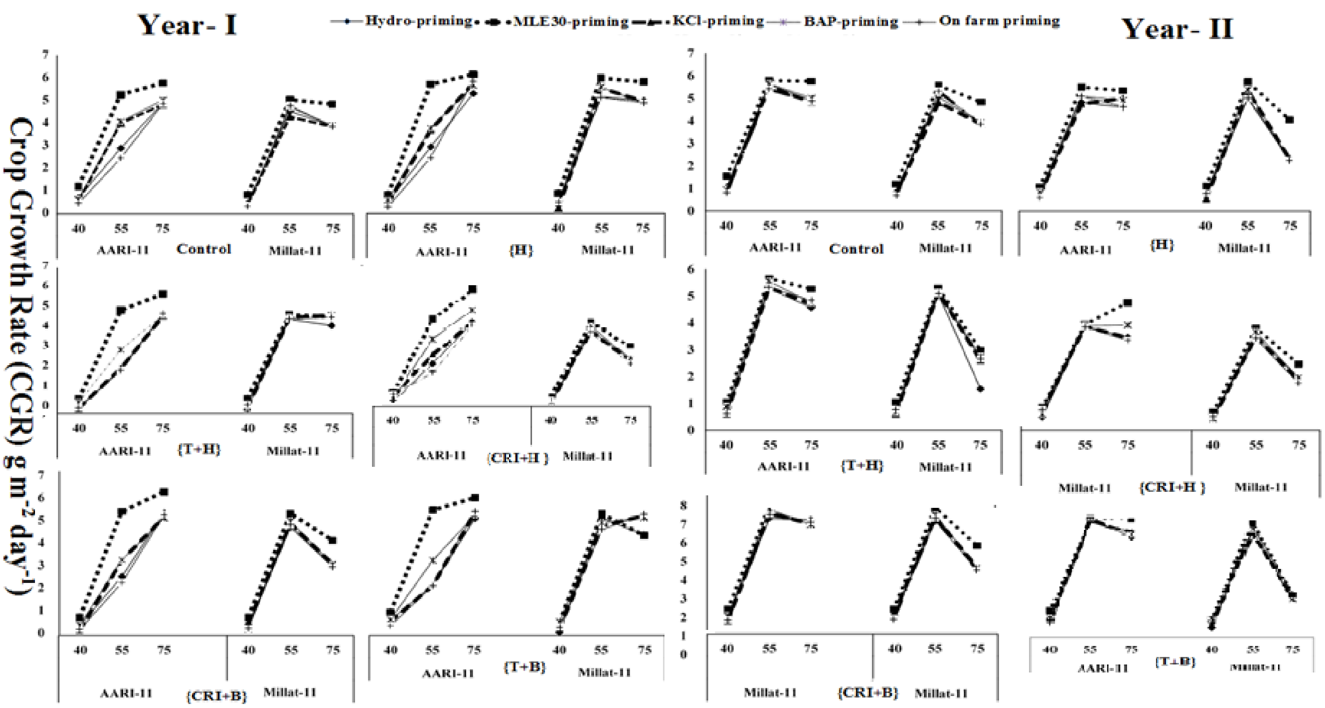

Figure 4. **Influence of different seed priming agents on crop growth rate of wheat cultivars under applied irrigation soil water deficit conditions ±S.E during 2013-2014 (Year-I), 2014-2015 (Year-II) {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}.**

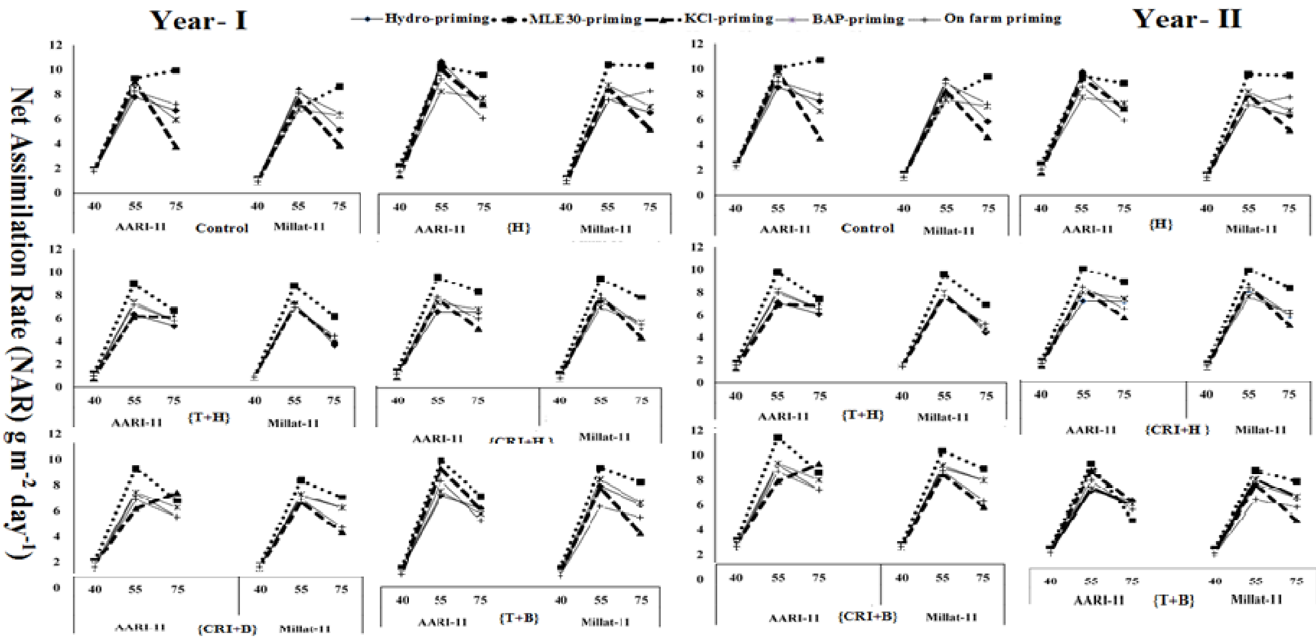

Figure 5. Influence of different seed priming agents on net assimilation rate of wheat cultivars under applied irrigation soil water deficit conditions ±S.E during 2013-2014 (Year-I), 2014-2015 (Year-II) {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}.

The interaction showed that cultivar AARI-11 produced maximum vales of chlorophyll contents ("*a*" and "*b*") under control followed by water stress levels at {H} and {CRI+H} stages (Table 3). However, interaction behaved differently during the second year trial, AARI-11 illustrated the highest values of chlorophyll ("*a*" and "*b*") under soil water deficit at heading stage {H}, as compared to control. (Table 3). The results regarding chlorophyll contents indicated that the same trait varied non-significantly as a function of experimental years (Table 3). The leaf K^+ contents in all priming treatments of both cultivars under different irrigation deficit regimes are presented in (Table 3). The results depicted that the maximum leaf K^+ contents were recorded for AARI-11 during year 2013-2014 and Millat-11 during experimental year 2014-2015. However, leaf K^+ contents under priming treatments i.e. MLE30 and BAP remained statistically at par under control level followed by water stress at {CRI+H} stages (Table 3).

The results illustrated that the interactive effect of fertile tillers and grains/spike, under irrigation deficit water-regimes for both wheat cultivars and exogenously applied priming agents, was significant during both the years of study (Table 4). The interaction depicted that MLE30 priming agent performed the best in AARI-11 cultivar for production of fertile tillers and number of grains/spike under control, followed by irrigation deficit at {H} and {CRI+H} stages (Table 4). The MLE30 application increased the 1000-grain weight of both cultivars under various soil water deficit regimes during both years of trial whereas (Table 4), maximum grain yield was harvested from MLE30 and BAP treatments (Table 5). However, the results depicted the significant interaction i.e. priming agents MLE30 and BAP improved the grain yield to certain extent in cultivar (AARI-11) under control, followed by {H} and {CRI+H}soil water deficit conditions during year-I and II (Table 5). Table 5 showed the non-significant result but among the priming treatment, MLE30 enhanced harvest index under the deficit irrigation water regimes (Table 5). However, interaction showed that priming with MLE30 and BAP performed better under water stress, especially at the critical growth stages {CRI+H} after control in AARI-11 by improving the biological yield during the both years of trial (Table 5). Table 6 showed the economic analysis among the priming agents and irrigation applications with average BCR of both cultivars, AARI-11 and Millat-11. Priming with MLE30 in wheat cultivar obtained maximum BCR at {CRI+H} irrigation deficit condition after control.

Table 1. Influence of different seed priming agents on total soluble protein (TSP), superoxide dismutase (SOD), peroxidase(POD) of wheat cultivars under applied water stress condition during 2013-2104 (Year-I), 2014-2015 (Year-II).

		Year-I											**Year-II**										
		Hydro-priming		**MLE30-priming**		**KCl (osmo-priming)**		**BAP-priming**		**On farm priming**			**Hydro-priming**		**MLE30-priming**		**KCl (osmo-priming)**		**BAP-priming**		**On farm priming**		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
TSP (mg g^{-1})	**Control**	0.78	0.14	1.55	1.74	0.35	0.89	0.59	1.68	0.40	0.12	**0.82c**	0.99s.u	0.36B	1.22i.k	0.52Z	1.05qr	0.34B	1.09o.q	0.42A	0.99s.u	0.35B	**0.73f**
	{H}	0.95	0.80	1.82	1.36	1.11	1.34	1.61	1.06	1.29	0.38	**1.17ab**	1.23ij	0.92v.y	1.44f	1.01r.t	1.07pq	0.89w.y	1.36g	0.98stu	1.17j.n	0.91v.y	**1.10d**
	{T+H}	0.89	0.57	1.99	1.48	0.55	0.46	1.56	1.21	0.81	1.07	**1.06bc**	1.03q.s	0.89w.y	1.06qr	0.94u.x	0.96t.v	0.88xy	1.05qr	0.91v.y	0.95u.w	0.86y	**0.95e**
	{CRI+H }	1.63	1.15	2.15	2.05	1.00	0.76	1.34	1.74	1.78	0.71	**1.43a**	1.84b	1.51e	1.94a	1.65c	1.80b	1.55e	1.86b	1.54e	1.80b	1.53e	**1.70a**
	{CRI+B}	1.14	0.89	2.09	1.93	1.11	0.66	0.99	1.46	1.02	0.88	**1.22ab**	1.29h	1.09o.q	1.65c	1.28hi	1.62cd	1.18j.n	1.56de	1.23ij	1.55e	1.15l.o	**1.36b**
	{T+B}	1.49	0.14	1.89	1.85	1.21	1.46	1.49	0.29	1.23	0.44	**1.15ab**	1.15l.o	1.14m.o	1.21j.l	1.19j.n	1.17j.n	1.14m.o	1.20j.m	1.17j.n	1.16k.n	1.13n.p	**1.16c**
	Mean	*1.15b*	*0.61c*	*1.91a*	*1.74a*	*0.89bc*	*0.93bc*	*1.26b*	*1.24b*	*1.09b*	*0.60c*		*1.25d*	*0.98g*	*1.42a*	*1.09e*	*1.28c*	*0.99g*	*1.35b*	*1.04f*	*1.27cd*	*0.99g*	
	Mean	*0.88c*		*1.83a*		*0.91c*		*1.25b*		*0.84c*			*1.12d*		*1.26a*		*1.13c*		*1.20b*		*1.13cd*		
		LSD 0.05*p*= **W*P*V** 0.9221, **W** 0.2916, **P** 0.2662, **P*V** 0.3764											**LSD** 0.05*p*= **W*P*V** 0.0606, **W** 0.0192, **P** 0.0175, **P*V** 0.0247										
SOD (IU min^{-1} mg^{-1} protein)	**Control**	13.69v.x	9.36x	22.24q.t	26.54n.q	17.32t.v	10.73wx	19.34r.u	18.66r.v	15.14u.w	8.85x	**16.18f**	16.78x.A	10.85zA	35.66o.A	38.06o.y	20.54u.A	12.85y.A	26.28s.A	24.74t.A	19.04w.A	10.18A	**21.49d**
	{H}	40.14i	18.29s.v	57.99fg	50.33h	30.21l.o	22.35q.t	46.11h	35.41i.k	23.41p.s	14.79u.w	**33.90d**	58.12g.o	23.51t.A	94.62b.e	86.89b.f	41.25n.x	27.83r.A	68.93f.m	50.82k.s	28.67r.A	17.51x.A	**49.81b**
	{T+H}	15.97uv	15.81u.w	37.19ij	49.85h	16.81uv	30.72k.o	35.32i.l	36.73ij	30.02m.o	17.48t.v	**28.59e**	17.52x.A	17.48x.A	46.65k.t	69.47e.l	18.50w.A	36.51o.y	43.51m.w	47.30k.t	35.94o.z	19.53v.A	**35.24c**
	{CRI+H }	38.31ij	28.35n.p	106.64a	80.00d	61.68f	30.77k.o	85.39c	47.04h	28.46n.p	25.69o.q	**53.23a**	44.89l.v	31.96p.A	130.81a	104.93bc	77.25d.j	38.80o.x	105.91a.c	56.99h.p	31.35q.A	45.56k.u	**66.84a**
	{CRI+B}	26.17n.q	31.05k.n	99.26b	57.68fg	27.04n.q	23.74p.r	61.26fg	40.38i	46.63h	24.78pq	**43.79b**	28.74r.A	37.07o.y	110.59ab	79.29d.i	30.22r.A	31.43q.A	82.59c.g	51.86jk.r	56.16i.q	28.57r.A	**53.65b**
	{T+B}	36.66ij	17.58t.v	67.06e	34.13j.m	50.36h	23.40p.s	56.47g	28.47n.p	58.04fg	16.71uv	**38.88c**	70.76e.k	19.78v.A	101.33b.d	42.20n.x	66.67g.n	27.18r.A	81.91c.h	34.20o.A	101.28b.d	18.63w.A	**56.39b**
	Mean	*28.48d*	*20.07f*	*65.06a*	*49.75b*	*33.90c*	*23.61e*	*50.64b*	*34.44c*	*33.61c*	*18.05f*		*39.46cd*	*23.44e*	*86.60a*	*70.14b*	*42.40c*	*29.10de*	*68.18b*	*44.31c*	*45.40c*	*23.33e*	
	Mean	*24.28e*		*57.41a*		*28.76c*		*42.54b*		*25.83d*			*31.45c*		*78.37a*		*35.75c*		*56.25b*		*34.36c*		
		LSD 0.05*p*= **W*P*V** 5.1953, **W** 1.6429, **P** 1.4998, **P*V** 2.1210											**LSD** 0.05*p*= **W*P*V** 25.483, **W** 8.0583, **P** 7.3562, **P*V** 10.403										
POD (mmol min^{-1} mg $protein^{-1}$)	**Control**	5.19AB	4.57B	7.95yz	6.79zA	5.72AB	4.50B	5.96AB	4.85AB	4.98AB	5.29AB	**5.58f**	6.54z.B	4.02D	9.13u.x	6.08A.C	7.03y.A	3.96D	7.23x.A	4.24CD	6.35z.B	4.74B.D	**5.93f**
	{H}	12.21uv	9.13xy	13.13tu	9.86w.y	10.76v.x	8.75y	11.17vw	9.39w.y	9.71w.y	8.36yz	**10.25e**	11.49st	8.54u.y	12.39rs	9.24u.w	10.08t.v	8.16v.z	10.43tu	8.79u.y	9.06u.x	7.79w.A	**9.60e**
	{T+H}	14.78q.t	13.71r.u	17.37n.p	14.64r.t	15.01q.t	13.62s.u	15.63p.r	14.22r.t	15.23q.s	13.87r.u	**14.81d**	20.67j.l	14.15p.r	26.39f	18.59mn	18.21mn	13.71p.r	23.01hi	16.73no	19.24lm	14.00pqr	**18.47c**
	{CRI+H }	35.18c	28.99e	43.29a	32.55d	35.54c	29.64e	40.07b	29.94e	35.26c	29.54e	**34.00a**	37.44c	29.20e	45.56a	32.78d	37.79c	29.86e	42.33b	30.15e	37.51c	29.75e	**35.24a**
	{CRI+B}	20.65j.l	14.13r.u	26.36f	18.57m.o	18.19m.o	13.69r.u	22.98hi	16.71o.q	19.21l.n	13.98r.u	**18.45c**	14.28p.r	13.25p.s	16.86no	14.17p.r	14.50pq	13.17q.s	15.12op	13.75p.r	14.73pq	13.41p.s	**14.33d**
	{T+B}	19.14l.n	18.30m.o	26.06fg	21.54i.k	24.05h	19.33lm	22.37h.j	19.65k.m	24.12gh	18.61m.o	**21.32b**	18.87lm	18.04mn	25.71fg	21.24i.k	23.71h	19.05lm	22.04h.j	19.36k.m	23.79gh	18.33mn	**21.01b**
	Mean	*17.86cd*	*14.81f*	*22.36a*	*17.33d*	*18.21c*	*14.92f*	*19.70b*	*15.79e*	*18.09cd*	*14.94f*		*18.22c*	*14.53f*	*22.67a*	*17.02d*	*18.55c*	*14.65f*	*20.03b*	*15.50e*	*18.45c*	*14.67f*	
	Mean	*16.33c*		*19.84a*		*16.57c*		*17.75b*		*16.51c*			*16.37c*		*19.84a*		*16.60c*		*17.77b*		*16.56c*		
		LSD 0.05*p*= **W*P*V** 1.9372, **W** 0.6126, **P** 0.5592, **P*V** 0.7909											**LSD** 0.05*p*= **W*P*V** 1.9372, **W** 0.6126, **P** 0.5592, **P*V** 0.7909										

Means not sharing the same letters differ significantly at 5% probability level. {crown root initiation (CRI), tillering (T), booting (B), heading (H) stage

Table 2. Influence of different seed priming agents on catalase (CAT), ascorbic Acid (AsA), total phenolic contents (TPC) of wheat cultivars under applied water stress condition during 2013-2104 (Year-I), 2014-2015 (Year-II).

Year-I

		Hydro-priming		**MLE30-priming**		**KCl (osmo-priming)**		**BAP-priming**		**On farm priming**		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**AARI-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
CAT (μ mol min^{-1} mg protein^{-1})	**Control**	6.06A.C	4.94BC	8.63yz	6.72AB	6.71AB	4.77C	7.11zA	5.72A.C	5.92A.C	4.85BC	**6.14f**
	{H}	12.13vw	9.80xy	14.92q.s	10.52w.y	12.89t.v	9.06y	14.43r.u	10.12xy	11.35v.x	9.01yz	**11.42e**
	{T+H}	17.23l.p	14.70r.t	20.09jk	16.02o.r	17.28l.p	14.86q.s	17.36l.p	15.47p.r	16.68n.q	14.29r.u	**16.40d**
	{CRI+H }	34.13b	24.80e.g	39.39a	30.66c	31.92c	24.85e.g	30.63c	26.91d	30.79c	25.48d.f	**29.96a**
	{CRI+B}	19.92jk	12.78uv	24.55e.h	15.84o.r	16.17o.r	12.70uv	22.81hi	14.52r.u	18.90kl	13.03s.v	**17.12c**
	{T+B}	18.64k.m	16.00o.r	26.08de	19.09kl	23.21gh	17.58l.o	24.14f.h	18.38k.n	21.20ij	16.93m.p	**20.13b**
	Mean	*18.02c*	*13.84f*	*22.28a*	*16.48d*	*18.03c*	*13.97f*	*19.42b*	*15.19e*	*17.47c*	*13.93f*	
	Mean	*15.93c*		*19.3a*		*16.00c*		*17.30b*		*15.70c*		
		LSD 0.05*p*= **W*P*V** 1.9036, **W** 0.6020, **P** 0.5495, **P*V** 0.7771										
AsA (m. mole g^{-1})	**Control**	54.40u	76.97m.p	61.78s	78.34m.o	54.61u	76.83n.p	59.45st	77.61m.o	57.50tu	77.69m.o	**67.52e**
	{H}	89.45c.f	84.21i.k	92.28bc	86.33f.i	90.38b.e	83.81i.k	87.59e.h	80.16lm	86.45f.i	79.95l.n	**86.06c**
	{T+H}	92.45bc	76.76n.p	93.00b	92.54bc	92.59bc	84.35h.k	92.38bc	91.19b.d	90.19b.e	70.95qr	**87.64b**
	{CRI+H }	97.47a	98.73a	98.167 a	99.88a	97.38a	98.78a	97.45a	98.83a	96.90a	97.25a	**98.08a**
	{CRI+B}	76.33op	68.69r	81.76kl	76.09op	74.09pq	68.90r	76.47op	75.73op	74.30p	70.14r	**74.25d**
	{T+B}	92.09bc	83.83i.jk	92.61bc	84.09i.k	91.97bc	82.76j.l	88.07d.g	82.02kl	85.69g.j	80.04l.n	**86.32c**
	Mean	*83.70bc*	*81.53d*	*86.60a*	*86.21a*	*83.50bc*	*82.57cd*	*83.57bc*	*84.26b*	*81.84d*	*79.34e*	
	Mean	*82.61c*		*86.40a*		*83.04bc*		*83.91b*		*80.59d*		
		LSD 0.05*p*= **W*P*V** 3.3033, **W** 1.0446, **P** 0.9536, **P*V** 1.3486										
TPC (mg g^{-1})	**Control**	2.38uv	1.87xy	2.70st	2.19vw	1.49zA	0.98C	2.59s.u	2.08wx	2.07wx	1.56zA	**1.99d**
	{H}	1.35AB	0.78CD	3.82h.k	3.26mn	2.03wx	1.47zA	3.29mn	2.73r.t	1.24B	0.68D	**2.07c**
	{T+H}	3.26mn	2.78q.s	3.47lm	3.00o.q	3.15n.p	2.68st	4.36f	3.89hi	3.94gh	3.47lm	**3.40b**
	{CRI+H }	3.63j.l	3.03op	5.26a	4.66de	3.78h.k	3.19no	5.10ab	4.50ef	3.68i.l	3.08n.p	**3.99a**
	{CRI+B}	4.45ef	2.94p.r	4.58de	4.57d.f	3.61kl	2.10w	3.19no	1.68yz	4.14g	2.63st	**3.39b**
	{T+B}	4.75cd	3.68i.l	4.66de	4.94bc	4.63de	3.89hi	2.54tu	1.47zA	4.91bc	3.84h.j	**3.93a**
	Mean	*3.30d*	*2.52g*	*4.08a*	*3.77b*	*3.11e*	*2.38h*	*3.51c*	*2.73f*	*3.33d*	*2.54g*	
	Mean	*2.91c*		*3.92a*		*2.75d*		*3.12b*		*2.94c*		
		LSD 0.05*p*= **W*P*V** 0.2138, **W** 0.0676, **P** 0.0617, **P*V** 0.0873										

Year-II

		Hydro-priming		**MLE30-priming**		**KCl (osmo-priming)**		**BAP-priming**		**On farm priming**		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
CAT (μ mol min^{-1} mg protein^{-1})	**Control**	8.06E.G	5.98G	11.49A.C	7.90E.G	8.63D.F	6.00G	9.79C.E	6.86fG	7.23FG	5.98G	**7.79e**
	{H}	14.10w.y	11.43A.C	16.97s.u	12.23y.B	14.75v.x	10.67B.D	16.45t.v	11.79z.C	13.16x.A	10.58B.D	**13.21d**
	{T+H}	21.56k.m	13.95w.z	26.50g	17.13r.u	17.62q.u	13.83w.z	24.65g.i	15.77u.w	20.47m.o	14.18w.y	**18.57c**
	{CRI+H }	34.33bc	28.81f	36.75a	35.05a.c	21.66j.m	28.96ef	35.69ab	31.02de	33.03cd	29.53ef	**31.48a**
	{CRI+B}	19.76m.q	17.04r.u	22.74i.l	18.46o.t	19.85m.p	17.18r.u	19.99m.p	17.87p.u	19.23n.r	16.62s.v	**18.87c**
	{T+B}	18.72o.s	17.46r.u	25.62gh	21.00l.n	23.82h.j	18.65o.t	23.39i.k	20.00m.p	22.69i.l	18.23p.t	**20.96b**
	Mean	*19.42c*	*15.78e*	*23.34a*	*18.63c*	*17.72d*	*15.88e*	*21.66b*	*17.22d*	*19.30c*	*15.85e*	
	Mean	*17.60c*		*20.99a*		*16.80d*		*19.44b*		*17.58c*		
		LSD 0.05*p*= **W*P*V** 2.2079, **W** 0.6982, **P** 0.6374, **P*V** 0.9014										
AsA (m. mole g^{-1})	**Control**	71.12wx	93.69f.i	78.50q	95.05fg	71.33v.x	93.55f.i	76.17r	94.33fg	74.21rst	94.41fg	**84.24e**
	{H}	97.38de	92.14h.j	100.21bc	94.26fg	98.31cd	91.74ij	95.52ef	88.10kl	94.38fg	87.88lm	**93.99b**
	{T+H}	93.31g.i	93.81f.i	93.52f.i	93.67f.i	93.52f.i	93.52f.i	71.88u.w	93.45f.i	72.02u.w	94.60fg	**89.33c**
	{CRI+H }	101.17b	98.81cd	106.52 a	101.02b	100.95b	98.60cd	101.02b	98.67cd	101.02b	98.67cd	**100.65a**
	{CRI+B}	75.48rs	67.83 y	80.90p	75.24r.t	73.24t.v	68.05y	75.61r	74.88rst	73.45s.u	69.29xy	**73.40f**
	{T+B}	94.17f.h	85.91mn	94.69fg	86.17l.n	94.05f.h	84.83n	90.14jk	84.10no	87.76lm	82.12op	**88.39d**
	Mean	*88.77c*	*88.69c*	*92.39a*	*90.90b*	*88.56cd*	*88.38cd*	*85.05e*	*88.92c*	*83.80f*	*87.82d*	
	Mean	*88.73b*		*91.64a*		*88.47b*		*86.99c*		*85.81d*		
		LSD 0.05*p*= **W*P*V** 2.0813, **W** 0.6582, **P** 0.6008, **P*V** 0.8497										
TPC (mg g^{-1})	**Control**	0.64	0.14	0.96	0.80	0.78	0.48	0.85	0.35	0.33	0.46st	**0.58d**
	{H}	0.50	0.31	2.98	2.42	1.19	0.63	2.45	1.89	0.40	0.61q.t	**1.34c**
	{T+H}	1.84	1.24	3.49	2.47	2.00	1.94	3.31	2.71	1.89	1.29n.q	**2.22b**
	{CRI+H }	3.05	2.94	3.56	3.08	2.94	2.47	3.73	3.38	3.38	3.26e.i	**3.18a**
	{CRI+B}	3.50	3.05	4.56	4.29	3.71	2.21	3.29	1.78	4.24	2.73.k	**3.34a**
	{T+B}	3.45	3.21	4.08	2.95	3.78	3.42	2.07	1.77	4.08	3.33	**3.21a**
	Mean	*2.16de*	*1.81f*	*3.27a*	*2.67b*	*2.40b.d*	*1.86f*	*2.62bc*	*1.98ef*	*2.39cd*	*1.95ef*	
	Mean	*1.99c*		*2.97a*		*2.13bc*		*2.30b*		*2.17bc*		
		LSD 0.05*p*= **W*P*V** 0.6888, **W** 0.2178, **P** 0.1988, **P*V** 0.2812										

Means not sharing the same letters differ significantly at 5% probability level. {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}

Table 3. Influence of different seed priming agents on chlorophyll "*a*" & "*b*" (mg g^{-1}), K^+ contents (mg g^{-1}) of wheat cultivars under applied water stress condition during 2013-2104 (Year-I), 2014-2015 (Year-II).

Year-I

Parameter	Treatment	Hydro-priming AARI-11	Hydro-priming Millat-11	MLE30-priming AARI-11	MLE30-priming Millat-11	KCl (osmo-priming) AARI-11	KCl (osmo-priming) Millat-11	BAP-priming AARI-11	BAP-priming Millat-11	On farm priming AARI-11	On farm priming Millat-11	Mean
Chlorophyll "*a*" (mg g-1)	**Control**	1.16i	1.07n	2.13a	2.04b	2.00c	1.91d	1.45e	1.36f	0.70m	0.61r	**1.44a**
	{H}	1.01q	0.95v	1.25g	1.18h	1.05p	0.98t	1.12k	1.05p	0.90z	0.83g	**1.03b**
	{T+H}	0.55t	0.45w	0.99r	0.89b	0.94x	0.84f	0.83g	0.73k	0.88c	0.79i	**0.79d**
	{CRI+H }	0.90A	0.85e	1.15j	1.10l	0.78j	0.73k	0.99r	0.94w	0.96u	0.91y	**0.93c**
	{CRI+B}	0.71l	0.65o	1.12k	1.05o	0.60s	0.54u	0.69n	0.62p	0.51v	0.45x	**0.69f**
	{T+B}	0.94w	0.79h	1.07m	0.99s	0.89c	0.85d	0.70m	0.61q	0.42y	0.33z	**0.76e**
	Mean	*0.88g*	*0.79h*	*1.28a*	*1.21b*	*1.04c*	*0.98d*	*0.96e*	*0.89f*	*0.73i*	*0.65j*	
	Mean	*0.84d*		*1.25a*		*1.01b*		*0.92c*		*0.69e*		
	LSD 0.05*p*= **W*P*V** 0.1019, **W** 0.04489 **P** 0.0381, **P*V** 0.0338											
Chlorophyll "*b*" (mg g^{-1})	**Control**	0.42hi	0.33no	0.75a	0.66b	0.57d	0.48e	0.75a	0.66b	0.21xy	0.12D	**0.50a**
	{H}	0.33no	0.26s.u	0.59c	0.40j	0.43gh	0.36lm	0.45f	0.38k	0.40j	0.33n	**0.39b**
	{T+H}	0.21y	0.11D	0.32o	0.22x	0.30p	0.20yz	0.24w	0.15C	0.29pq	0.19zA	**0.22e**
	{CRI+H }	0.30p	0.25u.w	0.37k	0.33no	0.25vw	0.20yz	0.32no	0.27rs	0.30p	0.25vw	**0.28d**
	{CRI+B}	0.25u.w	0.19A	0.44fg	0.37kl	0.27rst	0.21y	0.19A	0.12D	0.14C	0.07E	**0.22e**
	{T+B}	0.41ij	0.32o	0.48e	0.37k.m	0.36m	0.27r.t	0.26t.v	0.17B	0.37k.m	0.28qr	**0.33c**
	Mean	*0.32d*	*0.24g*	*0.49a*	*0.39b*	*0.36c*	*0.29ef*	*0.37c*	*0.29e*	*0.28f*	*0.21h*	
	Mean	*0.28d*		*0.44a*		*0.33c*		*0.33b*		*0.25e*		
	LSD 0.05*p*= **W*P*V**0.0126, **W**0.12001 **P** 0.1290, **P*V** 0.0974											
K^+ contents (mg g^{-1})	**Control**	1.54de	1.34g.i	1.74b	1.94a	1.67bc	1.24i.l	1.57cd	1.44e.g	1.37f.h	1.14l	**1.50a**
	{H}	0.64s.v	0.81o.q	0.93mn	0.92m.o	0.83n.q	0.72q.s	0.92m.o	0.86n.p	0.62s.w	0.75p.r	**0.80c**
	{T+H}	0.67r.t	0.58t.x	0.77p.r	0.86n.p	0.57t.y	0.62s.w	0.72q.s	0.66r.u	0.52w.A	0.55u.z	**0.65d**
	{CRI+H }	1.23j.l	1.34g.j	1.52de	1.15kl	1.26h.k	1.45e.g	1.46d.f	1.48de	1.00m	1.30h.j	**1.32b**
	{CRI+B}	0.30C.F	0.36B.E	0.41A.C	0.52v.A	0.27D.F	0.35B.E	0.38B.D	0.34B.F	0.23F.H	0.10I	**0.33e**
	{T+B}	0.50x.A	0.26E.G	0.59t.x	0.46y.B	0.44z.B	0.33C.F	0.34B.F	0.36B.E	0.14G.I	0.13HI	**0.35e**
	Mean	*0.81cd*	*0.78d*	*0.99a*	*0.97a*	*0.84c*	*0.78d*	*0.90b*	*0.86bc*	*0.65e*	*0.66e*	
	Mean	*0.80c*		*0.98a*		*0.81c*		*0.88b*		*0.65d*		
	LSD 0.05*p*= **W*P*V** 0.1132, **W** 0.0358, **P** 0.0327, **P*V** 0.0462											

Year-II

Parameter	Treatment	Hydro-priming AARI-11	Hydro-priming Millat-11	MLE30-priming AARI-11	MLE30-priming Millat-11	KCl (osmo-priming) AARI-11	KCl (osmo-priming) Millat-11	BAP-priming AARI-11	BAP-priming Millat-11	On farm priming AARI-11	On farm priming Millat-11	Mean
Chlorophyll "*a*" (mg g-1)	**Control**	2.13b.d	1.98e	2.16bc	1.60lm	1.57l.n	1.42q	2.19b	2.04de	1.75g.i	1.60lm	**1.84a**
	{H}	1.63k.m	1.44pq	2.34a	1.55l.o	1.72h.k	1.53m.p	1.20t.w	1.01yz	1.97e	1.78f.h	**1.61b**
	{T+H}	1.12wx	0.93zA	1.84fg	1.64j.l	1.73h.j	1.54m.p	1.46o.q	1.27s.u	1.65i.l	1.46o.q	**1.46d**
	{CRI+H }	2.06c.e	1.18u.w	2.15bc	1.60lm	2.07c.e	1.05xy	2.19b	1.41q	0.91zA	0.73B	**1.53c**
	{CRI+B}	1.20t.w	1.07xy	2.00e	1.86f	1.13v.x	1.00yz	1.25tu	1.12v.x	0.85A	0.72B	**1.22e**
	{T+B}	1.37q.s	1.30r.t	1.30r.t	1.22t.v	0.63BC	0.56C	1.47n.q	1.39qr	1.53m.p	1.46o.q	**1.22e**
	Mean	*1.58c*	*1.31f*	*1.96a*	*1.58c*	*1.47d*	*1.18g*	*1.63b*	*1.37e*	*1.44d*	*1.29f*	
	Mean	*1.45c*		*1.77a*		*1.33e*		*1.50b*		*1.36d*		
	LSD 0.05*p*= **W*P*V** 0.1006, **W** 0.0318, **P** 0.0290, **P*V** 0.0411											
Chlorophyll "*b*" (mg g^{-1})	**Control**	0.45f	0.36j	0.79a	0.70b	0.61c	0.52d	0.78a	0.69b	0.24rs	0.15z	**0.53a**
	{H}	0.36j	0.29op	0.62c	0.43g	0.46f	0.39i	0.48e	0.41h	0.43g	0.36j	**0.42b**
	{T+H}	0.23tu	0.13A	0.34l	0.24rs	0.32m	0.22uv	0.27q	0.17y	0.31mn	0.21v	**0.24e**
	{CRI+H }	0.28p	0.24st	0.36j	0.31mn	0.23s.u	0.19wx	0.31n	0.26q	0.28p	0.23s.u	**0.27d**
	{CRI+B}	0.24st	0.17y	0.43g	0.36j	0.26q	0.20w	0.18xy	0.11B	0.13A	0.06C	**0.21f**
	{T+B}	0.39i	0.30no	0.46f	0.35j.l	0.34kl	0.25qr	0.24rs	0.16z	0.35jk	0.26q	**0.31c**
	Mean	*0.33d*	*0.25g*	*0.50a*	*0.40b*	*0.37c*	*0.29ef*	*0.37c*	*0.30e*	*0.29f*	*0.21h*	
	Mean	*0.29d*		*0.45a*		*0.33c*		*0.34b*		*0.25e*		
	LSD 0.05*p*= **W*P*V** 0.0126, **W**0.1215, **P**0.12380, **P*V**0.10231											
K^+ contents (mg g^{-1})	**Control**	1.29i	1.48f	1.89a	1.81b	1.19k	1.61d	1.39h	1.51e	1.69c	1.68c	**1.55a**
	{H}	0.57wx	0.73s	0.86o	0.86o	0.65u	0.63v	0.76qr	0.83p	0.55x	0.76r	**0.72c**
	{T+H}	0.44A	0.49z	0.69t	0.79q	0.49z	0.59w	0.64uv	0.47z	0.59w	0.57w	**0.57d**
	{CRI+H }	1.08m	1.14l	1.67c	1.47f	0.98n	1.44g	1.17k	1.37h	1.47f	1.24j	**1.30b**
	{CRI+B}	0.42A	0.30F	0.52Y	0.40B	0.32E	0.20I	0.30F	0.37C	0.10K	0.27G	**0.32e**
	{T+B}	0.40B	0.04i	0.49z	0.37C	0.34D	0.27G	0.24H	0.24H	0.05i	0.17J	**0.26f**
	Mean	*0.70g*	*0.69g*	*1.02a*	*0.95b*	*0.66h*	*0.79d*	*0.75e*	*0.80c*	*0.74f*	*0.78d*	
	Mean	*0.70e*		*0.98a*		*0.72d*		*0.77b*		*0.76c*		
	LSD 0.05*p*= **W*P*V** 0.0216, **W** 0.0447, **P** 0.0679, **P*V** 0.0321											

Means not sharing the same letters differ significantly at 5% probability level. {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages

Table 4 Influence of different seed priming agents on fertile tillers, grain-Spike, 1000 grain weight of wheat cultivars under applied water stress condition during 2013-2104 (Year-I), 2014-2015 (Year-II).

		Year-I											Year-II										
		Hydro-priming		MLE30-priming		KCl (osmo-priming)		BAP-priming		On farm priming			Hydro-priming		MLE30-priming		KCl (osmo-priming)		BAP-priming		On farm priming		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
Fertile tillers (m^{-2})	**Control**	404c.e	396d.k	426a	414a.c	388h.r	395d.l	418ab	401d.g	406b.d	392e.o	**404a**	341c.f	311i.k	363a	329fg	325gh	310i.k	355ab	316hi	343b.e	307i.k	**330b**
	{H}	395d.l	389g.q	399d.i	402c.f	395d.l	393e.n	397d.j	396d.k	382m.u	392e.o	**394b**	350bc	354ab	363a	337d.g	351a.c	329fg	355ab	333e.g	347b.d	331e.g	**345a**
	{T+H}	383l.u	397d.j	396d.k	380v	384k.t	372t.x	388h.r	376r.x	380o.v	374s.x	**383d**	245n	210p.r	258m	226o	253mn	201q.u	256mn	212pq	246mn	206p.t	**231d**
	{CRI+H }	389g.q	378q.w	402cdef	394d.m	397d.j	369v.x	400d.h	380o.v	390f.q	374s.x	**387c**	303jk	300kl	307i.k	313h.j	303jk	304i.k	305i.k	307i.k	290l	303jk	**303c**
	{CRI+B}	386j.s	364x	393e.n	372t.x	385j.s	349y	369v.x	371.x	386j.s	366wx	**374e**	182vw	197s.u	189u.w	205p.t	181w	182vw	165x	204p.t	182vw	199r.u	**188f**
	{T+B}	387i.r	381n.v	396d.k	378q.w	386j.s	364x	391f.p	374s.x	379p.v	380o.v	**381d**	205p.t	201q.u	214op	198r.u	204p.t	184vw	209p.s	194t.v	197s.u	200q.u	**200e**
	Mean	*390.67bc*	*384.17d.f*	*402.00a*	*390.00bc*	*389.17b.d*	*373.67g*	*393.83b*	*383.00ef*	*387.17c.e*	*379.67f*		*271bc*	*262.17d*	*282.33a*	*268c*	*269.50bc*	*251.67e*	*274.17b*	*261d*	*267.50c*	*257.67d*	
	Mean	*387.42b*		*396.00a*		*381.42c*		*388.42b*		*383.42c*			*266.58b*		*275.17a*		*260.58c*		*267.58b*		*262.58c*		
		LSD 0.05*p*= **W*P*V** 12.862 , **W** 4.0674, **P** 3.7130, **P*V** 5.2510											**LSD** 0.05*p*= **W*P*V** 12.714 , **W** 4.2134, **P** 3.5040, **P*V** 5.3501										
Grain-Spike	**Control**	58a.c	46j.n	60a	48h.m	55a.f	43m.q	58a.c	45k.p	54b.g	42n.r	**51a**	47ab	44a.d	49a	46a.c	44a.d	41c.e	47ab	43b.d	43b.d	40d.f	**44a**
	{H}	53c.h	40o.s	57a.d	45k.o	56a.e	39q.u	56a.e	39q.u	54d.g	38r.v	**48b**	39d.g	35f.i	43b.d	40d.f	42cd	34g.j	42b.d	34h.j	40d.f	33h.k	**38b**
	{T+H}	52e.i	36s.w	56a.e	37r.v	52e.i	35s.x	57a.e	35s.x	50f.k	33v.y	**44cd**	27l.p	27l.p	27l.p	26m.q	23p.r	25o.q	22p.s	19r.t	25n.q	25o.q	**24d**
	{CRI+H }	49.33g.l	39p.t	55b.f	42n.r	52d.i	39q.u	51e.j	35t.x	54b.g	38q.u	**45c**	28k.p	35f.i	32h.l	36e.h	28k.p	34g.j	33h.k	34g.j	26m.q	32h.l	**31c**
	{CRI+B}	54b.g	33v.y	59ab	36s.w	56a.e	28y	44l.q	34u.x	53d.i	30xy	**42d**	24o.r	18s.u	29j.o	21q.s	26m.q	13u	14tu	19r.t	23p.s	15tu	**20e**
	{T+B}	53d.i	35s.w	55a.f	37r.v	52e.i	30w.y	52e.i	36s.w	48i.m	35s.w	**43d**	35f.i	34g.j	33h.j	31h.m	31h.n	25n.q	31h.n	31h.n	27l.p	30i.n	**31c**
	Mean	*53b*	*38d*	*57a*	*41c*	*54b*	*36e*	*53b*	*37de*	*52b*	*36e*		*33ab*	*32bc*	*35a*	*33b*	*32bc*	*29e*	*31b.d*	*30de*	*31c.e*	*29e*	
	Mean	*46b*		*49a*		*45bc*		*45bc*		*44c*			*33b*		*34a*		*30c*		*31c*		*30c*		
		LSD 0.05*p*= **W*P*V** 5.4236, **W** 1.7151, **P** 1.5657, **P*V** 2.2142											**LSD** 0.05*p*= **W*P*V** 5.4891, **W** 1.7358, **P** 1.5846, **P*V** 2.2409										
1000 Grain Weight (g)	**Control**	37.61bc	32.39e.g	42.88a	39.36b	32.38e.g	30.56g.j	37.38bc	36.69cd	30.51g.j	28.09k.o	**34.79a**	41.95bc	36.39e.i	48.88a	43.36b	38.38ef	34.56h.k	42.05bc	40.69cd	36.51e.h	32.09l.o	**39.49a**
	{H}	33.01ef	30.21g.k	36.91c	33.21ef	26.21o.s	25.51q.u	34.57de	31.31fghi	24.81r.v	25.51q.u	**30.12b**	34.63h.k	30.72o.s	35.73g.j	30.92o.q	34.33h.k	29.02p.t	33.63j.m	29.02p.t	34.23i.l	29.52p.t	**32.17c**
	{T+H}	28.62j.n	22.75v.y	31.95f.h	29.48i.m	25.92o.t	21.25yz	26.62n.r	23.71t.x	25.72p.u	23.55u.x	**25.95c**	30.62o.s	24.25v.y	33.95j.m	30.98o.q	27.92tu	22.75xy	28.62r.t	25.21vw	27.72tu	25.05vw	**27.70d**
	{CRI+H }	28.93j.m	25.27q.u	30.03h.l	25.47q.u	28.63j.n	23.57u.x	27.93l.p	23.57u.x	28.53j.n	24.07s.w	**26.60c**	37.01e.g	33.21k.n	40.91c	36.21f.i	30.21o.s	28.51st	38.57de	34.31h.k	28.81q.t	28.51st	**33.62b**
	{CRI+B}	21.17yz	20.97yz	22.47w.y	21.67x.z	20.17z	20.77yz	20.17z	20.77yz	21.07yz	20.57yz	**20.98e**	24.47v.y	23.96v.y	25.77uv	24.66v.x	23.47w.y	23.76v.y	23.47w.y	23.76v.y	24.37v.y	23.56v.y	**24.12f**
	{T+B}	26.25o.s	20.23z	27.35m.q	21.13yz	25.95o.s	20.03z	26.65n.r	21.83x.z	24.65r.w	21.23yz	**23.53d**	30.75o.r	22.53xy	31.85m.o	23.43w.y	30.45o.s	22.33y	31.15n.p	24.13v.y	29.15p.t	23.53w.y	**26.93e**
	Mean	*29.26b*	*25.30d*	*31.93a*	*28.38b*	*26.54c*	*23.61e*	*28.88b*	*26.31c*	*25.88cd*	*23.83e*		*33.23b*	*28.51f*	*36.18a*	*31.59c*	*30.79cd*	*26.82g*	*32.91b*	*29.52e*	*30.13de*	*27.04g*	
	Mean	*27.28b*		*30.16a*		*25.08c*		*27.60b*		*24.86c*			*30.87b*		*33.88a*		*28.80c*		*31.21b*		*28.58c*		
		LSD 0.05*p*= **W*P*V** 2.2319, **W** 0.7058, **P** 0.6443, **P*V** 0.9112											**LSD** 0.05*p*= **W*P*V** 2.2113, **W** 0.6993, **P** 0.6383, **P*V** 0.9028										

Means not sharing the same letters differ significantly at 5% probability level. {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}

Table 5. Influence of different seed priming agents on grain yield, biological yield, harvest index of wheat cultivars under applied water stress condition during 2013-2104 (Year-I), 2014-2015 (Year-II).

Year-I

		Hydro-priming		MLE30-priming		KCl (osmo-priming)		BAP-priming		On farm priming		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
Grain yield (t/ha)	**Control**	5.67a.c	4.27i.m	5.93a	4.87d.i	5.22b.f	3.85m.o	5.70a.c	3.86l.n	5.14c.g	2.87q.t	**4.74a**
	{H}	5.04d.h	2.21u.x	5.74ab	4.13k.n	5.36a.e	2.71q.u	5.38a.d	3.25o.q	4.45h.l	2.30t.w	**4.06b**
	{T+H}	3.85mn	1.35B.E	4.77e.j	1.96w.A	3.17p.r	1.37A.E	4.42i.m	1.50z.D	3.96l.n	1.33B.E	**2.77d**
	{CRI+H }	4.60g.k	2.01w.z	5.13c.g	3.21p.r	4.25j.m	1.55y.c	4.66f.k	2.73q.u	3.88l.n	1.57y.c	**3.36c**
	{CRI+B}	2.39s.w	1.65x.b	3.55n.p	2.33s.w	2.91q.s	1.32b.e	3.25pq	1.96w.a	2.64r.v	1.08b.e	**2.31e**
	{T+B}	2.46s.w	0.77E	3.62n.p	2.10v.y	2.53s.w	0.92DE	2.89q.t	1.43z.D	2.02w.z	1.00C.E	**1.97f**
	Mean	*4.00c*	*2.04g*	*4.79a*	*3.10e*	*3.91cd*	*1.95g*	*4.38b*	*2.45f*	*3.68d*	*1.69h*	
	Mean	*3.02c*		*3.95a*		*2.93c*		*3.42b*		*2.69d*		
		LSD 0.05*p*= **W*P*V** 0.5994, **W** 0.1895, **P** 0.1730, **P*V** 0.2447										
Biological Yield (t/ha)	**Control**	13.07b.h	10.68j.r	16.01a	12.52c.i	13.90b.d	10.37m.u	13.28b.f	10.58l.s	13.06b.h	10.53l.t	**12.40a**
	{H}	11.46g.o	10.99i.q	13.52b.e	13.12b.g	11.26i.p	11.37h.p	12.32d.j	12.44c.i	11.14i.p	10.90i.q	**11.85b**
	{T+H}	10.95i.q	7.30yz	12.20d.l	10.03o.w	9.18r.x	7.05z	10.72j.r	8.46w.z	9.06r.x	7.50x.z	**9.24e**
	{CRI+H }	11.71f.o	10.90i.q	14.37ab	12.34d.j	12.57c.i	9.75p.w	14.09bc	11.85e.n	12.30d.k	8.62v.z	**11.85b**
	{CRI+B}	9.34q.w	8.95s.y	12.47c.i	11.30i.p	8.76u.y	10.28n.v	11.44g.p	10.52l.t	10.59k.s	8.84t.y	**10.25d**
	{T+B}	10.28m.v	11.17i.p	13.44b.e	13.04b.h	10.16n.w	9.15r.x	11.99e.m	11.55g.o	10.25n.v	10.13o.w	**11.12c**
	Mean	*11.13c*	*10.00d*	*13.67a*	*12.06b*	*10.97c*	*9.66d*	*12.30b*	*10.90c*	*11.06c*	*9.42d*	
	Mean	*10.57c*		*12.86a*		*10.32c*		*11.60b*		*10.24c*		
		LSD 0.05*p*= **W*P*V** 1.7081, **W** 0.5402, **P** 0.4931, **P*V** 0.6973										
Harvest Index (%)	**Control**	41.97	33.64	43.02	35.03	38.80	32.05	46.10	30.38	38.56	24.20	**36.37a**
	{H}	39.20	22.39	43.47	35.62	40.96	27.96	41.45	31.49	37.42	25.45	**34.54a**
	{T+H}	38.01	14.93	44.37	18.64	32.86	15.58	42.35	15.48	40.04	15.91	**27.82c**
	{CRI+H }	41.70	22.91	43.68	28.86	40.56	22.27	40.73	25.69	37.36	20.01	**32.38b**
	{CRI+B}	25.23	19.73	33.09	26.56	31.12	18.07	32.28	22.95	29.21	16.16	**25.44d**
	{T+B}	31.88	14.08	38.45	22.78	37.45	16.31	32.79	17.74	31.67	17.80	**26.10cd**
	Mean	*36.33c*	*21.28ef*	*41.01a*	*27.92d*	*36.96bc*	*22.04ef*	*39.28ab*	*23.96e*	*35.71c*	*19.92f*	
	Mean	*28.81c*		*34.46a*		*29.50c*		*31.62b*		*27.82c*		
		LSD 0.05*p*= **W*P*V** 6.7256, **W** 2.1268, **P** 1.9415, **P*V** 2.7457										

Year-II

		Hydro-priming		MLE30-priming		KCl (osmo-priming)		BAP-priming		On farm priming		
		AARI-11	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**AARI-11**	**Millat-11**	**Mean**
Grain yield (t/ha)	**Control**	5.85ab	3.51m.r	6.14a	4.35g.k	5.06d.f	3.25n.t	6.02ab	3.84j.m	5.73a.c	2.03C.F	**4.58a**
	{H}	4.37g.j	2.62v.b	5.04d.f	3.12p.v	4.30g.k	2.48x.E	4.79e.g	2.86s.z	4.45g.i	2.52w.D	**3.65c**
	{T+H}	3.49m.r	1.98D.F	4.21h.l	2.54w.C	3.07q.w	1.99D.F	3.66l.p	2.41y.E	2.85t.z	2.07B.F	**2.83e**
	{CRI+H }	4.80e.g	3.02q.x	5.49b.d	3.81k.m	5.03d.f	3.01r.x	5.29c.e	3.40m.s	4.72f.h	2.35z.E	**4.09b**
	{CRI+B}	2.43y.E	1.58F.H	2.82t.z	2.15A.E	2.60v.B	1.40GH	2.68u.A	1.95E.G	2.38z.E	1.35H	**2.13f**
	{T+B}	3.74l.n	2.94s.y	4.35g.k	3.31m.t	3.57m.q	2.82t.z	4.16i.l	3.18o.u	3.69l.o	2.65u.A	**3.44d**
	Mean	*4.11c*	*2.61f*	*4.67a*	*3.21d*	*3.94c*	*2.49f*	*4.43b*	*2.94e*	*3.97c*	*2.16g*	
	Mean	*3.36c*		*3.94a*		*3.21cd*		*3.69b*		*3.06d*		
		LSD 0.05*p*= **W*P*V** 0.5512, **W** 0.1743, **P** 0.1591, **P*V** 0.2250										
Biological Yield (t/ha)	**Control**	15.19bc	12.38e.g	16.91a	14.24cd	14.48cd	11.36g.j	16.03ab	13.40d.f	13.69de	11.89gh	**13.96a**
	{H}	12.53e.g	10.26i.n	14.85b.d	11.63g.i	12.05fg	9.14l.u	13.73de	10.33i.m	11.23g.k	9.44l.t	**11.52b**
	{T+H}	9.65l.q	9.16l.u	11.34g.j	10.58h.l	9.65l.q	8.27q.y	10.37i.m	9.85k.p	9.05m.v	8.26q.y	**9.62c**
	{CRI+H }	10.37i.m	8.83n.w	12.53e.g	11.48g.i	9.92j.o	6.86yza	11.44g.i	9.30l.u	9.45l.t	8.14r.z	**9.83c**
	{CRI+B}	10.21i.n	8.03t.z	11.63g.i	9.00m.v	9.56l.r	7.26x.A	10.41i.m	8.61o.x	8.43p.x	6.74zA	**8.99d**
	{T+B}	7.61v.A	7.89u.z	9.96j.o	9.49l.s	6.80zA	6.70zA	8.76o.w	8.11st.z	6.44A	7.50w.A	**7.93e**
	Mean	*10.93cd*	*9.42f*	*12.87a*	*11.07c*	*10.41de*	*8.26g*	*11.79b*	*9.93ef*	*9.71f*	*8.66g*	
	Mean	*10.17c*		*11.97a*		*9.34d*		*10.86b*		*9.19d*		
		LSD 0.05*p*= **W*P*V** 1.4437, **W** 0.4565, **P** 0.4168, **P*V** 0.5894										
Harvest Index (%)	**Control**	40.78	32.96	50.15	36.31	37.51	31.33	45.24	34.74	42.75	19.29	**37.11a**
	{H}	38.71	23.89	40.52	25.20	36.60	21.89	38.31	24.54	33.15	20.00	**30.28c**
	{T+H}	32.14	25.51	37.27	30.26	33.45	27.47	34.31	29.18	31.62	28.06	**30.93c**
	{CRI+H }	38.21	28.27	41.24	31.05	37.59	28.78	40.16	30.99	39.04	28.60	**34.39b**
	{CRI+B}	23.58	18.18	30.40	19.12	22.69	13.88	26.27	18.63	22.82	15.86	**21.14d**
	{T+B}	32.45	26.29	36.46	30.94	35.14	25.57	36.38	27.52	34.95	24.52	**31.02c**
	Mean	*34.31bc*	*25.85ef*	*39.34a*	*28.81d*	*33.83c*	*24.82fg*	*36.78ab*	*27.60de*	*34.05c*	*22.72g*	
	Mean	*30.08b*		*34.07a*		*29.33b*		*32.19a*		*28.39b*		
		LSD 0.05*p*= **W*P*V** 6.5754, **W** 2.0793, **P** 1.8981, **P*V** 2.6844										

Means not sharing the same letters differ significantly at 5% probability level. {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages

Table 6. Economic analysis (Average of both cultivars) for the impact of seed priming agents under various irrigation deficit conditions at the critical growth stages of wheat during average of both years I & II {crown root initiation (CRI), tillering (T), booting (B), heading (H) stages}

Treatment		Total expenditure (US$ ha^{-1})	Gross Income (US$ ha^{-1})	Net Income (US$ ha^{-1})	Benefit Cost Ratio
Hydro-priming	Control	629.27	1164.45	535.18	1.85
	{H}	615.64	1127.32	511.68	1.84
	{T+H}	602	959.06	357.06	1.59
	{CRI+H }	602	981.12	379.12	1.63
	{CRI+B}	602	1035.89	433.89	1.73
	{T+B}	602	983.09	381.09	1.63
MLE30-priming	Control	633.82	1395.76	761.94	2.20
	{H}	620.18	1233.45	613.26	1.99
	{T+H}	606.55	1001.16	394.61	1.65
	{CRI+H }	606.55	1219.22	612.67	2.01
	{CRI+B}	606.55	1134.68	528.14	1.87
	{T+B}	606.55	1182.97	576.43	1.96
KCl-priming	Control	642.91	1190.08	547.17	1.86
	{H}	629.27	1065.05	435.78	1.69
	{T+H}	615.64	975.79	360.15	1.59
	{CRI+H }	615.64	915.71	300.07	1.49
	{CRI+B}	615.64	1051.00	435.36	1.71
	{T+B}	615.64	884.06	268.42	1.44
BAP-priming	Control	670.18	1232.07	561.89	1.84
	{H}	656.55	1214.23	557.68	1.85
	{T+H}	642.91	982.88	339.97	1.53
	{CRI+H }	642.91	1115.46	472.55	1.74
	{CRI+B}	642.91	1170.89	527.98	1.82
	{T+B}	642.91	937.19	294.29	1.46
On farm-priming	Control	629.27	1214.49	585.21	1.93
	{H}	615.64	1053.94	438.31	1.71
	{T+H}	602	904.46	302.46	1.51
	{CRI+H }	602	942.94	340.94	1.57
	{CRI+B}	602	987.06	385.06	1.64
	{T+B}	602	966.92	364.92	1.61

DISCUSSION

The priming with MLE30 improved the LAI under various irrigation deficit regimes, especially at the booting stage (55 DAS) which might be due to the maintenance of cell turgor pressure, which resulted into maximum uptake of water in leaves (Richards *et al.*, 2001). Usually the primed plants reach to their critical growth stage at a faster pace compared to control treatments which allow them to escape a drought spell for a specific growth period. In the present study, crop growth rate was higher in MLE30 primed plant as compared to control or other treatments. Therefore, the plants moved to next growth stage to save its progeny from the sever impacts of soil water deficit condition (Nawaz *et al*., 2016). As leaves are the main units of assimilatory system in plants, therefore, promotion of LAI by MLE30 primed seeds improved the drought tolerance of cultivar AARI-11 comparatively more than Millat-11 under deficit irrigation levels. It might be responsible for greater SLAD with better accomplishment of assimilates syntheses and partitioning especially at 55 DAS in both years of study (Hussain and Shah, 2002). This may have increased the accumulation of photosynthates/carbohydrates, particularly during the critical growth phases of {CRI+T}. In the present study, improvement in CGR and NAR of both cultivars by using different priming agents expressed the higher rates of dry matter accumulation that reduced the severity of irrigation deficit stress on the critical growth and development stages of wheat. MLE30 and BAP prominently ameliorated the irrigation deficit-imposed stress which might be due to the rapid dry matter accumulation during the irrigation deficit at crown root initiation and heading stages (Maqsood *et al*., 2012).

In plant defense mechanism, both enzymatic (SOD, POD, CAT) and non-enzymatic (AsA, TPC) antioxidants quenched the free radicals (ROS) and inhibited the oxidative reactions during abiotic stress conditions (Huseynova *et al*., 2010). The study demonstrated the increasing trend in the activity of enzymatic and non-enzymatic antioxidants in both wheat cultivars (AARI-11 and Millt-11) in response to various drought-imposed stress conditions, especially at {CRI+H} critical growth stages, and exogenous application of growth regulators. MLE30 explored the most effective treatment in this regard. SOD, POD and CAT are the essential enzymatic antioxidants and powerful scavenger of ROS molecules. These enzymes persuade the ionic changes during oxidative reactions and might be responsible for activation of the antioxidant defense system under deficit irrigation water-imposed stress conditions with MLE30 seed treatment (Wang *et al*., 2014). Potential of MLE30-primed AARI-11 seeds against drought stress, especially at {CRI} and {H}, might be due to enhanced activity of enzymatic antioxidants (SOD, POD, CAT) causing a significant removal of ROS and balancing ion homeostasis. Similarly, higher contents of non-enzymatic antioxidants (AsA, TPC) in AARI-11 cultivar ameliorated the water stress at {CRI+H} growth stages during the both years of trial. According to Yasmeen *et al*. (2013) stress tolerance at the critical growth stages of wheat can be improved by applying MLE30, because MLE30 has a rich source of Zeatin (Foidle *et al*., 2001). MLE30 priming alleviated the irrigation deficit stress by producing the better enzymatic and non-enzymatic antioxidants which maintained the stay green characteristics in the leaves of wheat cultivars (AARI-11 and Millat-11) (Yasmeen *et al*., 2012). The exogenous application of MLE30 and BAP promoted the maximum content of ascorbic acid and total phenolic contents that in return exerted the protective effects during the growth and development of wheat with remediation of drought-induced oxidative stress. Thus, the increase in TSP, SOD, POD, CAT, AsA and TPC contents were the important reasons to mitigate irrigation deficit conditions with MLE30 priming in wheat cultivars (Zhang and Ervin, 2008).

The assimilate syntheses of the crop is directly related to the leaf area and chlorophyll contents. As the photosynthetic abilities of the plants always dependent on these two. In the present study, the maximum leaf chlorophyll contents ("*a*" and "*b*") in control and irrigation deficit treatments {H} might be due to maximum availability of water which extended the leaf area and increased chlorophyll contents (Araus, 2008**)**. Increased leaf chlorophyll contents of wheat cultivar AARI-11 by MLE30 and BAP application, was the important character in the alleviation of drought stress during critical growth stages {CRI+T}, {CRI+B}, {T+B} and {T+H} and resulted in the expansion of the leaf area (Basra *et al*., 2011). Seed priming with growth enhancers relieved the ionic stress exhibited during toxic oxidative reactions which balanced the leaf and root membrane permeability (Abbasdokht and Edalatpisheh, 2013). Application of priming treatments with MLE30 and BAP promoted the accumulation of K^+ in leaves of cultivar AARI-11 and Millat-11under normal irrigation (control) and drought stress at {CRI+H}. Results of both years field trial narrated the clear supremacy of MLE30 priming due to its nutritional effect on K^+ contents that might have interacted with specific ion carriers to alleviate the drought stress (Samson and Visser, 1989).

Wheat grain yield is sum total of the number of productive/fertile tillers (m^{-2}) and grain spike^{-1} (Hussain *et al*., 2010). Among the priming agents, MLE30 treatment promoted the seed vigor of cultivar AARI-11 by enhancing the imbibition process which ultimately increased the fertile tillers and grain spike^{-1}, not only in control, but also in soil water deficit conditions at {H} and {CRI+H} critical growth stages of wheat plants (Farooq *et al*., 2014). Wheat grain yield is a final shared effect of various yield and yield related traits like number of grains spike^{-1}, grain size and grain yield etc. established under a given set of crop husbandry conditions (Saini and Westgate, 2000**)**. Exogenous application of growth regulators increased the 1000-grain weight of both cultivars

(AARI-11 and Millat-11) which ultimately amplified the grain yield under drought stress conditions during both years of study (Eskandari and Kazemi, 2010).

Tillering, booting and heading stages are the most critical stages of wheat to drought stress and seed priming with growth enhancers, especially MLE30 and BAP under limited irrigations at these stages promoted the stress tolerance (Wei *et al*., 2010). Seed priming ameliorated the drought stress at crown root initiation {CRI} and heading {H} stages by improving the grain-filling rate, leading to increased grain yield and harvest index during the both years of trail (Gupta *et al*., 2001). The MLE30 priming improved the harvest index of both cultivars during both years which might be due to efficient partitioning of assimilates for developing grains (Guoth *et al*., 2009). Economic analysis also indicated the maximum BCR in case of MLE30 application due to its low cost and easy availability.

Conclusion**:** The present study concluded that irrigation deficit regimes reduced the wheat productivity but the seed priming agent MLE30, helped in modulating the endogenous antioxidants activities and contents to mitigate the loss of grain yield against soil water deficit stress especially at crown root initiation and heading stages.

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