Research Article

Drought Stress Mitigation in Wheat (*Triticum aestivum* L.) through Physiological Enhancements

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Abstract | Drought stress is a major production constraint in wheat. There are promising mechanisms by which wheat can tolerate drought stress that can be measured in terms of foliar application of plant growth regulators and plant extracts. Wheat genotypes (Triple dwarf-1, Aas-2011; Faisalabad- 2008) were exposed to critical drought stage. The plants were exposed to normal irrigation, application of bio stimulants like 2µM ABA, 10 mM SA, 15% MLE and 10% MBLE were applied at grain filling stage but skipping irrigation. Maximum growth related parameters were observed by applying full irrigation. Comparing the bio stimulants application, the application of ABA significantly increased the plants population (95.55 m-2), plant height, tillers (88.77 m^{-2}), spike (287.17), spikelets per spike (18.56), grains per spike (55.21), spike length (12.38 cm) and thousand grain weight (40.95). Similar trend was also observed in case of grain yield (5708.51 kg ha^{-1}), biological yield (16380.9 kg ha^{-1}), harvest index (34.85 %), water use efficiency (4.78 kg ha^{-1} mm^{-1}), drought yield index (92.21%), protein contents (17.37 mg g^{-1}), leaf water contents (72.65 %), soil moisture contents (14.40 %). Comparing the genotypic performance Aas-2011 performed well as compared to Faisalabd-2008 and TD-1 wheat genotype.

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Introduction

There are about 1.2 billion poor who consume wheat as the main staple in their diet, and 2.5 billion wheat-consuming poor, living predominantly in Africa and Asia. Worldwide, more land is used to grow wheat than any other crop. Wheat is the second most important cereal for direct human consumption (rather than for livestock feed) and the most significant global source of non-animal protein. Around half of calories consumed in North Africa and West and Central Asia are from wheat. In order to meet future, demand the average annual increase in global wheat yield must jump from its current level of below 1 percent to at least 1.6 percent (Eskola *et al*., 2020). In Pakistan, wheat grain considered as main staple food (60% of caloric intake in daily diet) for a common person. It was cultivated on area of 9052,000 hectares, having production of about 25.75 million tonnes (Masood, 2015).

Wheat possesses a vital position in Pakistan's financial system to reduce the gap between food productions and consumption, therefore crucial for national food security (Alam *et al*., 2008). Rainfed areas are included in the major wheat-producing regions of Pakistan. However, wheat production in rainfed areas is around 50% of the irrigated areas. One of the main targets of Pakistan's national wheat breeding programs is an enhancement of drought resistance in wheat cultivars. Although breeders have successfully increased wheat yield at the national level, they have achieved limited success in agro-ecological zone where natural conditions are very uncertain and various stresses occur including drought, heat and salt (Agarwal *et al*., 2005). In case of wheat crop, genotypic performance evaluation is an important index for screening the drought tolerance under drought. Pre-anthesis and at anthesis stage, deficiency of water can cause a reduction in several spikes and quantity of grains per spike (Samarah *et al*., 2009; Chai *et al*., 2016). Among the growth parameters mostly effective yield attributes are grain weight and grain per spike. Wheat growth period from stem elongation to heading and heading to milking reported being more susceptible to a shortage of water stress (Gupta *et al*., 2002; Zhang *et al*., 2017).

Growth regulators like abscisic acid (ABA) play a key role in improving drought tolerance of field crops. Abscisic acid synthesizes under drought conditions and sent a signal to guard cell which results in the closure of stomata, which maintains the water balance of the cell, and improves the turgidity under stress conditions. ABA application under drought stress improved drought tolerance by conserving plant cell moisture and improving/maintaining plant growth (Hussain *et al*., 2010, 2012). Among the plant growth hormones, salicyclic acid is considered as an important hormone which promoted plant photosynthetic rates, production of plant biomass and crop leaf area (Fahad *et al*., 2017). It was noted that application of salicyclic acid increases the wheat resistance against osmotic stress caused by water deficit conditions (Fahad *et al*., 2015; Ahmad *et al*., 2019; Khan *et al*., 2019).

It was reported from the previous research that drought stress actually reduces cytokinin contents, which effect the produce yield and quality (Shahid *et al*., 2017). Leaf of moringa consist of different vitamins, growth regulators, anti-oxidants and essential nutrients (Foidl *et al*., 2002; Yasmeen *et al*., 2013). Abscissic acid, SA and MBLE are mostly being applied as growth stimulants used as foliar application as well as priming of seed of cereals. Biostimulants actually modify the plant growth by changing in metabolic process under different stresses (Yasmeen *et al*., 2013; Khan *et al*., 2017).

Application of plant water extracts like rice, wheat, sorghum, mulberry and moringa in low concentration under drought stress can also improve the drought tolerance in wheat genotypes. The leaf sap of moringa is a source of hormones and nutrients especially like zeatin and ascorbate, K^+, Ca^+ and Fe^+ (Makkar and Becker, 1996). It increased yield as it is enhances roots and enhance productivity upto 20-35% (Fuglie, 2001). Leaf extract of Mulberry is a rich source of anti-oxidant enzymes which prevent, stabilize and terminate the reactive oxygen species (ROS) production and protect cell from higher photo transpiration in chloroplast under abiotic stresses like salinity and drought stress (Haq *et al*., 2010). From the above positive and beneficial response of ABA, SA, moringa leaf extracts and mulberry leaf extracts it is imperative to investigate the drought stress impact on agronomic and yield attributes of wheat genotypes and compare the response of plant growth regulators on wheat growth under drought stress.

Materials and Methods

The research trial was held at research area of Ghazi University, Dera Ghazi Khan, Pakistan. Wheat genotypes were sown in line at 22 cm at field capacity after preparing the seedbed with one plowing and two cultivation and each cultivation followed by planking. One bag of urea, Di ammonium Phosphate (DAP) and Sulphate of Potash (SOP) were applied. All DAP, SOP and one bag of urea per acre were applied at first irrigation (25 days after sowing). After the first irrigation 250 g Logron extra per acre was applied to control the broad leaf weeds. Wheat genotypes (Triple dwarf-1, Aas-2011, and Faisalabad- 2008) were exposed to critical drought stage i.e. skipping irrigation at terminal stage (grain filling). The plants were exposed to normal irrigation, skipping irrigation with 2µM ABA, 10 mM SA, 15% MLE and 10% MBLE were applied at grain filling stage but skipping irrigation. The trial was designed accordingly to randomized complete block design (RCBD) with the factorial arrangement. Each treatment was repeated thrice. The growth and yield attributes of different genotypes were studied statistically by using RCBD factorial. The grain protein contents (mg/g) were estimated by the Kjeldahl method (Magomya *et al*., 2014). Water use efficiency (WUE) and Relative leaf water content (RWC) was computed by the formula given by (Sairam *et al*., 2002).

WUE%= grain yield (kg ha^{1}) / water use (mm)
RWC%= Fresh weight – dry weight/turgid weight - dry weight × 100

Soil moisture contents (%) measured after an interval of seven days treatments application. Data regarding studied parameters were statistically analyzed. Treatment means were compared at 5% level of significance.

Results and Discussion

Plant population is a single utmost factor contributing to the final crop yield. The impact of treatments and wheat genotypes was statistically non-significant on several plants m^{-2} (Table 1). There was a significant differences among treatments and genotypes means regarding yield related attributes such as number of plant m^{-2}, spike length (cm), plant height (cm), number of tillers, spike, yield parameters, harvest index (%) and biological yield (Tables 1 and 2). Data for varieties showed, Aas-2011 performed well for yield related parameters as compared to other wheat cultivar Faisalaabad-2008 and TD-1. The maximum value for yield attributes were noted in T_1 (full irrigations) followed by T_2, T_3 and T_4 while minimum was noted in T_5 where 10% MBLE was applied to three wheat genotypes at grain filling stage after skipping irrigation. Moreover, maximum grain yield (5873.33kg ha^{-1}) and biological yield (16525.14 kg ha^{-1}) were noted in T_1 and minimum grain yield (5130.34kg ha^{-1}) and minimum biological yield (16177.13 kg ha^{-1}) were found in T_5. Maximum harvest index of 35.35 % was noted in T_1 and minimum (31.93 %) was calculated in T_5 (Table 2).

Spikelet's spike^{-1} contributed positively to grain yield. The spike with more spikelet's contributed more for the grain yield. So, the cultivar selection having more spikelet's spike^{-1} ultimately results into better yielding lines (Tables 1 and 2). Thousand grain weight, length and reduced under drought stress while by applying ABA, SA and MLWE counter the impact of water shortage by improving yield and yield contributing parameters (Tables 1 and 2).

ABA application partially closes the stomata and conserves the plant moisture which ultimately improved the performance of wheat genotypes (Haq *et al*., 2010; Ahmad *et al*., 2014). The salicylic acid application also improved leaf area, rate of photosynthesis and production of plant dry matter. Moreover, it also induced plant security against pathogens (Ahmad *et al*., 2014). Salicyclic acid results into closure of stomata, chlorophyll contents and

Table 1: *Impact of drought management strategies on growth and yield of wheat genotypes.*

Treatments	Plants m^{-2}	Plant height (cm)	Tillers m^{-2}	Spikes m^{-2}	Spikelets spike^{-1}	Grains spike^{-1}	Spike length (cm)	1000-grain weight (g)
Drought management strategies								
T1=full irrigations, no ABA, SA, MLE and MBLE	98.68 A	90.44 A	297.81 A	287.72 A	20.07 A	57.55 A	13.36 A	43.55 A
T2=2µM ABA (- GF)	95.55 A	88.77 B	287.17AB	284.83 B	18.56 B	55.21 B	12.38 B	40.95 B
T3=10mM SA (- GF)	93.38 A	86.55 C	278.03 C	279.91 C	14.42 D	48.49 D	9.24 D	38.94 D
T4=15% MLE	94.61 A	88.11 BC	287 AB	276.87 D	17.82 C	51.88 C	11.17 C	40.76 C
T5=10% MBLE (- GF)	92.46 A	84.33 D	276.82 D	273.82 E	13.68 E	45.82 E	8 .59 E	37.75 E
LSD (0.5)		0.79	0.68	0.23	0.41	0.28	0.22	0.31
Wheat cultivars								
Aas-2011	96.99 A	91 A	292.20 A	283.62 A	18.89 A	54.05 A	12.12 A	42.54 A
Faisalabad-2008	95.46 A	87.46 B	285.63AB	280.91 B	16.11B	52.20 B	11 .35 B	40.56 B
TD-1	93.47 A	84.46 C	278.72 C	277.36 C	14 C	49.11 C	9.38 C	38.06 C
LSD (0.5)		0.38	0.33	2.89	0.20	0.14	0.10	0.15

Means sharing the same letter within the column and rows differ non-significantly at the 5% probability level. ABA: abscisic acid; SA: salicyclic acid; MLE: Moringa leaf water extract; MBLE: mulbery leaf water extract; (- GF), skipping irrigation at grain filling stage.

Table 2: *Impact of drought management strategies on growth, yield and water relations of wheat genotypes.*

Treatments	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index %	WUE (kg ha^{-1} mm^{-1})	Drought yield index (%)	Protein contents (mg g^{-1})	Leaf water contents (%)	Soil moisture contents (%)
Drought management strategies								
T_1=full irrigations, no ABA, SA, MLE and MBLE	5873.3 A	16612.6 A	35.3 A	6.18 A	100 A	19.41 A	75.14 A	16.27 A
T_2=2μM ABA (- GF)	5708.51B	16380.9 B	34.85 B	4.78 B	92.21B	17.37 B	72.65 B	14.40 B
T_3=10mM SA (- GF)	5391.59C	16284.5 D	33.17 C	4.33 C	91.78 C	14.50 C	72.41 C	13.92 C
T_4=15% MLE	5287.10D	16188.3 C	32.63D	4.51 D	89.95 D	14.24D	69.23 D	13.21 D
T_5=10% MBLE (- GF)	5130.34F	16059.3 E	31.93 E	3.81E	87.31 E	13.55 E	68.53 E	13.04 E
LSD (0.5)	0.41	0.21	0.71	0.65	0.71	0.22	0.78	0.67
Wheat cultivars								
Aas-2011	5711.24 A	16525.1 A	34.55 A	5.53 A	93.51 A	16.64 A	73.15 A	14.84A
Faisalabad-2008	5524.76 B	16213.2 B	34.09 B	4.39 B	93.43 B	15.26 B	72.24 B	14.22 B
TD-1	5198.55 C	16176 C	32.12 C	4.25 C	92.81 C	14.8 C	70 .39 C	13.45 C
LSD (0.05)	0.21	0.25	0.54	0.33	0.39	0.10	0.55	0.35

Means sharing the same letter within the column and rows differ non-significantly at the 5% probability level. ABA: abscisic acid; SA: salicyclic acid; MLE: Moringa leaf water extract; MBLE: mulbery leaf water extract; (- GF), skipping irrigation at grain filling stage; WUE: water use efficiency.

water use efficiency improvement, inter cellular concentration of carbon dioxide, respiratory-pathways and biochemical attributes (Rady *et al*., 2013; Ali *et al*. 2013). Mulbery leaf water extract application to wheat genotypes under drought conditions improved yield and yield components. It was observed by many researchers that under drought stress, 30 times diluted moringa leaf extract is beneficial for the growth of plant (Wajid *et al*., 2002; Yasmeen *et al*., 2013). This increase in yield and its components might be because of moringa leaf extract which is enriched with significant concentrations of essential nutrients (potassium and calcium), plant hormones (cytokinin, ascorbates, phenols) and zeatin (Afzal *et al*., 2008; Basra *et al*., 2009; Khan *et al*., 2017).

The impact of treatments on the plant population of wheat cultivars was nonsignificant (Table 1). It was due to the use of the same seed rate, planting geometry and other inputs that maintain the same plant population (Wajid *et al*., 2002). The use of bio stimulants significantly affected the plant height. The genotypic variation among the wheat cultivars is an important index of drought tolerance. This variation in genetic makeup of studied cultivars clarified that Aas-2011 is taller, Faisalabad-2008 is a medium and TD-1 is a dwarf cultivar. These results support the findings of an earlier report (Fahad *et al*., 2017) which indicated that genotypic variation among wheat cultivars contributed to drought tolerance. Similar findings were also observed by Ashraf *et al*. (2017) as they reported significant genotypic variation in plant height of wheat, oat and barley. Aas-2011 cultivar showed higher potential to produce tillers per plant as compare to Faisalabad-2008 and TD-1 (Table 1). This might be genetic variation of Aas-2011 plant to conserve more water under the limited availability of moisture. Water conservation in plant body under drought is an important index to differentiate between drought-sensitive and drought-resistant cultivars of field crops (Anjum *et al*., 2016; Hussain *et al*., 2012; Jena *et al*., 2017; Fahad *et al*., 2017).

Treatments and wheat cultivars had significant impact on plant physiological attributes such as crop relative water contents, WUE and maximum drought yield index of wheat genotypes (Table 2). T1 showed the maximum values of WUE (6.18 Kg ha^{-1} mm^{-1}), RWC (75.14 %) and drought yield index (87.31%) as compared to others treatments. Protein contents and soil moisture contents of wheat genotypes were affected by divergent treatments (Table 2). Maximum Protein contents (19.41 mg/g) and soil moisture contents (16.27 %) were noted in T_1 and minimum protein contents 13.55 (mg/g) and soil moisture contents (13.45 %) were estimated in T_5 (Table 2). Data for varieties showed that the maximum Protein contents, soil moisture contents WUE, RWC and drought yield index were found in Aas-2011 (Table 2). Similar results were also observed by some other researchers as they reported that the application of bio stimulants like ABA, MBLE and SA have a significant impact on biochemical and physiological attributes (Foidl *et al*., 2002; Abdalla, 2013; Mona, 2013).

Conclusion and Recommendations

The application of Abscisic acid, moringa leaf extract and salicylic acid had pronounced impact on wheat growth, and yield. It is concluded that exogenous application 2µM ABA to wheat genotype AAS-11 after skipping irrigation at grain filling stage produced maximum yield. This increase in yield was due to improving drought tolerance of wheat genotype as ABA helps the plant in water conservation. The foliar application of growth regulators with plant water extracts increased the yield and yield related attributes of Aas-2011 under water stressed conditions. Use of bio-stimulants as foliar and seed priming reduced the stress impact. On the base of current study results, it is recommended to use these bio-stimulants in blended form with fertilizers for a profitable yield.

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Novelty Statement

The current scenario of water shortage, increasing population and more food demand enforcing the researchers to search alternate shortgun approaches to get a productive crop yield. The application of growth regulators is also an aspect of such approaches, which are helpful to improve the plant growth under drought conditions.

Author's Contribution

Safdar Hussain: Designed and collected data.
Muhammad Naeem Mushtaq: Analyzed the data.
Ali Bakhsh and Muhammad Mudassar Maqbool: Designed this experiment.
Muhammad Sarwar and Muhammad Jan: Prepared the first draft of the article.
Safdar Hussain also finalized the draft after a careful reading of Muhammad Abdul Qayyum and Arif Hussain.

Conflict of interest

The authors have declared no conflict of interest.

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