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HORMONAL SEED PRIMING IMPROVES WHEAT (*TRITICUM AESTIVUM* L.) FIELD PERFORMANCE UNDER DROUGHT AND NON-STRESS CONDITIONS

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Abstract

Global warming and unexpected climatic change especially increased in temperature and drought incidence were forced the agri- scientist to develop long term future strategies required for all drought and temperature sensitive crops including wheat. The objective of this study was to explore the process of better wheat growth and development under premises of drought. Five wheat cultivars were used to study the effect of drought and to cope drought with hormonal priming. Wheat seeds were primed in 10^{-4} M concentration of Salicylic acid (SA) and Gibberellic acid (GA), control was also used. Yield and yield components were decreased under drought. PAKISTAN-13 had the highest grain yield under normal and stress condition. The highest yield reductions were found in CHAKWAL-50 under normal condition. Under stress condition CHAKWAL-50 also had minimum yield. Among five genotypes FSD-08 maintained its yield under drought stress as compared to other genotypes. Hormonal priming improved yield under normal condition and overcome the effect of stress under drought. Priming increased the grain yield in CHAKWAL-50 and other genotypes. PAKISTAN-13 had the highest harvest index under normal condition and also under stress condition. PAKISTAN-13 and FSD-08 had the highest stress tolerance index while SA priming increased the stress tolerance index in CHAKWAL-50. Total sugar and protein contents were increased under drought. In conclusion, under normal and drought stress genotypic difference was observed for yield and yield contributing traits. PAKISTAN 13 and FSD-08 were wining genotypes. Seed priming was able to overcome stress and increased yield. Stress tolerance index was also improved by using hormonal priming. Genotype response was different under normal and drought stress.

Key words: Wheat, Drought, Seed priming, GA and SA.

Introduction

Global warming and climate change are altering the socio-economic and agriculture prospects at global level. Many developing countries like Pakistan are in problems of glacier melting, flash floods on one end while drought, heat stress and inadequate water availability for agriculture crops at the other end. Agriculture sector ensures fulfillment of food and feed requirements of the people and is a big source of foreign exchange that contributes significantly in national GDP of the country. The water requirements of crop increased with the increase in climatic temperature to compete the harsh environmental conditions and water scarcity. The ability of a cultivars to produce high and satisfactory yield over a wide range of fluctuating environment is very important (Ahmad *et al.*, 2003).

Wheat (*Triticum aestivum* L.) is an important cereal and staple food of many countries. Wheat feeds one-third of the world population and fulfill nearly half of the protein requirements. The global demand for wheat may rise up to 750 million tons till 2025 (Mujeeb-Kazi, 2006). Water scarcity at seedling stage, mid season water stress or drought incidence at terminal stages are major threats to wheat productivity. At seedling stage, the poor germination, more mean emergence time, reduced seedling vigor, low growth and development rate effect the yield of wheat crop (Noorka *et al.*, 2009). Wheat is highly sensitive to water stress at flowering, anthesis and grain filling stages and any water shortage at these critical stages can lead to reduction in grain numbers and size that ultimately limits the grain yield (Gooding *et al.*, 2003). Many other morphological traits related to grain yield of wheat can also be affected by drought stress, due to reduction in number of fertile spike per unit area, number of grain per spike, 1000 grain weight, biological yield, harvest index and plant height (Cattivelli *et al.*, 2008).

In order to cope with the drought stress, wheat plants exhibit different physiological responses, morphological expressions and biochemical functions. Seed priming a practical, cheapest physiological approach that triggers drought tolerance mechanism in wheat genotypes under water deficit situations and helps during emergence and first development stage. Priming with salicylic acid related compounds activate induction and inhibition processes in plants (Gill & Tuteja, 2010). Salicylic acid improved crop yield and yield related morphological traits depending upon plant species types, plant development stage, concentration level and manner of application (Arfan *et al.*, 2007). Gibberellins (GAs) are generally involved in growth and development. They control seed germination, leaf expansion, stem elongation and flowering (Magome *et al.*, 2004). Priming with GA_3 induced increase in wheat grain yield was attributed to the GA3-priming-induced modulation of ions uptake and partitioning and hormones homeostasis under saline conditions (Iqbal & Ashraf, 2013).

The general objective of this study was to investigate the response of wheat genotypes to drought stress. Other objective was to check usefulness of phytohormones i.e., SA and GA as priming agents to improve the wheat performance in terms of yield and yield contributing traits under drought and non-stressed control conditions.. The research outcomes in this regard can help in wheat improvement in Himalayan region of PAKISTAN especially in Azad Kashmir.

Materials and Methods

Two field experiments were designed during 2014 and 2015 in split plot fashion at field area of University of Azad Jammu and Kashmir. Wheat seeds were soaked in 10^{-4} M solution of two growth regulators viz., Gibberellic acid (GA) and salicylic acid (SA) for 8h prior to sowing and continuous aeration was provided by aquarium pumps. All agronomic practices were done regularly. Under experimental units, main plot were subdivided into two sub-plots, i.e., control and drought. Sub-plots were further splited into three sub-sub-plots and considered as replicates. Within sub-sub-plots priming treatments and five cultivars were completely randomized as experimental treatments. Five cultivars viz., AARI-11, CHAKWAL-50, SHAHKAR, PAKISTAN-13 and FSD-08 were used. Fifteen sub-plots served as a control with proper irrigating the plots, whereas the group of other fifteen sub-plots was considered as drought stress group to which no irrigation was provided and was with water protected sheet. Single row hand drill method was used for seed sowing with row to row and plant to plant spacing of 20 cm and 1.5cm respectively.

Yield component traits: At maturity, from randomly selected plants the data regarding morphological attributes was recorded for plant height (cm), number of tillers, spike length (cm), number of spikelets per spike, extrusion length (cm), peduncle length (cm), number of grains per spike, grain yield (kg/h), biological yield (kg/h), 1000 grain weight (g) and harvest index (%). Spike length, spikelets grains spike^{-1} and thousand grains weight were measured from ten randomly selected spikes. Grain yield and harvest index were calculated by using following formulas;

$$\text{Grain yield (kg/ha)} = \frac{\text{Grain yield}}{\text{Sampled area}} \times 1000\text{m}^2$$

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

whereas;

$$\text{Stress tolerance index} = \frac{\text{Values under stress}}{\text{Values under control}} \times 100$$

Biochemical attributes

Total soluble sugar: Sugar content of the flag leaves of wheat was estimated according to previously described method (Dubois *et al.*, 1956). For this 1mL (5 % v/v) of phenol was added to 0.1mL supernatant and left for 1 h incubation. After completion of incubation, concentrated H_2SO_4 was added. The absorbance was taken at 420 nm. Standard curve of glucose was used to calculate the concentration of unknown samples.

Protein contents: Protein contents from the flag leaves were determined by following the previously reported method (Bradford, 1976). The colour of Coomassie Brilliant Blue G250 changed proportionally in the solution of dilute acid by binding of dye with protein. To make the Bradford's reagent, 25 mL of 95 percent ethanol was mixed with 50mg Coomassie Blue G250 dye and then the mixture was dissolved in 50 mL of 85 % *o*-phosphoric acid to make total volume of 500 mL using distilled water. Using the solution (1 mg mL^{-1}) of BSA (Bovine Serum Albumin), a standard curve was made on spectrophotometer at *A*595nm.

Calcium and Potassium ratio: For the determination of potassium (k^+) and calcium (ca^+), digested solution was made using flag leaves and perchloric acid. This digested solution of leaves was used for the estimation of potassium and calcium contents with the help of JENWAY PFP 7 Flame photometer. A standard curve was prepared using KOH and CaOH respectively for the reference of K^+ and Ca^+ in the sample. The results were described in µg per gram of flag leaves (Szabo-Nagy *et al.*, 1992).

Statistical analysis: The recorded data was analyzed statistically by applying descriptive statistics. Factorial analysis was used to analyze data. The significance between means for different responses was measured using Tucky's test at 5% probability level while all other statistical calculations were made in Microsoft Excel 2002 (Microsoft crop. Redmond, WA, USA) and XL-STAT. Values presented in tables and graphs were mean ± SE with different alphabets differ significantly from each other.

Results

All genotypes showed significant variation in plant height (cm) for both normal and drought conditions (Table 1). Under normal condition, AARI-11 presented the highest values (102.7±1.27) while CHAKWAL-50 showed the lowest values (91.1±1.15) for plant height in absence of any priming treatment. A slight increased in plant height as result of SA priming was observed in AARI-11, CHAKWAL-50 and PAKISTAN-13 whereas in case of GA priming, PAKISTAN-13, CHAKWAL-50 and FSD-08 depicted slight increased in plant height.

Under drought stress, like normal conditions the same behavior was observed for plant height as AARI-11 had the highest value of (95.0±5.21) and CHAKWAL-50 had lowest value of (78.8±1.42) for plant height in absence of any priming treatment.

Increasing trend in plant height with SA and GA priming was also observed in all tested genotypes under normal conditions. While under drought effects all genotypes showed significantly decreased in plant height. As economically genotype with lower plant height is desired. The combined mean date over the two consecutive years repealed highest plant height values for all the tested genotypes in 2014 than 2015, even though their mean differences were non-significant.

All genotypes showed significant variation in accordance with the number of tillars under both normal and drought conditions (Table 2). Maximum values (6.4±0.78) for number of tillers were observed for SHAHKAR under normal conditions and 3.8±0.33 for PAKISTAN-13 in drought conditions with no priming. Minimum values for number of tillers were depicted by CHAKWAL-50 (2.9±0.22) in drought conditions without any priming. Priming with both SA and GA showed a little bit increased in number of tillers for all tested genotypes with maximum values of (6.4±0.65) and (5.8±0.99) under both priming treatments respectively with their combined mean of (5.9±0.4) in normal conditions by PAKISTAN-13. In drought conditions, again PAKISTAN-13 exhibited the highest values of (4.8±0.60) and (4.2±0.26) with their combined mean of (4.2±0.26) for both priming treatments. The combined mean comparison analysis over two years repealed that number of tillers decreased in second year than in 2014 due to significant effect of drought and treatments.

In term of Spike length (cm) Significant variation was observed in all tested genotypes under normal and drought stress conditions (Table 3). Under normal condition without priming, PAKISTAN-13 exhibited the highest spike length (13.0±0.21) followed by AARI-11 (12.6±0.25), CHAKWAL-50 (11.2±0.15) and FSD-08 (11.0±0.27) with lower position attained by SHAHKAR scoring lowest values for spike length (10.3±0.22). Seed priming resulted in improvement of the spike length and priming treatments with SA increased the spike length in AARI-11followed by PAKISTAN-13 and SHAHKAR. Treatment with GA priming, spike length was also increased in all tested genotypes except PAKISTAN-13 which showed the decreased trend in spike length as compare to control under non priming.

Under drought stress, PAKISTAN-13 depicted the highest spike length (cm) with no priming (10.8±0.15) but, under priming treatment with SA and GA hormones FSD-08 (10.8±0.21) and AARI-11 (11.2±0.19) attained higher position for spike length respectively. Drought stress significantly decreased the spike length in all tested genotypes, and priming with SA and GA succeeded to overcome the drought effects. Overall mean data of both normal and drought conditions revealed the genotype AARI-11 at higher position for spike length having higher mean values of (11.950) than other genotypes. Mean analysis over the years also showed the decrease in spike length of the test genotypes.

Genotypes showed significant variation for number of spiklets per spike under both normal and drought conditions (Table 4). PAKISTAN-13 was top of the list among the other genotypes for the said attribute scoring higher values of (22.0±0.64), (22.3±0.47) and (22.8±0.41) in non priming or priming with SA and GA hormones respectively. CHAKWAL-50 showed the lowest values in both non-priming and priming experiments.

Under drought condition FSD-08 showed maximum number of spikelets (18.8±0.27) with no priming. Treatment with SA hormone (19.6±0.20) while in treatment with GA, SHAHKAR genotype was on top to number of spikelets (19.8±0.32). Priming improved the spikelet numbers and the increasing trend moves to all tested genotypes in both hormonal priming treatments except FSD-08. In case of GA priming treatment in the spikelet numbers decreased as compare to non priming. Overall mean analysis for both normal and drought conditions revealed that PAKISTAN-13 had highest mean value (20.52) and CHAKWAL-50 had lowest value (18.7). As a result of drought and global warming effects like other traits same trend in mean values for number of spikelet was observed for all genotypes in all experiments in both consecutive years of 2014 and 2015.

Significant variation was observed in all tested genotypes under normal and drought conditions in term of extrusion length (cm). Under normal condition, FSD-08 had the highest extrusion length (13.8±0.81) in absence of any priming treatment (Table 5). While priming with SA and GA treatments PAKISTAN-13 had highest extrusion length (16.0±0.68) and (16.5±0.40) respectively. Under drought stress, FSD-08 got first rank for extrusion length scoring values of (12.1±066) within no priming experiments and (12.6±0.681) in treatment with GA. In priming with SA experiment the highest position getting genotype was SHAHKAR (12.0±0.44). Drought stress significantly decreased the extrusion length in all tested genotypes. Overall, under normal and drought stress condition FSD-08 had the highest mean value (13.61) while CHAKWAL-50 had the lowest value (11.88).

Non significant variation was observed in all tested genotypes for both normal and drought conditions in term of peduncle length (cm). Under normal condition, PAKISTAN-13 was at top for peduncle length (34.5±1.16) while CHAKWAL-50 was at bottom due to lowest values for peduncle length (30.5±0.80) in absence of any priming treatment (Table 6). Seed priming increased slightly peduncle length on SA priming in all genotypes except SHAHKAR that showed decreased in peduncle length on SA priming. Priming with GA showed increasing trend in peduncle length in all tested genotypes.

Under drought stress with no priming, FSD-08 and PAKISTAN-13 were two top ranking genotypes owing to same values for peduncle length (31.7±0.49) while CHAKWAL-50 again scored the lowest position with lowest values for peduncle length (28.5±0.40). Non significant results were shown by all genotypes on priming with SA while with GA all genotypes showed a little increased in peduncle length in AARI-11 and CHAKWAL-50 as compared to non priming.

Drought stress significantly decreased the peduncle length in all tested genotypes. Overall mean data analysis for both normal and drought conditions showed that PAKISTAN-13 was at higher position with highest mean value (33.39) and CHAKWAL-50 attained lower position with lowest value (31.90).

All tested genotypes depicted significant variability for number of grains under both normal and drought conditions (Table 7). PAKISTAN-13 showed top position while CHAKWAL-50 was at bottom for number of grain having values of (62.3±1.24) and (50.7±0.61) respectively under normal condition with no priming treatment. Seed priming with SA increased number of grains significantly in AARI-11, CHAKWAL-50 and FSD-08 while priming with GA showed increased in all tested genotypes. Like normal condition with no priming treatment the same results were obtained under drought stress with top position of PAKISTAN-13 (55.6±1.07) and lowest position of CHAKWAL-50 (43.6±0.68) in absence of any priming treatment. Number of grains was raised on SA priming in all tested genotypes except PAKISTAN-13. Priming with GA was able to increase the number of grains in all tested genotypes.

Drought stress significantly decreased the number of grains in all tested genotypes. Overall mean data analysis, under normal and drought stress condition PAKISTAN-13 and FSD-08 had same magnitude of high mean value (59.0) while CHAKWAL-50 had the lowest value (50.0).

Table 1. Effect of seed priming and drought on plant height (cm) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	102.7±1.27g-i	103.9±0.81i	101.1±0.83g-i	102.6±0.60e	84.9±1.27a-c	85.4±2.04a-c	90.7±1.52cd	87.0±1.09	94.92
CHAKWAL-50	91.1±1.15cd	94.6±0.92d	95.4±0.86	93.7±0.70d	78.8±1.42a	82.03±0.64a	82.3±1.32a	81.0±0.74a	87.40
SHAHKAR	95.6±1.44d-g	96.4±1.11d-h	96.0±1.44d-g	96.0±0.73d	79.0±1.07a	84.4±1.12a-c	80.6±0.44a	81.3±0.75a	88.70
PAKISTAN-13	101.0±0.72f-i	103.5±0.79hi	103.5±0.77i	102.6±0.50e	82.9±1.12ab	90.1±1.79b-d	85.8±1.24bc	86.2±1.05bc	94.47
FSD-08	96.5±0.56d-h	97.3±0.78ef-i	98.7±1.17fg-i	97.5±0.52d	80.7±2.07a	82.6±1.04a	84.6±1.08a-c	82.6±0.88ab	90.10
Years									
2014	97.64	100.08	100.18	94.69	80.56	85.40	86.41	84.12	91.53a
2015	96.14	98.28	98.46	97.96	82.02	83.47	84.28	83.59	90.67a
Mean	96.89	99.18	99.27	98.61	81.29	84.94	85.32	83.69	91.15

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 2. Effect of seed priming and drought on number of tillars of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	3.0±0.68a	4.3±0.84a	3.8±1.01a	4.7±0.48ab	3.1±0.48ab	3.3±0.22a	3.5±0.66a	3.3± 0.26a	4.067
CHAKWAL-50	4.6±0.36a	4.9±0.85a	4.7±0.51a	3.7±0.35a	2.9±0.22a	3.2±0.11a	3.5±0.71a	3.2±0.24a	3.519
SHAHKAR	6.4±0.78a	5.9±0.82	5.4±0.89a	4.7±0.45ab	3.5±0.15a	3.4±0.38a	2.9±0.28a	3.3±0.16a	4.039
PAKISTAN-13	5.7±0.62a	6.4±0.65a	5.8±0.99a	5.9±0.43b	3.8±0.33a	4.8±0.60a	4.0±0.37a	4.2±0.26ab	5.089
FSD-08	5.3±0.76a	4.9±0.76a	3.1±0.93a	6.02±0.45b	3.3±0.22a	3.9±0.65a	3.8±0.78a	3.7±0.33a	4.875
Years									
2014	5.59	5.81	5.64	5.68	3.45	4.31	3.96	3.90	4.588a
2015	4.48	4.52	4.58	4.52	3.31	3.56	3.28	3.38	4.048a
Mean	5.04	5.15	5.11	5.10	3.38	3.94	3.62	3.64	4.37

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 3. Effect of seed priming and drought on spike length (cm) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	12.6±0.25e-h	13.7±0.35h	13.2±0.23h	13.1±0.19d	10.6±0.18bcd	10.3±0.25a-d	11.2±0.19de	10.7±0.14b	11.950
CHAKWAL-50	11.2±0.15de	11.0±0.22cd	11.7±0.37defg	11.3±0.16bc	8.8±0.23a	9.3±0.15ab	9.6±0.15abc	9.2±0.12a	10.300
SHAHKAR	10.3±0.22bcd	11.7±0.08d-g	11.6±0.26def	11.2±0.19bc	9.3±0.18ab	9.7±0.29abc	9.3±0.15ab	9.4±0.12a	10.350
PAKISTAN-13	13.0±0.21gh	13.3±0.20h	12.8±0.35fgh	13.0±0.15d	10.8±0.15cd	10.6±0.29bcd	10.71±0.14bcd	10.7±0.11b	11.900
FSD-08	11.0±0.27cd	11.5±0.24def	12.8±0.27fgh	11.8±0.23c	10.3±0.24bcd	10.8±0.21cd	10.8±0.30cd	10.6±0.14b	11.236
Years									
2014	11.66	12.40	12.41	12.16	9.89	10.36	10.46	10.23	12.19a
2015	11.68	12.12	12.46	12.08	10.12	9.96	10.23	10.10	11.09a
Mean	11.67	12.26	12.44	12.12	10.00	10.16	10.34	10.17	11.14

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 4. Effect of seed priming and drought on spikelets of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	20.5±0.42d-i	20.9±0.32e-i	21.5±0.32ghi	21.0±0.21b	18.5±0.46a-e	18.8±0.45a-f	18.9±0.38a-f	18.7±0.23a	19.88
CHAKWAL-50	17.9±0.41ab	19.8±0.73b-h	20.5±0.14c-i	19.4±0.37a	16.4±0.41a	18.6±0.52a-e	18.9±0.21a-f	18.0±0.34a	18.72
SHAHKAR	21.0±0.69e-i	21.5±0.40ghi	21.4±0.42ghi	21.3±0.29b	18.0±0.47abc	19.1±0.26b-g	19.9±0.16b-h	19.0±0.26a	20.20
PAKISTAN-13	22.0±0.64e-i	22.3±0.47f-i	22.8±0.41hi	21.4±0.302b	18.2±0.29a-d	18.7±0.18a-e	19.8±0.36b-h	19.0±0.17a	20.52
FSD-08	21.5±0.40ghi	21.8±0.55hi	22.6±0.32i	21.9±0.26b	18.8±0.27a-f	19.6±0.20b--h	18.6±0.32a-e	18.9±0.22a	20.20
Years									
2014	20.92	21.74	21.88	21.51	18.74	19.96	20.11	19.94	20.05a
2015	19.78	19.78	21.12	20.22	17.94	19.02	20.40	19.78	19.76a
Mean	20.35	20.76	21.5	20.87	18.34	18.99	19.25	18.86	19.86

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 5. Effect of seed priming and drought on extrusion length(cm) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	13.0±0.84a-e	15.1±1.03cde	14.9±0.77cde	14.3±0.53bc	10.1±0.56ab	11.5±0.58a-d	12.0±0.66a-e	11.2±0.38a	12.82
CHAKWAL-50	11.7±1.05a-d	13.1±0.72a-e	13.8±0.57a-e	12.9±0.48abc	9.7±0.35a	11.0±0.40abc	11.7±1.13a-d	10.81±0.43a	11.88
SHAHKAR	12.8±0.90a-e	14.6±0.75b-e	15.4±0.69c-e	14.32±0.50bc	11.5±0.56a-d	12.0±0.44a-e	12.4±0.71a-e	11.9±0.32ab	13.16
PAKISTAN-13	13.0±0.98a-e	16.0±0.68de	16.5±0.40e	15.20±0.54c	11.6±0.71a-d	11.9±0.83a-d	12.1±0.76a-e	11.9±0.42a	13.55
FSD-08	13.8±0.81a-e	15.3±1.14cde	15.9±0.63de	15.03±0.52c	12.1±0.66a-e	11.8±0.39a-d	12.6±0.61a-e	12.18±0.32ab	13.61
Years									
2014	12.973	14.24	15.06	14.09	10.83	11.360	13.25	11.42	13.16a
2015	13.20	14.39	15.21	14.27	11.22	11.360	12.06	12.33	12.84a
Mean	13.09	14.31	15.13	14.18	11.03	11.36	12.30	11.75	12.96

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 6. Effect of seed priming and drought on peduncle length (cm)of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	32.9±1.26abc	33.8±0.80abc	35.4±0.73bc	34.1±0.58bcd	30.9±1.11ab	32.0±0.76ab	31.7±0.74ab	31.5±0.47ab	32.97
CHAKWAL-50	30.5±0.80ab	33.9±1.73abc	34.4±0.66bc	32.9±0.76a-d	28.5±0.40a	32.4±0.55abc	31.2±0.61ab	30.7±0.51a	31.90
SHAHKAR	33.9±1.54abc	33.5±0.77abc	35.2±0.89bc	34.2±0.63bcd	30.6±0.78ab	31.4±0.70ab	31.0±0.81ab	31.0±0.45a	32.34
PAKISTAN-13	34.5±1.16bc	35.0±1.06bc	37.6±0.61c	35.7±0.62d	31.7±0.82ab	31.5±0.48ab	32.6±0.94abc	31.9±0.36abc	33.39
FSD-08	33.7±1.04abc	35.3±1.04bc	35.1±0.75bc	34.7±0.54cd	31.7±0.49ab	30.4±0.83ab	32.6±0.51abc	31.6±0.42a	32.77
Years									
2014	33.64	33.84	35.04	34.17	32.80	32.84	33.34	31.26	32.95
2015	31.86	32.30	34.33	32.83	29.72	30.84	31.55	31.84	32.79
Mean	32.75	33.07	34.69	33.50	31.26	32.84	32.45	32.84	32.97

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

In case of 1000-grain weight significant variation was observed in all tested genotypes under normal and drought conditions (Table 8). The highest as well as the lowest 1000-grain weight showing genotypes were SHAHKAR (40.6±0.82) and CHAKWAL-50(35.3±0.78) respectively in absence of any priming treatment under normal condition. Priming with SA resulted in slight increase in the said attribute in AARI-11, CHAKWAL-50 and PAKISTAN-13 along with slight improvement in 1000-grain weight in SHAHKAR, PAKISTAN-13, CHAKWAL-50 and FSD-08 on priming with GA.

Drought stress tolerating genotype was PAKISTAN-13 that depicted highest 1000-grain weight (34.6±0.33) under drought stress condition with no priming while SHAHKAR had the lowest values (31.5±0.71). Seed priming with both hormones raised the 1000-grain weight in all tested genotypes. Same drought effects were observed in all genotypes while comparing the results of both normal and drought stress conditions as drought stress showed the decreased in the said plant traits.

All the tested genotypes showed significant variation for the grain yield for both normal and stress conditions (Table 9). PAKISTAN-13 was at top for grain yield (1910.1±30.79) under normal conditions while FSD-08 had the highest values (1583.5±76.21) under drought conditions in the absence of any priming treatment. CHAKWAL-50 showed the lowest values for the gain yield (1289.3±40.98) and (936.1±26.70) in both conditions without any priming. Significant increased in grain yield was observed on SA priming in CHAKWAL-50, SHAHKAR, PAKISTAN-13 and FSD-08 under normal conditions while all tested genotypes showed an increase in the said plant trait under drought conditions.

In case of GA priming, improvement in grain yield was observed in CHAKWAL-50, SHAHKAR and FSD-08 under normal conditions while AARI-11, CHAKWAL-50, SHAHKAR and PAKISTAN-13 under drought conditions except FSD-08 that showed non-significant effect on GA priming. Drought stress significantly decreased the grain yield in all tested genotypes. Overall, under normal and drought stress condition PAKISTAN-13 had the highest mean value (1764.77) while CHAKWAL-50 has the lowest value (1189.66).

Among all significantly variable genotypes FSD-08 got higher position for the values of biological yield (5873.3±119.44) and (5120.1±95.15) respectively under both conditions (Table 10). CHAKWAL-50 was at lowest position for the biological yield (4983.0±64.11) under normal and (4579.8±75.74) under drought conditions in absence of any priming treatment. The impact of priming revealed the results in increased in biological yield in CHAKWAL-50, SHAHKAR, PAKISTAN-13 and FSD-08 on SA while slightly increased in AARI-11, CHAKWAL-50 and SHAHKAR on GA priming. The effects of priming under drought conditions showed that except FSD-08 all genotypes were improved for biological yield on priming with SA while all genotypes exhibited increased in biological yield on priming with GA. Over all mean data analysis for both normal and drought stress revealed the effects of drought on biological yield with highest and lowest mean values of FSD-08 (5498.11) and CHAKWAL-50 (4859.83) respectively.

The highest harvest index was observed in PAKISTAN-13 genotype under both normal (31.8±1.18) and drought (27.0±2.32) conditions (Table 11). CHAKWAL-50 showed the lowest values of harvest index (24.4±0.74) and (18.8±0.41) for both conditions in absence of any priming treatment.

Slightly increased in harvest index on SA priming was observed in AARI-11and CHAKWAL-50 under normal conditions and in all tested genotypes in drought conditions. In case of GA priming, harvest index was increased slightly in PAKISTAN-13, CHAKWAL-50 and FSD-08 under normal conditions while in all genotypes in drought stress conditions. Under overall mean analysis data FSD-08 had highest mean values of 29.350 and CHAKWAL-50 had lowest value (23.24) under both conditions. Overall, for all traits mean values for the year showed that 2014 experiment had the maximum yield and yield contributing parameters as compared to 2015 although difference of the year is non significant. Data revealed that effect of drought and treatments were significant.

Stress tolerance index (STI %): Stress tolerance index (STI %) had been widely used by researchers to identify sensitive and tolerant genotypes. In term of plant height PAKISTAN-13 and FSD-08 had maximum stress tolerance index (Table 12). Number of tillars was tolerated in CHAKWAL-50. PAKISTAN-13 had the maximum STI in term of Spike length while all genotypes have maximum stress tolerance in number of spikelet except CHAKWAL-50. Numbers of grains was high in PAKISTAN-13 and had maximum STI. Highest stress tolerance index was found in FSD-08 in case of grain weight and grain yield. PAKISTAN-13 had the maximum stress tolerance index for bio yield, while FSD-08 and PAKISTAN-13 had the maximum Stress tolerance for Harvest index. Overall, priming increased the stress tolerance index in all tested genotypes (Table 13). We concluded that all yield parameters were interlinked and correlated. Based on all these parameters we were able to screen genotypes.

Many researchers worked on maize to select tolerant hybrids under normal and stress condition. They found that STI, GMP indices showed the highest correlation with grain yield can be used as selection criteria for stress tolerance (Jafari *et al.*, 2012). They also reported that Stress tolerant Index (STI) was more effective tool to screen corn tolerant cultivars under normal and stress condition. Under favorable environmental conditions yield progress were much better but under different environmental conditions genetic increased in yield were difficult task for breeders (Richards *et al.*, 2002). Thus, drought indices have been used that were important to determine the yield loss under different environmental conditions to measure yield loss under drought for screening drought-tolerant genotypes (Mitra, 2001). If the strategy of breeding program was to improved yield in a small stress or non-stress environment, it may be possible to explain local adaptation to increased gains from selection conducted directly in that environment (Mardeh *et al.*, 2006). The result of previous authors showed that level of stress was important to choose the indices on target environment. Stress sensitivity index SSI was recommended as valuable marker for selection of wheat where level of stress was severe. If stress level were less severe MP, GMP, TOL HM and STI are used, whears STI, GMP and MP were used in the both conditions either level of stress were severe or not severe for selection of high yielding genotypes (Mohammadi *et al.*, 2003) (Mohammadi *et al.*, 2012).

Table 7. Effect of seed priming and drought on number of grains of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	57.2±1.16f-j	59.3±0.71h-k	59.3±1.21g-k	58.6±0.62de	49.5±1.23	52.1±1.07	56.0±1.01	52.5±0.88bc	55.59
CHAKWAL-50	50.7±0.61b-f	55.3±0.82d-h	55.4±0.85d-h	53.839±0.67bc	43.6±0.68	48.3±0.99	49.4±0.92	47.1±0.77a	50.49
SHAHKAR	57.2±1.31f-j	56.5±0.62f-j	62.8±1.21jkl	58.8±0.90def	47.9±0.78	52.0±0.62	55.7±0.83	51.8±0.87b	55.37
PAKISTAN-13	62.3±1.24h-l	60.3±1.02h-l	64.9±1.12kl	62.5±0.76ef	55.6±1.07	54.6±1.52	59.4±1.71	56.5±0.93cd	59.82
FSD-08	60.7±1.99h-l	62.4±1.17i-l	66.0±1.09l	63.0±0.96f	53.1±0.59	57.2±0.87	59.3±0.86	56.5±0.75cd	59.55
Years									
2014	59.47	59.36	62.84	60.56	50.38	53.98	57.10	53.16	57.86a
2015	55.82	58.24	60.58	58.21	49.58	53.74	54.89	52.73	55.47a
Mean	57.65	58.80	61.71	59.39	49.98	52.86	56.00	52.94	56.16

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 8. Effect of seed priming and drought on thousand grain weight (g) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	37.3±0.95b-i	40.0±0.66f-i	39.8±1.22e-i	39.0±0.60cd	32.9±0.67abc	34.5±0.57a	34.3±0.74a-e	33.9±0.39a	36.52
CHAKWAL-50	35.3±0.78a-g	38.1±1.00b-i	38.3±1.32c-i	37.2±0.66bc	31.7±0.75a-f	32.7±1.04ab	33.5±0.76a-d	32.6±0.505a	34.98
SHAHKAR	40.6±0.82ghi	39.0±0.70d-i	39.3±1.44e-i	39.7±0.58cd	31.5±0.71a	34.9±0.67a-g	35.0±1.01a-f	33.8±0.59a	36.78
PAKISTAN-13	39.6±1.29e-i	41.0±0.82hi	41.6±0.60i	40.7±0.55d	34.3±1.04a-e	35.0±0.70a-h	35.6±0.82a-h	35.0±0.48ab	37.90
FSD-08	39.3±1.05e-i	39.7±1.10ghi	40.9±0.76hi	39.9±0.56cd	34.6±0.33a-f	36.9±0.91a-e	35.0±1.26a-g	35.2±0.51ab	37.62
Years									
2014	40.01	40.99	42.44	41.55	34.65	36.45	37.43	36.51	37.25a
2015	35.50	37.35	38.95	37.27	31.17	33.86	34.64	33.89	36.27a
Mean	37.76	38.271	39.20	38.41	34.41	35.16	36.04	35.20	36.80

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 9. Effect of seed priming and drought on grain yield (kg/hec) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	1696.3±42.23i-l	1636.3±48.301-l	1632.1±59.74h-l	1654.9±28.35d	1220.5±30.13 a-e	1227.1±31.62 a-f	1388.3±18.72e-i	1278.6±23.99b	1466.80
CHAKWAL-50	1289.3±40.98b-h	1368.8±42.29c-l	1458.5±68.36d-i	1372.2±32.85bc	936.1±26.70a	987.3±27.35 ab	1097.8±21.15abc	1007.1±21.32a	1189.66
SHAHKAR	1533.5±56.75e-j	1641.5±46.66i-l	1659.0±63.13i-l	1611.3±33.18d	1146.1±42.73 a-d	1174.0±75.14a-d	1278.8±48.63a-g	1199.6±34.00b	1405.50
PAKISTAN-13	1910.1±30.79kl	1917.5±87.27kl	1911.1±60.54kl	1912.9±34.63e	1463.0±144.83 d-i	1579.5±35.52 g-k	1648.0±35.18i-l	1616.6±29.81d	1764.77
FSD-08	1849.0±26.37g-l	1947.1±36.72l	1935.1±37.27	1910.4±21.19e	1583.5±76.21 g-k	1618.3±40.07 g-l	1571.1±108.23f-k	1537.8±59.11cd	1724.16
Years									
2014	1719.733	1754.267	1742.86	1738.956	1384.133	1374.000	1475.867	1411.33	1566.25
2015	1531.600	1563.600	1595.53	1563.578	1108.933	1227.200	1311.133	1215.755	1454.11
Mean	-	-	-	-	-	-	-	-	-

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 10. Effect of seed priming and drought on biological yield (kg/hec) of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	5827.8±87.31h-i	5709.8±128.54ghi	5949.6±125.55i	5829.1±66.91f	4709.0±66.84abc	4762.0±97.28a-d	4896.6±59.81a-f	4789.2±45.64ab	5309.167
CHAKWAL-50	4983.0±64.11a-f	5166.6±46.53e-g	5487.1±186.34f-i	5212.2±81.07cd	4579.8±75.74abc	4610.5±58.05a	4631.8±48.54ab	4507.3±37.71a	4859.833
SHAHKAR	5325.3±81.33d-h	5456.8±57.08f-i	5345.3±80.03d-h	5375.8±42.34de	4846.0±77.28a-e	5031.6±78.59b-f	5068.1±76.12b-f	4981.9±48.12bc	5178.889
PAKISTAN-13	5789.8±71.16hi	5813.1±132.55hi	5426.3±143.40e-i	5676.4±77.97ef	5076.0±103.13b-f	5134.5±89.39c-g	5225.3±62.63b-g	5111.9±47.4cd	5394.194
FSD-08	5873.3±119.44hi	5948.3±189.28i	5864.6±109.10hi	5895.4±78.49f	5120.1±95.15b-g	5078.8±59.90b-f	5103.3±69.02b-f	5100.7±41.51cd	5498.111
					Years				
2014	5670.80	5753.13	5706.00	5709.97	5094.80	5180.00	5272.53	5115.77	5303.98
2015	5288.93	5184.80	5363.26	5279.00	4810.93	4853.66	4930.93	4831.84	5192.08
Mean	5479.86	5468.96	5534.63	5494.48	4831.84	5215.77	4951.73	4954.86	5224.67

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 11. Effect of seed priming and drought on harvest index (%)of wheat during 2014 and 2015.

Genotypes	Control			Mean	Drought			Mean	Overall mean
	NP	SA	GA		NP	SA	GA		
AARI-11	27.0±0.57d-h	28.6±0.69fh	27.7±0.29d-h	27.8±0.33c-e	22.5±0.52	24.2±0.43b-f	20.8±0.27a-c	22.5±b0.40	25.20
CHAKWAL-50	24.4±0.74c-h	25.2±1.20d-h	25.0±0.34c-g	24.9±0.46bc	18.8±0.41a	20.5±0.24a-c	21.3±0.06ab	19.5±0.23a	23.24
SHAHKAR	28.5±0.29e-f	28.8±0.10f-h	28.7±0.62f-h	28.6±0.22d-f	20.8±0.27b-f	22.0±0.17a-c	24.4±0.50a-c	22.1±0.43ab	25.40
PAKISTAN-13	31.8±1.18h	28.9±0.70f-h	29.2±1.06	29.9±0.62ef	27.0±2.32d-h	28.3±0.85a-e	30.1±0.54gh	26.9±0.79cd	29.35
FSD-08	30.9±1.10h	31.2±1.22g-h	31.5±0.99	30.9±0.61f	23.3±0.85d-h	27.3±1.78d-h	28.9±1.10fgh	27.7±1.0cde	28.48
					Years				
2014	27.87	29.24	30.31	29.14	21.34	24.27	25.6	23.7	26.61a
2015	26.27	28.52	29.61	28.13	20.47	23.28	23.79	22.52	25.66a
Mean	27.07	28.88	29.96	28.64	20.91	23.783	24.70	23.13	25.88

Np = Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 12. Stress tolerance index (STI %) of wheat genotypes based on morphological parameters across both years priming treatments.

Genotypes	Plant height (%)	Tillars (%)	Spikelegth (%)	Spikelets (%)	Extrusion (%)	Peduncle (%)	Grains (%)	Grain weight (%)	Grain yield (%)	Bio yield (%)	Harvest index (%)
AARI-11	84.83	70.43	81.37	89.16	78.29	92.54	89.63	86.84	77.26	82.16	81.06
CHAKWAL-50	86.52	86.32	81.85	82.39	84.19	93.18	87.58	85.28	73.39	86.48	74.63
SHAHKAR	84.74	69.07	84.18	89.23	83.71	90.72	88.13	87.68	74.45	92.67	77.08
PAKISTAN-13	84.04	70.74	82.14	88.40	78.30	89.42	90.48	86.00	80.39	90.06	89.88
FSD-08	84.76	61.90	90.44	86.66	81.08	91.01	89.71	88.13	84.62	86.52	89.74

NP= Non primed, SA= Salicylic acid and GA= Gibberellic acid

Table 13. Stress tolerance index (STI %) of wheat genotypes based on morphological parameters across both years and priming treatments.

Genotypes	Seed priming	Plant height (%)	Tillars (%)	Spikelegth (%)	Spikelets (%)	Extrusion (%)	Peduncle (%)	Grains (%)	Grain weight (%)	Grain yield (%)	Bio yield (%)	Harvest index(%)
AARI-11	NP	82.69	62.71	84.26	90.04	78.03	93.88	86.49	88.25	71.95	80.80	83.27
	SA	86.57	55.79	79.20	80.52	83.38	93.56	80.12	87.01	67.38	81.88	77.01
	GA	82.61	61.88	90.18	85.88	89.77	90.33	83.67	77.65	74.74	91.00	85.59
CHAKWAL-50	NP	82.08	74.29	82.68	87.06	88.66	91.85	89.36	86.80	76.59	87.67	86.11
	SA	83.66	57.51	93.83	87.76	87.27	94.07	87.59	88.28	85.64	87.18	87.26
	GA	82.17	63.21	75.33	89.59	75.96	94.54	87.84	86.31	74.99	83.40	84.66
SHAHKAR	NP	86.65	74.90	84.29	94.12	84.12	95.53	87.38	83.22	72.13	85.36	81.65
	SA	87.62	69.73	82.70	88.79	82.23	93.69	92.07	89.47	71.52	92.21	73.02
	GA	87.05	81.23	80.20	88.03	74.61	90.00	90.47	85.44	82.37	88.33	80.68
PAKISTAN-13	NP	84.90	62.08	93.78	89.92	77.12	86.23	91.57	90.57	83.11	85.38	90.21
	SA	89.73	71.81	84.87	87.91	80.89	89.38	94.44	86.05	85.06	82.30	75.19
	GA	86.34	72.60	82.10	92.20	84.96	90.53	89.18	87.50	75.27	82.59	77.21
FSD-08	NP	83.97	62.46	80.34	92.94	80.09	88.26	88.65	89.00	77.08	94.81	72.69
	SA	82.93	62.02	83.62	90.02	73.66	86.64	91.55	85.79	82.21	94.45	96.10
	GA	85.69	70.94	84.53	82.47	79.48	92.88	89.90	85.63	85.16	87.02	91.70

NP= Non primed,SA= Salicylic acid and GA= Gibberellic acid

Biochemical attributes: In case of sugar contents, significant variation was observed in all tested genotypes under normal and drought stressed condition (Fig. 1). Under both condition, without priming treatment FSD-08 had the highest sugar accumulation while CHAKWAL-50 had the lowest sugar accumulation. Under normal condition, Sugar accumulation was decreased significantly on SA priming in AARI-11, while increased in CHAKWAL-50 and SHAHKAR. In case of GA priming, sugar accumulation was increased significantly in PAKISTAN-13 and CHAKWAL-50 while non-significant effect on other genotypes. Under drought stress, sugar accumulation was significantly raised on SA priming in SHAHKAR and FSD-08 while decreased in other genotypes. Drought stress significantly increased the sugar accumulation in SHAHKAR while decreased in AARI-11 and CHAKWAL-50. SA priming raised the Sugar accumulation under drought as compared to control condition in SHAHKAR. In case of GA priming Sugar accumulation increased under drought as in normal condition in SHAHKAR while decreased in AARI-11 and PAKISTAN-13.

When protein contents were observed, slight variation was observed in all tested genotypes under normal and drought stressed condition (Fig. 2). Under normal condition, there was non-significant effect in the absence of any priming treatment on protein contents. When priming treatment was applied slight change was observed in all genotypes. Under drought stress, protein contents were increased as compared to normal. AARI-11, FSD-08 and PAKISTAN-13 showed increased protein content under drought as compared to normal. Priming with SA and GA enhanced protein content but to a minor level.

Under normal condition, SHAHKAR had the highest Potassium (K^+) ratio while PAKISTAN-13 had the lowest K^+ ratio in absence of any priming treatment (Fig. 3). Potassium K+ ratio were decreased significantly on SA priming in FSD-08, and SHAHKAR while increased in PAKISTAN-13. In case of GA priming, K^+ ratio was increased significantly in AARI-11and PAKISTAN-13 while decreased in FSD-08 and SHAHKAR. Under drought stress, SHAHKAR had highest K^+ ratio while PAKISTAN-13 had lowest K^+ ratio in absence of any priming treatment. Potassium K^+ ratio were significantly raised on SA priming on CHAKWAL-50 and PAKISTAN-13 while decreased in FSD-08. Priming with GA was able to increase the K+ ratio in AARI-11, CHAKWAL-50 while decreased in FSD-08. Drought stress significantly increased the K^+ ratio in AARI-11 and PAKISTAN-13 while decreased in SHAHKAR. Priming with SA raised the K^+ ratio under drought as compared to control condition in CHAKWAL-50 and PAKISTAN-13. In case of GA priming K^+ ratio increased under drought as in normal condition in AARI-11, CHAKWAL-50 and in SHAHKAR.

Under normal condition, PAKISTAN-13 had the highest calcium (Ca^+) ratio while FSD-08 had lowest Ca^+ ratio in absence of any priming treatment (Fig. 4). The Ca^+ ratio was decreased significantly on SA priming in AARI-11 and PAKISTAN-13 while increased in FSD-08 under normal condition. In case of GA priming, Ca^+ ratio was increased significantly in PAKISTAN-13 while decreased in SHAHKAR. Under drought stress, CHAKWAL-50 had the highest Ca^+ ratio while FSD-08 had the lowest Ca^+ ratio in absence of any priming treatment. Ca^+ ratio was significantly raised on SA priming only in PAKISTAN-13 while there was no effect in other genotypes. Priming with GA was able to increase the Ca^+ ratio in AARI-11, PAKISTAN-13and FSD-08. Drought stress significantly decreased the Ca^+ ratio in AARI-11 and PAKISTAN-13. While SA priming raised the Ca^+ under drought as compared to control condition in PAKISTAN-13 while decreased in FSD-08. In case of GA priming Ca^+ ratio increased under drought as in normal condition in PAKISTAN-13and AARI-11.

Discussion

There is a dire need to ensure sustainable and drought tolerant wheat genotypes having ability to cope with diverse climatic changes. All the factors affecting crop productivity under drought caused changes at physiological, biochemical and molecular levels (Saeedipour, 2012). The extent of drought stress tolerance exhibited by plants varied from species to species and even within a species (Taheri *et al.*, 2011). The selection of superior varieties having better performance under drought stress depends upon the apprehension of morpho-anatomical and physio-biochemical characteristics under changing climatic conditions (Martínez *et al.*, 2007). Therefore, screening of drought tolerant genotypes along with effects of plant growth regulators against drought stress were the objectives of the present study.

Among tested genotypes, AARI-11 was top of the list for plant height under both drought and normal conditions in the absence of any seed priming. But under priming with GA and SA growth regulators, improvement in the plant height was observed and as a result genotype sensitivity towards drought was reduced by priming treatment. Our results matched with previous findings in which significantly higher plant height, number of productive branches and seed yield due to foliar spray of GA_3 at 50 percent flowering were reported in fenugreek, (Vasudevan *et al.*, 2010). Moreover, an experiment on cowpea revealed the same findings of increased plant height, first nodal height, leaf area and number of leaves per plant as a result of exogenous application of GA_3 (Emongor, 2007). There are reports of the increased plant growth in the wheat genotypes due to the increased level of cell division by stimulating the mitotic system of the apical meristem of seedling root while drought stress reduced the cell growth at vegetative stage that caused decrease in plant height (Shakirova *et al.*, 2003). The higher plant height after treatment with different concentrations of SA has been reported (Moghaddam *et al.*, 2011). In another study, decrease in plant height owing to drought effects and its enhancement by application of salicylic acid was observed in common beans (Saeedipour, 2012).

In present study, the drought effects on wheat genotypes in relation with number of tillers as compared to control were also analyzed. SHAHKAR and PAKISTAN-13 showed tolerance to drought and also exhibited improvement by priming with both SA and GA. It has been reported that plant height, no of tillers, leaf area and leaf area index were more in wheat irrigated with 20ppm GA_3, while the effect was more when it was applied at earlier stages of wheat development than at flowering and grain filling stage (Akram *et al.*, 2004). While comparing to morphological responses, the drought sensitive genotypes showed more drastic effects than tolerant cultivars. The present study revealed reduction in no of tillers, spike length, numbers of spikelets and 1000-grain weight under drought as compared to control that showed the independent effects of stress on wheat genotypes under study.

(Khairallah *et al.*, 1998), observed a significant decrease in spike.m^{-2}, grain.$spike^{-1}$ and 1000-grain weight in an experiment on 12 cultivar of wheat under drought stress conditions. Moreover, (Kubota *et al.*, 2008). Pointed out the causes of reduced size and grain weight as reduction in remobilization and assimilations and reduction in 1000-grain weight and grain.$spike^{-1}$ lead to reduction in grain yield.

Drought has negative effects on number of grains and water deficiency at flowering stage and results in floret abortion and ultimately the reduced numbers of grains in wheat. The grain yield has positive association with number of grains and reduced grain number as less number of flowers are transformed into grains under water deficit conditions. It has been confirmed that water scarcity results in less or now photosynthesis that disturbed source to sink relationship in leaves especially that hampers the translocation of material during grain formation and grain filling stage and consequently the grain yield is reduced. The translocation of material from phloem depends upon turgor pressure, water potential and water deficiency, decreases the phloem potential and finally the grain yield also decreases accordingly. Furthermore, water stress at grain filling stage induces the reduction of the anthesis and consequently reduction of number of grains per spike. Previous literature supports our findings that plant growth regulators, especially GA has important role in growth, development and grain yield as well as quality of wheat (Bari & Jones, 2009) due to improved photosynthesis capacity, delaying of leaf senescence and increased seed number (Zhang *et al.*, 2013).

Like other morphological plant attributes, 1000 grain weight was also affected by drought stress. Current study revealed that genotype SHAHKAR scoring highest values of 1000-grain weight among all tested genotypes of wheat showed less sensitivity to drought stress. However, AARI-11, CHAKWAL-50 and PAKISTAN-13 showed improvement in 1000-graiin weight on priming with SA while priming with GA improved it all genotypes. The lack of moisture at grain filling stage after pollination leads towards abnormal grain formation that ultimately reduce the grain weight. The reduced grain formation under drought was due to reduction in amount of photosynthesis, speed and duration of grain formation (Pandey *et al.*, 2001). Gooding *et al.*, 2003 conducted a study to analyze the effects of intensity and duration of drought stress in wheat reported that drought stress caused a reduction in 1000-grain weight and hectoliter by shortening the grain formation period. Water deficit after anthesis shortened the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume. It has been reported that drought stress at stage of grain filling could significantly decrease 1000 seed weight (Sharafizad *et al.*, 2013). The priming with growth regulators enhances the ability of genotypes to produce higher 1000-grain weight as reported earlier that 1000-kernel weight of mung bean and sunflower was enhanced by application of salicylic acid (Dawood *et al.*, 2012).

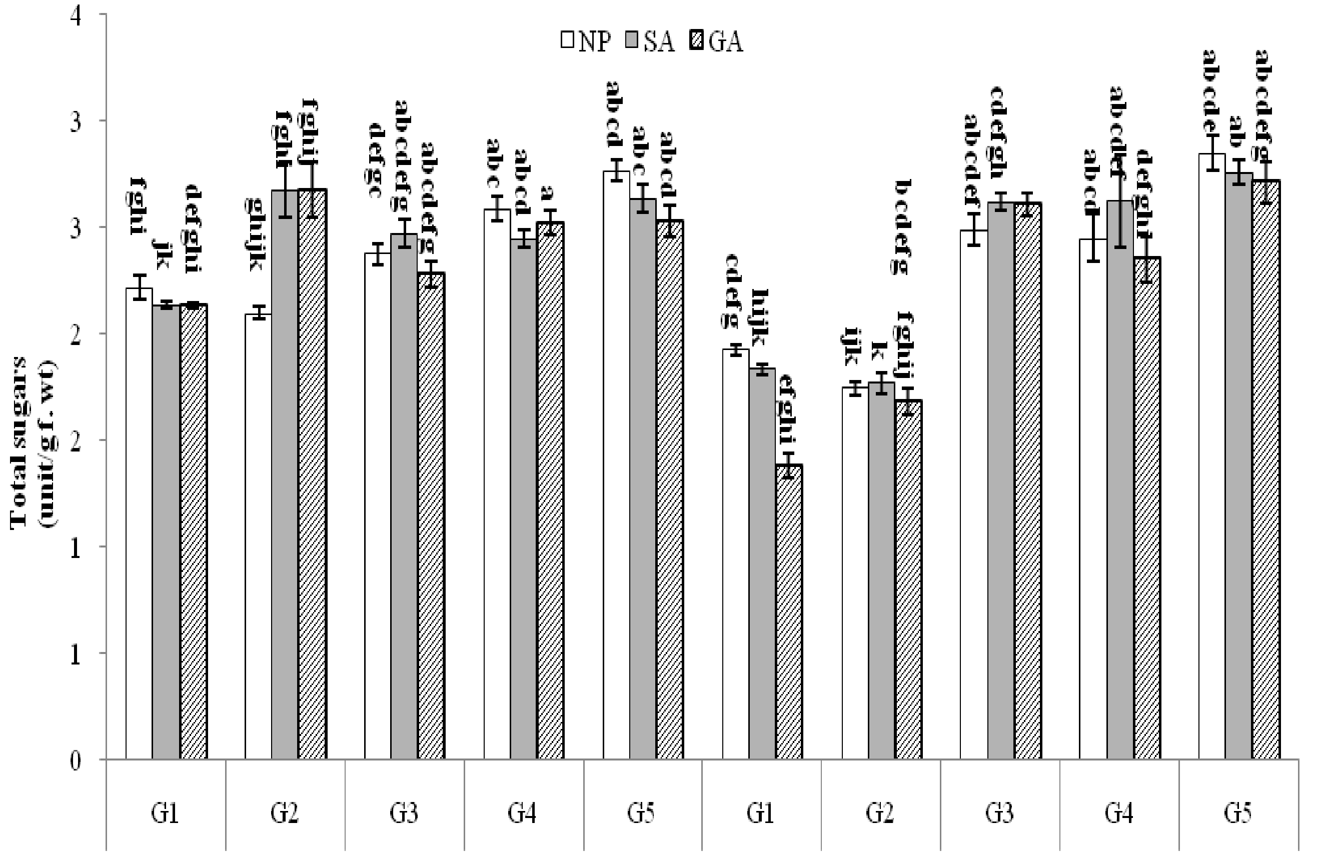

Fig. 1. Sugar contents in flag leaves of wheat genotypes grown under control and drought stress along with NP-non primed, SA-Salicylic Acid and GA-Gibberellic Acid priming. G1: AARI-11, G2: CHAKWAL-50, G3: SHAHKAR, G4: PAKISTAN-13, G5: FSD-08.

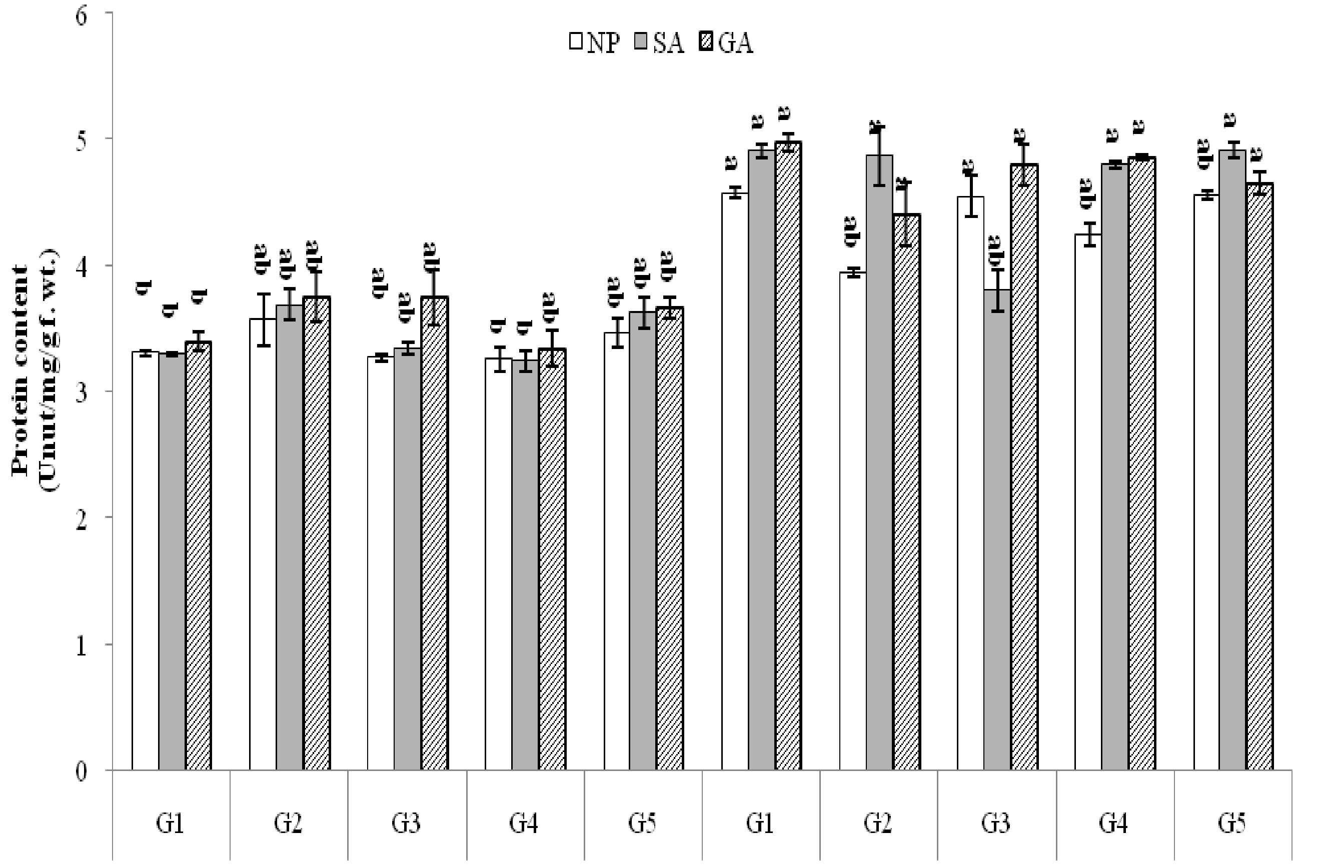

Fig. 2. Protein contents in flag leaves of wheat genotypes grown under control and drought stress along with NP-non primed, SA-Salicylic Acid and GA-Gibberellic Acid priming G1: AARI-11, G2: CHAKWAL-50, G3: SHAHKAR, G4: PAKISTAN-13, G5: FSD-08.

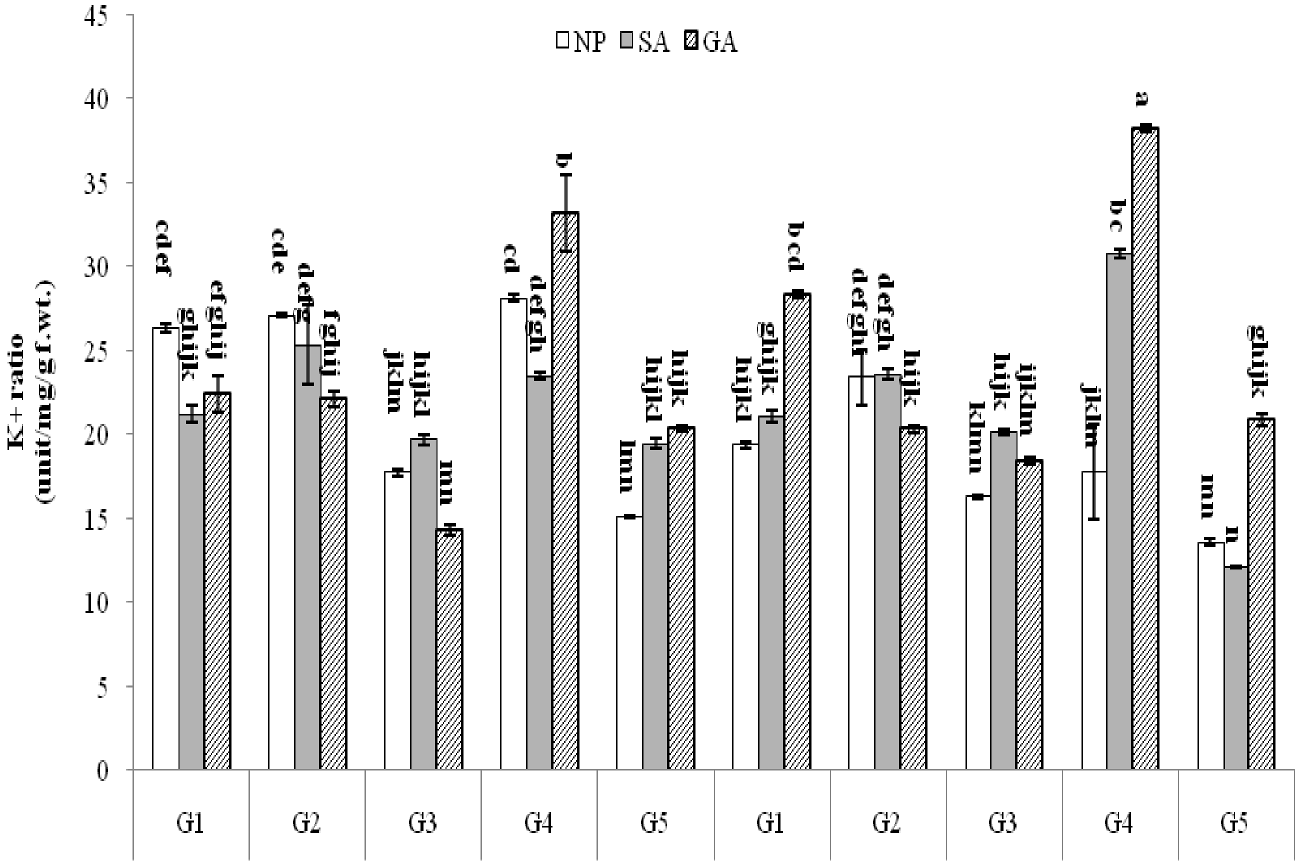

Fig. 3. Potassium ratio in flag leaves of wheat genotypes grown under control and drought stress along with NP-non primed, SA-Salicylic Acid and GA-Gibberellic Acid priming G1: AARI-11, G2: CHAKWAL-50, G3: SHAHKAR, G4: PAKISTAN-13, G5: FSD-08.

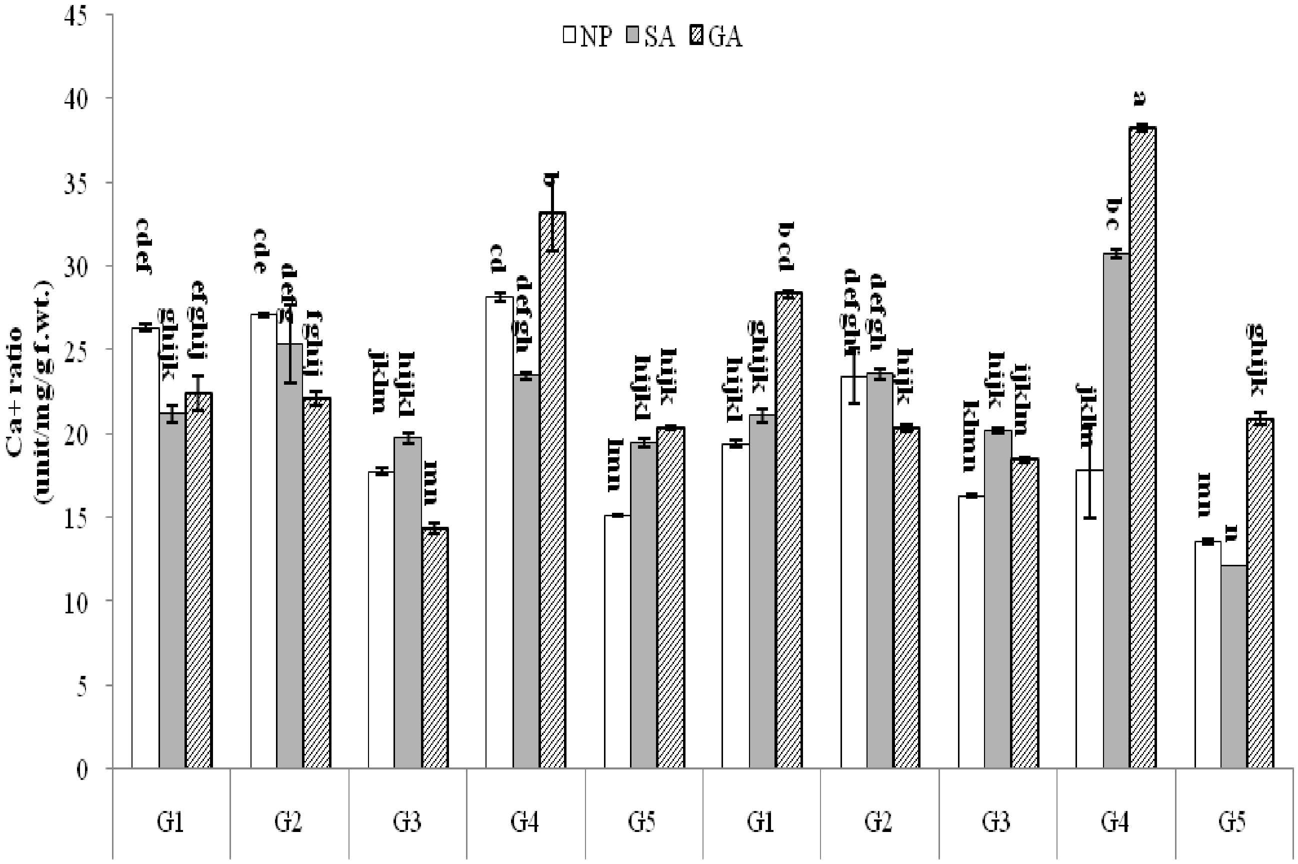

Fig. 4. Calcium ratio in flag leaves of wheat genotypes grown under control and drought stress along with NP-non primed, SA-Salicylic Acid and GA-Gibberellic Acid priming G1: AARI-11, G2: CHAKWAL-50, G3: SHAHKAR, G4: PAKISTAN-13, G5: FSD-08.

It has been established that primed seed with salicylic acid increased the yield, caused early floral initiation, produced more flowers and pods per plant (Kulshrestha *et al.*, 2013). Similar finding were reported that primed crop seeds were able to produced higher yields than non-primed seeds (Harris *et al.*, 2005). improved growth and yield of crop under stress and non-stress conditions by salicylic acid treatment has been reported (Moghaddam *et al.*, 2011). Salicylic acid increased wheat yield (Shakirova *et al.*, 2003) and it affects the physiological and biochemical responses during vegetative stage and active assimilation translocation from source to sink that increases kernel yield and yield components (Dawood *et al*., 2012).

FSD-08 possessed higher biological yield during both drought and normal conditions and showed e less sensitivity to drought than other tested genotypes. The reduction in biological yield in all other genotypes as a result drought stress was observed tats was improved on priming with growth regulators. Reduction in biomass in wheat under drought stress as compared to irrigated crop is well documented in literature (Shamsi & Kobraee, 2013). Priming effect on biomass was also present in previous studies, the increased in biological yield might be due to better early seedling growth and plant nutrition as reported earlier (Zhang *et al.*, 2007). These results were in line with other authors who stated that soaked seeds had more biomass as compared to non-soaked seeds. our results also support the results that biomass and dry weight increased on priming treatment as compared with the control (Rashid *et al.*, 2002). The reason of increased the biological yield under full irrigation is due to the fact that irrigated plants showed good vegetative growth and broad leaf surface area received more light to better photosynthesis rate and consequently higher biological yield.

Higher grain yield showing genotype PAKISTAN-13 also showed highest harvest index. The result of the recent study was consistent with previous findings (Reynolds *et al.*, 2009) reporting the positive association of grain yield with harvest index and concluded that higher grain yield possessing genotype also had higher harvest index. The harvest index was highly affected by drought stress with a reduction in our studies. It has been reported that harvest index is greatly affected if irrigation is skipped at different growth stages(Galavi & Moghaddam, 2012). Distribution of photosynthetic material among plant parts is determined by harvest index, and drought reduced the transformation of material to grain and ultimately harvest index was reduced. Many studies confirmed the lower rate of photosynthesis on reduced soil moisture which resulted in lower translocation of assimilates to the grain. No doubt there was reduction of photosynthesis in water deficit soil but increased remobilization of assimilates from the straw to the grains was also presented (Asseng & Van Herwaarden, 2003) (Plaut *et al.*, 2004).

The improvements of harvest index on priming with growth regulators as revealed in our study was also reported previously. In a previous study similar results as in present study under drought and normal condition for days to flowering, days to maturity, biological yield, grain weight, grain yield and harvest index different wheat cultivars were reported (Shahryari *et al.*, 2011). Literature reports that response of different cultivars varies in term of accumulation of soluble sugars in flag leaf of wheat. Genetic makeup justifies the tolerance of wheat crop to water stress. Accumulation of higher amount of soluble compounds was found in drought tolerant wheat plants than the sensitive cultivars (Nayyar & Walia, 2003). In present study, sugar accumulation was significantly raised on SA priming in SHAHKAR and FSD-08 Under drought stress.

It has been reported that nutrients uptake was decreased significantly under drought stress as compared to normal plants. However, under normal conditions, when Si was exogenously applied on wheat at anthesis stage it resulted in accumulation of maximum plant nutrients. (Bukhari *et al.*, 2015)

Role of K^+ has been studied under salinity stress in wheat and a significant decrease of K^+ was observed in wheat cultivars due to salinity stress. Priming with GA^3 was able to enhance shoot K^+ concentration in controlled plants. It wass also observed that under drought stress, susceptible genotype had more K^+ than tolerant genotype (Nayyar & Walia, 2004).

In conclusion, Priming had the positive effect on morphological parameters. Among genotypes PAKISTAN-13 and FSD-08 were winning genotypes followed by AARI-11, SHAHKAR and CHAKWAL-50. From all above discussions it was concluded that genotypes having same dimension under normal and drought stress condition had good tolerance against stress. PAKISTAN-13, FSD-08 and AARI-11 had maximum plant attributes under both conditions. Seed priming had significant positive effect on different aspects of seed germination. Our results showed significant improvement in germination and early growth of wheat due to GA priming and SA priming treatment compared to control. Application of growth regulator improved the physiological efficiency and all the yield components with grain filling stage being more responsive.

Conclusion

Based on present findings, it was concluded that seed priming with plant growth regulators like GA and SA can significantly enhance wheat performance in terms of morphological parameters and yield attributes both under drought and normal conditions. Higher yield was recorded in PAKISTAN-13 and FSD-08 while higher yield in PAKISTAN-13 may be due to rapid emergence and more vigorous seedling.

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