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Seed priming enhances wheat yield and its crop productivity under irrigation regime

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Abstract

The field experiment was carried out at a private farm, Eneiybes, Juhayna, Sohag governorate, Egypt which is located at 26° 73^{-} $67^{=}$ N latitude and 31° 47^{-} $56^{=}$ E longitude during two consecutive growing winter seasons of 2019/20 and 2020/21 to assess the effect of seed priming on wheat yield and water productivity under drought stress. The experiment was laid out in a split plots design with three replicates. The main plots were assigned to drought stress (90, 75, and 60% field capacity, FC). The split plots were allocated to seed priming treatments (No, Hydro and $CaCl_2$). The obtained results indicated that 90% FC with No priming treatment realized the highest amount of water consumptive use, WCU, 4866.45 m^3 ha^{-1} and irrigation water applied, IWA, 6469.19 m^3 ha^{-1} as an average value of both seasons. While the lowest amount of WCU and IWA were obtained at 60% FC with $CaCl_2$ treatment since they were 3887.57 and 5169.66 m3 ha^{-1}, respectively. The highest field irrigation water use (1.61 kg m^{-3}) and crop water productivity (2.14 kg m^{-3}) were attained at 60% FC with $CaCl_2$ as an average value of both seasons While the lowest values were obtained at 90% FC with No priming treatment for the corresponding parameters since they were 1.20 and 1.59 kg m^{-3} , respectively. Wheat yield and grain N content were significantly influenced by irrigation regime, as well as by seed priming. The highest grain yield was recorded with $CaCl_2$ treatment since it was 8.520 $Mgha^{-1}$ at 90% FC in the 1st season and 9.320 Mg ha^{-1} at 75% FC in the 2nd season. The lowest grain yield (6.960 and 7.277 Mg ha^{-1} in the 1st and 2nd seasons, respectively) was recorded at 60% FC with No priming. The highest grain nitrogen content (2.94%) was recorded at 60% FC with $CaCl_2$ as an average value of both seasons. While the lowest value (2.22%) was recorded at 90% FC with No priming as an average value of both seasons. It could be concluded that seed priming is a very useful practice that effectively mitigates abiotic stresses of water deficit at the same time increases crop water productivity and enhances wheat yield traits and its quality.

Keywords: seed priming, water productivity, wheat yield, irrigation regime.

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1. Introduction

Soil water deficits and salinization are the two most pivotal abiotic stresses that restrain the generation of the world's nourishment crops (Munns, 2011). To meet the developing request for nourishment and to differentiate the negative impacts of climate alter on yields, it is essential to produce crops that build strides resistance to dry and salinity conditions which utilize water efficiently as well as might increase crop productivity with less water consumption. This information is stressing indeed within the most profitable trimming situations, brief periods of water lack are mindful for significant decreases in seed and biomass yields each year (Eckardt *et al.*, 2009). Drought influences plant execution and productivity by causing cellular dehydration that diminishes the cytosolic and vacuolar volumes and fortifies the generation of receptive oxygen species that contrarily influence cellular structures and digestion system (Bartels *et al.*, 2005). Wheat (*Triticum aestivum* L.) is one of the main staple food crops in the world, and it has been predicted that global wheat production should increase by 60% from the current yield level of 3.3 t ha^{-1} to 5 t ha^{-1} by 2050, to feed a population of more than 9 billion (Daryanto *et al.*, 2016). Wheat is susceptible to drought stress, resulting in reduced grain yield and quality (Wang *et al.*, 2014). Zahra *et al.* (2021) detected that drought stress and other sorts of stress (heat) during wheat grain formation affect grain development. Irrigation at the jointing and filling stages could delay flag leaf senescence, and increase the WUE, grain filling rates, and the grain yields (Guo *et al.*, 2015; Li *et al.*, 2010). However, water deficit during these two stages can lead to a serious decline in the grain yields. Reducing the irrigation frequencies before the jointing stage could promote wheat roots growth into deep soil layer search for water to be absorbed resulting in improved WUE (Xu *et al.*, 2016). This roots behavior reveals that irrigation can obviously affect wheat water utilization directly during different growth stages. (Wang *et al.*, 2019). Under current climate conditions in Egypt, Eid *et al.* (2006) found that the reference wheat evapotranspiration (ETo) is 426 mm, 547 mm and 632 mm for Sakha, Giza, and Shandaweel variety, respectively. The ETo of Shandaweel strain is 48% more than that of Sakha and 16% more than that of Giza. The wheat water requirements (ETa) are 351 mm, 453 mm and 519 mm for the three varieties respectively. El-Sayed (2007) found that the seasonal Eta values were 579.40, 554.99 and 483.97 mm at 13, 50 and 75% soil moisture depletion (SMD), respectively. Also, he showed that ETa at the diverse stages was slightly increased in winter season of 2005/06 compared to that of 2004/2005. Kaczmarek *et al.* (2017) found that barley seeds priming with $CaCl_2$ improves drought tolerance. Furthermore, the beneficial effects of calcium preconditioning interact significantly with genetically determined drought tolerance. This research aims to test the effect of wheat seeds presoaking on water or $CaCl_2$ on its drought stress and yield.

2. Materials and methods

A Field experiment was carried out at a private farm, Eneiybes, Juhayna, Sohag governorate, Egypt which is located at 26° 73$^-$ 67$^=$ N latitude and 31° 47$^-$ 56$^=$ E longitude during two consecutive growing winter seasons of 2019/2020 and 2020/2021 to assess the effect of seed priming on wheat yield and water productivity under drought stress. The experiment was laid out in a split plots design with three replicates. The main plots were assigned to drought stress (90, 75 and 60% field capacity, FC). The split plots were allocated to seed priming treatments (No, Hydro and $CaCl_2$).

2.1 Soil analysis of the experimental site

Soil sampling was taken down to 60 cm soil depth with a 15 cm increments using a spiral auger. In the laboratory, the samples were air dried, ground and sieved (particle size < 2 mm) and prepared for chemical and physical analysis according to Page *et al*. (1982) and Klute (1986) (Table 1). Also, undisturbed soil samples were taken using the core method technique.

Table (1): Some soil properties of the experimental site.

Property	Soil depth (cm)			
	0-15	15-30	30-45	45-60
pH (1: 2.5)	7.77	7.80	7.87	8.00
EC_e (dS/m)	0.85	0.87	0.90	0.91
$CaCO_3$ (%)	5.25	5.28	5.56	5.71
OM (%)	2.12	1.87	1.45	1.13
Sand (%)	51.00	50.80	50.50	50.20
Silt (%)	30.00	30.00	30.00	30.00
Clay (%)	19.00	19.20	19.50	19.80
Texture class	loam	loam	loam	loam
Bd (Mg/m^3)	1.38	1.40	1.41	1.43
SP	66.00	66.32	66.67	67.00
FC (%)	35.70	35.34	35.60	35.83
WP (%)	17.65	17.50	17.50	17.34
AW (%)	18.05	17.84	18.10	18.49

2.2 Field capacity (FC) and permanent wilting point (PWP)

Field capacity (FC) and permanent wilting point (PWP) were determined using the pressure cooker and pressure membrane apparatus. A saturated undisturbed and disturbed soil samples were equilibrated at suction pressures of 0.33 and 15 bar, respectively, according to Shawky (1967). The available water capacity (AWC) was calculated by the differences in water content at field capacity and permanent wilting point as follows:

$$AWC = FC - PWP$$

2.3 Agronomic practices

In both winter seasons (2019/2020 and 2020/2021), wheat seeds (*Triticum aestivum vulgar*) were sown in rows of 800 cm long and 15 cm apart on November 20 under the flooding irrigation system (each plot included 33 rows). All the agriculture practices were applied as commonly used for growing wheat and carried out according to the recommendations set by the Ministry of Agriculture. Nitrogen fertilizer was applied in the form of ammonium nitrate (33.5% N) at a level of 240 kg ha^{-1} in two equal doses, the first one before the post planting irrigation and the second dose at the tillering stage (before the second irrigation). Phosphorus fertilizer in the form of calcium super phosphate (15.5% P_2O_5) was added at a level of 200 kg ha^{-1} in one dose during soil preparation. Potassium fertilizer in the form of potassium sulphate (48% K_2O) was supplemented at a level of 100 kg ha^{-1} in two equal portions at the same time of adding nitrogen fertilizer. Wheat plants were harvest 140 days after planting.

2.4 Actual water consumptive use (ETa)

Actual evapotranspiration of wheat crop was estimated by soil sampling method to calculate soil moisture according to the method of Israelsen and Hansen (1962) using the following formula:

$$CU = (\theta 2 - \theta 1)\ Bd * ERZ$$

Where CU is the amount of consumptive water use (mm), θ2 is soil moisture percentage after irrigation, θ1 is soil moisture percentage before the following irrigation, Bd is bulk density (g/cm^3) and ERZ is the effective root zone.

2.5 Irrigation water requirement and water supply

The experimental plots received volumes of water to boost the moisture of 60 cm soil depth to the field capacity. The volume of applied water was equal to the difference between moisture at the field capacity and the soil moisture content before irrigation (for each irrigation treatment) plus 10% of applied water to ensure a uniform distribution.

2.6 Crop water productivity

Crop water productivity (CWP) was calculated according to Vites (1965) using the following equations:

$$CWP = \text{grain yield (kg ha}^{-1}\text{)} / \text{Seasonal ETa (m}^3\text{ ha}^{-1}\text{)}$$

At harvest time, four square meters (2m x 2m) from the centric area of each plot were collected to estimate the grain and straw yield, then the recorded values calculated for the whole ha. Dried grounded grain of 0.20 g was digested using 10 mL of a mixture of 7: 3 ratios of sulfuric to perchloric acids (Jackson, 1973), then were analyzed for the total N content.

2.7 Statistical analysis

Analysis of variance (ANOVA) was performed using the SPSS statistical 11.0 package. For comparison of the means, Duncan's multiple range tests were used for significant differences ($p<0.05$). All the assessed attributes were analyzed with Principle Component Analysis (PCA) variance regression ordination, using R Studio software programs.

3. Results and Discussion

3.1 Effect of irrigation regime and seeds priming on wheat water consumptive use (ETa) and irrigation water applied (IWA)

The time and amount of irrigation water play an important role in the production of wheat crops in arid and semi-arid regions. Water consumptive use (ETa) and irrigation water applied for wheat as affected by irrigation regime and seeds priming during the 2019/2020 and 2020/2021 growing seasons is shown in Table (2). In general, the amount of water consumptive use (ETa) and irrigation water applied (IWA) decreased as the irrigation regime increased and with seed priming. On the average basis of both growing seasons, the amounts of applied irrigation water (IWA) were 6447, 5942.18 and 5205.47 m^3 ha^{-1} while, water consumptive use (ETa) were 4823.75, 4472.57 and 3914.40 m^3 ha^{-1} at 90, 75 and 60% FC, respectively regardless seeds priming. It was noticed that the amount of applied irrigation water was higher in the 2nd season than that in the 1st one (table 2). The highest value of ETa and IWA were realized under 90% FC with No priming treatment since they were 4879.05 and 6483.79 m^3 ha^{-1}, respectively in the 2nd season (Table 2). The lowest values of ETa and IWA were attained under 60% FC with $CaCl_2$ treatment since they were 3865.02 and 5136.24 m^3 ha^{-1}, respectively in the 1st season. Similar results were obtained by Khalil et al. (2006) whom reported that water consumptive use (WCU) increased as the available soil moisture increased in the root zone. While subjecting wheat plants to soil water deficit caused a decrease in WCU. According to El-Sayed (2007) and Yan-Wen Gui *et al*. (2020) subjecting wheat plants to soil water deficit caused a decrease in water consumptive use and irrigation water applied.

3.2 Crop water productivity

Crop water productivity (CWP) and irrigation water productivity (IWP) as affected by the irrigation regime and wheat seeds priming in the winter season of 2019/20 and 2020/21 are presented in Table (3). The CWP and IWP were significantly increased due to the irrigation regime and seed priming.

Table (2): Effect of irrigation regime and seeds priming on wheat water consumptive use and irrigation water applied.

Treatments		Water consumptive use (m^3 ha^{-1})		Mean	Irrigation water applied (m^3 ha^{-1})		Mean
Irrigation regime	priming	2019/20	2020/21		2019/20	2020/21	
90 % F.C	No	4853.85	4879.05	4866.45	6454.59	6483.79	6469.19
	Hydro	4810.51	4826.41	4818.46	6448.40	6459.33	6453.87
	$CaCl_2$	4795.63	4830.53	4813.08	6441.41	6470.90	6456.16
Mean		4820.00	4845.33	4832.66	6448.13	6471.34	6459.74
75 % F.C	No	4594.61	4639.81	4617.21	6100.12	6175.71	6137.91
	Hydro	4482.46	4511.76	4497.11	5944.90	5998.88	5971.89
	$CaCl_2$	4428.15	4453.85	4441.00	5879.11	5921.10	5900.10
Mean		4501.74	4535.14	4518.44	5974.71	6031.90	6003.30
60 % F.C	No	4071.87	4127.07	4099.47	5429.17	5493.98	5461.57
	Hydro	3902.96	3935.26	3919.11	5180.46	5230.28	5205.37
	$CaCl_2$	3865.02	3910.12	3887.57	5136.24	5203.09	5169.66
Mean		3946.62	3990.82	3968.72	5248.62	5309.12	5278.87

The irrigation regime treatments affected CWP and IWP through both seasons since they were increased at 60% FC treatment but they decreased at 90% FC treatment through both seasons. The highest values of CWP (2.28 kg m^{-3}) and IWP (1.72 kg m^{-3}) were recorded at 60% FC with $CaCl_2$ in the 2nd season. The lowest values of CWP (1.54 kg m^{-3}) and IWP (1.16 kg m^{-3}) were recorded at 90% FC with No priming in the 2nd season. In general, the CWP and IWP increased with seed priming. On the average basis of both growing seasons, CWP values were 1.65, 1.79, and 1.96 kg m^{-3} while, IWP values were 1.24, 1.34, and 1.47 kg m^{-3} at No, hydro and $CaCl_2$, respectively regardless of the irrigation regime.

Table (3): Effect of irrigation regime and priming on wheat crop water productivity and irrigation water productivity.

Treatments		Crop water productivity (kg m^{-3})		Mean	Irrigation water productivity (kg m^{-3})		Mean
Irrigation regime	priming	2019/20	2020/21		2019/20	2020/21	
90 % F.C	No	1.65 e	1.54 f	1.59	1.24 e	1.16 f	1.20
	Hydro	1.73 cd	1.72 e	1.73	1.29 cd	1.29 e	1.29
	$CaCl_2$	1.78 c	1.81 d	1.79	1.32 c	1.35 d	1.34
Mean		1.72	1.69	1.70	1.28	1.27	1.28
75 % F.C	No	1.52 f	1.74 e	1.63	1.15 f	1.31 e	1.23
	Hydro	1.63 e	1.77 e	1.70	1.23 e	1.33 e	1.28
	$CaCl_2$	1.81 c	2.09 b	1.95	1.36 c	1.57 b	1.47
Mean		1.65	1.87	1.76	1.25	1.40	1.33
60 % F.C	No	1.71 d	1.76 e	1.74	1.28 d	1.32 e	1.30
	Hydro	1.95 b	1.93 c	1.94	1.47 b	1.45 c	1.46
	$CaCl_2$	2.00 a	2.28 a	2.14	1.50 a	1.72 a	1.61
Mean		1.89	1.99	1.94	1.42	1.50	1.46

It was noticed that the amount of applied irrigation water was higher in the 2nd season than that in the 1st one (Table 3).

Improving CWP can be achieved by increasing the production per unit of water consumed or reducing the amount of water consumed per unit yield of production (Dong *et al*., 2011; Reichstein *et al*., 2002). The obtained results were consistent with those obtained by El-Saei (2006), Tahar *et al*. (2010) and Jin *et al*. (2018) whom concluded that the field water use efficiency increased as the soil moisture stress increased.

3.3 Wheat traits and its yield

Wheat traits and its yield as affected by irrigation regime and seeds priming in the winter season of 2019/2020 and 2020/2021 are presented in Tables (4 and 5). The Plant height was significantly increased due to the irrigation regime and seed priming. The irrigation regime treatments affected plant height through both seasons since they were increased at 90% FC treatment but they decreased at 60% FC treatment through both seasons. The highest value of plant height (110.71 cm) was recorded at 75% FC with $CaCl_2$ in the 1st season. The lowest value of Plant height (96.00 cm) was recorded at 60% FC with No priming in the 1st season (Table 4).

Table (4): Effect of irrigation regime and seeds priming on wheat plant height and seed index.

Treatments		Plant height (cm)		Mean	Seed index (g)		Mean
Irrigation regime	Priming	2019/20	2020/21		2019/20	2020/21	
90 % F.C	No	102.23f	103.35 c	102.79	40.00e	41.40 de	40.70
	Hydro	106.32 d	105.44 b	105.88	41.83 d	41.53 d	41.68
	$CaCl_2$	108.45 b	108.25 a	108.35	44.83 a	41.70 d	43.27
Mean		105.67	105.68	105.67	42.22	41.54	41.88
75 % F.C	No	103.11 f	103.23 c	103.17	38.43 f	38.07 g	38.60
	Hydro	107.17 c	105.50 b	106.34	41.63d	38.77 f	39.85
	$CaCl_2$	110.71 a	108.00 a	109.36	43.73 b	42.70 c	43.22
Mean		107.00	105.58	106.29	41.26	39.85	40.56
60 % F.C	No	96.00 g	97.00 e	96.50	38.60 f	41.33 e	39.97
	Hydro	102.45 f	100.75 d	101.60	42.23 c	44.00 b	43.12
	$CaCl_2$	104.35 e	106.00 b	105.18	42.37 c	45.57 a	43.97
Mean		100.93	101.25	101.09	41.07	43.63	42.35

In general, the plant height increased with seed priming. On the average basis of both growing seasons, plant height was 100.83, 104.60, and 107.63 cm at No, hydro, and $CaCl_2$, respectively regardless of the irrigation regime. The seed index was significantly increased due to the irrigation regime and seed priming. The irrigation regime treatments affected the seed index through both seasons since they were increased as the irrigation regime increased through both seasons. The highest value of seed index (44.83 g) was recorded at 90% FC with $CaCl_2$ in the 1st season. The lowest value of the seed index (38.43 g) was recorded at 75% FC with No priming in the 1st season (Table 4). In general, the seed index increased with seed priming. On the average basis of both growing seasons, the seed index was 39.75, 41.55, and 43.48 g at No, hydro and $CaCl_2$, respectively regardless the irrigation regime.

Table (5): Effect of irrigation regime and seeds priming on wheat grain and straw yield.

Treatments		Grain yield (Mg ha^{-1})		Mean	Straw yield (Mg ha^{-1})		Mean
Irrigation regime	Priming	2019/20	2020/21		2019/20	2020/21	
90 % F.C	No	8.000 c	7.510h	7.755	11.20d	10.91i	11.06
	Hydro	8.320 b	8.320 d	8.320	11.60c	11.82 e	11.71
	$CaCl_2$	8.520 a	8.743c	8.632	11.77b	12.89 b	12.33
Mean		8.28	8.19	8.24	11.52	11.87	11.70
75 % F.C	No	7.000g	8.073 e	7.537	9.80h	11.78 f	10.79
	Hydro	7.300f	7.987 f	7.643	10.20g	11.88 d	11.04
	$CaCl_2$	8.000 c	9.320 a	8.660	12.20a	13.91 a	13.06
Mean		7.43	8.46	7.95	10.73	12.52	11.63
60 % F.C	No	6.960h	7.277i	7.118	9.80h	10.99 h	10.39
	Hydro	7.600e	7.591 g	7.596	10.60f	11.26 g	10.93
	$CaCl_2$	7.720d	8.923 b	8.322	10.80e	12.65 c	11.73
Mean		7.43	7.93	7.68	10.40	11.63	11.02

3.4 Wheat grain and straw yield

Wheat grain and straw yield were significantly increased due to the irrigation regime and seed priming. The highest value of wheat grain yield (9.32 Mg ha^{-1}) was recorded at 75% FC with $CaCl_2$ in the 2nd season. The lowest value of wheat grain yield (6.960 Mg ha^{-1}) was recorded at 60% FC with No priming in the 1st season (table 5). In general, the grain yield increased with seed priming. On the average basis of both growing seasons, grain yield was 7.47, 7.85 and 854 Mg ha^{-1} at No, hydro, and $CaCl_2$, respectively regardless the irrigation regime. Furthermore, the highest value of straw yield (13.91 Mg ha^{-1}) was recorded at 75% FC with CaCl2 in the 2nd season. The lowest value of straw yield (9.80 Mg ha^{-1}) was recorded at 75% and 60% FC with No priming in the 1st season (table 5). In general, the straw yield increased with seed priming. On the average basis of both growing seasons, the straw yield was 10.75, 11.22, and 12.37 Mg ha^{-1} at No, hydro, and $CaCl^2$, respectively regardless of the irrigation regime. Qayyum et al. (2021) found that the water deficit treatments had substantial effects on germination and vegetative growth traits of wheat. The results are in agreement with those obtained by Amin (2003), Sidrak (2003), Khalil et al. (2006), and El-Sayed (2007) who reported that the amount of irrigation water applied was closely related to grain yield due to increased number of grains/spike and single grain weight which were greatly affected by the soil moisture condition. Calcium is an important component of cell structure and is involved in cell elongation and cell division processes. It plays a significant role in regulating nutrient absorption across cell membranes and improving water absorption (Summart *et al*., 2010). Seed priming with $CaCl_2$ in particular not only improved the wheat yield under well-watered conditions, it mitigated the detrimental effects of drought imposed at vegetative and tasseling stages on yield due to a substantial upgrading of yield-related traits. Water and nutrient absorbance under deficit water conditions due to a well-developed root system, more root length with higher root proliferation, might be the cause of improvement in yield-related traits in wheat subjected to $CaCl_2$ under drought stress. Similar results were obtained by Tahar *et al*. (2010) and Bazil *et al*. (2017) who reported that priming treatments significantly increased the strength of the seeds to face the moisture or stress conditions of the field under drought.

3.5 Grain nitrogen content

Grain nitrogen content as affected by irrigation regime and seeds priming in winter season of 2019/2020 and 2020/2021 is presented in Table (6).

Table (6): Effect of irrigation regime and seeds priming on wheat grain nitrogen content.

Treatments		Nitrogen of grain (%)		Mean
Irrigation regime	Priming	2019/20	2020/21	
90 % F.C	No	2.20 e	2.24 e	2.22
	Hydro	2.34 d	2.27 e	2.31
	$CaCl_2$	2.70 b	2.77 b	2.73
Mean		2.41	2.43	2.42
75 % F.C	No	2.34 d	2.42 d	2.38
	Hydro	2.37 d	2.51 d	2.44
	$CaCl_2$	2.78 b	2.83 b	2.80
Mean		2.50	2.59	2.54
60 % F.C	No	2.51 c	2.63 c	2.57
	Hydro	2.90ab	2.95 a	2.92
	$CaCl_2$	2.91 ab	2.98 a	2.94
Mean		2.77	2.85	2.81

Grain nitrogen content was significantly increased due to the irrigation regime and seeds priming. The irrigation regime treatments affected grain nitrogen content through both seasons since they were increased at 60% FC treatment but they decreased at 90% FC treatment through both seasons. The highest value of grain nitrogen content (2.98%) was recorded at 60% FC with $CaCl_2$ in the 2nd season. The lowest value of grain nitrogen content (2.20%) was recorded at 90% FC with No priming in the 1st season (Table 6). In general, grain nitrogen content increased with seeds priming. On the average basis of both growing seasons, grain nitrogen content was 2.39, 2.56 and 2.82% at No, hydro and $CaCl_2$, respectively regardless the irrigation regime. Similar findings are given by Harris *et al*. (2001), Giri *et al*. (2003), Farooq *et al*. (2006), Tian *et al*. (2014)

and Toklu *et al*. (2015).

3.6 The principle component analysis

The original data of all measured wheat traits were examined by the principle component analysis (PCA) as shown in Figure (1). This analysis gives clear details of all possible positive and negative correlations among all assessed growth and productivity traits. The distances between the attributes on both axes illustrate the degree of trend-similarity, the closer the distance, the greater the resemblance and vice versa. Thus, PCA biplot indicated great contrariness between the IWA indicator and ETa (the left-hand half of Figure 1) and plant height and grain yield (the right-hand half). PCA dimension1 (Dim1) captures about 63.1% of the cumulative percentage followed by the second one (31.2%). Plant traits on the first PCA axis explained strong positive correlations among CWP, IWP, N and plant growth traits (plant height). Also, they positively correlated with productivity attributes such as straw and grain yield. All of these traits were arranged on the right-hand side half of PCA correlation biplot. Meanwhile, they were negatively correlated with the IWA. Also, ETa showed clear significant positive correlation with IWA and they both arranged on the left-hand half of the PCA biplot. Second PCA axis showed another direction of traits correlation, i.e. the assessed CWP, IWP and N were negatively correlated with the IWA and ETa. Also, Plant height, grain yield and seed index were negatively correlated with CWP, IWP and N.

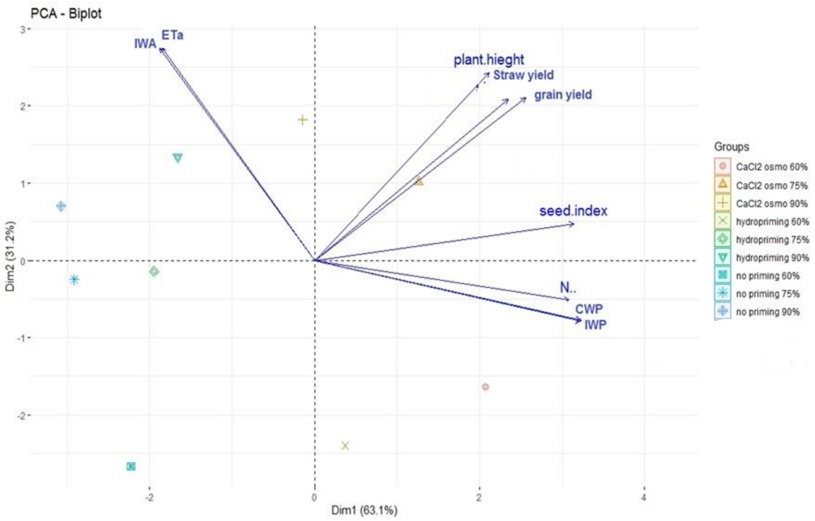

Figure (1): The principle component analysis.

4. Conclusion

It could be concluded that pose water stress on wheat plants that emerged from seeds treated by $CaCl_2$ as a priming agent realized the highest wheat crop productivity and yield quantity and quality. So, seed priming is a very useful practice that effectively mitigates abiotic stresses including water deficit in the same time increases crop water productivity and enhances wheat yield traits and its quality.

References

Afzal, I., Basara, S. M. A., Farooq, M. and Nawaz, A. (2006), "Alleviation of salinity stress in spring wheat by hormonal priming with ABA, salicylic acid and ascorbic acid", *International Journal of Agriculture and Biology*, Vol. 8, pp. 23–28.

Amin, I. A. (2003), *Selection for drought tolerance in wheat*, Ph.D. Thesis, Faculty of Agriculture, El-Menia University, Minia, Egypt.

Bartels, D. and Sukar, R. (2005), "Drought and salt tolerance in plants", *Critical Reviews in Plant Sciences*, Vol. 24, pp. 23–58.

Boutraa, T., Akhkha, A., Al-Shoaibi, A. A. and Alhejeli, A. M. (2010), "Effect of water stress on growth and water use efficiency (WUE) of some wheat cultivars (*Triticum durum*) grown in Saudi Arabia", *Journal of Taibah University for Science*, Vol. 3, pp. 39–48.

Dong, G., Guo, J., Chen, J., Sun, G., Gao, S., Hu, L. and Wang, Y. (2011), "Effects of spring drought on carbon sequestration, evapotranspiration and water use efficiency in the Songnen meadow steppe in north-east China", *Eco hydrology*, Vol. 4, pp. 211–224.

Eckardt, N. A., Cominelli, E., Galbiati, M. and Tonelli, C. (2009), "The future of science: food and water for life", *Plant Cell*, Vol. 21, pp. 72–368.

Eid, H. M., El Marsafawy, S. M. and Ouda, S. A. (2006), *Climate change and crop water use and productivity in Egypt*, Policy Research Working Paper, CEEPA, University of Pretoria, Vol. 6 No. 7, South Africa.

El-Saei, M. A., El-Hadidi, E. M. and Talaat, A. (2006), "Water Saving by applying potassium fertilization and water stress with wheat crop", *Journal Agriculture Mansoura University*, Vol. 31, pp. 4825–4835.

El-Sayed, M. M. (2007), *Water requirements of wheat and sunflower under different irrigation systems*, M.Sc Thesis, Faculty of Agriculture Assiut University, Egypt.

Giri, G. S. and Schillinger, W. F. (2003), "Seed priming winter wheat for germination, emergence, and yield", *Crop Science*, Vol. 43, pp. 2135–2141.

Guo, Z., Shi, Y., Yu, Z. and Zhang, Y. (2015), "Supplemental irrigation affected flag leaves senescence post–anthesis and grain yield of winter wheat in the Huang–Huai–Hai Plain of China", *Field Crops Research*, Vol. 180, pp. 100–109.

Harris, D., Raghuwanshi, B. S., Gangwar, J. S., Singh, S. C., Joshi, K. D., Rashid, A. and Hollington P. A. (2001), "Participatory evaluation by farmers of on-farm seed priming in wheat in India, Nepal and Pakista", *Experimental Agriculture*, Vol. 37, pp. 403–415.

Israelsen, O. W. and Hansen, V. E. (1962), *Irrigation Principles and Practices*, 3rd Edition, John Wiley and Sons Inc, New York, USA.

Jackson, M. L. (1973), *Soil chemical analysis*, Prentice–Hall, India.

Jin, N., Ren, W., Tao, B., He, L., Ren, Q., Li, S. and Yu, Q. (2018), "Effects of water stress on water use efficiency of irrigated and rain fed wheat in the Loess Plateau", *China, Science of the Total Environment*, Vol. 642, pp. 1–11.

Kaczmarek, M., Fedorowicz-Stron´ska, O., Głowacka, K., Was´kiewicz, A., Sadowski, J. (2017), "$CaCl_2$ treatment improves drought stress tolerance in barley (*Hordeum vulgare* L.)", *Acta Physiol Plant*, Vol. 39, Article No. 41.

Khalil, F. A. F., Tammam, A. M., Amin, I. A. and Mohamed, K. A. (2006), "Scheduling irrigation for some wheat cultivars under upper Egypt conditions", *Journal of Agriculture Science Mansoura University*, Vol. 31, pp. 561–572.

Klute, A. (1986), *Methods of soil analysis, Part 1: Physical and Mineralogical Methods*, 2nd Edition, American Society of Agronomy, Madison, Wisconsin, USA.

Munns, R. (2011), "Plant adaptations to salt and water stress: differences and commonalities", *Advances in Botanical Research*, Vol. 57, pp. 1–32.

Page, A. L., Miller, R. H. and Keeny, D. R. (1982), *Methods of Soil Analysis. Part Π. Chemical and microbiological properties*, 2nd ed., American Society of Agronomy, Monograph No. 9 Madison, Wisconsin, USA.

Qayyum, A., Al Ayoubi, S., Sher, A., Bibi, Y., Ahmad, S., Shen, Z. and Jenks, M. A. (2021), "Improvement in drought tolerance in bread wheat is related to an improvement in osmolyte production, antioxidant enzyme activities, and gaseous exchange", *Saudi Journal of Biological Sciences*, Vol. 28, pp. 5238–5249.

Quan Qi, L., Bao Di, D., Yun Zhou, Q., Meng Yu, L. and Ji Wang, Z. (2010), "Root growth, available soil water, and water–use efficiency of winter wheat under different irrigation regimes applied at different growth stages in North China", *Agricultural Water Management*, Vol. 97, pp. 1676–1682.

Reichstein, M., Tenhunen, J. D., Roupsard, O., Ourcival, J., Rambal, S., Miglietta, F., Peressotti, A., Pecchiari, M., Tirone, G., Valentini, R. (2002), "Severe drought effects on ecosys-tem CO_2 and H_2O fluxes at three Mediterranean ever green sites: revision of current hypotheses?", *Global Change Biology*, Vol. 8, pp. 999–1017.

Shawky, M. E. (1967), *Micro and macro pore-spase distribution in profiles of typical Egyptian soils and factors affecting them*, M.Sc Thesis, Faculty of Agriculture, Cairo University, Egypt.

Sidrak, N. N. (2003), *Scheduling irrigation of wheat using the evaporation pan method under different times and rates of nitrogen fertilizer*, M.Sc Thesis, Faculty of Agriculture, Zagazig University, Egypt.

Singh, B. A., Gangwar, C. B. S., Singh, B. and Maurya, C. L. (2017), "Effect of seed priming on quality parameters of wheat (*Triticum aestivum* L.) seeds harvested under irrigated & rainfed conditions", *Journal of Pharmacognosy and Phytochemistry*, Vol. 6, pp. 1646–1650.

Summart, J., Thanonkeo, P., Panichajakul, S., Prathepha, P. and McManus, M. T. (2010), "Effect of salt stress on growth, inorganic ion and proline accumulation in Thai aromatic rice, KhaoDawk Mali 105, callus culture", *African Journal of Biotechnology*, Vol. 9 No. 2, pp. 145–152.

Tian, Y., Guan, B., Zhou, D., Yu, J., Li, G. and Lou, Y. (2014), "Responses of seed germination, seedling growth, and seed yield traits to seed pretreatment in maize (*Zea mays* L.)", *Scientific World Journal*, Vol. 2014, Article ID: 834630.

Toklu, F., Baloch, F.S., Karaköy, T., Özkan, H. (2015), "Effects of different priming applications on seed germination and some agro-morphological characteristics of bread wheat (*Triticum aestivum* L.)", *Turkish Journal of Agriculture and Forestry*, Vol. 39, pp. 1005–1013.

Vites, F. G. Jr. (1965), "Increasing water efficiency by soil management", *American Society of Agronomy*, Vol. 26, pp. 259–274.

Wang, Y., Liu, H., Huang, Y., Wang, J., Wang, Z., Gu, F., Xin, M., Kang, G., Feng, W. and Guo, T. (2019), "Effects of cultivation management on the winter wheat grain yield and water utilization efficiency", *Scientific Reports*, Vol. 9 No. 1, Article ID: 12733.

Xu, C., Tao, H., Tian, B., Gao, Y., Ren, J. and Wang, P. (2016), "Limited–

irrigation improves water use efficiency and soil reservoir capacity through regulating root and canopy growth of winter wheat", *Field Crop Research*, Vol. 196, pp. 268–275.

Zahra, N., Wahid, A., Hafeez, M. B., Ullah, A., Siddique, K. H. M. and Farooq, M. (2021), "Grain development in wheat under combined heat and drought stress: Plant responses and management", *Environmental and Experimental*, Vol. 188, Article ID: 104517.