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Effect of water stress and ascorbic acid on yield components of Egyptian Barley cultivars

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Water is one of the most important environmental factors that regulate plant growth and development. In order to study the interaction between water stresses with ascorbic acid on some yield components of some Egyptian barley cultivars experiment was investigated. The main treatments were three levels of water stress (75%, 60% and 40% of water holding capacity (WHC), sub main were two levels of ascorbic acid (zero and 10 ppm) under open field conditions. Significant decrease in grain yield parameters of barley cultivars observed with water stress whether with 60% or 40% of water holding capacity as compared to control (75% of WHC). Application of 10 ppm ascorbic acid improved yield parameter to some extent under water stress condition. Barley cultivars (Giza 125, Giza 126, Giza 128, Giza 129, Giza 133 and Giza 135) severely affected by increasing water stress. Barley Giza 123, Giza 124, Giza 131, Giza 132 and Giza 2000 showed slight decrease in grain yield with increasing water stress up to 40% of WHC. Grain yield of barley cultivars (Giza 125, Giza 131, Giza 132, Giza 135 and Giza 2000) improved due to spraying ascorbic acid. Results clouded that foliar spray of ascorbic acid improved barley production which will have benefits for human nutrition and possibly enhance their tolerance to drought stress.

Keywords: Ascorbic acid, tiller number, spike length, grain yield

INTRODUCTION

Drought represents the most important a biotic stress factor worldwide, that affects yield stability, severely limits plant growth and development as well as agricultural characteristics including the final yield productivity of crops in Mediterranean areas, where drought is a severe inhibitor of sustainable agriculture(Kosová et al.,. 2014) and (Fita et al.,. 2015)For this reason, drought-related studies have been the focus of interest for many years (González et al.,2010) Water deficit led to decrease in photosynthesis, transpiration and other biochemical processes that highly correlated with plant growth, development and crop productivity (Tiwari, et al.,2010).Also, a biotic stress lead to oxidative stress in the plant cell resulting in a higher leakage of electrons towards O_2 during photosynthetic and respiratory processes which leading to enhancement of reactive oxygen species (ROS) generation (Asada, 2006).In cereals, drought resistance strategies are mainly based on maintenance of the cell water potential under limited water supply, drought avoidance. Thus, the plants try to maximize water uptake by roots and to minimize water release by leaves in order to reach a sustainable balance between water uptake by roots and water release by shoots (Kosová et al.,. 2014).Under low soil water content, the soil water potential decreases exponentially with decreasing soil water content (Lawlor, 2013).Water uptake into the cells is regulated in protein channels located in the plasma membrane of root hair cells (Tyerman et al.,2002) Barley is one of the most important cereal crops grown in many developing countries, where it is often subject to extreme drought stress that significantly affects production (Ceccarelli et al.,2007).It is adapted to a severe water regime compared with other cereals (Sánchez et al.,2002).However, its productivity is limited by terminal drought stress during grain filling (Reynolds et al.,2005).Samarah (Samarah, 2005).showed that drought stress during seed filling period reduced grain yield by decreasing the number of fertile spikes and grains per plant. Late drought stress decreased grain yield by decreasing the number of grains per spick and grain weight.

Ascorbic acid plays an important role in photosynthesis process and also has a role in the defense against oxidative stress. Ascorbic acids would affect the metabolism of plant reactions and would lead to many changes in them. These changes are sometimes accounted for as adaptabilities which increase the tolerance or resistance of plants against the environmental factors . (Metwally et al.,2003)

The objective of this experiment was to study the effect of the severity of water stress during growth season on yield components of barley cultivars and the role of ascorbic acid to alleviate the water stress effects. This approach may enhance the success of selection of tolerant cultivars for breeders and scientists as well.

MATERIALS AND METHODS

Pot experiments were conducted at El-Gharbia government, Egypt, under natural weather conditions (climate of middle delta). Barley cultivars (Giza 123, Giza 124, Giza 125, Giza 126, Giza 127, Giza 128, Giza 129, Giza 130, Giza 131, Giza 132, Giza 133, Giza 134, Giza 135, Giza 136, Giza 2000) obtained from Agricultural Research Center (ARC, Giza, Egypt) cultivated in open field pots experiment to examined its effect of water stress with absent or present the foliar application of ascorbic acid on yield parameters. Before planting, the field capacity of the pots was determined by saturating the soil with water. The pots were covered with plastic sheets and left to drain for 3 days. Pot weights were recorded after 3 days of drainage. The weight of soil moisture at field capacity was calculated as the difference between the soil weight after drainage and soil weight after oven drying for 105 °C for 24 h.

In clean plastic pots (29 × 25 cm in diameter and depth, respectively) containing 10 kg of clayey soil, 15 cultivars of barley sown in each pot on 20th November, 2016 and irrigated up to 100% of field capacity=75% water holding capacity. The experimental soil has pH, 7.92; EC, 1.09 dS m^{-1} and 50 ppm of available N. The pots were placed under natural filed conditions during the growth winter season of 2016 and arranged in a factorial complete randomized design in three replicates. The main treatments were three levels of water stress (75%, 60% and 40% of water holding capacity (WHC), sub main were two levels of ascorbic acid (0 and 10 ppm).

After 8 days from sowing, plants were thinned to 10 plants/pot and all pots were watered till the field capacity. The water stress treatment was started after the appearance of the fourth leaf on day 15. While water was totally withheld from the stressed plants until the soil moisture content reached 60% and 40% of WHC. The stressed plants were raised at this moisture content until ripening by weighing the pots weekly and watering as required(irrigated once a week). The control pots were irrigated normally to 75% of water holding capacity) until ripening. Ascorbic acid was added at 10 ppm after 25 and 50 days from sowing *via* a foliar application. In addition, for improving and accelerating the growth of plants, the macronutrient (NPK) (20: 20: 20) was added to the pots by 20 g/pot through life cycle of plant.

At harvest (in 30th April, 2017), plant height, number of total spikes/pot, number of tillers/plant, 1000 kernel weight, and total grain, straw weight were recorded. The data were statistically analyzed according to (Gomez and Gomez1984).The least significant differences (LSD) were used to compare differences among treatment means at 5% level.

RESULTS AND DISCUSSION

Plant height

Data indicated that the plant height values were increased for Giza 124 without spraying ascorbic acid while Giza 130 (81.3 cm) followed by Giza 124 (79.5 cm) gained the highest values after spraying ascorbic acid, which reflected in straw yield. Regardless water stress, spraying ascorbic acid has a negative effect on most barley cultivars under investigation. This may induce reduction in straw yield. Egyptian barley cultivars gets affected by spraying ascorbic acid, the Giza 132 (10.4%), Giza 128 (6.3%) and the lowest ones was Giza 136 and Giza 131> with respect to the water stress and its effect on plant height, the rank of plant height relative to water stress treatment could be arranged in descending order as follows: WHC at 75% > 60 > 40 and the highest values were recorded at Giza 124, while Giza 126 recorded the lowest ones at 40% of WHC (Figure 1). The estimated changes percentage was positive under all examines barley cultivars. The highest decreased percentage resulted from water stress at 60% of WHC relative to control attained at Giza 125 (23.5%) and the lowest ones was observed at Giza 123 = Giza 124 (3.4%), while under 45% water stress treatment, the highest reduction percentage were attained at Giza 126 (46%) and Giza 124 (9.9%) in same sequence as compared with 75% of WHC. Water deficit led to decrease in photosynthesis, transpiration and other biochemical processes that highly correlated with plant growth, development and crop productivity (Tiwari, et al.,2010).A biotic stress lead to oxidative stress in the plant cell resulted in a higher leakage of electrons towards O_2 during photosynthetic and respiratory processes which affect plant growth and development (Asada, 2006).

Number of Tiller per plant

The results of the comparative experiment showed significant decrease in the number of tiller/plant and number of tiller/pot at harvest, under water stress (drought) conditions. Although the number of plant/pot is fixed before application the drought treatments, the number of tiller/plant for most of barley cultivars was affected by water stress treatments. It was noticed that the decreasing percentage in number of tiller/plant varied from 11% (Giza 127) to 37% (Giza 123) at decreasing the soil humidity up to 60% WHC, this phenomena was increased with decreasing the soil humidity up to 40% of WHC, which varied from 24% (Giza 125) to 58% (Giza 135) in Table 1. In addition, the cultivar of Giza 128 that has the highest number of tiller/plant under experimental condition weather affected by the individual or the combined treatments. Spraying 10 ppm ascorbic acid showed increase in number of tiller with increasing the soil water stress as compare to control treatment (without ascorbic acid application). Some of Egyptian barley cultivars showed significant increase in number of tiller per plant for Giza 136 (18%), Giza 123 (16%) and Giza 129 (14%) due to application of ascorbic acid as foliar spray. Ascorbic acids would affect the metabolism of plant reactions which accounted for adaptabilities which increase the resistance of plants against the environmental factors (Metwally et al.,2003)

Figure 2 showed the above same trend, *i.g.* each of Giza 127, Giza 125 and Giza 128, they were highly tolerance for irrigation water deficit compared with the other cultivars under study, which appeared the minimum decreasing in the number of plant /pot underwater stress of 60% WHC and 40% WHC compared with the control treatment (75% of WHC). The barley cultivars Giza 136, Giza 123, Giza 129 and Giza 135 showed significant increase in tiller number per pot by spraying ascorbic acid.

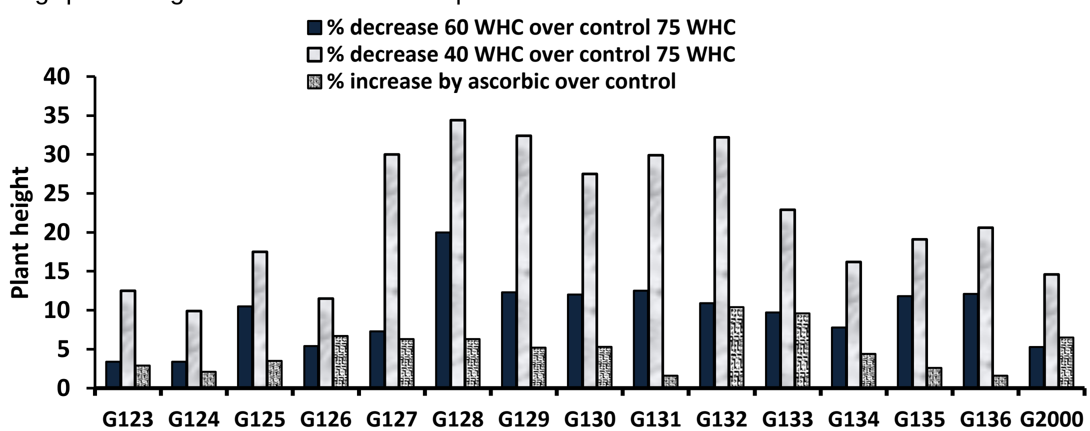

Figure 1: Plant height barley cultivars as affected by water stress

Spike length and spike number per plant

Regarding to the spike length and spike number per plant, spraying ascorbic acid had a positive effect on spike length, while increased water stress had a negative effect. Also data indicated that the increased percentage of spike length was clearly observed at cultivars Giza 129 (7.9%) and Giza 123 (7.4%) while the lowest ones were attained for cultivars Giza 136 and Giza 127 after treatment by ascorbic acid (Table 2). Regarding to water stress treatments and their effects on spike length, results showed that, there was a significant decrease under water stress regimes of 75 to 60% of WHC ranged from 2.6 % (Giza 130) to 15.3% (Giza 125) whereas increased water stress up to 45% of WHC led to a dramatic decreased by about 26.8% (Giza 128), 23.3% (Giza 123) and the lowest reduction percentage was recorded at Giza 126 (10.6%).

Table 1: Number of tiller per plant of barley cultivars as affected by ascorbic acid under water stress

Barley cultivars	Water Holding Capacity (a)						LSD at 0.05		
	75%		60%		40%		WHC (a)	Ascorbic Acid (b)	(a*b)
	Control	Ascorbic Acid	Control	Ascorbic Acid	Control	Ascorbic Acid			
Giza 123	4.3	4.6	2.5	3.1	1.8	2.5	0.032	0.045	0.062
Giza 124	3.8	4.1	2.7	2.9	2.3	2.6	0.007	0.018	0.01
Giza 125	3.1	4.1	2.8	3.1	2.6	2.9	0.021	0.039	0.045
Giza 126	4.0	4.2	2.9	3.2	2.4	2.6	0.021	0.022	0.028
Giza 127	5.5	6.1	5.1	5.2	4.0	4.2	0.039	0.023	0.047
Giza 128	7.8	8.1	5.9	7.3	4.8	4.9	0.051	0.053	0.089
Giza 129	5.3	6.4	3.9	4.1	2.8	3.4	0.052	0.056	0.093
Giza 130	5.1	6.1	4.0	4.1	2.3	2.5	0.078	0.038	0.101
Giza 131	5.3	6.4	3.9	4.0	2.5	2.8	0.066	0.047	0.098
Giza 132	4.3	4.5	3.1	3.2	2.1	2.2	0.044	0.013	0.042
Giza 133	5.6	6.9	4.0	4.4	2.7	2.9	0.051	0.041	0.077
Giza 134	5.3	6.0	4.3	4.7	3.1	3.2	0.053	0.026	0.064
Giza 135	6.1	7.2	4.5	5.2	2.7	2.9	0.083	0.061	0.129
Giza 136	4.5	5.5	3.6	4.2	2.1	2.7	0.067	0.062	0.114
Giza 2000	3.7	3.9	2.4	2.8	1.4	1.8	0.028	0.005	0.018

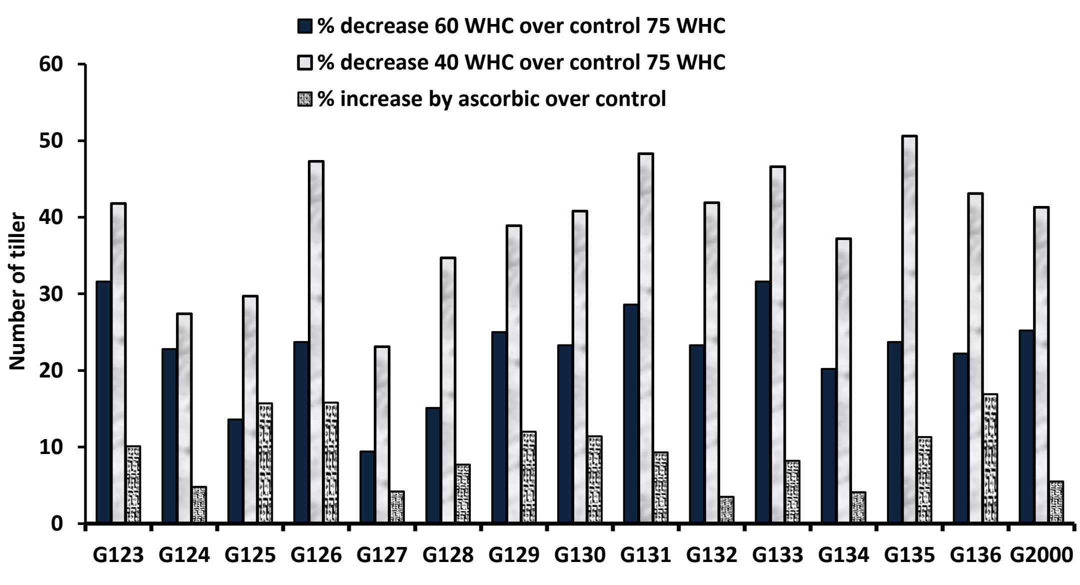

Figure 2: Number of tiller/pot of barley cultivars as affected by water stress

With respect to spike number per plants, the highest values of spike number per plants were attained after spraying ascorbic acid under water stress values 75% of WHC and the lowest values were recorded without spraying ascorbic acid under water stress 40% of WHC. The effect of spraying ascorbic acid that had a positive effect on spike number per pot was illustrated in Figure (3).

The rate of change in percentage relative to the water stress treatment was ranged between 4.5% (Giza 131) to 15.5% (Giza 124) and 13% for Giza 2000. Also data indicated that, the reduction percentage of number of spike per plants was higher at water stress of 40% than 60% of WHC as compared with 75% of WHC. The highest reduction at 40% of WHC were attained for Giza 130 (42.5%), Giza 126 (36.7%) whereas the lowest reduction percentage was recorded at Giza 135 (2.5%), followed by Giza 123 (8.2%) under 60% of WHC and Giza 125 (19.5%) under 40% water stress, respectively. (Samarah, 2005) and (Reynolds et al.,2005).showed that drought stress during seed filling period reduced grain yield by decreasing the number of fertile spikes and grains per plant. Late drought stress decreased grain yield by decreasing the number of grains per spick and grain weight.

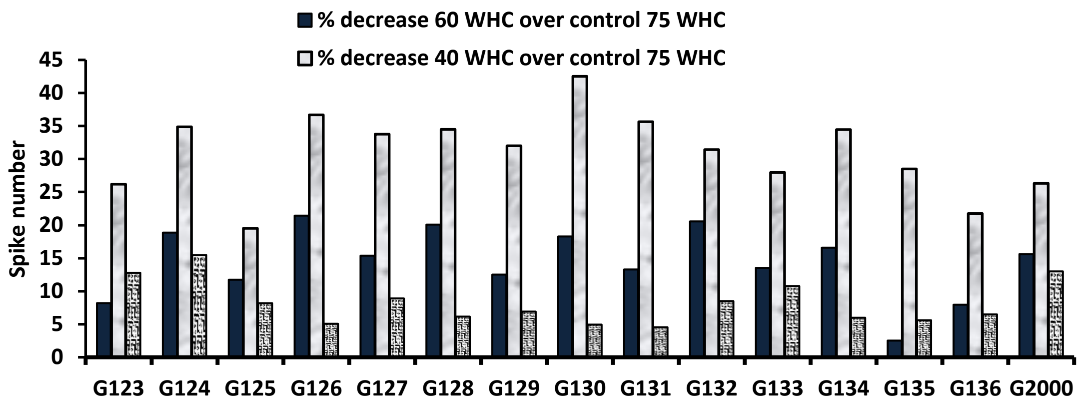

Figure 3: Spike number/pot of barley cultivars as affected by water stress

Table 3: 1000 Kernel weights of barley cultivars as affected by ascorbic acid under water stress

Barley cultivars	Water Holding Capacity (a)						LSD at 0.05		
	75%		60%		40%		WHC (a)	Ascorbic Acid (b)	(a*b)
	Control	Ascorbic Acid	Control	Ascorbic Acid	Control	Ascorbic Acid			
Giza 123	42.7	46.0	40.8	42.3	35.0	38.4	2.68	2.43	5.06
Giza 124	48.0	48.3	46.4	46.6	36.2	39.2	4.66	1.02	5.63
Giza 125	44.5	47.0	42.8	43.3	40.4	42.8	1.10	1.60	2.65
Giza 126	42.9	44.4	37.5	40.6	32.2	35.5	2.43	2.33	4.71
Giza 127	47.4	47.8	45.0	46.3	36.7	37.2	3.81	0.68	4.44
Giza 128	45.1	47.8	43.0	44.8	36.3	37.8	3.00	0.12	3.07
Giza 129	35.0	38.1	34.2	34.9	31.6	32.9	1.18	0.68	1.81
Giza 130	39.7	44.5	37.2	38.5	33.2	34.4	1.38	0.95	2.28
Giza 131	41.4	44.9	39.2	40.1	34.7	35.1	1.73	0.20	1.88
Giza 132	41.9	46.8	41.2	41.6	37.4	38.5	0.81	1.09	1.85
Giza 133	43.2	47.1	41.3	42.8	36.7	37.6	1.19	0.68	1.82
Giza 134	38.6	40.8	37.4	38.2	36.9	37.3	0.24	1.04	1.23
Giza 135	34.9	39.5	32.6	34.4	32.0	35.5	0.28	2.96	3.19
Giza 136	44.7	45.2	41.0	44.7	38.8	40.5	1.04	1.70	2.69
Giza 2000	45.9	46.6	44.8	45.4	43.8	44.1	0.45	0.46	0.86

1000 kernel weight

The manifested data in Table (3) showed the effect of water stress (drought) and Ascorbic acid treatments as the individual treatment or combined among them on 1000 Kernel weight of barley cultivars in the open field pot experiment. Results indicated that the mean values of 1000 Kernel weight of barley cultivars were significantly decreased with increasing water stress from 60% of WHC to 40% of WHC compared the control treatment (75% of WHC). The decreased percent of 1000 Kernel weight ranged between 2.5% up to 10% at 60% of WHC and from 5% up to 22% at 40% of WHC as compare to control treatment of 75% WHC. The barley cultivars, Giza 124, Giza 125, Giza 127, Giza 128, Giza 134, Giza 163 and Giza 2000 recorded the lowest reduction of 1000 Kernel weight as affected by water stress under both 60% and 40% of WHC. On the other hand, the 1000 Kernel weight for most of barely cultivars were positively and significantly affected by application of ascorbic acid treatment. The highest increase of 1000 Kernel weight recorded for Giza 135 (9.1%), Giza 126 (6.6%) and Giza 23 (6.5%) and the lowest increased registered for Giza 128. Giza 127, Giza 138 and Giza 2000 due to spraying of 10 ppm ascorbic acid as compare to without application of ascorbic acid.

Grain Yield

The data presented in Table (4) indicated that, the grain yield of all barely cultivars was significantly decreased as a result of water stress (drought) treatments.

The highest values of grain yield was recorded for the barley cultivars Giza 126, Giza 127, Giza 130 and Giza 133 and the lowest values was for the barley cultivars Giza 131, Giza 134 and Giza 2000. The lowest decrease of grain yield of barley cultivars (Giza 123, Giza 124, Giza 131,Giza 130, Giza 133, Giza 134 and Giza 2000= Giza 130=Giza 125) were attained at 60% of WHC as compare to 75% WHC as control treatment and the decreasing percentage in grain yield for theses variety were ranged from 10.0 % to 17%.Whereas under 40% of WHC, the decreasing percentage in grain yield was ranged from 28 to 59%, compared to the control (75%of WHC). Barley productivity is limited by terminal drought stress during grain filling (Sánchez et al.,2002)and (Reynolds et al.,2005)

Application of 10 ppm ascorbic acid foliar spray significantly increased grain yield of barley cultivars (Giza 132, Giza 135, Giza 133, Giza 125 and Giza 2000). The highest increased of grain yield were recorded for Giza 135 = Giza 132 (18%) and the lowest increased were 2.6% (Giza 128), 3.9 (Giza 134), 6% (Giza 136= Giza 124= Giza 123) and 7.5% (Giza 131= Giza 127=Giza 126) as compare to control treatment.

Table 4: Grain yield per pot of barley cultivars as affected by ascorbic acid under water stress

Barley cultivars	Water Holding Capacity (a)						LSD at 0.05		
	75%		60%		40%		WHC (a)	Ascorbic Acid (b)	(a*b)
	Control	Ascorbic Acid	Control	Ascorbic Acid	Control	Ascorbic Acid			
Giza 123	41.3	45.6	37.1	39.2	30.5	32.0	0.37	0.23	0.55
Giza 124	47.6	48.5	41.9	43.1	29.0	34.8	0.95	0.23	1.13
Giza 125	48.0	48.5	33.7	46.8	21.9	30.0	0.85	1.05	1.85
Giza 126	56.6	56.8	39.5	46.1	21.7	25.0	1.40	0.36	1.71
Giza 127	56.0	59.6	39.9	46.4	30.1	30.4	0.67	0.38	1.00
Giza 128	55.3	55.4	39.2	39.9	23.6	25.9	1.20	0.34	1.09
Giza 129	43.1	46.1	34.9	37.7	22.0	22.5	0.95	0.13	1.03
Giza 130	51.0	52.9	42.7	45.0	29.2	35.8	1.00	0.40	1.35
Giza 131	35.6	38.5	31.2	35.6	25.2	25.6	0.31	0.21	0.47
Giza 132	46.7	51.2	32.3	42.5	22.8	30.7	0.64	1.10	1.68
Giza 133	50.6	54.1	34.8	49.1	25.5	27.3	0.61	0.92	1.48
Giza 134	38.5	42.3	35.8	36.0	26.3	26.4	0.63	0.20	0.58
Giza 135	43.7	44.2	28.5	42.2	21.1	28.0	0.43	1.02	1.40
Giza 136	41.4	45.7	33.3	35.8	27.7	28.2	0.27	0.19	0.41
Giza 2000	40.8	49.9	35.5	39.8	29.3	31.5	0.33	0.68	0.97

The statistical analyses for data were presented in Table (4) showed significantly decreasing in grain yield of all Egyptian barley cultivars with increasing the drought stress as individual effect particularly at decreasing the soil water content up to 40% of WHC compared the control (70% of WHC), it was classified to: (1) Sensitively to drought stress, Barley cultivars Giza 125, Giza 126, Giza 128, Giza 129, Giza 133 and Giza 135 which severely affected by increasing water stress and (2) Tolerance to drought stress, barley Giza 123, Giza 124, Giza 131, Giza 132 and Giza 2000 which showed slight decrease in grain yield with decreasing in soil water content up to 40% of WHC. Egyptian barley cultivars (Giza 125, Giza 131, Giza 132, Giza 135 and Giza 2000) improved grain yield due to spraying ascorbic acid.

Straw yield

It was noticed that the straw yield for most of the barley cultivars was significantly decreased by decreasing soil water content compared the control (75% of WHC). The values presented in Table (5) showed the effect of studied treatments on straw yield for different barley cultivated in open field pot experiment. The straw yield differs from variety of barley to other as affected by water stress. The highest values of straw yield was attained for barley cultivars Giza 131, Giza 127 and Giza 134 with spraying ascorbic acid under 75% of WHC compare to other treatments while the lowest one recorded for Giza 123, Giza 126 and Giza 130. The water stress significantly decreased straw yield with increasing soil water stress. The decreased percent of straw yield was ranged from 7 to 34% for Giza 125 and Giza 133 at 60% WHC respectively, this decreasing was augmented with decreasing soil water content up to 40%, it ranged from 38% (Giza 126) to 62% (Giza 132) as compare to 75% WHC (control treatment).

Table 5: Grain yield per pot of barley cultivars as affected by ascorbic acid under water stress

Barley cultivars	Water Holding Capacity (a)						LSD at 0.05		
	75%		60%		40%		WHC (a)	Ascorbic Acid (b)	(a*b)
	Control	Ascorbic Acid	Control	Ascorbic Acid	Control	Ascorbic Acid			
Giza 123	70.8	73.7	52.9	59.4	36.3	42.6	2.6	1.6	4.0
Giza 124	82.4	88.2	78.2	78.5	46.1	50.2	1.8	1.1	2.7
Giza 125	86.5	94.0	81.8	85.3	41.6	45.6	1.5	2.4	3.7
Giza 126	73.5	74.9	53.4	72.3	38.4	53.0	2.9	1.4	4.1
Giza 127	104.0	108.7	80.1	80.3	47.5	49.6	2.1	0.6	2.5
Giza 128	93.0	94.6	60.1	78.5	41.6	44.8	1.5	1.9	3.2
Giza 129	79.0	96.9	57.6	68.9	40.9	48.0	1.3	1.8	2.9
Giza 130	74.0	80.5	51.5	67.3	39.1	46.2	1.7	1.7	3.2
Giza 131	109.4	113.2	74.4	78.3	43.1	58.9	1.4	0.9	2.1
Giza 132	86.6	93.8	55.8	68.3	31.7	37.7	1.1	0.8	1.7
Giza 133	84.4	92.6	55.2	60.9	34.5	49.4	2.1	0.6	2.5
Giza 134	96.5	97.7	72.4	74.3	48.6	58.7	3.0	1.9	4.7
Giza 135	78.9	84.5	57.5	62.5	38.9	43.6	1.6	1.5	2.9
Giza 136	92.7	93.6	67.3	75.7	48.5	65.1	1.7	0.7	2.2
Giza 2000	89.3	91.8	63.0	70.2	49.0	50.0	2.4	1.2	3.4

CONCLUSION

Furthermore, most of variety that was sensitive to drought stress whether at 60% or 40% of WHC, where also able to increase its straw yield after using 10 ppm of ascorbic acid as foliar application, this increases ranged from 3% for Giza 127 up to 17% for Giza 128 = Giza 129. The straw yield of Giza 133, Giza 132, Giza 136 = Giza 128 were significantly increased by 14, 13 and 11%, respectively after using ascorbic acid application.

Regression analysis

The regression equation of mean weight value of the investigated plant characters was linear with highly significant (0.714**) between 60 and 75% WHC, while it was linear and less significance if we studied 40 with 75 % WHC. This finding means that, it is obvious that exposing the plant to water stress led to decrease in most of the investigated barley cultivars.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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