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Effects of Drought Stress and Humic Acid on Plant Growth, Yield Quality and Its Components of Quinoa (*Chenopodium quinoa* Willd)

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ABSTRACT

BACKGROUND: Drought stress limits the growth and development of plants. The use of Humic acid (HA) is one of the topics commonly addressed by researchers to study the physiological efficiency and yield of crops under drought stress.

OBJECTIVES: Based on this, a study was conducted to investigate drought stress and different levels of HA on the performance characteristics of quinoa.

METHODS: Current research was conducted as a randomized complete block statistical design in the form of split plots with three replications. Treatments include main plots with three levels of drought stress including 60% evaporation from class A evaporation pan or non-application of drought stress, 90% evaporation from class A evaporation pan or medium stress and 120% evaporation from class A evaporation pan or severe stress and four levels of HA included non-consumption and doses of 50, 100, 150 mg.l^{-1} in the subplot.

RESULT: The results showed that in the treatment without drought stress and consumption of 100 mg.l^{-1} HA, the highest biological yield of 6508 kg.ha^{-1} was obtained. The lowest rate was obtained in the treatment of severe drought stress and non-use of HA at the rate of 3068.6 kg.ha^{-1}. Moreover, according to results, in the treatment without drought stress and consumption of 100 mg.l^{-1} HA, the highest grain yield was obtained at 2105.4 kg.ha^{-1} and the lowest obtained in the treatment of severe drought stress and no consumption of HA (999 kg.ha^{-1}). Under drought stress, the application of HA fertilizer reduces the effect of drought stress on the growth processes of quinoa. In this study, it was found that the performance of quinoa at 100 mg.l^{-1} HA showed a better response than other levels of HA. Considering the improvement of quinoa yield components by optimally increasing HA and obtaining more grain yield, the results indicate the appropriate response of quinoa to HA.

CONCLUSION: In general, the results show that drought stress had a significant effect on growth characteristics, quinoa yield. Considering the improvement of quinoa yield components by optimally increasing HA and obtaining more grain yield, the results indicate the appropriate response of quinoa to HA.

KEYWORDS: *Biological yield, Grain nitrogen, Harvest index, Protein yield, Quinoa.*

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1. BACKGROUND

The world population is increasing day by day, while the expansion and development of agricultural lands are very small due to the lack of fertile land. Therefore, one of the important goals to coordinate with the increase in world population is to increase the yield of crops (Maleki *et al*., 2011). Quinoa is a plant of the Chenopodiaceae family that as a relatively new plant has attracted the attention of many researchers (Fathi and Kardoni, 2020; Taheri *et al*., 2021). This plant has been planted for many years by farmers living in the Andes from Colombia, Bolivia, Peru, Ecuador, Chile and Argentina. Due to the importance and nutritional value of quinoa, the United Nations has named 2013 the International year of Quinoa. However, in recent years the demand for planting and consumption of quinoa has increased significantly (Fathi and Kardoni, 2020). Water scarcity and drought stress are important factors in reducing yields and challenging food security, especially in arid and semi-arid regions. Drought stress disrupts many morphological features and physiological processes associated with plant growth (Maleki and Fathi, 2019; Ezati *et al*., 2020). The researchers said that quinoa yield was limited by drought stress and therefore there was a significant difference between potential yield and actual yield. The researchers stated that drought stress reduces nutrient uptake, water uptake, reduced plant element transport, and ultimately reduced quinoa yield (Taheri *et al*., 2021). Researchers reported that drought stress reduced altitude, shoot dry weight, chlorophyll, and nitrogen content of quinoa leaves (Yang *et al*., 2016). Other researchers have reported that drought stress reduces the quantitative and qualitative yield of quinoa (Sun *et al*., 2014; González *et al*., 2009). HA has beneficial effects on increasing and improving agricultural production due to the presence of hormonal compounds (Sam Deliri *et al*., 2018). One of the important benefits of HA is the ability to chelate nutrients to overcome nutrient deficiencies (Sam Deliri *et al*., 2018). HA, which is a natural organic polymer compound, can increase the yield and quality of the product by improving these properties (Ghorbani *et al*., 2010). The results of a study showed that foliar application of millet leaves with HA increased plant height, root length, panicle length, grain yield, 1000-seed weight, crude protein content and number of seeds per panicle in the common millet (Kuvuran and Babat, 2011). The results of another study showed an additive effect of HA on morphological traits and the yield of wheat (Tufail *et al*., 2014).

2. OBJECTIVES

Based on this, a study was conducted to investigate drought stress and different levels of HA on the performance characteristics of quinoa.

3. MATERIALS AND METHODS

3.1. Field and Treatments Information

This experiment was carried out in the cropping year 2020-2021 in Malekshahi city of Ilam province. The project was located at 33 degrees and 19 minutes north latitude, 46 degrees and 28 minutes east longitude. To determine the physical and chemical properties of farm soil, the soil was sampled from 0 to 30 cm depth before conducting research. The results of the analysis of the soil samples of the test site are shown in table 1. This research was conducted as a split-plot in a randomized complete block design with three replications. Treatments include three levels of irrigation in the main plots including 60% evaporation from class A evaporation pan or non-application of drought stress, 90% evaporation from class A evaporation pan or medium stress and 120% evaporation from class A evaporation pan or severe stress and four levels HA including non-consumption and doses of 50, 100, 150 $mg.l^{-1}$ were administered in subplots with three replications.

Table 1. Results of physical and chemical analysis of soil at the test site

Depth (cm)	soil texture	PH	O.C (%)	Total N (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Sand (%)	Silt (%)	Clay (%)
0-30	Clay Loam	7.4	1.3	0.08	10	243	29	31	40

3.2. Farm Management

Each experimental unit consisted of six planting rows at a distance of 50 cm and a length of four meters. The distance between the plants on the row was 10 cm. A row of distances was considered between the two plots and the distance between the two replicates was set at three meters. Quinoa seed was Titicaca cultivar. Seeds were sown on planting lines at a depth of 1 to 2 cm. Land preparation operations including plowing and disc were carried out optimally before planting.

3.3. Measured Traits

The final harvest was performed after the physiological maturation of the seeds. To determine the yield and yield components of the grain, by removing the side rows and 50 cm from the beginning and end of each plot as a margin effect, one square meter was taken from the middle of each plot and then transferred to the laboratory. Simultaneously with harvest, five plants from each plot were measured separately for plant height selection, stem diameter, 1000 seeds weight, number of seeds per plant, number of clusters in the inflorescence. Kjeldahl method (K1100 model) was used to determine the percentage of grain nitrogen (Emami, 1996). Protein yield was obtained by multiplying the percentage of protein in grain yield.

3.4. Statistical Analysis

After data collection, the statistical calculation was performed using SAS 9.3 and the comparison of means was performed using LSD test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. Plant height

The results of the analysis of variance showed that the effect of drought stress and HA treatment at the level of one percent on the height of the quinoa plant was significant. The interaction of drought stress and HA on plant height was not significant (Table 2). The results showed that the lowest plant height in the treatment of severe drought stress was 66.16 cm, which was reduced by 30.2% compared to the treatment without drought stress (Table 3).

Table 2. Result of analysis of variance effect of treatment on measured traits

S.O.V	df	Plant height	Stem diameter	No. clusters in inflorescence	Seeds weight	No. seeds per plant	Biological yield
Replication	2	13.58^{ns}	6.15*	48.59**	0.64^{ns}	4402716^{ns}	2671315.03*
Drought stress (D)	2	2473.68**	17.76**	157.01**	3.98*	22600392^{ns}	14168301.1**
Error I	4	9.50	0.51	2.04	0.32	3856525	192329.3
Humic acid (H)	3	1256.42**	4.58**	100.01**	2.11**	17416101**	3812405.4**
D × H	6	39.67^{ns}	0.49^{ns}	0.42^{ns}	0.01^{ns}	1294736^{ns}	329617.2**
Error II	18	26.03	0.72	1.99	0.05	1609353	80800.84
CV (%)	-	6.3	17.35	14.8	15.83	29	10.03

ns, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Continue of table 2.

S.O.V	df	Seed yield	Harvest index	Seed nitrogen	Percentage of seed protein	Protein yield
Replication	2	222645.4^{ns}	5.87^{ns}	0.28*	11.38*	9177.41^{ns}
Drought stress (D)	2	1876766.4**	3.21^{ns}	2.21**	81.02**	123396.49**
Error I	4	33522.4	2.65	0.02	0.82	1712.37
Humic acid (H)	3	956924.8**	39.87**	3.18**	128.51**	109350.77**
D × H	6	92929.1**	3.84**	0.09**	4.44**	12363.21**
Error II	18	16732.8	0.69	0.01	0.59	429.85
CV (%)	-	12.19	12.4	5.2	5.6	9.3

ns, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Water deficiency reduces vegetative growth in quinoa. Researchers have reported that a decrease in quinoa plant height in response to drought stress may be due to reduced cell length, cell turbulence, cell volume, and ultimately cell growth (Elewa *et al*., 2017). The results showed that in the treatment of 150 mg.l-1 HA, the highest plant height of 94.2 cm was obtained, which increased by 28.7% compared to the treatment of not using HA fertilizer (control) (Table 3). The use of HA increases growth by increasing the absorption of nutrients required by the plant (Sam Deliri *et al.*, 2018). In another study, consumption of 30 gr.m^{-2} HA increased plant growth and height by affecting plant metabolism and increasing nutrient uptake, especially nitrogen content (Ayas and

Gulser, 2005). The researchers reported that the application of three L/h of HA under drought stress conditions increased the height and number of sub-branches compared to the control treatment, which confirms the results of this study (Karimi and Tadayyon, 2018).

Table 3. Mean comparison effects of treatments on quinoa properties

Treatments		Plant height (cm)	Stem diameter (cm)	No. clusters in inflorescence	Seeds weight (gr)	Number of seeds per plant	Biological yield ($kg.ha^{-1}$)
Drought stress	Severe	66.16*c	3.03c	6.24c	2.95c	5227.58a	3246.67c
	Moderate	79.17b	3.94b	9.16b	3.66b	7170.50a	4455.58b
	Control	94.83a	5.44a	13.43a	4.09a	7878a	5415.08a
Humic acid ($mg.l^{-1}$)	Control	67.15d	3.66b	6.16d	3.19c	5161.89b	3703.89d
	50	74.37c	3.53b	7.86c	3.16c	6139.33b	4018.78c
	100	84.51b	4.25b	10.68b	3.76b	7410.56a	4586.67b
	150	94.20a	5.10a	13.76a	4.17a	8323a	5180.44a

*In each column, the means of each treatment that have common letters are not significantly different from each other based on LSD test.

Continue of table 3.

Treatments		Biological yield ($kg.ha^{-1}$)	Seed yield ($kg.ha^{-1}$)	Harvest index (%)	Seed nitrogen (%)	Percentage of seed protein (%)	Protein yield ($kg.ha^{-1}$)
Drought stress	Severe	3246.67*c	1088.33c	33.43a	1.85c	11.55c	129.10c
	Moderate	4455.58b	1538.08b	34.37a	2.07b	12.92b	207.11b
	Control	5415.08a	1876.67a	34.28a	2.68a	16.57a	330.23a
Humic acid ($mg.l^{-1}$)	Control	3703.89d	1188.67c	32.15c	1.62d	9.90d	120.34d
	50	4018.78c	1308.22c	32.63c	1.86c	11.65c	156.92c
	100	4586.67b	1585.33b	34.56b	2.34b	14.65b	242.88b
	150	5180.44a	1921.89a	36.77a	2.96a	18.52a	368.44a

*In each column, the means of each treatment that have common letters are not significantly different from each other based on LSD test.

4.2. Stem diameter

The results of the analysis of variance showed that the effect of drought stress and HA treatment at the level of 1% on quinoa stem diameter was significant. The interaction of drought stress and HA on stem diameter was not significant (Table 2). The results showed that the lowest stem diameter in severe drought stress treatment was 3.03 cm, which was reduced by 44.3% compared to treatment without drought stress (Table 3). The results showed that in the treatment of 150 mg.l-1 HA, the highest stem diameter of 5.1 cm was obtained, which increased by 30.7% compared to the treatment of 50 $mg.l^{-1}$ of HA fertilizer (Table 3). Researchers confirmed the significant effect of HA on sunflower stem diameter (Heidari *et al.*, 2020). The use of HA in drought stress conditions increases the photosynthetic capacity and leaf water content and increases the metabolism of antioxidant compounds in plant. This improves the growth and increases the traits associated with plant growth (Heidari *et al.* 2020).

4.3. Number of clusters in the inflorescence

The results of the analysis of variance showed that the effect of drought stress and HA treatment at the level of one percent on the number of clusters in the quinoa inflorescence was significant. But the interaction of drought stress and HA on this trait was not significant (Table 2). The results showed that in non-drought stress treatment, the highest number of clusters in the inflorescence was 13.43 which decreased by 53% compared to severe drought stress treatment (Table 3). Drought stress disrupts plant photosynthesis, which ultimately affects the growth and physiological processes of quinoa. It seems that the greatest effect of drought stress in quinoa is on the number of spikes in the inflorescence. By reducing the amount of water, the accumulation of photosynthetic materials is reduced, which further reduces the dry matter produced. In this case, it has the most negative impact on the yield components and plant yield. The results showed that in the treatment of 150 mg.l^{-1} HA, the highest number of spikes in the inflorescence was 13.7, while the lowest was 6.16 in the control treatment (Table 3). The use of HA stimulates the growth of aerial organs, which is due to the increased absorption of elements such as nitrogen, calcium, phosphorus, potassium, manganese, iron, zinc and copper (Barekati *et al*., 2020).

4.4. Weight of a thousand seeds

The results of the analysis of variance showed that the effect of drought stress treatment at the level of five percent and the effect of HA at the level of one percent on the weight of 1000 quinoa seeds were significant. The interaction of drought stress and HA on weight of a thousand seeds was not significant (Table 2). The results showed that in stress-free conditions, 1000-seed weight was 4.09 g, while in severe stress, 1000-seed weight was 2.95 g (Table 3). Lack of soil moisture reduces the growth and development of the quinoa plant, which ultimately reduces the flower production and filling of quinoa seeds. Therefore, the number and weight of 1000 seeds are reduced. Drought stress reduces leaf gas exchange and thus reduces the size of the source and reservoir in the plant, in which case the discharge and distribution of photosynthetic material in the plant are impaired (Farooq *et al*., 2009). Researchers report that drought stress causes weight loss of 1000 quinoa seeds (Elewa *et al*., 2017). The results showed that in the treatment of consumption of 150 mg.l^{-1} HA, the weight of 1000 seeds was 4.17 g, but in the treatment of non-consumption of HA, the weight of 1000 seeds was 3.19 g (Table 3). The researchers examined different levels of HA with values of 0, 100, 200, 300, 400 and 500 mg.l^{-1} and reported that the use of the highest amount of HA by improving soil fertility and nitrogen availability, has increased yield and yield components (Rahimi et al., 2016). In another report, researchers examined the effect of different levels of HA (0, 1.5 and 3 g.$^{-1}$) and confirmed the significant effect of 1.5 g on morphological traits and weight of 1000 sunflower seeds (Heidari *et al*., 2020). It seems that HA has increased the 1000-seed weight by affecting the transfer of more photosynthetic materials from leaf to seed.

4.5. Number of seeds per plant

The results of analysis of variance showed that the effect of HA at the level of one percent on the number of seeds per quinoa plant was significant, the interaction between drought stress and HA and the main effect of drought stress on the number of seeds per plant were not significant (Table 2). The results showed that in the treatment of 150 $mg.l^{-1}$ HA, the highest number of seeds per plant was 8323, while in the absence of HA, 5161 seeds were obtained per plant (Table 3). When sufficient nutrients are provided to the plant, photosynthesis will follow well and the accumulation of nutrients in the plant will be sufficient (Mohsen Nia and Jalilian, 2012). HA seems to have played a positive role in increasing yield components by improving environmental conditions. According to researchers, HA increases the growth characteristics of plants and their yield components and yield through positive physiological effects such as the effect on plant cell metabolism and increasing leaf chlorophyll concentration (Nardi *et al*., 2002).

4.6. Biological yield

The results of the analysis of variance showed that the effect of drought stress treatment and the effect of HA on the level of 1% probability on the biological yield of quinoa were significant. Also, the interaction of drought stress and HA on biological yield was significant at the level of 5% (Table 2). The results showed that in the treatment of drought stress and consumption of 100 $mg.l^{-1}$ HA, the highest biological yield of 6508 kg.ha-1 was obtained and the lowest in the treatment of severe drought stress and no consumption of HA (3068.6 $kg.ha^{-1}$). Obtained (Table 4). Researchers have found that stress reduces plant biomass yield, leading to reduced uptake and nutrients, reduced stomatal conductance, and consequently reduced quinoa photosynthetic power (Yang *et al*., 2016). Some researchers have reported that quinoa biomass decreases under drought stress (Hirich *et al*., 2014; Elewa *et al*., 2017). HA has a role in increasing nitrogen uptake due to its hormonal-like effect and improving cellular metabolism. By affecting cell membrane permeability, it increases nutrient uptake and improves overall growth conditions and biological function (Safaee *et al*., 2016).

4.7. Grain yield

The results of the analysis of variance showed that the effect of drought stress and HA treatment at the level of one percent on quinoa grain yield was significant. Also, the interaction of drought stress and HA on grain yield was significant at the level of one percent (Table 2). The results showed that in the treatment without drought stress and consumption of 100 $mg.l^{-1}$ HA, the highest grain yield was obtained at 2105.4 $kg.ha^{-1}$ and the lowest in the treatment of severe drought stress and no consumption of HA (999 $kg.ha^{-1}$). Was obtained. (Table 4). One of the plant's reactions to drought stress is the closing of the stomata. By closing the pores, it reduces the absorption of carbon dioxide, which ultimately reduces photosynthesis. Researchers have reported that under drought stress, quinoa yield decreases (Elewa *et al*., 2017).

Table 4. Mean comparison interaction effect of treatments on quinoa properties

Drought stress	Humic acid (mg.l^{-1})	Biological yield (kg.ha^{-1})	Seed yield (kg.ha^{-1})	Harvest index (%)	Seed nitrogen (%)	Percentage of seed protein (%)	Protein yield (kg.ha^{-1})
Control	Control	4851*c	1556.67cd	32.15fg	1.85e	10.98ef	157.36d
	50	5811b	2023.67b	34.90cd	2.30cd	14.38cd	225.59c
	100	6508a	2105.48a	38.70a	3.01b	18.79b	380.72b
	150	4490.3cd	1407cde	32.35fg	3.54a	22.15a	557.24a
Moderate stress	Control	4136.6d	1369de	33.11ef	1.57fg	9.81fg	119.95ef
	50	4654.3c	1603c	34.45cde	1.70ef	10.60ef	145.80de
	100	5393.3b	1974.67b	36.39b	2.15d	13.42d	215.46c
	150	3638e	1220.67efg	33.54def	2.85b	17.83b	347.23b
Severe stress	Control	3068.6f	999gh	31.61g	1.42g	8.90g	83.71g
	50	3294.6ef	1129.33fgh	34.33cde	1.59fg	9.96fg	99.38fg
	100	3640e	1283.67ef	35.23bc	1.88e	11.75e	132.45def
	150	3983.3c	1150.33ef	32.57fg	2.49c	15.58c	200.85c

*In each column, the means of each treatment that have common letters are not significantly different from each other based on LSD test.

Continue of table 4.

Drought stress	HA (mg.l^{-1})	Biological yield (kg.ha^{-1})	Seed yield (kg.ha^{-1})	Harvest index (%)	Seed nitrogen (%)	Percentage of seed protein (%)	Protein yield (kg.ha^{-1})
Control	Control	4851*c	1556.67cd	32.15fg	1.85e	10.98ef	157.36d
	50	5811b	2023.67b	34.90cd	2.30cd	14.38cd	225.59c
	100	6508a	2105.48a	38.70a	3.01b	18.79b	380.72b
	150	4490.3cd	1407cde	32.35fg	3.54a	22.15a	557.24a
Moderate stress	Control	4136.6d	1369de	33.11ef	1.57fg	9.81fg	119.95ef
	50	4654.3c	1603c	34.45cde	1.70ef	10.60ef	145.80de
	100	5393.3b	1974.67b	36.39b	2.15d	13.42d	215.46c
	150	3638e	1220.67efg	33.54def	2.85b	17.83b	347.23b
Severe stress	Control	3068.6f	999gh	31.61g	1.42g	8.90g	83.71g
	50	3294.6ef	1129.33fgh	34.33cde	1.59fg	9.96fg	99.38fg
	100	3640e	1283.67ef	35.23bc	1.88e	11.75e	132.45def
	150	3983.3c	1150.33ef	32.57fg	2.49c	15.58c	200.85c

*In each column, the means of each treatment that have common letters are not significantly different from each other based on LSD test.

Anwar *et al*. (2016) reported that the highest weight of a thousand seeds, grain and biological yield were obtained at a rate of 15 kg.ha^{-1} HA. Safaee *et al*. (2017) attributed the increase in grain yield due to HA to the high leaf area index and plant dry weight. According to these researchers, by increasing the leaf area index, lighter is received by the plant, resulting in more photosynthesis, Crop growth rate and dry matter accumulation also increase and lead to increased yield. In the present study, foliar application of HA increased yield compared to control treatment, which may be due to the effect of HA on plant growth, photosynthesis and better absorption of nutrients by the plant.

4.8. Harvest index

The results of the analysis of variance showed that the effect of HA treatment at the level of one percent on the quinoa harvest index was significant. Also, the interaction between drought stress and HA on the harvest index was significant at the level of one percent (Table 2). The results showed that in the treatment without drought stress and consumption of 100 $mg.l^{-1}$ HA, the highest harvest index was 38.7% and the lowest in the treatment of severe drought stress and no consumption of HA was 31.6% (Table 4). Drought stress affects the biochemical processes related to photosynthesis and indirectly affects the entry of carbon dioxide into the pores, which reduces plant growth and development by limiting photosynthetic products. Drought stress has been reported to cause pollen grains sterilization and disruption of pollination, current photosynthesis and transfer of stem reserves to the spike, reducing the number of seeds per spike and consequently reducing grain yield (Richards *et al*., 2001). Sarwar *et al*. (2017) stated that the maximum wheat grain yield was obtained by applying 50 $kg.ha^{-1}$ of HA, which was 16% higher than the control. Madhavi *et al*. (2017) investigated the effect of HA fertilizer on grain corn yield and reported that the highest grain yield was obtained in the application of 30 $kg.ha^{-1}$ of HA fertilizer.

4.9. Grain nitrogen

The results of the analysis of variance showed that the main effect of drought stress and HA treatment at the level of 1% on quinoa grain yield was significant. Also, the interaction of drought stress and HA on grain nitrogen was significant at the level of one percent (Table 2). The results showed that in the treatment without drought stress and consumption of 150 $mg.l^{-1}$ HA, the highest grain nitrogen was obtained by 3.54%. The lowest rate was obtained in the treatment of severe drought stress and no consumption of HA (1.42%). (Table 4). The results of this study show that drought stress had a significant effect on grain nitrogen and the effects of drought stress were reduced by the use of HA. Important benefits of HA include chelating of various nutrients such as sodium, magnesium, zinc, potassium, iron, copper, calcium and other elements to compensate for nutrient deficiencies. This ultimately increases the growth and development of crops (Verlinden *et al*., 2009).

4.10. Percentage of grain protein

The results of the analysis of variance showed that the main effect of drought stress treatment and HA at the level of one percent on the percentage of quinoa seed protein was significant. Also, the interaction between drought stress and HA on the percentage of grain protein was significant at the level of one percent (Table 2). The results showed that in the treatment without drought stress and consumption of 150 $mg.l^{-1}$ HA, the highest percentage of grain protein was 22.15% and the lowest in the treatment of severe drought stress and no consumption of HA was 8.9%. Came. (Table 4). The decrease in protein synthesis or breakdown under stress may be due to increased protease enzyme activity. Higher protein concentrations maintain photosynthesis and increase drought resistance by preserving leaf chlorophyll (Farooq *et al*., 2009; Maleki *et al*., 2020). It seems that by increasing the consumption of HA, the negative effects of drought stress are reduced and the amount of grain protein is increased. HA increases photosynthetic activity in the crop (Delfine *et al*., 2005). Researchers have reported that HA improves the production of sugars, proteins, and vitamins in plants, which ultimately has a positive effect on corn yield and quality (Sharif *et al*., 2002).

4.11. Protein yield

The results showed that the main effect of drought stress treatment and HA at the level of 1% on quinoa protein yield was significant. Also, the interaction of drought stress and HA on protein yield was significant at the level of one percent (Table 2). The results showed that in the treatment without drought stress and consumption of 150 $mg.l^{-1}$ HA, the highest protein yield was obtained at 557.24 $kg.ha^{-1}$ and the lowest in the treatment of severe drought stress and no consumption of HA (83.71 kg). Per hectare (Table 4). Grain protein yield is obtained by multiplying grain yield by the percentage of grain protein. The use of HA seems to reduce the effects of drought stress and ultimately increase protein yield. The researchers reported that foliar application of HA increased bean seed yield by 16% compared to the control treatment due to increased nutrient availability for the plant in HA treatments (Jahan *et al*., 2013). Barekati *et al*. (2020) reported that the use of HA increases grain and biological yield by increasing the absorption of elements such as N, P, K, Ca, Mn, Fe and Cu.

5. CONCLUSION

The results showed that in conditions of drought stress, the application of HA fertilizer reduces the effect of drought stress on the growth processes of quinoa. In this study, it was found that the performance of quinoa at 100 $mg.l^{-1}$ HA showed a better response than other levels of HA. In general, the results show that drought stress had a significant effect on growth characteristics, quinoa yield. Considering the improvement of quinoa yield components by optimally increasing HA and obtaining more grain yield, the results indicate the appropriate response of quinoa to HA.

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FOOTNOTES

AUTHORS' CONTRIBUTION: All authors are equally involved.

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