

The Improving Effects of Humic Acid and Biochar on Yield Components of Barley under Drought Stress

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Abstract: In order to evaluate the improving effects of humic acid and biochar on yield components of barley (*hordeum vulgare* L.) under drought stress, a greenhouse study was carried out (2022-23) in Baquba, Diyala Province, Iraq (33° 74' north and 44° 64' east with a hot desert climate, average temperature of 22.8 °C, 186 mm of precipitation and 2200m altitude) (IBA 99 cultivar). The study was done as factorial experiment in a completely randomized design with three replications. The studied factors were drought stress at three levels (irrigation after draining 33%, 66% and 100% of field capacity) and fertilizer (biochar and humic acid). Measured traits were the number of ears, the number of grains per ear, weight of 1000 grains, grain yield and harvest index. Humic acid consumption plus stress 33% had the highest number of ear and grain yield. Biochar was not very successful in repairing the negative effects of drought. Overall, at all levels of drought stress, humic acid was better than biochar and under the same conditions as the present study, it seems reasonable to use humic acid to eliminate the adverse effects of drought stress and increase the yield without causing environmental problems.

Keywords: biochar, humic acid, barley, drought stress, yield, harvest index

Introduction

Cereals have a great contribution to the nutrition of humans and animals, and important civilizations in history were formed based on the cultivation of cereals. Barley is one of the most important and oldest crops which shows the highest adaptation to different climatic conditions compared to other crops and is cultivated as the fourth most important grain in terms of production after wheat, corn and rice all over the world (Thabet et al. 2020).

During their life, plants are constantly exposed to abiotic stresses such as drought. Drought is the most common environmental stress that can affect the growth and development of plants all over the world, especially in arid and semi-arid regions. Therefore, drought has become the main limitation of crop production such as barley (Payandeh and Derogar, 2018).

Biochar is a stable form of charcoal that has a good potential for carbon sequestration (capturing and storing atmospheric carbon dioxide). Due to its aromatic chemical structure and resistance to microbial degradation, biochar is useful for long-term carbon storage. Carbon sequestration of biochar continues for 1000-2000 years. Therefore, it can be considered a tool to curb global warming and a platform to reduce climate change caused by carbon dioxide emissions and to control greenhouse gases. In addition, biochar improves soil health by increasing porosity and maintaining soil moisture, increasing soil nutrient supply capacity, and thus increasing crop production (Gupta et al. 2020).

Humic acid

Humic substances are the main part of soil-forming organic substances, which include humic acid and fulvic acid. Humic acid has direct and indirect roles in the plant, which are dependent on its concentration (Haghighi and Najafi, 2019). Humic acid improves soil fertility, makes elements available, and thus increases plant growth and yield. Humic substances increase the moisture retention capacity of the soil. These materials can be used to reduce drought stress by expanding the root system. Another mechanism is to reduce open stomata for reducing transpiration and increasing water absorption through the roots (Haghighi and Najafi, 2019).

Considering the growing problem of water scarcity and the fact that agricultural soils have suffered problems due to frequent use, the use of materials such as biochar and humic acid can play an effective role in improving soil fertility. Therefore, this research was conducted with a new method in order to improve soil fertility and its effects on the growth and performance of barley plants under drought stress.

Materials and methods

This experiment was conducted (2022-03) in a greenhouse located in Diyala province of Iraq - Baquba city (33° 74' north and 44° 64' east). Baquba region has a hot desert climate (BWh) based on the Koppen method. The amount of precipitation in winter is much more than in summer. The long-term average temperature is 22.8 degrees Celsius and the long-term average annual rainfall is about 186 mm.

The research was conducted as a factorial experiment in a completely randomized design with three replications. Barley cultivar was IBA 99. The experimental factors were drought stress at three levels (100, 66 and 33% of field capacity) and fertilizer (biochar and humic acid). Biochar was purchased from Biofire Company and liquid humic acid 12% was purchased from Iraq Garden Company. Before planting, biochar was completely mixed with the soil at the rate of five percent. The amounts of humic acid were 650 ml for 100% field capacity, 429 ml for 66%, and 214 ml in 33%, which were added to the soil of the pots in the first irrigation. In order to determine the field capacity (FC), the weight method was used. The traits measured in this study were plant height, number of tillers, root weight, leaf area index, total dry weight, biological yield, ear number, thousand grains weight, grain yield and harvest index.

The pots were made of clay with a diameter of 25 cm and a height of 20 cm. Three pots were considered for each experimental replication. The substrate used was the soil of the college farm. No type of fertilizer was used except for experimental treatments. About 12 grains were planted in each pot, and after two-leaf stage, the number of seedlings were reduced to six.

Depending on the drought stress treatment, the irrigation cycle of pots were two days, three days and four days. Weed control was done manually.

Obtained data were analyzed using SAS program and mean comparison was performed based on Duncan's multi-range test at a probability level of 5%. EXCEL 2013 was used to draw the graphs.

Results and discussion

The number of ears

The interaction effect of fertilizer and drought stress on the number of ears was significant ($p < 0.05$) (Table 1). The highest number of ears (4.15) was observed in humic acid plus 60% stress, which was not statistically different from the same level of fertilizer plus stress 33% or biochar plus 33%. Biochar plus stress 100% had the lowest number of ears (1.76).

Humic acid has been able to compensate the negative effects of low irrigation stress. Molecules of humic acid form a bond with water molecules which prevents water evaporation. As a result, humic acid moderates tillering reduction under water stress conditions which leads to higher ear numbers. In the study of Salem Almarshadi and Ismail (2014) on barley, humic acid significantly increased

the number of ears per unit area. Izhar Shafi et al. (2020) reported that the use of humic acid increased the number of ears per unit area of wheat.

Sources of variations	Degrees of freedom	Mean squares				
		Ear Number	Grain Number per Ear	Thousand grains weight	Grain yield	Harvest Index
Fertilizer	1	3.42**	112.04**	217.84*	98.02**	299.23**
Drought Stress	2	3.89**	134.41**	608.62**	59.53**	330.26**
Fertilizer × Drought Stress	2	0.34*	12.87 ^{ns}	78.71 ^{ns}	6.68 ^{ns}	7.70 ^{ns}
Error	12	0.08	6.29	26.47	1.11	14.00
CV (%)		14.17	14.37	18.86	7.49	13.45

^{ns}, * and **: non-significant. Significant at 5% probability level and Significant at 1% probability level

	Ear Number	Grain Number per Ear	Thousand grains weight	Grain yield	Harvest Index
Fertilizer					
Humic Acid	3.76a	19.96a	23.8b	1.64a	31.9a
Biochar	2.88b	14.97b	30.76a	1.17b	23.74b
Drought Stress					
33%	3.97a	21.04a	23.77b	1.62a	33.29a
66%	3.58b	16.25b	19.43b	1.56b	25.79b
100%	2.42c	12.09c	38.63a	1.05c	19.37c

In each column, there is no significant difference between means with at least one common letter using Duncan test (5% probability level)

Fertilizer	Drought Stress	Ear Number	Grain Number per Ear	Thousand grains weight	Grain yield	Harvest Index
Humic Acid	33%	4.03a	25.21a	23.78b	1.97a	36.31a
	66%	4.15a	16.75bc	16.21c	1.4b	27.07ab
	100%	3.08b	13.9cd	31.41ab	1.27c	23.31b
Biochar	33%	3.78a	17.75bc	23.77b	1.42b	30.27ab
	66%	3.12b	16.86bc	22.64b	1.28c	25.52b
	100%	1.76c	10.28d	40.86a	0.83d	15.43c

In each column, there is no significant difference between means with at least one common letter using Duncan test (5% probability level)

The number of grains per ear

The effect of fertilizer on the number of grains per ear was very significant. The highest number of grains (19.96) belonged to humic acid. The effect of drought stress was also very significant on this trait and stress 33% had the highest number of grains per ear (3.97). By increasing the drought stress, the number of grains showed a decreasing trend. Mean Comparison results indicated significant differences between the levels of treatments interaction. The highest number of grains per ear (25.21) was observed in humic acid plus stress 33%. Biochar plus water stress 100% had the lowest number of grains in the ear (10.28).

It seems that under stress conditions, few photosynthetic materials are produced and as a result, the growth of different parts of the plant is disturbed. Therefore, decreased number of grains under water stress can be attributed to the lower photosynthetic materials. The use of humic acid under stress condition has led to improved number of grains per ear, probably through improving photosynthesis and plant growth. The lower number of grains due to drought stress can also be due to the sterility of terminal flowers of the ear. It seems that the increase in the number of grains by humic acid is due to the prevention of falling or sterility of the florets of ear under water stress. Humic acid increases auxin, cytokinin and gibberellin hormones in the plant. Increasing these hormones, increases the distribution of cultivated materials in favor of grains and the number of grains will be increased (Sadaghat and Imam, 2016). Amiri et al. (1401) reported in their study on sorghum that the number of grains per spike was increased by humic acid under drought stress. In the studies of Mahmoudi Zovik et al. (2015) and Izhar Shafi et al. (2020) on wheat, an increase in the number of grains per spike was reported after the use of humic acid.

Thousand grains weight

The effect of fertilizer on thousand grains weight was significant ($p < 0.05$). The highest weight belonged to biochar (30.76g) and the lowest one belonged to humic acid. The effect of drought stress was also very significant ($p < 0.01$) on this trait, and stress 100% had the highest weight while the stress 60% produced the lowest one, which was not different from 33%. Mean Comparison results of the interaction levels indicated significant differences between these levels and the highest thousand grains weight (44.33g) was observed in biochar plus stress 33%, while humic acid plus stress 60% had the lowest weight (16.21g).

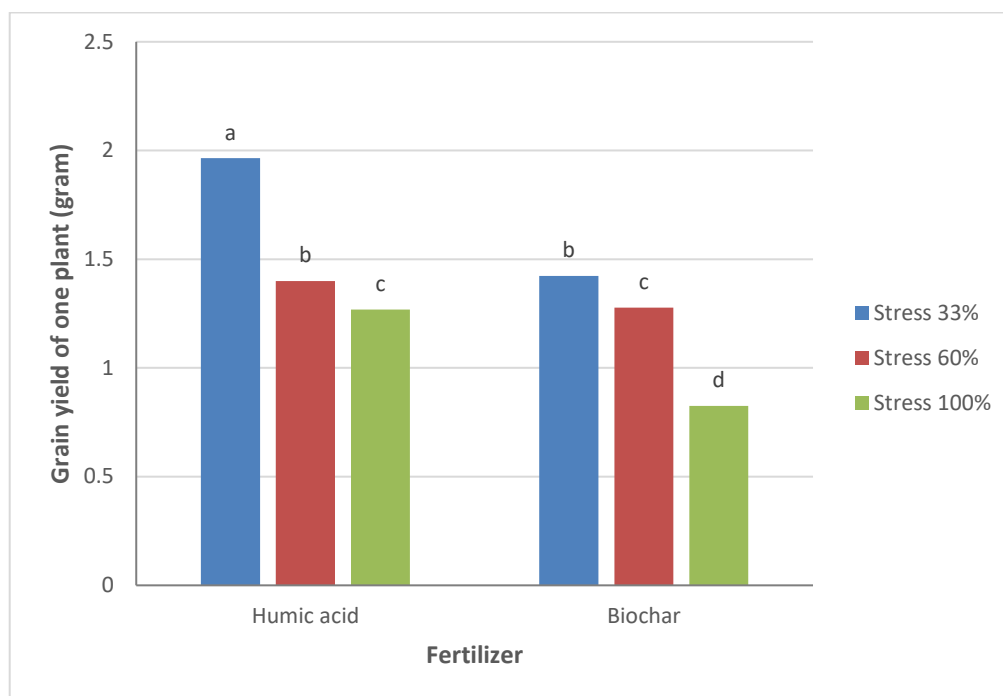
In general, the lack of water in the vegetative and reproductive stages caused decrease in thousand grains weight due to the increased competition for water and food. The reason can be shorter vegetative and reproductive growth periods which shorten the effective period of grain filling and also reduce the production and transferring of photosynthetic substances to grains. This leads to decrease in the weight of a thousand grains. Raza et al. (2023) in a study on wheat reported an increase in 1000 grains weight by using biochar. The reason for that was the proper storage of water by biochar. Hafez et al. (2020) reported the decrease in the weight of a thousand grains weight due to drought and its increase following the use of biochar. Sali et al. (2020) reported that the use of biochar increased 1000 grains weight of corn under drought stress. Salem Almarshadi and Ismail (2014) reported in their study on barley that the use of humic acid did not affect thousand grains weight but Shahbazi et al. (2014) reported that humic acid increased this trait by affecting the transfer of photosynthetic substances from leaves to grains. In their study on wheat, Mahmoudi Zovik et al. (2014) and Izhar Shafi et al. (2020) reported increase in thousand grains weight following the consumption of humic acid.

Grain yield

The effect of fertilizer on grain yield was very significant ($p < 0.01$). The highest grain yield belonged to humic acid (1.64 g). The effect of drought stress was also very significant ($p < 0.01$) on this trait, and stress 33% had the highest weight (1.62g). The interaction effect of fertilizer and drought stress on grain yield was not significant but mean comparison results of the interaction levels indicated significant differences between these levels. The highest grain yield (1.97g) was observed in humic acid plus stress 33% while biochar plus stress 100% had the lowest grain yield (0.83g).

Smaller size of vegetative organs because of limited growth and cell division under drought stress leads to a decreased production and transfer of photoassimilates to the reproductive organs and results in lower grain yield. Humic acid increases shoot growth and grain yield by increasing the absorption of elements such as nitrogen, phosphorus, potassium, manganese, iron, zinc and copper. Also, humic acid has beneficial effects on increasing plant production with its quasi-hormonal effects. It is obvious that enough nutrients cause better photosynthesis and higher accumulation of nutrients in the plant sinks (Tourfi and Shokuhfar, 2020). Salem-Almarshadi and Ismail (2014) reported higher grain yield of barley after the use of humic acid. Mahmoudi Zovik et al. (2014) and

Izhar Shafi et al. (2020) also reported increase in grain yield following the consumption of humic acid.



Harvest index

Fertilizer affected harvest index very significantly ($p < 0.01$). The highest harvest index belonged to humic acid (31.9%). The effect of drought stress was also very significant on this trait. stress 33% had the highest harvest index (33.29%) whereas stress 100% produced the lowest harvest index (19.37%). By increasing the stress, harvest index was decreased. Mean Comparison results of the interaction levels showed significant differences between these levels and the highest harvest index (36.31%) was observed in humic acid plus stress 33% while biochar plus stress 100% had the lowest harvest index (15.43%).

The reduction of the harvest index under drought stress can be due to the lower photosynthetic area and also reduction of assimilate remobilization in grain filling stage. Shahbazi et al. (2014) reported that humic acid increased plant's growth via hormonal effects and by affecting the metabolism, as well as by increasing chelating power and nutrients absorption. In their experiment, foliar application of humic acid increased harvest index of wheat by seven percent. In the study of Izhar Shafi et al. (2020), an increase in the wheat harvest index was reported following the use of humic acid.

Conclusion

According to the results, humic acid had the highest averages of all traits except thousand grains weight. Biochar was not very successful in repairing the negative effects of drought and in most cases produced lower averages even from low humic acid levels. Humic substances improved plant growth and also reduced the adverse effects of drought stress due to increased absorption of nitrogen, potassium, phosphorus, calcium and magnesium. In general, under conditions similar to the current study, it seems reasonable to use humic acid to eliminate the adverse effects of water stress and increase yield components.

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