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Effect of seed priming with gibberellic acid (GA3) on seed germination and seedling growth of some barley varieties (*Hordeum vulgare* L.)

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ABSTRACT

An experiment was carried out in a laboratory of the Field Crops Department/College of Agriculture/Tikrit University to study the effect of treating the seeds of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four concentrations (0, 50, 100, and 150 mg L^{-1}) of gibberellic acid on percentage of seed germination, germination vigor, germination speed, shoot length, root length, and total dry weight. The experiment was carried out using a completely randomized design (C.R.D.) with four replicates (Petri dish) for each treatment. The results showed that there were significant differences among the concentrations of gibberellic acid and among the varieties in affecting all the studied traits. Seeds treated with a concentration of (100 mg L^{-1}) of gibberellic acid was superior in all studied traits. Aksad variety was superior to all cultivars in most of the studied traits, which are germination percentage (98.17%), germination vigor (61.83%), germination speed (50.20), and total dry weight (0.04078 g $plant^{-1}$), while Samir and Shueae were superior in shoot length (19.42 and 19.38 cm), respectively and Samir was superior in the root length (12.79 cm). There was also a significant interaction between cultivars and gibberellic acid concentrations for all studied traits. The interaction of (Samir x 100) was superior to all combinations for all studied traits except dry weight trait, which the interaction (Aksad x 100) was superior.

تأثير معاملة البذور بحامض الجبريليك (GA3) على انبات بذور ونمو بادرات بعض اصناف الشعير(*Hordeum vulgare* L.)

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الخلاصة

نفذت تجربة في مختبر قسم المحاصيل الحقلية / كلية الزراعة/ جامعة تكريت لدراسة تأثير معاملة بذور خمسة أصناف من الشعير وهي (سمير، امل، اكساد، الخير، شعاع) في اربعة تراكيز من حامض الجبريليك وهي (0 و 50 و 100 و 150 ملغم لتر$^{-1}$) على صفات: نسبة انبات البذور وقوة الانبات وسرعة الانبات وطول المجموع الخضري وطول المجموع الجذري والوزن الجاف الكلي. نفذت التجربة باستخدام التصميم العشوائي الكامل وباربعة مكررات (طبق بتري) لكل معاملة. أظهرت النتائج وجود اختلافات معنوية بين تراكيز حامض الجبريليك وبين الأصناف في التأثير على جميع الصفات المدروسة. تفوقت البذور المعاملة بتركيز (100 150 ملغم لتر$^{-1}$) من حامض الجبرليك في جميع الصفات المدروسة. تفوق الصنف اكساد على جميع الأصناف في اغلب الصفات وهي نسبة الانبات (98.17%) وقوة الانبات (61.83%) وسرعة الانبات (50.20) و الوزن الجاف الكلي (0.04078 غم)، في حين تفوق الصنفين سمير وشعاع في صفة طول المجموع الخضري (19.42 و 19.38 سم)، على التوالي. وتفوق الصنف سمير في صفة طول المجموع الجذري (12.79 سم). أيضا كان هناك تداخل معنوي بين الأصناف وتراكيز الجبرلين ولجميع الصفات المدروسة. تفوق التداخل (سمير* 100) على جميع التوليفات ولجميع الصفات المدروسة عدا صفة الوزن الجاف والتي تفوق فيها التداخل (اكساد * 100).

الكلمات المفتاحية: أصناف الشعير, حامض الجبرليك, نسبة الانبات, قوة الانبات, سرعة النبات, طول المجموع الخضري, طول المجموع الجذري, الوزن الجاف

INTRODUCTION

Barley crop *Hordeum vulgare* L. is one of the important cereal crops. It comes fourth in the term of importance and productivity after wheat, rice, and maize. In 2022, the total harvested land area of barley was 48.59 million hectares, with a productivity of 145.08 million metric tons worldwide (USDA, 2022). In Iraq, this crop comes after wheat in terms of cultivated area and production, which amounted 0.267 million metric tons (Lafta, 2020; CSO, 2021). In 2020/2022 agricultural season, European Union is the major producer of barley, which amounted 52.75 million metric tons. Russia was the second largest producer of this crop with 17.5 million metric tons. These two major producers are followed by Australia, Ukraine, Canada, Argentina, Turkey, Morocco, Iran, Unites States, and Kazakhstan (Statista, 2023).

Barley crop has a good level of adaptability to hard environmental conditions in arid and semi-arid regions such as cold, drought, alkaline and salinity soils, poor soils. Also, it is considered tolerance and competitive to weeds compared to wheat and other cereal crops due to its rapid growth and maturity (Gurel et al., 2016; Giraldo et al., 2019). Most of the barley production, whether in the form of green plants, grains, or straw, is used as animal feed. In addition, it is considered as a healthy food for millions of people, as well as its use as a main source of malting, brewing, starch and biofuels production (Langridge, 2018; Tricase et al., 2018). Barley grain is characterized by its high contents of starch (65-68%), dietary fiber (11-34%), protein (10-17%), β-glucans (4-9%), free lipids (2-3%), and mineral elements (1.5-2.5%). The percentage of these components is varied according to the varieties and the environmental conditions of each agricultural region (Hussain et al., 2021; Geng et al., 2022). The low percentage of seed germination and slow seedling growth leads to an increase the risk of disease and insects as well as delays the performance of the crop and thus negatively affects the yield (Damalas et al., 2019; Khaeim et al., 2022). The percentage of germination is affected by many factors, some of which are related to the seed, such as genetic structure, seed viability, seed vigor, and the internal enzymatic system, as well as the environment and its interaction with these factors. Seed germination requires an effective enzymatic system to carry out the processes of construction and demolition during the germination process, and it was found that this enzymatic system is impacted under the influence of plant hormones, especially gibberellic acid (GA3) (Carrera-Castano et al., 2020). Gibberellins play an important and major role in plant growth and development such as increasing seed germination and seedling growth, breaking seed dormancy, stimulating root, leaf and stem elongation, stimulating flowering initiation and seed development, and then increasing grain yield. This plant hormone performs many physiological functions, including its responsibility for stimulating seed germination through its control over the synthesis of enzymes necessary for germination (Gupta and Chakrabarty, 2013; Gomez et al., 2016; Carrera-Castano et al., 2022).

Furthermore, many scientific studies have confirmed that gibberellic acid has clear physiological effects in increasing the percentage of germination for different types of seeds, as well as stimulating the plant to form branches or tillers (Abdel-Hamid and Mohamed, 2014; Du et al., 2022). Gibberellic acid is one of the growth regulators that stimulate crop growth and has the ability to produce positive effects on yield (Almubarak, 2009; Miceli et al. 2019). Many researchers have studied the effect of gibberellic acid on the germination of seeds of many crops, including barley. They found that soaking the seeds with gibberellins had a significant effect on increasing the percentage of seed germination, germination speed, germination vigor, root length, shoot length, and total dry weight of seedlings (Munzuroglu and Zengin, 2006; Cavusoglu and Kabar, 2007; Bradford et al., 2008; Akman, 2009; Terzi and Kocacaliskan, 2010; Abdel-Hamid et al., 2014; Amri et al., 2016). The aim of this study was to treat the seeds of five barley varieties with four concentrations of gibberellic acid to see its effect on germination percentage and seedling growth. The aim of this study was to treat the seeds of five barley varieties with four concentrations of gibberellic acid to find out: its effect on the percentage of germination and seedlings growth, the best concentration, variety and combination between the concentrations of gibberellin and the varieties.

MATERIALS AND METHODS

An experiment was carried out in the laboratory of the Field Crops Department/ College of Agriculture/ Tikrit University in order to study the effect of soaking five barley varieties seeds (Samir, Amil, Aksad, Alkhayr, Shueae) in four concentrations of gibberellic acid (GA3), which were (0, 50, 100, and 150 mg L^{-1}) on germination percentage and determination the optimum concentration for each variety. Barley varieties were obtained from The Seed Technology Center/Agricultural Research Office/ Iraqi Ministry of Science and Technology. Gibberellic acid concentrations were prepared by dissolving 1 gm of GA3 in distilled water with continuous stirring and completing the solution to a liter of distilled water. The required concentrations (50, 100 and 150 mg L^{-1}) were prepared from the standard solution according to the following equation of dilution:

$C1\ V1 = C2\ V2$

Where,

C1= initial concentration; V1= initial volume; C2= final concentration; V2= final volume

Before planting, the seeds of the five varieties were sterilized with 5% Clorax solution (NaCIO) for 10 minutes, then washed with sterilized distilled water three times. After that, sterilized seed were dried on filter paper with air current in the dark. Drying seed were soaked before planting with prepared concentrations of GA3 (0 [distilled water], 50, 100, 150 mg, L^{-1}) for 24 hours, then seeds were air-dried in the dark. Seeds of each variety that treated with different concentrations of gibberellic acid were planted in Petri dishes with a diameter of (9 cm) using two layers of filter papers. Twenty-five seeds were placed in each Petri dish for each treatment, at the rate of 16 Petri dishes for each variety. The experiment was carried out using a completely randomized design (C.R.D.) with four replications for each treatment. The germination process was carried out in the growth chamber at a temperature of 25 °C ± 2 for eight days. Germinated seeds (root length 2 mm) were recorded daily for eight days. Then according to ISTA (2005), the following characteristics were taken and calculated: germination percentage, germination vigor, germination speed, shoot length (cm), root length (cm). After that, the seedlings were dried in the dryer at 65 °C, until the weight stabilized. Then the dry weight was taken by weighing it with a sensitive scale.

The percentage of seed germination was measured by converting the results into a percentage according to the following equation:

Germination percentage = number of germinated seeds/total number of seeds x 100

Germination vigor (%) = the number of germinated seeds on the first count day/ total number of seeds x 100

Germination speed was calculated by using the following equation of Wardle et al. (1991)

Germination speed = total seeds germinated on the first day/1 + ... + total seeds germinated on the eighth day/8

Shoot length and root length (cm): measured by using a ruler

Dry weight (g): After drying and weighing stability, the dry weight of the entire seedling (shoot + root) was taken using a sensitive scale.

The data of the study were analyzed statistically as a C. R. D. using PROC MEANS and PROC GLM in SAS (Version 9.4, SAS Institute, 2011, Cary, NC). The means were compared using Fisher's Least Significant Difference (L.S.D) test at $\boldsymbol{\alpha} = 0.05$. The curves were plotted using SigmaPlot version 13 (Systat Software).

RESULT AND DISCUSSION

Analysis of variance (Table 1) showed significant differences among barley varieties for all studied traits, which indicated that there was a genetic variation among evaluated barley varieties. Highly significant effects were also observed for all studied traits due to gibberellic acid concentrations. Moreover, interaction between varieties x GA3 concentrations was significant for all studied traits. Similar findings were given by Munzuroglu and Zengin (2006), Akman (2009), Abdel-Hamid and Mohamed (2014), Amri et al.(2016), and Du et al.(2022).

The low percentage of seed germination and slow seedling growth leads to an increase the risk of disease and insects as well as delays the performance of the crop and thus negatively affects the yield (Damalas et al., 2019). Table (2) showed the mean percentage of seed germination of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) soaked with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l^{-1}). The mean germination percentage of barley varieties ranged from 92.83 to 98.17%. Aksad variety was superior and gave the highest germination percentage (98.17%) while the Shuaa variety gave the lowest germination percentage (92.83%). This result confirmed the genetic variation among evaluated barley varieties. As for the GA3 concentrations, the mean germination percentage ranged from 93.27 to 98.27 %. Seeds treated with 100 mg l^{-1} of gibberellic acid were superior to the all GA3 concentrations for the germination percentage trait, as this treatment gave the highest seed germination percentage (98.27%), while the control treatment gave the lowest germination percentage (93.27%).

Table 1. Analysis of variance of five varieties of barley (Samir, Amil, Aksad, Alkhayr, Shueae), four concentrations of gibberellic acid (0, 50, 100, and 150 mg L^{-1}), and their interaction for germination percentage, germination vigor (%), germination speed, shoot length (cm), root length (cm), and total dry weight (g).

Source of Variance	Degree of Freedom (d. f.)	Germ. Percentage (%)	Germ. Vigor (%)	Germ. Speed	Shoot Length (cm)	Root Length (cm)	Total Dry Weight (g)
Varieties (V)	4	77.54***	142.73*	25.87*	11.63***	27.51***	4.75E-5***
GA3 Conc.	3	96.19***	989.43***	113.54***	397.59***	10.63***	4.33E-5***
V x GA3	12	20.37*	238.95***	19.06*	2.09*	3.43*	9.4E-6*
Error	60	9.61	46.04	8.11	0.916	1.67	4.29E-6

*** Significant at the 0.001 probability level.
* Significant at the 0.05 probability level.

Table 2. Mean of germination percentage (%) of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean (%)
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	93.33	100.00	100.00	96.00	97.33
Amil	91.00	96.67	99.33	95.00	95.50
Aksad	95.33	97.33	100.00	100.00	98.17
Alkhayr	95.33	100.00	97.33	97.33	97.50
Shueae	91.33	92.00	94.67	93.33	92.83
L.S.D. (0.05)	**4.34**				**2.17**
Mean (%)	93.27	97.20	98.27	96.33	
L.S.D. (0.05)	**1.94**				

The value of germination percentage combinations ranged from 91 to 100%. The interactions of (Samir x 50 mg l^{-1}), (Samir x 100 mg l^{-1}), (Aksad x 100 mg l^{-1}), (Aksad x 150 mg l^{-1}) and (Alkhayr x 50 mg l^{-1}) gave the highest germination percentage (100%) while (Amil x 0 mg l^{-1}) interaction gave the lowest germination percentage (91%). These results confirm the role of gibberellins in increasing the germination percentage. These results are consistent with the concept that treating seeds with gibberellic acid improves the percentage of germination (Gupta and Chakrabarty, 2013; Abdel-Hamid and Mohamed, 2014; Amri et al., 2016; Gomez et al., 2016; Carrera-Castano et al., 2022; Du et al., 2022).

Germination vigor indicates the ability of the seed embryo to resume its metabolic activity in a consistent and sequential method. It is considered a complex agricultural trait including seed longevity, speed of germination, the growth of seedling, and early tolerance of stress condition (Rajjou et al., 2012; Reed et al., 2022). The mean of germination vigor of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) treated with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l^{-1}) showed in Table 3. The mean germination vigor of barley varieties ranged from 54.50 to 61.83%. Aksad variety was superior and gave the highest germination vigor (61.83%) while the Amil variety gave the lowest germination percentage (54.50%). As for the GA3 concentrations, the mean germination vigor ranged from 48.80 to 63.87 %. Seeds treated with 100 mg l^{-1} of gibberellic acid were superior to the all GA3 concentrations for the germination vigor trait and gave the highest germination vigor (63.87%) while the control treatment gave the lowest germination vigor (48.80%). The value of germination vigor interactions ranged from 42.67 to 76%. The interactions of (Samir x 100 mg l^{-1}), (Aksad x 50 mg l^{-1}) and (Samir x 50 mg l^{-1}) gave the highest germination vigor which amounted to 76%, 73.33%, and 68%, respectively while (Samir x 0 mg l^{-1}) interaction gave the lowest germination vigor (42.67%). These results are consistent with the concept that treating seeds with gibberellic acid improves the germination vigor ((Rajjou et al., 2012; Giraldo et al., (2019); Reed et al., 2022).

Table 3. Mean of germination vigor (%) of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean (%)
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	42.67	68.00	76.00	48.00	58.67
Amil	49.33	54.67	61.33	52.67	54.50
Aksad	50.00	73.33	66.67	57.33	61.83
Alkhayr	54.00	64.67	59.33	55.33	58.33
Shueae	48.00	51.33	56.00	66.00	55.33
L.S.D. (0.05)	**9.50**				**4.75**
Mean (%)	48.80	62.40	63.87	55.87	
L.S.D. (0.05)	**4.25**				

Germination speed indicates the germination percentage in terms of the seed total number that germinate in interval of a time. Higher value of germination speed indicates faster and greater seed germination (Ranal and Santana, 2006; Damalas et al. 2019). Table (4) showed the mean percentage of germination speed of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) soaked with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l^{-1}). The mean of germination speed of barley varieties ranged from 46.99 to 50.2. Aksad variety was superior and gave the highest germination speed (50.20) while the Shuaa variety gave the lowest germination speed (46.99). As for the GA3 concentrations, the mean germination speed ranged from 46.10 to 51.12. Seeds treated with 100 mg l^{-1} of gibberellic acid were superior to the all GA3 concentrations for the germination speed trait, as this treatment gave the highest germination speed (51.12), while the control treatment gave the lowest germination speed (46.10). The value of germination speed combinations ranged from 43.74 to 55.25. The interaction of (Samir x 100 mg l^{-1}) gave the highest value of germination speed (55.25), followed by (Samir x 50 mg l^{-1}) and (Aksad x 100 mg l^{-1}) with germination speed value of 53.08 and 52.75, respectively. While (Shueae x 0 mg l^{-1}) interaction gave the lowest germination speed (43.74). All interactions among varieties and GA3 concentrations (50, 100, and 150 mg l^{-1}) were significantly superior to interactions among varieties and control treatment of GA3, which confirmed the role of gibberellins in increasing the sped germination (Ranal and Santana, 2006; Abdel-Hamid and Mohamed, 2014; Damalas et al. 2019).

Table 4. Mean of germination speed of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	44.69	53.08	55.25	45.30	49.58
Amil	46.80	48.34	50.45	47.47	48.26
Aksad	47.83	51.98	52.75	48.25	50.20
Alkhayr	47.45	51.42	48.82	48.78	49.12
Shueae	43.74	47.17	48.32	48.74	46.99
L.S.D. (0.05)	**3.99**				**1.99**
Mean	46.10	50.40	51.12	47.71	
L.S.D. (0.05)	**1.78**				

The mean of shoot length of five barley varieties (Samir, Amil, Aksad, Alkhayr, and Shueae) treated with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l^{-1}) showed in Table 5. The mean shoot length of barley varieties ranged from 17.65 to 19.42 cm. Samir and Shueae varieties were superior and gave the highest shoot length 19.42 and 19.38 cm, respectively, while the Alkhayr variety gave the lowest shoot length (17.65 cm). As for the GA3 concentrations, the mean shoot length ranged from 12.28 to 22.41 cm. Seeds treated with 100 mg l^{-1} of gibberellic acid were superior to the all GA3 concentrations for the shoot length trait and gave the highest shoot length (22.41 cm) while the control treatment gave the lowest shoot length (12.28 cm) compared to all GA3 concentrations. The value of shoot length interactions ranged from 11.71 to 24.05 cm. The interactions of (Samir x 100 mg l^{-1}) and (Shueae x 100 mg l^{-1}) gave the highest value of shoot length (24.05 cm and 23.03 cm, respectively) while (Alkhayr x 0 mg l^{-1}) and (Aksad x 0 mg l^{-1}) interactions gave the lowest shoot length (11.71 cm and 11.76 cm, respectively). Furthermore, all interactions among varieties and GA3 concentrations (50, 100, and 150 mg l^{-1}) were significantly superior to interactions among varieties and control treatment of GA3. These results are consistent with the concept that indicates seeds treatment with gibberellic acid increases cells division and elongation then increases the length of the vegetative system (Gupta and Chakrabarty, 2013; Gomez et al., 2016; Carrera-Castano et al., 2022).

Table 5. Mean of shoot length (cm) of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean (cm)
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	12.69	19.84	24.05	21.08	
Amil	12.21	18.49	21.71	19.63	
Aksad	11.76	17.43	21.97	20.85	
Alkhayr	11.71	17.67	21.27	19.95	
Shueae	13.02	20.72	23.03	20.75	
L.S.D. (0.05)	**1.34**				**0.67**
Mean (cm)	12.28	18.83	22.41	20.45	
L.S.D. (0.05)	**0.60**				

Table (6) showed the mean of root length of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) soaked with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l^{-1}). The mean root length of barley varieties ranged from 9.54 to 12.79 cm. Samir variety was superior and gave the highest root length value (12.79 cm) while the Amil variety gave the lowest root length value (9.54 cm). As for the GA3 concentrations, the mean root length ranged from 9.92 to 11.38 cm. Seeds treated with 100 and 50 mg l^{-1} of gibberellic acid were superior to the other GA3 concentrations for the root length trait, as these tow treatments gave the highest root length (11.38 and 11.33 cm, respectively) while the control treatment gave the lowest root length (9.92 cm). The value of root length combinations ranged from 9.03 to 13.72 cm. The interactions of (Samir x 100 mg l^{-1}) and (Samir x 50 mg l^{-1}) gave the highest root length values (13.72 and 13.47 cm, respectively) while (Alkhayr x 0 mg l^{-1}) interaction gave the lowest root length (9.03 cm). These results confirm the role of gibberellic acid in increasing stem and root elongation through its role as a growth regulator in increasing cell division and elongation (Abdel-Hamid and Mohamed, 2014; Gomez et al., 2016; Khaeim et al., 2022; Haj Sghaier et al., 2022).

Table 6. Mean of root length (cm) of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean (cm)
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	11.68	13.47	13.72	12.29	12.79
Amil	9.15	10.51	9.34	9.17	9.54
Aksad	10.27	12.28	11.34	10.96	11.21
Alkhayr	9.03	10.05	11.39	9.69	10.04
Shueae	9.49	10.35	11.11	9.93	10.22
L.S.D. (0.05)	**1.81**				**0.90**
Mean (cm)	9.92	11.33	11.38	10.41	
L.S.D. (0.05)	**0.81**				

Dry weight is a good indicator of seedling growth, which is considered one of most remarkable seed quality and seedling performance tests. Wherefore, Seed germination and seedling growth stages are the most crucial stages in plant life (Haj Sghaier et al., 2022; Khaeim et al., 2022). The mean of total dry weight of five barley varieties (Samir, Amil, Aksad, Alkhayr, and Shueae) treated with four concentrations of gibberellic acid (0, 50, 100, and 150 mg l- 1) showed in Table 7. The mean dry weight of barley varieties ranged from 0.03611 to 0.04078 gm. Aksad variety was superior and gave the highest dry weight 0.04078 gm, while the Shueae variety gave the lowest dry weight value (0.03611 gm). As for the GA3 concentrations, the mean dry weight ranged from 0.03692 to 0.04036 gm. Seeds treated with 100 mg l- 1 of gibberellic acid were superior to the all GA3 concentrations for the total dry weight trait and gave the highest dry weight value (0.04036 gm) while the control treatment gave the lowest value of dry weight (0.03692 gm) compared to all GA3 concentrations. The value of dry weight interactions ranged from 0.03492 to 0.04272 gm. The interactions of (Aksad x 100 mg l- 1) gave the highest value of dry weight (0.04272 gm, followed by (Alkhayr x 100 mg l- 1) (Aksad x 150 mg l- 1) with dry weight values 0.04142 gm and 0.04126 gm, respectively. While (Shueae x 0 mg l- 1) and (Shueae x 150 mg l- 1) interactions gave the lowest dry weight values (0.03492 gm and 0.03497 gm, respectively). Furthermore, all concentrations of gibberellic acid were significantly superior to the control treatment. These results confirm that the treatment of seeds with gibberellic acid increases cells elongation and division, and then increases the length of shoot and root and thus the total dry weight (Bradford et al., 2008; Akman, 2009; Almubarak, 2009; Terzi and Kocacaliskan, 2010; Abdel-Hamid et al.,2014; Miceli et al., 2019; Du et al., 2022).

Table 7. Mean of total dry weight (gm) of five barley varieties (Samir, Amil, Aksad, Alkhayr, Shueae) with four gibberellic acid (GA3) concentrations (0, 50, 100, and 150 mg L^{-1}).

Varieties of Barley	GA3 concentrations				Mean (gm)
	0 mg L^{-1}	50 mg L^{-1}	100 mg L^{-1}	150 mg L^{-1}	
Samir	0.03664	0.03899	0.04029	0.03694	0.03821
Amil	0.03757	0.03821	0.03923	0.03807	0.03827
Aksad	0.03870	0.04044	0.04272	0.04126	0.04078
Alkhayr	0.03675	0.03889	0.04142	0.03894	0.03900
Shueae	0.03492	0.03641	0.03814	0.03497	0.03611
L.S.D. (0.05)	**0.0029**				**0.0014**
Mean (gm)	0.03692	0.03859	0.04036	0.03804	
L.S.D. (0.05)	**0.0013**				

CONCLUSION

All studied traits were significantly affected by barley varieties and gibberellic acid concentrations. Aksad variety was superior to all varieties in most of the studied traits. Treated seeds with a concentration of (100 mg L^{-1}) of gibberellic acid was superior in all studied traits due to the role of GA3 in increasing cells elongation and division, then increasing germination, shoot and root length and thus total dry weight.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

REFERENCES

Abdel-Hamid, A. M., and Mohamed, H. I. (2014). The effect of the exogenous gibberellic acid on two salt stressed barley cultivars. European Scientific Journal, 10(6), 228-245.

Akman, Z. (2009). Effects of plant growth regulators on nutrient content of young wheat and barley plants under saline conditions. Journal of Animal and Veterinary advances, 8(10), 2018-2021.

Almubarak, N. F. (2009). Effect of gibberellic acid (GA3) and potassium fertilizer in percentage of grain protein to two varieties from barley *Hordium valgare* L. Diyala Journal of Human Research, (32),133-146.

Amri, B., Khamassi, K., Ali, M. B., da Silva, J. A. T., and Kaab, L. B. B. (2016). Effects of gibberellic acid on the process of organic reserve mobilization in barley grains germinated in the presence of cadmium and molybdenum. South African Journal of Botany, 106, 35-40. https://doi.org/10.1016/j.sajb.2016.05.007

Bradford, K. J., Benech-Arnold, R. L., Come, D., and Corbineau, F. (2008). Quantifying the sensitivity of barley seed germination to oxygen, abscisic acid, and gibberellin using a population-based threshold model. Journal of Experimental Botany, 59(2), 335-347. https://doi.org/10.1093/jxb/erm315

Carrera-Castano, G., Calleja-Cabrera, J., Pernas, M., Gómez, L., and Onate-Sánchez, L. (2020). An updated overview on the regulation of seed germination. Plants, 9(6), 703. https://doi.org/10.3390/plants9060703.

Castro-Camba, R., Sanchez, C., Vidal, N., and Vielba, J. M. (2022). Plant development and crop yield: The role of gibberellins. Plants, 11(19), 2650. https://doi.org/10.3390/plants11192650

Cavusoglu, K., and Kabar, K. (2007). Comparative effects of some plant growth regulators on the germination of barley and radish seeds under high temperature stress. EurAsian Journal of BioSciences, 1(1), 1-10.

Central Statistical Organization Iraq (CSO). (2021). Production of wheat and Barley. Agricultural Statistics Directorate. Ministry of Planning. Iraq. Pp. 1-16.

Damalas, C. A., Koutroubas, S. D., and Fotiadis, S. (2019). Hydro-priming effects on seed germination and field performance of faba bean in spring sowing. Agriculture, 9(9), 201. https://doi.org/10.3390/agriculture9090201

Du, G., Zhang, H., Yang, Y., Zhao, Y., Tang, K., and Liu, F. (2022). Effects of Gibberellin Pre-Treatment on Seed Germination and Seedling Physiology Characteristics in Industrial Hemp under Drought Stress Condition. Life, 12(11), 1907. https://doi.org/10.3390/life12111907

Geng, L., Li, M., Zhang, G., and Ye, L. (2022). Barley: a potential cereal for producing healthy and functional foods. Food Quality and Safety, 6, 1-13. https://doi.org/10.1093/fqsafe/fyac012

Giraldo, P., Benavente, E., Manzano-Agugliaro, F., and Gimenez, E. (2019). Worldwide research trends on wheat and barley: A bibliometric comparative analysis. Agronomy, 9(7), 352. https://doi.org/10.3390/agronomy9070352

Gomez, M. D., Ventimilla, D., Sacristan, R., and Perez-Amador, M. A. (2016). Gibberellins regulate ovule integument development by interfering with the transcription factor ATS. Plant physiology, 172(4), 2403-2415. https://doi.org/10.1104/pp.16.01231

Gupta, R., and Chakrabarty, S. K. (2013) Gibberellic acid in plant: still a mystery unresolved. Plant Signal Behav, 8 (9). https://doi.org/10.4161/psb.25504

Gurel, F., Ozturk, Z. N., Ucarlıi C., and Rosellini, D. (2016). Barley genes as tools to confer abiotic stress tolerance in crops. Frontiers in plant science, 7, 1137. https://doi.org/10.3389/fpls.2016.01137

Haj Sghaier, A., Tarnawa, Á., Khaeim, H., Kovács, G. P., Gyuricza, C., and Kende, Z. (2022). The Effects of Temperature and Water on the seed germination and seedling development of rapeseed (Brassica napus L.). Plants, 11(21), 2819. https://doi.org/10.3390/plants11212819

Hussain, A., Ali, S., Hussain, A., Hussain, Z., Manzoor, M. F., Hussain, A., ... and Hussain, M. (2021). Compositional profile of barley landlines grown in different regions of Gilgit-Baltistan. Food Science & Nutrition, 9(5), 2605-2611. https://doi.org/10.1002/fsn3.2215

International Seed Testing Association (ISTA). (2005). International rules for seed testing. Adopted at the Ordinary Meeting. 2004, Budapest, Hungary.

Khaeim, H., Kende, Z., Balla, I., Gyuricza, C., Eser, A., and Tarnawa, Á. (2022). The Effect of temperature and water stresses on seed germination and seedling growth of wheat (*Triticum aestivum* L.). Sustainability, 14(7), 3887. https://doi.org/10.3390/su14073887

Lafta, A. H. (2020). Economic analysis of barley crop in Iraq by estimating the supply and demand functions for the period (1990-2017). Plant Archives, 20(1), 253-256.

Langridge, P. (2018) Economic and academic importance of barley, In: Stein, N., Muehlbauer, G. (eds), The barley genome. Compendium of Plant Genomes. Springer, Cham. pp.1-10 https://doi.org/10.1007/978-3-319-92528-8_1

Miceli, A., Moncada, A., Sabatino, L., and Vetrano, F. (2019). Effect of gibberellic acid on growth, yield, and quality of leaf lettuce and rocket grown in a floating system. Agronomy, 9(7), 382. https://doi.org/10.3390/agronomy9070382

Munzuroglu, O., and Zengin, F. K. (2006). Effect of cadmium on germination, coleoptile and root growth of barley seeds in the presence of gibberellic acid and kinetin. Journal of Environmental Biology, 27(4), 671-677.

Rajjou, L., Duval, M., Gallardo, K., Catusse, J., Bally, J., Job, C., and Job, D. (2012). Seed germination and vigor. Annual review of plant biology, 63, 507-533. https://doi.org/10.1146/annurev-arplant-042811-105550

Ranal, M. A., and Santana, D. G. D. (2006). How and why to measure the germination process?. Brazilian Journal of Botany, 29, 1-11.

Reed, R. C., Bradford, K. J., and Khanday, I. (2022). Seed germination and vigor: ensuring crop sustainability in a changing climate. Heredity, 128(6), 450-459. https://doi.org/10.1038/s41437-022-00497-2

Statista. (2023). Major barley producers worldwide in 2021/2022, by country. https://www.statista.com/statistics/254305/global-barley-production-by-country/ Access: February 2023.

Terzi, I., and Kocaçalişkan, I. (2010). The effects of gibberellic acid and kinetin on overcoming the effects of juglone stress on seed germination and seedling growth. Turkish Journal of Botany, 34(2), 67-72. https://doi.org/10.3906/bot-0905-17

Tricase, C., Amicarelli, V., Lamonaca, E., Rana, R.L. (2018) Economic analysis of the barley market and related uses. Grasses as food and feed, 10, 25-46.

USDA-FAS. 2022. World agricultural production. Circular series WAP 7-22. https://downloads.usda.library.cornell.edu/usda-esmis/files/5q47rn72z/3197zt68h/cz30r0703/ production.pdf , Access: February 2023.

Wardle, D., Ahmed, M., and Nicholson, K.S. (1991). Allelopathic influence of nodding thistle (*Carduus nutans* L.) seeds on germination and radicle growth of pasture plants. New Zealand Journal of Agricultural Research, 34(2), pp. 185–191.