International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

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Effect of seed soaking with kinetin on seed germination and seedling growth of five barley cultivars (*Hordeum vulgare* L.)

Abdullah Hassn Mohammed *

Department of Field Crops, College of Agriculture, Tikrit University, Iraq.

International Journal of Science and Research Archive, 2023, 08(02), 506–515

Publication history: Received on 27 February 2023; revised on 09 April 2023; accepted on 11 April 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.8.2.0291

Abstract

A laboratory experiment was conducted in the Department of Field Crops/College of Agriculture/Tikrit University to determine the effect of seeds priming of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin on the parameters of germination and seedling growth. The factorial experiment was laid out in completely randomized design (CRD) with four replications. There was a significant effect on all studied traits due to cultivars, kinetin, and cultivars x kinetin interaction, which indicated high genetic variation among evaluated barley cultivars. Buraq cultivar was superior to all cultivars in all studied traits: germination percentage, speed, and vigor, root and shoot length, and dry weight with values of 98.38%, 48.76, 56.19, 10.35cm, 18.47cm, and 0.03776g, respectively. All concentrations of kinetin were significantly superior to the control treatment for all studied traits. Seeds treated with 60 ppm of kinetin gave the highest values of germination percentage (90.75%) and root length (10.81cm), while the concentration 120 ppm gave highest value of germination vigor (45.60) and shoot length (19.96 cm). The combination of (Buraq x 60 ppm) was superior for all studied traits except the trait of total dry weight, where the interactions of Buraq, Arevat, and Rihan cultivars with 120 ppm of kinetin were superior.

Keywords: Barley cultivars; Kinetin; Seed germination; Germination speed; Germination vigor; Root length; Shoot length; Total dry weight

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most important field crops worldwide. It ranks fourth in terms of cultivated area and global production after wheat, rice and maize. In Iraq, barley comes second place after wheat in terms of cultivated area and production. The importance of this crop is due to the many uses such as healthy food for humans, fodder for animals (grazing, silage, straw, hay, or grains), and the many industrial uses such as the manufacture of malting, brewing, starch and biofuels. Barley cultivation in Iraq suffers from many problems that led to a significant decrease in the yield per unit area compared to the high global rates, as the area cultivated annually was about 0.60 million hectares with a production rate of 1.17 metric ton per hectare in Iraq, compared to the global rates, which amounted to 49.30 million hectares and 2.96 metric tons per hectares, in 2021/2022 [1,2]. The reasons for the low yield of barley and the cultivated area in Iraq are due to several factors, the most prominent of which are the low percentage of germination, the speed of germination, the vigor of seedlings, and the deterioration of cultivated varieties as a result of continuous cultivation and the lack of preservation of their purity with the increase in its sensitivity to disease as well as the increase in the percentage of saline soils and drought [3]. The ability of the seed to germinate and establish strong seedlings in a wide range of environmental conditions is a prerequisite for achieving high grain production. Low-quality seeds contribute greatly to the failure of germination or to give an inconsistent appearance to plants in the field because they are very sensitive to adverse conditions and stress which occurs as a result of environmental conditions surrounding these seeds. The size of the seed is one of its quality related to the size and strength of the embryo and the amount of carbohydrates stored in the endosperm of the seed. as the size of this storage is increased, the faster and

* Corresponding author: Abdullah Hassn Mohammed, Email:abdullah@tu.edu.iq

stronger the seedlings grow and appear above the soil surface faster than those that have less stock [4,5]. Many studies have indicated that high values of germination percentage, germination strength, and germination speed exceed their impact on field emergence and the production of active seedlings, and thus improving the performance of the plants resulting from them in the field, which is reflected in giving higher grain yield compared to low values [5,6]. [7] reported that the most vulnerable and critical phase in the plants life cycle is seed germination. Seed germination is affected by many factors such as temperatures, soil pH, salt stress, water deficit, phytohormones, seed vitality and strength, and genetic structure [8]. Seed germination and seedling emergence are critical stages in the plant life cycle. The poor ability of seeds to germinate and the lack of a good field establishment is one of the most important reasons for the lack of crops production [9]. Growth regulators, including cytokinins, play a major role in the process of seed activation, thus increasing the average germination rate, decreasing the time required for germination, and improving seedling growth in appropriate and unsuitable conditions [10]. The technology of seed enhancement like seed priming leads to start the first metabolic processes of germination without moving to full germination, but it is close to the point of germination. The principle of seed activation is to protect seeds from environmental stresses, rapid and homogenous emergence of seedlings [11,12]. Seed priming with plant growth regulators helps the plant to resist the environmental stresses that the plant may face, and its importance increases with the increase of these stresses. Also, it enhances the strength of the seeds to withstand the stresses as well as gives high and homogenous germination rate and speed germination [13,14]. In addition, it leads to an increase in the rate of field emergence under natural environmental and stress conditions, as well as its importance in improving the ability of the seedling to compete with the weed, homogenous emergence of the seedling and harvesting the crop at the same time, and thus increasing the yield [15]. The needs of seeds for germination and plants for growth depend not only on water, temperature, light, carbon dioxide and mineral elements, but they also need plant hormones, which are organic substances that represent binding factors that their function is to stimulate seeds to germinate and plant to grow. Plant growth regulators are the main source of vital activities and physiological processes associated with germination and plant growth [16,17]. Kinetin is one of the most important plant growth regulators, cytokinins, which leads to increase cell division, cell elongation and enlargement, affects cell differentiation, and RNA activation, thus increasing vital reactions in the cell. It also affects the activation of enzymes necessary for vital reactions and increases the building of chlorophyll and proteins and thus works to delay the aging of leaves and increases the transfer of nutrients to active tissues and their representation [18,19,20,21]. Many studies have indicated the effectiveness of this technology in increasing and harmonizing germination and field emergence percentage, improving seedling vigour and growth characteristics, and thus increasing the crops yield [22,23,24,25,26,27,28,29,30]. The objective of this study was to find out the effect of soaking the seeds of five barley cultivars in four concentrations of the plant growth regulator, kinetin on the parameters of germination and seedling growth, and to determine the best variety, best concentration, and best combination between concentrations and cultivars to improve the traits of germination and seedling growth.

2. Material and methods

A laboratory experiment was conducted in the Department of Field Crops / College of Agriculture/ Tikrit University to determine the effect of seeds priming of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin on the parameters of germination and seedling growth. The required concentrations of kinetin (60, 120, 180 ppm) were prepared by dissolving each of the following amounts (60, 120, 180 mg) separately in 1 ml of 1 N of Hydrochloric acid, then diluted to 100 ml of distilled water. Healthy and uniform seeds size of each of the five barley cultivars were surface sterilized with 1% NaClO solution (Clorax) for 10 mins, then rinsed three times with sterilized distilled water. Then, seed were soaked in (0 [hydropriming], 60, 120, 180 ppm) solution of kinetin for 12 hours. After that, soaked seeds were placed on filter paper in the dark at room temperature with an air-dry current for 12 hours in order to dry the treated seeds. Twenty-five seeds were taken from the treated and air-dried seeds, for each of the five barley cultivars that soaked with different concentrations of kinetin, and placed on two layers of filter papers (Whatman No. 42) in Petri dishes (90 mm). Planted dishes were irrigated with 10 ml of distiled water then placed in growth chamber for eight days at 25 °C ± 2. The factorial experiment was laid out in a completely randomized design (CRD) with four replications. Germinated seeds, when radicle reached to 2 mm or more in length, were recorded daily for eight days [27,31]. The following parameters of germination and seedling growth were recorded: percentage of germination, speed of germination, germination vigor, root length, shoot length, and total dry weight [32]. The following equations were used for calculating the germination parameters:

Percentage of Germination= (n/N) x 100, where n is number of germinated seeds, N is total number of seeds [33].

Speed of Germination= $n_1/d_1 + n_2/d_2 + ... + n_8/d_8$, where n is the germinated seeds number, d is the days number [34,35].

Germination vigor (%) = the number of germinated seeds on the first count day/ total number of seeds x 100 [36].

Root and shoot length (cm) were measured by using a ruler

Dry weight (g) of seedlings was measured by using a sensitive scale after seedlings were dried in oven drying at 70 °C until the weight was stabilized.

Data for all studied traits were collected, tabulated, and analyzed statistically according to the method of analysis of variance for factorial experiments using a completely randomized design (C. R. D.) by using PROC MEANS and PROC GLM in SAS (Version 9.4, SAS Institute, 2011, Cary, NC). Significant differences between the means were tested using the Fisher's least significant difference test (L.S.D.) at probability level of 0.05.

3. Results and discussion

The analysis of variance (Table 1) indicated a highly significant effects on all studied characteristics due to barley cultivars and kinetin concentrations. Also, there was a significant interaction between barley cultivars x kinetin concentrations all the studied characteristics. The significant effects among barley cultivars, kinetin concentration, and cultivars x Kinetin concentration indicates high genetic variation among evaluated barley cultivars. Similar results were finding by [23,25,26,27,28,29,30,37].

Table 1 Analysis of variance of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan), four concentrations (0, 60, 120, and 180 ppm) of kinetin, and their interaction for percentage of germination, speed of germination, germination vigor (%), root length (cm), shoot length (cm), and total dry weight (g)

Source of variance	Germination percentage (%)	Germination speed	Germination vigor (%)	Root length (cm)	Shoot length (cm)	Total dry weight (g)
Varieties (V)	***	***	***	***	***	***
Kinetin concentrations	***	***	***	***	***	***
V x Kinetin	***	*	***	***	*	*

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

The germination of seeds and the emergence of seedlings are among the most important critical stages in the life cycle of a plant, and the poor ability of seeds to germinate, which leads to the failure of a good field establishment, is one of the reasons that lead to low yield of crop. For this reason, choosing a good cultivar and stimulating the seeds by soaking with plant growth regulators such as kinetin is very important to obtain a high germination percentage, fast and homogeneous germination, strong seedlings, good field establishment, and increase the strength of the germinated seeds to withstand environmental stresses, and thus a high and homogeneous yield. Mean germination percentage of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) treated with four concentrations (0, 60, 120, and 180 ppm) of kinetin showed in Table 2.

The barley cultivars showed significant differences in the trait of seed germination percentage. Buraq cultivar gave the highest germination percentage (98.38%) followed by Rihan cultivar (97.13%), which were superior to all cultivars, while Arevat cultivar gave the lowest value amounted to 65.44%. Furthermore, the concentrations of kinetin (60, 120, and 180 ppm) showed significant differences in the effect on the seed germination rate. All concentrations of kinetin were significantly superior to the control treatment (0 ppm). Seeds soaked with concentration 60 ppm of kinetin gave the highest germination rate 90.75%, which was superior to all concentrations, while the control treatment (0 ppm) gave the lowest germination rate, which amounted to 77.75%. Also, there was a significant interaction between barley cultivars and kinetin concentrations in affecting the seed germination percentage. The interactions of the Buraq cultivar with concentrations 60 and 180 ppm of kinetin gave the highest germination percentage (full germination) 100% followed by the interaction of (Rihan x 60 ppm) with value 99.25% of germination percentage, while the interaction of (Arifat x 0 ppm) gave the lowest germination percentage, which amounted to 54.00%. These results confirmed the high genetic variation among evaluated barley cultivars as well as the effective role of kinetin, at low concentration, in increasing seed germination percentage through the role of this plant growth regulator in the induction of latent genes that contribute to the representation of nucleic acids (DNA and RNA), increase cell division, increase the activity of the α-amylase enzyme, and increase the efficiency and number of mitochondria [20,21,23,38,39,40].

Table 2 Mean of germination percentage (%) of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	Kinetin concentrations				Mean (%)
	0 ppm	60 ppm	120 ppm	180 ppm	
Arevat	54.00	73.25	69.25	65.25	65.44
Alwarkaa	60.75	85.25	68.00	69.25	70.81
Alhadher	86.00	96.00	94.75	92.00	92.19
Buraq	94.75	100.00	98.75	100.00	98.38
Rihan	93.25	99.25	97.25	98.75	97.13
L.S.D. (0.05)	6.07				3.03
Mean (%)	77.75	90.75	85.60	85.05	
L.S.D. (0.05)	2.71				

Germination speed is one of the important germination parameters, which the high value means that there is a speed and a high germination percentage [41]. Table 3 showed the mean germination speed of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) treated with four concentrations (0, 60, 120, and 180 ppm) of kinetin. Barley cultivars showed significant differences in the trait of seed germination speed. Buraq cultivar gave the highest germination speed (48.76), and it was superior to all cultivars, followed by Rihan cultivar (46.71), while Alwarkaa and Arevat cultivar gave the lowest value amounted to 21.09 and 22.96, respectively.

Table 3 Mean of germination speed of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	Kinetin concentrations				Mean
	0 ppm	60 ppm	120 ppm	180 ppm	
Arevat	22.21	24.51	22.76	22.35	22.96
Alwarkaa	15.94	22.98	24.93	20.52	21.09
Alhadher	39.96	46.63	50.62	44.74	45.49
Buraq	46.80	50.58	48.41	49.25	48.76
Rihan	42.22	49.93	48.95	45.74	46.71
L.S.D. (0.05)	3.95				1.97
Mean	33.42	38.93	39.13	36.52	
L.S.D. (0.05)	1.76				

Also, kinetin concentrations showed significant differences in the effect on the germination speed trait. Seeds soaked with all concentrations of kinetin (60, 120, and 180 ppm) were significantly superior to the control treatment (0 ppm). Seeds treated with kinetin concentration of 60 and 120 ppm gave the highest germination speed 38.93 and 39.13, while the control treatment (0 ppm) gave the lowest value of germination speed, which amounted to 33.42. In addition, the interaction between barley cultivars and kinetin concentrations was a significant in affecting the germination speed trait. The combinations of (Alhadher x 120 ppm) and (Buraq x 60 ppm) showed highest germination speed values amounted to (50.62 and 50.58, respectively) followed by the interactions of (Rihan x 60 ppm) and (Buraq x 180 ppm). While the interaction of (Alwarkaa x 0 ppm) gave the lowest value of seed germination speed, which amounted to 15.94. Similar findings were produced by [17,25,26,27,42,43].

Mean germination vigor of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) soaked with four concentrations (0, 60, 120, and 180 ppm) of kinetin showed in Table 4.

Table 4 Mean of germination vigor (%) of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	Kinetin concentrations				Mean (%)
	0 ppm	60 ppm	120 ppm	180 ppm	
Arevat	6.75	16.00	24.00	18.75	16.38
Alwarkaa	0.00	0.00	13.25	4.75	4.50
Alhadher	43.25	50.75	70.00	53.25	54.31
Buraq	42.00	62.75	60.00	60.00	56.19
Rihan	38.75	62.00	60.75	54.75	54.06
L.S.D. (0.05)	7.87				3.94
Mean (%)	26.15	38.30	45.60	38.30	
L.S.D. (0.05)	3.52				

The barley cultivars showed significant differences in the trait of germination vigor. Buraq cultivar gave the highest germination vigor (56.19%) followed by Alhadher and Rihan cultivars (54.31 and 54.06%, respectively), which were superior to the other cultivars, while Alwarkaa cultivar gave the lowest value amounted to 4.50%. In addition, the concentrations of kinetin (60, 120, and 180 ppm) showed significant differences in the effect on the germination vigor trait. All concentrations of kinetin were significantly superior to the control treatment (0 ppm). Seeds treated with concentration 120 ppm of kinetin gave the highest germination vigor 45.60%, which was superior to all concentrations, while the control treatment (0 ppm) gave the lowest value, which amounted to 26.15%. Furthermore, there was a significant interaction between barley cultivars and kinetin concentrations in affecting the germination vigor trait. The interactions of (Alhadher x 120 ppm) and (Buraq x 60 ppm) gave the highest germination vigor values (70.00 and 62.75%, respectively) followed by the interactions of (Rihan x 60,120 ppm) and (Buraq x 120, 180 ppm), while the interactions of (Alwarkaa x 0, 60 ppm) gave the lowest germination vigor 0.00%. These findings confirmed the present of high genetic variation among evaluated cultivares, and confirmed the concept of the importance of kinetin in increasing the germanation vigor of the treated seed [20,27,40].

The growth of strong and active roots is necessary to obtain good growth and activity for the shoot system and for all stages of the plant. Root length is one of the tests that indicate the vigor of the seeds and seedlings [9]. Mean root length of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) treated with four concentrations (0, 60, 120, and 180 ppm) of kinetin showed in Table 5. Barley cultivars showed significant differences in the trait of root length. Buraq cultivar gave the longest root (10.35 cm) followed by Rihan cultivar with root length amounted to 9.92 cm, and they were superior to all cultivars. While Alwarkaa cultivar gave the shortest root amounted to 5.37 cm. Also, kinetin concentrations showed significant differences in the effect on the root length trait. Seeds soaked with all concentrations of kinetin (60, 120, and 180 ppm) were significantly superior to the control treatment (0 ppm). Seeds treated with kinetin concentration of 60 ppm gave the highest value of root length (10.81 cm), while the control treatment (0 ppm) gave the lowest value of root length, which amounted to 5.72 cm. In addition, the interaction between barley cultivars and kinetin concentrations was a significant in affecting the root length trait. The combinations of (Rihan x 120 ppm) and (Buraq x 60 ppm) showed highest values of root length amounted to (12.85 and 12.59 cm, respectively) followed by the interaction of (Buraq x 180 ppm) with root length value (11.63 cm). While the interaction of (Alwarkaa x 0 and 120 ppm) gave the lowest value of root length, which amounted to 3.67 and 3.98 cm, respectively. These findings confirmed the importance of kinetin in increasing cell division, cell elongation and enlargement, affecting cell differentiation, and RNA activation, thus increasing vital reactions in the cell [18,19,20,21,23].

Table 5 Mean of root length (cm) of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	Kinetin concentrations				Mean (cm)
	0 ppm	60 ppm	120 ppm	180 ppm	
Arevat	6.00	10.65	9.37	8.51	8.63
Alwarkaa	3.67	7.57	3.98	6.28	5.37
Alhadher	4.88	10.41	5.19	8.25	7.18
Buraq	7.89	12.59	9.31	11.63	10.35
Rihan	6.18	12.85	10.41	10.22	9.92
L.S.D. (0.05)	1.3428				0.6715
Mean (cm)	5.72	10.81	7.65	8.98	
L.S.D. (0.05)	0.6006				

Shoot length is an important characteristic for measuring seedling strength because it is directly related to field emergence and seedling resistance to external conditions surrounding the seedbed [9]. Table 6 showed the mean shoot length of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) treated with four concentrations (0, 60, 120, and 180 ppm) of kinetin showed. The barley cultivars showed significant differences in the trait of shoot. Buraq cultivar gave the longest shoot (18.47 cm) followed by Arevat cultivar (17.84 cm), which were superior to all cultivars, while Alwarkaa cultivar gave the lowest value of shoot length amounted to 13.25 cm. Furthermore, the concentrations of kinetin (60, 120, and 180 ppm) showed significant differences in the effect on the shoot length trait. All concentrations of kinetin were significantly superior to the control treatment (0 ppm). Seeds soaked with concentration 120 ppm of kinetin gave the highest value of shoot length (19.96 cm), which was superior to all concentrations, while the control treatment (0 ppm) gave the shortest shoot, which amounted to 12.23 cm. Also, there was a significant interaction between barley cultivars and kinetin concentrations in affecting the shoot length trait. The interactions of (Buraq x 120 ppm), (Arevat x 120 ppm), and (Rihan x 120 ppm) gave the highest values of shoot length (21.87, 21.59, and 20.79 cm, respectively), while the interaction of (Alwarkaa x 0 ppm) gave the shortest shoot, which amounted to 8.12 cm. These results confirmed the high genetic variation among evaluated barley cultivars as well as the effective role of kinetin in increasing shoot length due to its role to increase cell division and cell elongation and enlargement. Similar findings were produced by [23,24,25,43].

Table 6 Mean of shoot length (cm) of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	Kinetin concentrations				Mean (cm)
	0 ppm	60 ppm	120 ppm	180 ppm	
Arevat	14.85	15.95	21.59	18.95	17.84
Alwarkaa	8.12	13.51	17.48	13.89	13.25
Alhadher	11.79	14.95	18.08	15.31	15.03
Buraq	14.76	18.10	21.87	19.14	18.47
Rihan	11.61	16.49	20.79	16.93	16.45
L.S.D. (0.05)	2.16				1.08
Mean (cm)	12.23	15.80	19.96	16.85	
L.S.D. (0.05)	0.9682				

Dry weight of the seedlings expresses the value of the nutrients accumulated in all parts of the plant, and the production of the dry matter of the crop depends on the balance between the processes of photosynthesis and respiration. It was also found that the field emergence of seedlings has strong positive correlation to the speed of germination, seedling length and dry weight [9,44]. Mean of total dry weight of five barley cultivars (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) treated with four concentrations (0, 60, 120, and 180 ppm) of kinetin showed in Table 7. Barley cultivars showed significant differences in the trait of total dry weight. The cultivars of Buraq and Arevat gave the highest values of total dry weight (0.03776 and 0.03664 g seedling^{-1}, respectively), and they were superior to all cultivars, while Alwarkaa cultivar gave the lowest value of total dry weight amounted to 0.02635 g seedling^{-1}. Also, kinetin concentrations showed significant differences in the effect on the total dry weight trait. Seeds soaked with all concentrations of kinetin (60, 120, and 180 ppm) were significantly superior to the control treatment (0 ppm). However, there was no significant difference among these concentrations of kinetin (60, 120, and 180 ppm) with values (0.03288, 0.03380, and 0.03321g seedling^{-1}) of total dry weight, while the control treatment (0 ppm) gave the lowest value of total dry weight, which amounted to 0.03139 g seedling^{-1}. In addition, the interaction between barley cultivars and kinetin concentrations was a significant in affecting the total dry weight trait. The combinations of (Buraq x 120 ppm) and (Arevat x 120 ppm) showed highest total dry weight values amounted to (0.03943 and 0.03905 g seedling^{-1}, respectively) followed by the interactions of (Buraq x 180 ppm), (Arevat x 180 ppm) and (Buraq x 60 ppm). While the interaction of (Alwarkaa x 0 ppm) gave the lowest value of total dry weight, which amounted to 0.02535g seedling^{-1}, followed by the interactions of Alwarkaa with (180, 60, and 120 ppm, respectively) of kinetin. Similar findings were produced by [22,24,25,26,27,37,42,43].

Table 7 Mean of total dry weight (gm) of five cultivars of barley (Arevat, Alwarkaa, Alhadher, Buraq, Rihan) with four concentrations (0, 60, 120, and 180 ppm) of kinetin

Varieties of Barley	**Kinetin concentrations**				**Mean (gm)**
	0 ppm	**60 ppm**	**120 ppm**	**180 ppm**	
Arevat	0.03460	0.03518	0.03905	0.03774	0.03664
Alwarkaa	0.02535	0.02674	0.02677	0.02653	0.02635
Alhadher	0.02971	0.03280	0.03074	0.03180	0.03126
Buraq	0.03639	0.03740	0.03943	0.03781	0.03776
Rihan	0.03089	0.03231	0.03302	0.03215	0.03209
L.S.D. (0.05)	0.0025				0.0013
Mean (gm)	0.03139	0.03288	0.03380	0.03321	
L.S.D. (0.05)	0.0011				

4. Conclusion

There was a significant effect on all studied traits due to barley cultivars, kinetin concentrations, and interactions of cultivars x kinetin. These results indicate high genetic variation among evaluated barley cultivars. Buraq cultivar was superior to all barley cultivars in all studied traits. All concentrations of kinetin (60, 120, and 180 ppm) were significantly superior to the control treatment (0 ppm) for all studied traits. Seeds treated with 60 ppm of kinetin gave the highest values of germination percentage and root length, while the concentration 120 ppm gave highest value of germination vigor and shoot length. There was not significant difference between 60 and 120 ppm of kinetin for germination speed and not significant differences among 60, 120 and 180 ppm for total dry weight.

Compliance with ethical standards

Acknowledgments

This study was supported by Field Crops Dept., College of Agriculture, Tikrit University, which is greatly appreciated.

Disclosure of conflict of interest

The authors declare no conflict of interest.

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