Response of Newly Introduced Barley (*Hordeum vulgare* L.) Genotypes to Iron Spraying

Saad J. Ali* Muhammad A. Hashem Mahmoud T. A. Al-Jayashi
*Corresponding author email: agrcr.grad.saad2122@mu.edu.iq
Department of Field Crops/ College of Agriculture/ Muthanna University/ Iraq

Abstract

A field experiment was carried out on 15/11/2022 in a private agricultural field at longitude 45.26° east and latitude 31.31° north in Muthanna Governorate, during the winter agricultural season (2022 - 2023) with the aim of studying: response of four genotypes of barley crop (*Hordeum vulgare* L.); three of them were newly introduced to Iraq, namely: Gzmeab, Gzmemb, and Cos-Aluetmarpc 2, and the fourth was one of the varieties cultivated Ibaa 265, to foliar spraying with four concentrations of metallic iron 6% (0, 50, 100, and 150 mg L^{-1}) on the plant's shoots. The experiment was designed according to a randomized complete block design (RCBD) and a split plot arrangement with organization for a factorial experiment consisting of two factors. The first factor included four barley genotypes that represented the main plots, while the second factor included four iron concentrations that represented the secondary plots with three replicates for each treatment, and all combinations of the factors' treatments were distributed randomly within each block, including the entire experiment, 48 experimental units.

Results were summarized by the Gzmeab genotype recording the lowest significant mean for the number of days from emergence to 75% flowering (90.47 days). The significant superiority of the Ibaa 265 genotype was in achieving the highest significant mean for plant height (116.98 cm). The highest significant mean were recorded for the number of fertile spikes (457.00 spike m^{-2}) and the biological yield (20.18 ton ha^{-1}) in the Gzmemb genotype. The Cos-Aluetmarpc 2 genotype was significantly superior in the number of grains per spike (59.61 grain $spike^{-1}$). The significant role of mineral iron at a concentration of 150 mg L^{-1} in recording the highest significant means for the number of days from emergence to 75% flowering (94.75 days), plant height (114.95 cm), number of tillers (549.50 tiller m^{-2}), and number of fertile spikes (437.50 spike m^{-2}), grains yield (7.919 ton ha^{-1}), and biological yield (18.88 ton ha^{-1}). Also, the interaction of genotypes with iron at the highest concentration (150 mg L^{-1}) achieved the best combinations for the best results for growth indicators, yield and its components for the barley crop with the same single effect of each factor.

Keywords: genotype, barley, iron.

Introduction

Barley (*Hordeum vulgare* L.), is a cereal crop belonging to the Gramineae family (Poaceae). It is widely spread throughout the world and is characterized by its multiple uses for food, feed, and the beverage industry. The genotypes of barley differ in their agricultural characteristics of yield, disease resistance, and nutritional value [1; 2]. Barley is grown as a commercial crop in many countries, and ranks fourth in total cereal production in the world after wheat, rice, and maize [3].

Barley is also an important grain crop that is necessary for the life of global societies, especially Iraq. It is a strategic crop grown in relatively large areas and its production is linked to food security for almost all developing countries, including Iraq [4; 5]. Barley plays an important role in international trade, as global reports indicate that food

ISSN 2072-3857

shortages are mainly due to the lack of wheat and barley production [6]. In Iraq, the cultivated area for the year 2022 with the barley crop was estimated at 2,309 thousand dunams, which is 25.30% less than the cultivated area for the year 2021, with a production of 144 thousand tons for the winter season, in which Muthanna Governorate ranked second after Al-Qadisiyah Governorate, with a production estimated at 24.80 thousand tons, or 17.20% of production, the total for the country in the year 2022 [7].

Many studies have investigated the genetic diversity of barley genotypes. The study by [8] showed an analysis of the genetic diversity of 96 barley genotypes from different regions of the world using molecular markers, and recorded great genetic diversity among the genotypes, with some genotypes showing unique genetic traits that can be used to improve crop traits. While [9] study found significant differences in yield and its components for 38 barley genotypes.

Iron is an essential micronutrient for plant growth and development, as it participates in many biochemical processes, including photosynthesis, respiration, and nitrogen fixation. Iron deficiency in plants can lead to chlorosis, poor growth, and reduced yield [10; 11]. Foliar spraying of crops with mineral iron is also a promising strategy to address iron deficiency in them. This advanced agricultural practice includes foliar spraying of minerals that contain iron, with the aim of enhancing nutrient absorption and improving plant health [12], so the response of barley crops to spraying with iron has been mineral attention; due to its ability to overcome challenges associated with traditional soil-based iron supplementation methods [13]. The complex interplay between soil conditions, plant physiology, and the unique properties of iron mineral compositions contribute to the complexity of this phenomenon [14]. By examining advanced references from the scientific literature, the study aims to clarify the complex relationships between iron use and crop physiology, and ultimately improve the productivity and quality of barley genotypes. Understanding these dynamics is pivotal to improving agricultural practices and ensuring sustainable barley production in light of confronting evolving environmental and nutritional challenges according to the available capabilities through knowing the performance of barley. Barley genotypes studied in terms of growth, productivity and determining the most appropriate amount of mineral iron added, as well as determining the best combination of genotypes and mineral iron that produces superior growth and yield of the barley crop.

Materials and Methods

1. Experiment site

A field experiment was carried out on 15/11/2022 in one of the agricultural fields whose location appears on the map at longitude 45.26° east and latitude 31.31° north in Muthanna Governorate near the second agricultural research station affiliated with the College of Agriculture/ Muthanna University, which is specifically located in Al Bandar village, southwest of Muthanna Governorate, 3 km from the center of Samawa city/ Muthanna Governorate, during the winter agricultural season (2022-2023) for soil with known characteristics (Table 1) with the aim of studying the response of newly introduced genotypes of barley crop (*Hordeum vulgare* L.) to iron spraying.

Table (1) some chemical and physical properties of field soil before planting for the winter agricultural season (2022-2023)*

Property			Value	Unit
Chemical properties	pH		7.8	
	EC		4.4	ds m^{-1}
	Available nitrogen		20.30	mg kg^{-1}
	Available phosphorus		13.20	mg kg^{-1}
	Available potassium		179.60	mg kg^{-1}
	Available Iron		1.67	mg kg^{-1}
	Organic matter		0.73	%
Physical properties	Soil components	Sand	11.47	%
		Silt	35.61	%
		Clay	52.92	%
	Soil texture		Clay Loam	

* The analyses were carried out in the soil and plant analysis laboratory / College of Agriculture / Muthanna University according to [15].

2. Experiment factors

The experiment included two factors, the first included four barley genotypes (three of which were newly introduced to Iraq, namely: Gzmeab, Gzmemb, and Cos-Aluetmarpc 2, and the fourth was one of the cultivated varieties Ibaa 265), while the second factor included spraying 6% mineral iron with four concentrations (0, 50, 100, and 150 mg L^{-1}), which are equivalent to 100% mineral iron (0, 833.3, 16667, and 2500 mg L^{-1}) by foliar spraying on the plant's shoot.

3. Experiment design

The experiment designed according to a randomized complete block design (RCBD) and a split plot arrangement with organization two-factor for a factorial experiment. The first factor included four barley genotypes that represented the main plot, while the second factor included four iron concentrations that represented the sub plot, with three replicates for each treatment. All combinations of the factors' treatments were distributed randomly within each block, including the entire experiment, 48 experimental units.

4. Agricultural processes and experiment implementation

The experimental field was plowed using a rotary plow after carrying out the irrigation process. It was then smoothed using disc harrows and then leveled using a leveling machine. It was divided according to the design used into 48 experimental units (plates), each of which had an area of 4 m^2 (2 m × 2 m), and 1 m^2 was left between one experimental unit and another, as well as between one block and another, to avoid interaction of treatments. In addition, one experimental unit included ten agricultural lines in preparation for planting barley genotypes using the lines method.

The seeds of the barley crop genotypes were planted at an amount of 100 kg ha^{-1} using the lines method and were covered with soil using hand rakes on 15/11/2022 [16], and then the implementation rate was given immediately

after the completion of the planting process and with complete control over the flow water to avoid seed drift, and other irrigations were given according to field need, while the genotypes of the barley crop were treated with different concentrations of iron by foliar spraying on the shoots in the elongation and budding stages of the barley crop.

The fertilization process was carried out according to the addition of triple superphosphate fertilizer as a source of phosphorus in one batch at planting at a rate of 80 kg P ha^{-1}, and the applied of urea fertilizer (N 46%) as a source of nitrogen at a rate of 200 kg N ha^{-1} and in four equal amounts, the first was done at the planting stage. Emergence, the second at the tiller stage, the third at the elongation stage, and the fourth at the budding stage, while potassium sulphate fertilizer (K 42%) was applied as a source of potassium at a rate of 60 kg K ha^{-1} in two equal batches, the first after emergence and the second at the tiller stage [17].

5. Studied characteristics

- Number of days from emergence to 75% flowering (day): It was calculated on the basis of the number of days from emergence of the barley genotypes to 75% flowering for all experimental units.
- Plant height (cm): The height of the plants was measured at harvest, starting from the soil surface to the end of the spike, excluding the stem, using a metric ruler for ten plants taken randomly from each experimental unit (from the experimental lines) and for all replicates. The mean was then extracted by dividing the sum of the height of the plants by each experimental unit depends on its number.
- Tillers number (tiller m^{-2}): The number of tillers in the middle two lines of each experimental unit was calculated at harvest and then converted to square meters.
- Number of fertile spikes (spike m^{-2}): The number of fertile spike was calculated after they reached full maturity for all plants harvested from two central lines from each experimental unit.
- Grain yield (ton ha^{-1}): The grains yield of the group of plants harvested manually was estimated from the middle lines of each experimental unit after manual threshing and isolating the straw from the grains, then weighing them and extracting the mean grain yield in units (g m^{-2}), which was mathematically converted to unit (ton ha^{-1}).
- Biological yield (ton ha^{-1}): The biological yield was calculated from the weight of the entire midline plants from each experimental unit immediately after harvesting and extracting the mean biological yield in units (g m^{-2}), which was converted mathematically to units (ton ha^{-1}).

6. Statistical analysis

The data for the studied traits were statistically analyzed using the Genstst Discovery 4 statistical program, and the means were compared using the least significant difference (LSD) test at the 0.05 significance level to diagnose statistical differences between the means of the treatments [18].

Results and Discussion

1. Number of days from emergence to 75% flowering (day)

Results in table (2) showed that there are significant differences between the four genotypes in number of days from emergence to 75% flowering; The two genotypes Gzmeab

ISSN 2072-3857

and Gzmemb required the shortest duration to reach flowering, with an mean of 90.47 and 90.75 days, respectively, with a significant difference between them, compared to the genotype Ibaa 265, which required the longest duration to reach flowering, with an mean of 103.50 days, followed by the Cos-Aluetmarpc 2 genotype, which recorded 103.00 days. This could be due to differences in genotype, [19] reported that barley cultivars differ in the number of days from emergence to flowering. Flowering time is an important agronomic trait in barley, which greatly affects yield and grain quality. Multiple factors influence flowering, including genotype, environmental conditions, and agricultural practices such as iron spraying. Understanding the complex interplay between these factors is crucial to improve barley production [20]. This result is consistent with was found by [21]; [22]; [23]; [24]; [25] regarding the presence of significant differences between varieties (genotypes) in terms of the number of days from planting or emergence until flowering. Barley varieties also have diverse flowering dates due to differences in their genotype, as several genes have been identified as key regulators of flowering, including the VRN (Vernalization) genes that control the plant's requirements for exposure to low (cold) temperatures for the transition from vegetative growth to reproductive growth, PPD (Photoperiod) genes that cause plants to respond to changes in day length and begin flowering, and ELF (Early flowering) genes that promote early flowering under long-day conditions [26], as these genes interact in a complex network, and these differences in their alleles lead to differences in flowering date between genotypes, and the study of [27] showed that choosing barley varieties with specific genetic structures can significantly affect the flowering date and ultimately on grains yield.

Results also showed that spraying the plant with iron at concentrations of 50, 100, and 150 mg L^{-1} led to a significant decrease in the mean number of days from emergence to 75% flowering compared to spraying with irrigation water (0 mg L^{-1}), which recorded 97.75 days, as the decrease was the mean number of days was more evident at the iron concentration of 150 mg L^{-1}, which recorded the shortest duration of flowering, with an mean of 94.75 days. The reason for this is that iron plays a vital role in the various physiological processes of the plant, including chlorophyll synthesis, photosynthesis, and enzyme activity, and its deficiency is a common problem in barley cultivation, especially in alkaline and calcareous soils [28]. It has been suggested to spray iron as a potential strategy to improve iron levels in plants and improve productivity. Many studies have studied the effect of spraying with iron on the timing of flowering in barley. Some studies indicate a slight delay in flowering, while other studies indicate non-significant effect [29]. Discrepancies in results can be attributed to several factors, most notably the timing of iron addition, the dose or concentration, and soil conditions. Results indicated a non-significant interaction between genotypes and iron spray.

ISSN 2072-3857

Table (2) Effect of genotypes, iron spraying and their interaction on number of days from emergence up to 75% flowering (day) of barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ibaa 265	105.00	104.00	103.00	102.00	103.50
Gzmeab	89.00	93.78	93.10	86.00	90.47
Gzmemb	92.00	91.00	90.00	90.00	90.75
Cos-Aluetmarpc 2	105.00	103.00	103.00	101.00	103.00
Mean of Fe spraying	97.75	97.95	97.28	94.75	
LSD ($P \leq 0.05$)	Genotypes = 4.51		Fe = 2.30		Interaction = N.S

2. Plant height (cm)

Results in table (3) showed that there were significant differences between the four genotypes in the plant height mean. Ibaa 265 genotype was significantly superior in recording the highest plant height mean of 116.98 cm, followed by the Gzmeab genotype with a mean of 111.68 cm, and then the Cos-Aluetmarpc 2 genotype, which recorded 112.52 cm, while the plant height mean of Gzmemb genotype was the lowest significantly with a mean of 106.26. cm, and this is due to the difference in genotype between varieties that interact with environmental factors and affect growth characteristics in a different way depending on the extent to which these characteristics are related to the genetic factor and its influence by the environmental conditions accompanying them in the different stages of growth, and the result was consistent with reached [24]; [25]; [30] showed that there were significant differences between varieties in plant height. Barley plants show varying heights due to differences in their genotype. The genes that control plant height mainly affect the culm length, which is determined by the genes that regulate the elongation of internodes and cell division [31; 32]. It also affects the synthesis of gibberellin, which is the main plant growth hormone that promotes stem elongation, and variations in genes involved in GA biosynthesis or transmission pathways affecting plant height [33]. On the other hand, genes that affect cell wall thickness, lignin content, and root development contribute to resistance to lodging, which indirectly affects plant height [34; 35]. Modern breeding programs use these genetic differences strategically to develop barley cultivars with desired plant heights, as shorter plants are often preferred for resistance to lodging, while taller cultivars may be advantageous for higher light interception in denser growing conditions [36].

Results also showed that spraying plants with iron at concentrations of 50, 100, and 150 mg L^{-1} significantly increased plant height mean compared to spraying with water (0 mg L^{-1}), which recorded 106.66 cm. The mean of height increased with the increase in the concentration used (50, 100 and 150 mg L^{-1}) to 113.26, 113.58 and 114.95 cm, respectively and with a significant superiority between them, as iron is a vital factor for various physiological processes of the plant, including chlorophyll synthesis, photosynthesis, and

ISSN 2072-3857

enzyme function, and a deficiency can lead to iron causes stunted growth and decreases the height of barley plants [37], and iron spraying has been proposed as a strategy to address iron deficiency and enhance plant growth in barley, as studies have shown that applied iron can significantly increase plant height, especially in soils suffering from iron deficiency, however, effectiveness depends on various factors such as soil conditions, application timing and dosage [38; 39].

As for the results of the significant interaction between the genotypes and iron spray, they showed the significant superiority of the genotype Ibaa 265 treated with different concentrations of iron over the other genotypes treated with the same concentrations under study, as the interaction (Ibaa 265 × 150 mg L^{-1}) achieved the highest significant mean for plant height of 119.30 cm compared to the rest of the other interactions listed in table (3). In addition, the plant height characteristic was clear in the genotype Ibaa 265 even without treating it with iron compared to the other genotypes treated with different concentrations of iron, which achieved its highest height of 115.00 cm when Cos-Aluetmarpc 2 genotype treated with the highest concentration of iron used, which is lower than what was recorded by the genotype Ibaa 265 without treatment with iron (115.63 cm) compared to 119.30 cm when treated with the highest concentration of iron used. The combined effect of genotypes and spraying with iron on the height of barley plants is due to several factors, including: differential absorption and use of iron. Different genotypes may show varying abilities to absorb iron from the soil or applied fertilizers, and this can lead to different responses to iron spraying in terms of plants height. Genetic regulation of iron balance through genes involved in iron absorption, transport and storage within plants also affects the response to iron deficiency and the subsequent effects on plant growth and height. On the other hand, the effect resulting from iron deficiency can lead to various physiological changes that limit cell division and growth, and genotypes with a high ability to tolerate stress may be less affected by iron deficiency and show less response to iron spray.

Table (3) Effect of genotypes, iron spraying and their interaction on plant height (cm) of barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ibaa 265	115.63	116.13	116.87	119.30	116.98
Gzmeab	111.68	113.77	112.33	112.93	112.68
Gzmemb	88.49	111.77	112.23	112.57	106.26
Cos-Aluetmarpc 2	110.83	111.37	112.87	115.00	112.52
Mean of Fe spraying	106.66	113.26	113.58	114.95	
LSD ($P \leq 0.05$)	Genotypes = 6.83		Fe = 4.45		Interaction = 9.59

ISSN 2072-3857

3. Tillers number (tiller m^{-2})

The results of the genotypes indicated non-significant effects for tillers number (Table 4). Regarding the significant effect of spraying with iron at concentrations of 50, 100, and 150 mg L^{-1}, it led to an increase in the mean of tillers number with increasing concentration, achieving 384.80, 437.30, and 549.50 tiller m^{-2}, respectively, compared to spraying with water (0 mg L^{-1}) with a mean the least significant (355.55 tiller m^{-2}), as iron plays a vital role in chlorophyll synthesis, photosynthesis, and various metabolic processes, and iron deficiency can greatly affect the development of shoots in barley, leading to a decrease in the tillers number and poor growth [40]. Results also showed the non-significant effect of the interaction between genotypes and iron spraying.

Table (4) Effect of genotypes, iron spraying and their interaction on tillers number (tiller m^{-2}) for barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ibaa 265	356.5	399.0	405.0	488.0	412.1
Gzmeab	308.3	326.0	465.0	525.0	406.1
Gzmemb	387.0	404.0	450.0	630.0	467.8
Cos-Aluetmarpc 2	370.0	410.0	429.0	555.0	441.0
Mean of Fe spraying	355.5	384.8	437.3	549.5	
LSD ($P \leq 0.05$)	Genotypes = N.S		Fe = 34.22		Interaction = N.S

4. Number of fertile spikes (spike m^{-2})

The results in table (5) showed that there were significant differences between the four genotypes in the mean of number of fertile spike; The Gzmemb genotype outperformed significantly by recording the highest in the mean of number of fertile spike, amounting to 457.00 spike m^{-2}, followed by the Gzmeab genotype, which recorded 383.84 spike m^{-2}, and then the Cos-Aluetmarpc 2 genotype, with a mean of 369.90 spike m^{-2}, while the mean of number of fertile spike for the genotype was the genotype Ibaa 265 was the least significant, reaching 339.75 spike m^{-2}. This result is consistent with the findings of [22]; [24]; [25]; [41] that the variation in the number of fertile spike came as a result of the variation in genetic compositions (varieties) in their genetic ability to produce shoots due to the production of representative materials that it supports the growth of shoots until they turn into shoots bearing fertile spike. Barley varieties show inherent differences in the number of fertile spike due to differences in their genotype, as the genes that control shoot emergence and development ultimately determine the number of potential shoot-bearing shoots [42]. Genes related to grain size, number per spike, and overall plant growth also indirectly affect the number of fertile spike by influencing resource allocation [43].

Results also showed that spraying plants with iron at concentrations of 50, 100, and 150 mg L^{-1} significantly increased the in the mean of number of fertile spike of barley crop compared to spraying with water (0 mg L^{-1}),

which recorded 329.00 spike m^{-2}, as the mean number increased. Fertile ears with increasing concentration used (50, 100, and 150 mg L^{-1}) significantly increased to 343.25, 385.00, and 437.50 spike m^{-2}, respectively, and with a significant superiority among them, as iron plays a determining role in various plant processes, including that is, chlorophyll synthesis, photosynthesis, carbohydrate metabolism, and iron deficiency can significantly affect the reproductive development of barley, leading to decreased spike fertility and ultimately a lack of fertile spikes [44]. Studies have shown that the application of iron can significantly increase the number of fertile spikes, especially in iron-deficient soils, depending on various factors such as soil conditions, timing of application, and dosage [12; 45; 46].

As for the results of the significant interaction between the genotypes and iron spray, they showed that the Gzmemb genotype treated with different concentrations of iron had a significant superiority over the other genotypes treated with the same concentrations under study, as the interaction (Gzmemb × 150 mg L^{-1}) achieved the highest significant in the mean of number of fertile spike. It reached 560.00 spike m^{-2} compared to the rest of the other interventions listed in table (5). In addition, the characteristic of the number of fertile ears was clear in the Gzmemb genotype even without treating it with iron (413.00 spike m^{-2}) compared to the other genotypes. On the other hand, both interventions (Gzmeab × 150 mg L^{-1} and Gzmemb × 100 mg L^{-1}) achieved the same in the mean of number of fertile spike, reaching 430.00 spike m^{-2}, while the genotype Ibaa 265 without treatment with iron recorded the lowest significant in the mean of number of fertile spike amounted to 316.00 spike m^{-2}. The combined effect of genotypes and iron application on the number of fertile spikes in barley is due to several factors, including differential absorption and use of iron. Different genotypes may show varying abilities to absorb iron from the soil or added fertilizers, and this may lead to this leads to varying responses to iron spraying in terms of the number of fertile spikes. Genes related to iron absorption, transport, and allocation within plants can affect the response to iron deficiency and the subsequent effects on spike growth and fertility, which affects the growth of floral organs and the vitality of the ovules. Genetic structures with high potential may be it is less susceptible to iron deficiency and shows less response to iron spray.

Table (5) Effect of genotypes, iron spraying and their interaction on number of fertile spikes (spike m^{-2}) for barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ibaa 265	316.00	325.00	358.00	360.00	339.75
Gzmeab	365.16	367.20	373.00	430.00	383.84
Gzmemb	413.00	425.00	430.00	560.00	457.00
Cos-Aluetmarpc 2	370.00	371.00	365.54	373.05	369.90
Mean of Fe spraying	329.00	343.25	385.00	437.50	
LSD ($P \leq 0.05$)	Genotypes = 9.07		Fe = 5.12		Interaction = 11.75

ISSN 2072-3857

5. Grains yield (ton ha^{-1})

Results in table (6) showed that spraying plants with iron at concentrations of 50, 100 and 150 mg L^{-1} it significantly increased the mean grain yield of the barley crop compared to spraying with water (0 mg L^{-1}), which recorded 6.279 ton ha^{-1}, as the mean grain yield increased with the increase in the concentration used (50, 100 and 150 mg L^{-1}). Significantly to 6.634, 7.379 and 7.919 ton ha^{-1}, respectively, and with a significant superiority between them, and this depends on the yield indicators represented by the number of grains in the spike and the weight of 1000 grains, as iron plays a decisive role in various plant processes, including chlorophyll synthesis. Photosynthesis, enzyme activity, and iron deficiency is a widespread problem in barley, especially in calcareous or high-pH soils, which leads to a decrease in the photosynthesis process, poor nutrient absorption, and ultimately a decrease in grain yield [47; 48]. As for the results of the significant interaction between genotypes and iron spraying, the interaction (Gzmemb × 150 mg L^{-1}) achieved the highest significant mean for grain yield, amounting to 9.729 ton ha^{-1}, compared to the rest of the other interactions listed in table (6). In addition, the trait grain yield was clear in the Gzmemb genotype even without treating it with iron (7.072 ton ha^{-1}) compared to the other genotypes. On the other hand, some of the interactions included in the Gzmeab genotype were the least significant for grain yield, as shown in table (6). It is possible that the combined effect of genotypes and iron spraying on barley grain yield arises from several factors. Different genotypes may show varying abilities to absorb iron from soil or added fertilizers, and this could lead to different responses to iron spraying in terms of grain yield. Genes involved in iron uptake, transport, and allocation within plants can influence the response to iron deficiency and subsequent effects on photosynthesis, nutrient uptake, and resource allocation to grain production.

Table (6) Effect of genotypes, iron spraying and their interaction on grains yield (ton ha^{-1}) for barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ebaa 265	6.261	6.767	8.322	7.769	7.280
Gzmeab	5.177	5.853	6.752	7.423	6.301
Gzmemb	7.072	7.606	8.090	9.729	8.124
Cos-Aluetmarpc 2	6.604	6.309	6.351	6.755	6.505
Mean of Fe spraying	6.279	6.634	7.379	7.919	
LSD ($P \leq 0.05$)	Genotypes = N.S		Fe = 0.549		Interaction = 2.346

6. Biological yield (ton ha^{-1})

Table (7) showed the effect of the genotypes, spraying with iron, and their interaction in the mean biological yield (ton ha^{-1}) of the barley crop. Results showed that the four genotypes of the crop had different effects on the mean biological yield, and the Gzmemb genotype had a significantly higher mean biological yield of 20.18 ton ha^{-1} compared to the other genotypes under study, in addition to the Cos-Aluetmarpc 2 genotype recording mean the

least significant biological yield for the barley crop was 15.21 ton ha^{-1}. The reason may be that the biological yield of the barley crop is an important indicator of production efficiency and achieving food security, as barley varieties show wide variation in biological yield, as a result of their differences in genotype, as genotype determines the number of spikelets in a spike, the number of grains in spike, and the weight of 1000 grains [49; 50]. Genotypes also determine barley's tolerance to nutrient deficiencies [51]. On the other hand, genotype determines the efficiency of barley in using available resources, such as water and nutrients [52]. Result agreed with [24]; [25]; [53]; [54].

Regarding the significant effect of spraying with iron at concentrations of 50, 100, and 150 mg L^{-1}, it led to an increase in the mean biological yield with increasing concentration by achieving 16.25, 17.39, and 18.88 ton ha^{-1}, respectively, compared to spraying with water (0 mg L^{-1}) with higher yield. The biological yield was significantly lower, with a mean of 14.34 ton ha^{-1}, as spraying with iron leads to an increase in the biological yield of barley, by increasing the chlorophyll content in the leaves, which enhances the process of photosynthesis and increases the production of carbohydrates [47]. Iron helps improve the absorption of other nutrients, such as nitrogen, phosphorus, and potassium, which contributes to increased plant growth and development [55]. Results also showed the significant effect of the interaction between the genotypes and spraying with iron, as the interaction (Gzmemb × 150 mg L^{-1}) achieved the highest significant mean of the biological yield, amounting to 24.50 ton ha^{-1}, while the interaction of the same genotype with iron at a lower concentration (100 mg L^{-1}) achieved the second highest mean biological yield reached 20.93 ton ha^{-1} compared to other interventions with significantly lower mean for the biological yield, which reached below 12.67 ton ha^{-1} with the Gzmeab genotype without treatment with iron (0 mg L^{-1}). Spraying with iron can interfere with the genotype of barley to affect biological yield. In some varieties, spraying with iron may lead to a significant increase in biological yield, while its effect may be minimal or nonexistent in other varieties. This interaction can be explained by the effect of genotypes on barley's tolerance to iron deficiency. Varieties that tolerate iron deficiency better may not respond to spraying with iron, while varieties that tolerate iron deficiency poorly may respond significantly to iron spraying.

Table (7) Effect of genotypes, iron spraying and their interaction on biological yield (ton ha^{-1}) for barley crop

Barley genotypes	Fe concentrations (mg L^{-1})				Mean of barley genotypes
	0	50	100	150	
Ibaa 265	12.85	16.75	17.50	17.00	16.03
Gzmeab	12.67	15.07	16.00	18.00	15.43
Gzmemb	17.03	18.27	20.93	24.50	20.18
Cos-Aluetmarpc 2	14.80	14.90	15.13	16.00	15.21
Mean of Fe spraying	14.34	16.25	17.39	18.88	
LSD ($P \leq 0.05$)	Genotypes = 2.10		Fe = 1.08		Interaction = 2.61

ISSN 2072-3857

Conclusion

Recording the lowest means for the number of days from emergence to 75% flowering with the genotype Gzmeab, and achieving the highest means for plant height with the genotype Ibaa 265, and reaching the highest means for the number of fertile spikes, grains yield, and biological yield with the genotype Gzmemb, in addition to recording the highest means for tillers number with Cos-Aluetmarpc 2 genotype. The role of iron at a concentration of 150 mg L^{-1} was clear in recording the highest means for the indicators under study for the barley crop. Interfering the genotypes with iron at the highest concentration (150 mg L^{-1}) achieved the best combinations for the best results for growth indicators, yield and its components for the barley crop .

References

1. Borneo, R., Lie, S. & Nugroho, W. 2019. The role of barley in human health: Review of recent research. International Journal of Food Science and Technology, 54(8), 2309-2316.

2. Li, H. 2020. Identification of QTL for nitrogen use efficiency traits at seedling stage in barley (*Hordeum vulgare* L.) using association mapping. Euphytica, 216, 156-168.

3. Naghaii, V. and Asgharipour, M. R. 2011. Difference in drought stress responses of 20 barley genotypes with contrasting drought tolerance during grain filling. Advances in Environmental Biology,5(9), 3042-3049.

4. Al-Haboby, A., Breisinger, C., Debowicz, D., El-Hakim, A.H., Ferguson, J., van Rheenen, T. and Telleria, R. 2014. Agriculture for development in Iraq? Estimating the impacts of achieving the agricultural targets of the national development plan 2013-2017 on economic growth, incomes, and gender equality (Vol. 1349). Intl Food Policy Res Inst.

5. Qader, S. H., Dash, J. & Atkinson, P. M. 2018. Forecasting wheat and barley crop production in arid and semi-arid regions using remotely sensed primary productivity and crop phenology: A case study in Iraq. Science of the Total Environment, 613, 250-262.

6. Mittal, S. 2022. Wheat and Barley Production Trends and Research Priorities: A Global Perspective. In New Horizons in Wheat and Barley Research: Global Trends, Breeding and Quality Enhancement (pp. 3-18). Singapore: Springer Singapore.

7. Directorate of Agricultural Statistics. 2022. Wheat and Barley Production 2022. Central Bureau of Statistics - Ministry of Planning, Republic of Iraq, 78 p.

8. Khazaei, H. 2016. Genetic diversity of barley genotypes (*Hordeum vulgare* L.) based on molecular markers. Frontiers in Plant Science, 7, 207-2020.

9. Ahmad, M. 2018. Yield and yield-related traits of barley (*Hordeum vulgare* L.) genotypes under different nitrogen levels. Emirates Journal of Food and Agriculture, 30(5), 391-399.

10. Briat, J. F. & Dubos, C. 2010. Iron nutrition, biomass production, and plant product quality. Trends in Plant Science, 15(9), 466-474.

11. Hassan, W. A., Awadalla, S. A. and Khalafalla, M. M. 2019. Effect of iron and

molybdenum spraying on yield, quality, and nutrient content of barley (*Hordeum vulgare* L.) under sandy soil conditions. Communications in Soil Science and Plant Analysis, 50(10), 1178-1190.

12. Yaman, K. P. & Mehta, C. 2019. Effect of Azospirillum and foliar application of iron (Fe) on growth and yield attributes of barley. Journal of Emerging Technologies and Innovative Research, 6, 373-393.

13. Kaya, C. and Ashraf, M., 2023. Foliar Fertilization: A Potential Strategy for Improving Plant Salt Tolerance. Critical Reviews in Plant Sciences, pp. 1-23.

14. Therby-Vale, R., Lacombe, B., Rhee, S. Y., Nussaume, L. & Rouached, H. 2022. Mineral nutrient signaling controls photosynthesis: Focus on iron deficiency-induced chlorosis. Trends in Plant Science, 27(5), 502-509.

15. Estefan, G., Sommer, R. and Ryan, J. 2013. Methods of Soil, Plant, and Water Analysis. A Manual for the West Asia and North Africa Region (3rd Ed.), International Center for Agriculture Research in the Areas (ICARDA), pp. 244.

16. Al-Abedi, J. I. 2011. Guide to the uses of chemical and organic fertilizers in Iraq. General Authority for Agricultural Guidance and Cooperation, Ministry of Agriculture, Republic of Iraq.

17. Bashkin, I. L. 2013. Balanced fertilization, soil fertility and sustainable production. Springer. Chapter 3: The Role of Balanced Fertilization in Sustainable Crop Production, pp. 45-62.

18. Al-Rawi, K. M. and Khalaf Allah, A. M., 2000. Design and analysis of agricultural experiments. Dar Al-Kutub for Printing and Publishing - Mosul, 2nd ed., College of Agriculture and Forestry, University of Mosul, Iraq.

19. Aynewa, Y., Tadesse, D. and Wondimu, B. 2013. Participatory evaluation of malt barley (*Hordeum vulgare* L.) genotypes for yield and other agronomic traits at North-West Ethiopia. Wudpecker Journal of Agricultural Research, 2(8), 218-222.

20. Cooper, L. L. D., Zitzewitz, J. V., Skinner, J. S., Szűcs, P., Karsai, I., Francia, E. & Hayes, P. M. 2006. The genetic basis of vernalization responses in barley. In Cold hardiness in plants: molecular genetics, cell biology and physiology. Seventh International Plant Cold Hardiness Seminar, Sapporo, Japan, 10-15 July 2004 (pp. 64-75). Wallingford UK: CABI Publishing.

21. Ahmed, A. A. and Al-Amiri, M. A., 2012. Evaluation of the characteristics of new barley varieties under aquatic conditions. Mesopotamian Agriculture Journal, 40(1), 282-305.

22. Ahmed, A. A. and Al-Taweel, M. S., 2012. Evaluation of new barley genotypes under conditions in Nineveh Governorate. Mesopotamian Agriculture Journal, 40(1), 318-331.

23. Al-Rawashda, Y., Salama, S. and Al-Nasser, F., 2013. Response of some barley varieties to seed rates and nitrogen fertilizer levels under rain-fed agricultural conditions in southern Jordan. Damascus University Journal of Agricultural Sciences, 29(2), 134-150.

24. Al-Kafaei, M. H. K., 2018. Response of newly introduced varieties of wheat and barley to different planting dates. Master's thesis, College of Agriculture, Al-Muthanna University, Iraq.

25. Shamkhi, A. J., 2020. The effect of seed specific gravity resulting from planting dates on seed viability and growth yield of four varieties of barley, *Hordeum vulgare* L. Master's thesis, College of Agriculture, Al-Muthanna University, Iraq.

ISSN 2072-3857

26. Distelfeld, A., Li, C. & Dubcovsky, J. 2009. Regulation of flowering in temperate cereals. Current Opinion in Plant Biology, 12(2), 178-184.
27. Tarawneh, R. A., Alqudah, A. M., Nagel, M. & Börner, A. 2020. Genome-wide association mapping reveals putative candidate genes for drought tolerance in barley. Environmental and Experimental Botany, 180, 22-37.
28. Zohlen, A. 2002. Chlorosis in wild plants: Is it a sign of iron deficiency? Journal of Plant Nutrition, 25(10), 2205-2228.
29. Choudhary, S., Yadav, L. R., Yadav, S. S., Sharma, O. P. & Keshwa, G. L. (2013). Integrated use of fertilizers and manures with foliar application of iron in barley (*Hordeum vulgare*). Indian Journal of Agronomy, 58(3), 363-367.
30. Al-Bayati, B. S. N. and Siddiq, F. A. 2014. Study of some quantitative characteristics to determine the manufacture of malt with high enzymatic activity for eight varieties of barley, *Hordeum vulgare* L. Tikrit University Journal of Agricultural Sciences, 14 (2), 62-75.
31. Davies, P. J. 1995. The plant hormone concept: concentration, sensitivity and transport. In Plant hormones: physiology, biochemistry and molecular biology (pp. 13-38). Dordrecht: Springer Netherlands.
32. Nakamura, A., Fujioka, S., Sunohara, H., Kamiya, N., Hong, Z., Inukai, Y. & Matsuoka, M. 2006. The role of OsBRI1 and its homologous genes, OsBRL1 and OsBRL3, in rice. Plant Physiology, 140(2), 580-590.
33. Wang, Y., Zhao, J., Lu, W. & Deng, D. 2017. Gibberellin in plant height control: old player, new story. Plant Cell Reports, 36, 391-398.
34. Niu, J., Liu, C., Huang, M., Liu, K., & Yan, D. 2021 a. Effects of foliar fertilization: a review of current status and future perspectives. Journal of Soil Science and Plant Nutrition, 21, 104-118.
35. Niu, Y., Chen, T., Zhao, C. & Zhou, M. 2021 b. Improving crop lodging resistance by adjusting plant height and stem strength. Agronomy, 11(12), 2421.
36. Niu, Y., Chen, T., Zhao, C. & Zhou, M. 2022. Lodging prevention in cereals: Morphological, biochemical, anatomical traits and their molecular mechanisms, management and breeding strategies. Field Crops Research, 289, 1-15.
37. Rout, G. R. & Sahoo, S. 2015. Role of iron in plant growth and metabolism. Reviews in Agricultural Science, 3, 1-24.
38. Khursheed, M. Q., Salih, Z. R. & Saber, T. Z. 2018. Response of barley (*Hordeum vulgare* L.) plants to foliar fertilizer with different concentrations of Hoagland solution. Rafidain Journal of Science, 27(2), 1-7.
39. Sheikh Abdulla, S. M. & Mohammed, S. M. 2018. Response of some six rowed barley varieties (*Hordeum vulgare* L.) to micronutrient Fe for growth and yield under dry farming condition. Euphrates Journal of Agriculture Science, 10(3), 1-15.
40. Shaibur, M. R., Adjadeh, T. A. & Kawai, S. 2013. Effect of phosphorus on the concentrations of arsenic, iron and some other elements in barley grown hydroponically. Journal of Soil Science and Plant Nutrition, 13(1), 79-85.
41. Al-Amiri, M. M. A. and Al-Obaidi, M. A., 2016. Evaluation of several genotypes of wheat and triticale crops under the conditions of organic agriculture in Sulaymaniyah Governorate. Anbar Journal of Agricultural Sciences, 41(4), 163-171.
42. Haas, M., Schreiber, M. & Mascher, M. 2019. Domestication and crop evolution of wheat and barley: Genes, genomics, and future

directions. Journal of Integrative Plant Biology, 61(3), 204-225.
43. Liu, Y., Chen, J., Yin, C., Wang, Z., Wu, H., Shen, K. & Guo, Z. 2023. A high-resolution genotype-phenotype map identifies the TaSPL17 controlling grain number and size in wheat. Genome Biology, 24(1), 196-210.
44. Kumar, S., Patial, M. & Sharma, R. 2020. Efficient barley breeding. Accelerated Plant Breeding, Cereal Crops, 1, 309-364.
45. Sarkar, D. R. 2014. Effect of micronutrients on the growth and yield of wheat. Doctoral dissertation, Department of Soil Science, Faculty of Agriculture Sher-e-Bangla Agricultural University, Dhaka.
46. Kovalenko, T. M. 2023. Influence of spring barley plant nutrition optimization on yield formation in the rightbank Foreststeppe of Ukraine. Сільське господарство та лісівництво, 1(28), 46-61.
47. Alabdalsayid, K. K., & Al-Freeh, L. M. 2021. Effect of phosphate fertilization and iron spraying on growth parameter and yield of oat (*Avena sativa* L.). In IOP Conference Series: Earth and Environmental Science, 923(1), 1-6.
48. Abas, F. M. 2022. Effect of spraying different fertilizer sources of iron on the growth and yield of barley (*Hordeum vulgare* L.) plant irrigated with different quality of water. International Journal of Agricultural & Statistical Sciences, 18, 75-90.
49. Miralles, D. J., Abeledo, L. G., Prado, S. A., Chenu, K., Serrago, R. A. & Savin, R. 2021. Barley. In Crop physiology case histories for major crops (pp. 164-195). Academic Press.
50. Albahri, G., Alyamani, A. A., Badran, A., Hijazi, A., Nasser, M., Maresca, M., & Baydoun, E. 2023. Enhancing essential grains yield for sustainable food security and bio-safe agriculture through latest innovative approaches. Agronomy, 13(7), 1709 -1730.
51. Elakhdar, A., Solanki, S., Kubo, T., Abed, A., Elakhdar, I., Khedr, R. & Qualset, C. O. 2022. Barley with improved drought tolerance: Challenges and perspectives. Environmental and Experimental Botany, 201, 1-18.
52. Nadolska-Orczyk, A., Rajchel, I. K., Orczyk, W. & Gasparis, S. 2017. Major genes determining yield-related traits in wheat and barley. Theoretical and Applied Genetics, 130, 1081-1098.
53. Hamdan, M. I., Muhammad, A. O., Hashem, I. K., Mahdi, A. H. and Salman, K. A., 2013. Evaluation of genotypes of durum wheat (*Triticum durum*) introduced under central conditions from Iraq. Anbar Journal of Agricultural Sciences, 31(2), 180-188.
54. Al-Tahir, F. M. M. and Al-Hamdawi, S. I. R., 2017. The contribution of the flag leaf, lower leaves, and parts of the spike to the production of dry matter and grain yield composition of three varieties of wheat, *Triticum aestivum* L. Muthanna Journal of Agricultural Sciences, 4(2), 163-171.
55. Daryoush-Karimi, N., Mojaddam, M., Lak, S., Payandeh, K. and Shokuhfar, A. 2024. Effect of spraying iron, zinc and using superabsorbent on grain yield and some biochemical properties of maize under drought stress. Journal of Plant Nutrition, 47(5), 681-689.

ISSN 2072-3857