Interaction of Wheat Cultivars and Potassium Foliar Application in Enhancing Growth Traits and Grain Yield

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Abstract

The study was conducted at the Desert Studies Center Research Station during the 2024–2025 winter season to investigate the response of four bread wheat cultivars to foliar application of potassium fertilizer. A split-plot arrangement within a randomized complete block design with three replications was used. Potassium concentrations were allocated to the main plots at levels of 0, 2000, and 4000 mg L^{-1}, while the subplots included the cultivars IPA 99, Bohouth 22, Al-Rasheed, and Abu Ghraib 3. The results indicated that the cultivar IPA 99 outperformed others in flag leaf area with 40.15 cm^2, number of spikes per square meter with 442 spikes m^{-2}, and number of grains per spike with 62.18 grains $spike^{-1}$. In contrast, the cultivar Bohouth 22 recorded the highest grain yield at 7.16 tons ha^{-1}. Plants treated with 4000 mg L^{-1} potassium showed the highest mean values in plant height (101.6 cm), flag leaf area (39.14 cm^2), number of spikes per square meter (478.6 spikes m^{-2}), number of grains per spike (62.20 grains $spike^{-1}$), 1000-grain weight (44.50 g), and grain yield (6.64 tons ha^{-1}). A significant interaction was observed between the IPA 99 cultivar and the 4000 mg L^{-1} potassium concentration, resulting in the highest flag leaf area of (42.05) cm^2 and 1000-grain weight of (45.60) g. Additionally, a significant interaction occurred between the Bohouth 22 cultivar and the 4000 mg L^{-1} potassium concentration in grain yield, which reached (7.95) tons ha^{-1}.

Keyword: Cultivars, Potassium, Grain Yield, Physiological Traits

تداخل أصناف الحنطة ورش البوتاسيوم في تحسين صفات النمو وحاصل الحبوب

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المستخلص

طبق البحث في محطة ابحاث مركز دراسات الصحراء خلال الموسم الشتوي لعام 2024 – 2025 لمعرفة استجابة اربع أصناف من حنطة الخبز للرش بسماد البوتاسيوم، استخدم ترتيب الالواح المنشقة وفق تصميم القطاعات الكاملة المعشاة وبثلاثة مكررات. توزعت تراكيز البوتاسيوم في الالواح الرئيسية وهي (0، 2000، 4000) ملغم لتر−1، فيما تضمنت الالواح الثانوية الأصناف وهي (أباء 99، بحوث 22، الرشيد، ابو غريب 3). اظهرت نتائج الدراسة تفوق صنف اباء99 في صفة مساحة ورقة العلم 40.15 سم2 وعدد السنابل بالمتر المربع 442 سنبلة م−2 وعدد الحبوب بالسنبلة (62.18) حبة سنبلة−1، اما الصنف بحوث22 فقد تفوق في حاصل الحبوب (7.16) طن هـ−1. سجلت النباتات التي رشت بالتركيز 4000 ملغم لتر−1 اعلى متوسط لصفة ارتفاع النبات (101.6) سم ومساحة ورقة العلم (39.14) سم2 وعدد السنابل بالمتر المربع (478.6) سنبلة م−2 وعدد الحبوب بالسنبلة 62.20 حبة سنبلة−1 ووزن1000حبة (44.50) غم وحاصل الحبوب (6.64) طن هـ−1. كما حصل تداخل معنوي بين الصنف اباء99 والتركيز 4000 ملغم لتر−1 في مساحة ورقة العلم (42.05) سم2 ووزن1000حبة (45.60) غم، وايضاً حصل تداخل للصنف بحوث22 مع التركيز 4000 ملغم لتر−1 في حاصل الحبوب (7.95) طن هـ−1.

الكلمات المفتاحية: الاصناف، البوتاسيوم، حاصل حبوب، صفات فسلجية.

Introduction

Wheat (*Triticum aestivum* L.) is considered one of the most important strategic food crops globally, as it constitutes a primary source of carbohydrates and contributes significantly to food security for millions of people. Increasing wheat production can be achieved through improved cultivar selection, fertilization, and effective soil and crop management (Abu-Dhahi & Al-Younis 1988, Jadou 2003). Wheat is also the world's leading field crop used as food in terms of economic importance, cultivated area, and annual production volume, as its grains are the primary source It is a food that humans need due to its high nutritional value, as it contains a high percentage of proteins and carbohydrates, in addition to containing quantities of fats, vitamins, some minerals, and essential amino acids that humans need. It is also easily preserved, transported, and manufactured to produce easily digestible products (Vera Verbeke & Delcour 2002). Yield improvement can also result from optimizing the interaction between cultivar performance, environmental conditions, and applied fertilizer rates. Each genetic makeup has distinct agronomic and nutritional characteristics, making the selection of the appropriate genotype a critical factor in achieving high productivity and

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superior quality (Abdulhamed & Ghadir, 2021). Global demand for wheat is increasing at a rate of 2% annually, while yield increases in irrigated wheat are estimated at no more than 1%, indicating that global demand is growing at nearly twice the current production rates. Wheat remains a key crop in national food security strategies, yet its productivity in many regions, including Iraq, remains below global averages due to various challenges, most notably environmental and climatic stressors and nutrient deficiencies in soils particularly under conditions of climate change and limited adoption of modern agricultural management practices (Abood et al., 2019). Among the essential factors influencing wheat growth and productivity is potassium, a vital nutrient for plant development. Potassium contributes to improved photosynthetic efficiency, regulates stomatal opening and closure, and enhances plant tolerance to environmental stresses (Ali et al., 2025). Additionally, potassium plays a direct or indirect role in activating over 120 enzymes, including those involved in energy production and nitrogen metabolism in the plant. Numerous studies have shown that foliar application of potassium can effectively compensate for soil nutrient deficiencies and improve crop productivity. Potassium enhances essential plant physiological functions such as stomatal regulation for respiration and transpiration, facilitates the translocation of carbohydrates and starch to the grains, increases grain weight, strengthens stems, and reduces lodging (Abdulhamed et al., 2021). Most Iraqi soils tend to be alkaline, which limits the availability of nutrients for plant uptake despite their sufficient presence in the soil. Therefore, foliar application is often preferred, especially when applying carefully determined and effective levels (Khalid & Al-Issawi 2024m Muhammed & Al-Joboory 2024). Accordingly, this study was conducted to investigate the effects and significance of potassium foliar feeding, to identify the optimal application level that enhances vegetative growth traits, yield, and its components, and to determine the most responsive bread wheat cultivar that achieves the highest productivity under potassium foliar application.

Materials and Methods

A field experiment was conducted at the Desert Studies Center Research Station during the 2024–2025 winter season, with sowing carried out on November 18, 2024. The objective was to evaluate the response of four wheat genotypes (IPA 99, Bohouth 22, Al-Rasheed, and Abu Ghraib 3), which were assigned to the subplots, to foliar application of potassium fertilizer at three concentrations (0, 2000, and 4000 mg K L^{-1}), allocated to the main plots. The experiment was arranged in a split-plot design within a randomized complete block design (RCBD) with three replications. Each replication consisted of 12 experimental units resulting from the combinations of the study factors. Seeds of the cultivars were sown in plots measuring 2 × 4 meters. Each plot contained 10 rows, each 4 meters long, with 20 cm spacing between rows. A 1-meter buffer zone was maintained between experimental units to avoid overlap during foliar application. The field was plowed twice in perpendicular directions, then leveled and smoothed. Before planting, random soil samples were collected from the 0–30 cm depth for physical and chemical analysis, as presented in Table 1.

A seeding rate of 140 kg ha^{-1} was used, with seeds sown in rows. Urea (46% N) was applied as the nitrogen source at a rate of 200 mg N ha^{-1}, split into two equal doses: the first at planting along with 100 mg ha^{-1} of P_2O_5 from triple superphosphate (46% P_2O_5), and the second 30 days after sowing (Al-Taher & Al-Naser 2021). The field was irrigated immediately after planting, and crop management practices including irrigation, hoeing, and weeding were carried out as needed. Potassium fertilizer was applied at the specified concentrations as foliar spray using potassium sulfate (K_2SO_4) containing 41.5% K, at the stem elongation stage (Sarhan 2024). The solution was sprayed early in the morning until complete plant coverage, using a wetting agent to enhance adherence and absorption.

Table 1. Selected physical and chemical properties of the soil before planting

Parameter	Unit	Value
pH	—	7.9
Electrical conductivity (EC)	dS m^{-1}	2.43
Available nitrogen	mg kg^{-1} soil	19.75
Available phosphorus	mg kg^{-1} soil	10.67
Available potassium	mg kg^{-1} soil	123.6
Organic matter	g kg^{-1} soil	10.22
Sand	g kg^{-1} soil	408
Silt	g kg^{-1} soil	340
Clay	g kg^{-1} soil	252

Characters of the Study

1. Plant height (cm): Measured from the soil surface to the tip of the main spike (excluding awns) after flowering, based on the average of ten randomly selected plants per experimental unit.
2. Flag leaf area (cm²): Calculated by multiplying leaf length by its maximum width.
   Number of spikes per square meter: Counted in a 1 m² area within each plot.
3. Number of grains per spike: Determined as the average number of grains from fifty randomly selected spikes per experimental unit.
4. Thousand grain weight (g): Measured from a random grain sample taken from the harvested yield of each plot, adjusted to 14% moisture content.
5. Grain yield (tons ha⁻¹): Estimated based on the weight of grain harvested from 1 m² in each experimental unit, then converted to tons per hectare.

The statistical analysis of the data was conducted using the (RCBD) to evaluate the effect of different treatments on the studied traits. Analysis of Variance (ANOVA) was used to test the significance of differences among the treatments. After confirming the presence of significant differences at the probability level of 0.05, the (LSD) test was employed to compare the means.

Results and Discussion

Plant height (cm)

The data in Table (2) show Table 2 significant differences among wheat cultivars in plant height. The cultivar Al-Rasheed recorded the highest mean plant height at 98.0 cm, while Abu Ghraib 3 exhibited the lowest at 87.2 cm. This variation is likely attributed to differences in the number of nodes and internodes, as well as the varying hormonal content among the cultivars. Taller cultivars tend to have higher levels of growth-promoting hormones, which enhance cell elongation, consistent with the findings of (Abdul-Nabi & Lehmood 2024, Khatlan & Al-Issawi 2024). The same table also shows significant differences among potassium fertilizer levels. The highest level of potassium application (4000 mg L^{-1}) resulted in the greatest plant height (101.6 cm), whereas the control treatment (0 mg L^{-1}) produced the lowest plant height (86.3 cm). The increase in plant height with elevated potassium levels can be attributed to the role of potassium in enhancing photosynthetic activity, promoting cell division, and stimulating the growth of meristematic tissues (Abd et al., 2021, Musa et al., 2023). Furthermore, a significant interaction was observed between cultivar and potassium fertilizer level. An increase in potassium application led to increased plant height across all cultivars. The highest value was recorded in the Al-Rasheed cultivar at the 4000 mg L^{-1} level (107.9 cm), which was not significantly different from IPA 99 under the same potassium level (106.0 cm). This reinforces the role of potassium in stimulating cell division and internode elongation, thereby contributing to increased plant height.

Table 2. Effect of potassium fertilizer and wheat cultivars on plant height (cm)

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	89.7	95.3	106.0	97
Bohouth 22	83.6	92.2	99.8	91.9
Al-Rasheed	90.9	95.3	107.9	98.0
Abu Ghraib 3	81.4	87.6	92.5	87.2
Mean	86.3	92.6	101.6	
L.S.D	(V):1.22 , (K): 1.73, (VxK):3.43			

Flag Leaf Area (cm²):

Table 3 shows that the cultivar IPA 99 recorded the highest mean flag leaf area at 40.15 cm², with a statistically significant difference compared to the other cultivars. In contrast, Al-Rasheed had the lowest mean value at 31.87 cm². The observed variation among cultivars in this trait is likely due to differences in their genetic makeup, which influences both the duration of flag leaf development and its expansion. These findings are consistent with those reported by (Al-Rawi & Abood 2021, Al-Hadithi 2018). Regarding potassium foliar application, the results indicate that plants treated with the 4000 mg L^{-1} concentration exhibited the highest mean flag leaf area at 39.14 cm². Conversely, plants sprayed with distilled water (control treatment) recorded the lowest mean at 34.31 cm². The superior performance of potassium-treated plants in terms of flag leaf area can be attributed to the positive role of potassium in several physiological and biochemical processes, including enhanced cell division and expansion, differentiation and growth, improved photosynthetic efficiency, and increased nutrient uptake, which collectively promote larger leaf area (Marasini et al., 2016, Abood & Salh 2018). Moreover, a significant interaction between cultivars and potassium application levels was observed. The highest flag leaf area was found in IPA 99 treated with 4000 mg L^{-1} potassium, reaching 42.05 cm². In contrast, the lowest value was recorded in Al-Rasheed under the 0 mg L^{-1} treatment, with a mean of 29.64 cm².

Table 3. Effect of potassium fertilizer and wheat cultivars on flag leaf area (cm²)

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	42.05	39.59	42.05	40.15
Bohouth 22	39.80	38.23	39.80	37.42
Al-Rasheed	33.87	23.09	33.87	31.87
Abu Ghraib 3	40.85	37.55	40.85	37.30
Mean	39.14	36.87	39.14	
L.S.D	(V):1.22, (K): 1.73, (VxK):3.4			

Number of Spikes per Square Meter

Table 4 reveals significant differences among cultivars in the number of spikes per square meter. The cultivar IPA 99 recorded the highest mean at 442.6 spikes m^{-2}, which was not significantly different from Al-Rasheed (438.7 spikes m^{-2}). In contrast, Abu Ghraib 3 had the lowest value at 405.3 spikes m^{-2}. The number of spikes is one of the earliest yield components to develop and continues to evolve until shortly before flowering. As such, it is highly sensitive to environmental factors, particularly temperature and photoperiod, and is strongly influenced by the genetic makeup of the cultivar. Significant differences were also observed among potassium fertilizer levels. The 4000 mg L^{-1} treatment resulted in the highest spike density, reaching 478.6 spikes m^{-2}, while the control treatment (0 mg L^{-1}) recorded the lowest at 378.4 spikes m^{-2}. The positive effect of potassium on this trait is likely related to its role in activating more than 75 enzymes involved in physiological processes essential for tiller development and spike formation (Hafeez et al., 2021, Ibrahim & Abdulhamed 2023). There was no significant interaction between cultivar and potassium level for this trait, indicating that all cultivars responded similarly to potassium application in terms of spike number.

Table 4. Effect of potassium foliar application and wheat cultivars on number of spikes per m²

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	394.2	447.5	486.1	**442.6**
Bohouth 22	366.2	472.3	474.3	**422.7**
Al-Rasheed	387.5	430.1	498.7	**438.7**
Abu Ghraib 3	365.1	395.1	455.1	**405.3**
Mean	378.4	425	478.6	
L.S.D	(V):11.21, (K): 7.65, (VxK): NS			

Number of Grains per Spike (grains spike^{-1})

Table 5 presents significant differences among the studied wheat cultivars in the number of grains per spike. The cultivar IPA 99 recorded the highest mean at 62.18 grains spike^{-1}, while Al-Rasheed exhibited the lowest mean of 52.81 grains spike^{-1}. This variation among cultivars is likely attributed to genetic differences influencing the number of fertile florets per spike. These florets ultimately determine the final grain number, and their development may be affected by both genetic and environmental factors as well as their interactions. Several studies, including those by (Fadel et al., 2022, Abas et al., 2024). have reported that the success of pollen germination and fertilization is influenced by factors such as appropriate sucrose concentrations. Furthermore, a high rate of floret abortion within a spike is often associated with limited availability of assimilates due to intra-plant competition among flowers. The same table also shows that potassium application significantly influenced this trait. The highest number of grains per spike (62.20 grains spike^{-1}) was observed at the 4000 mg L^{-1} potassium level, while the control treatment (0 mg L^{-1}) resulted in the lowest mean (49.86 grains spike^{-1}). The positive effect of potassium is attributed to its role in enhancing nitrogen uptake, which subsequently increases grain protein content (Hamad et al., 2024). This improvement in nitrogen and potassium nutrition enhances photosynthetic efficiency and facilitates the translocation of assimilates from source leaves to developing reproductive organs, particularly during flowering. In addition, potassium contributes to the regulation of plant hormones that govern flower formation, pollination, and fertilization processes.

It is also evident from the table that the interaction between cultivar and potassium level was not significant, indicating a consistent response across all cultivars to potassium application in terms of grain number per spike.

Table 5. Effect of potassium foliar application and wheat cultivars on number of grains per spike (grains spike^{-1})

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	64.90	69.87	62.18	97
Bohouth 22	60.63	61.76	57.45	91.9
Al-Rasheed	51.12	59.87	52.81	98.0
Abu Ghraib 3	56.11	57.32	54.48	87.2
Mean	49.86	58.12	62.2	
L.S.D	(V):3.34, (K): 2.53, (VxK): NS(			

1000 Grain Weight (g)

The results presented in Table 6 indicate that there was no significant effect of the studied cultivars on thousand grain weight. However, the potassium fertilizer levels had a significant influence on this trait. The application of 4000 mg K L^{-1} resulted in the highest thousand grain weight, recording 44.50 g, which was significantly superior to both the 2000 mg L^{-1} and control (0 mg L^{-1}) treatments. The control treatment recorded the lowest mean value of 39.06 g. Additionally, a significant interaction was observed between potassium fertilizer levels and wheat cultivars. The highest value was recorded in IPA 99 treated with 4000 mg K L^{-1}, reaching 45.60 g, while the lowest was observed in Al-Rasheed under the control treatment (distilled water), with a mean of 34.44 g (Fellahi et al., 2018, Saleh et al., 2024).

Table 6. Effect of potassium foliar application and wheat cultivars on thousand grain weight (g)

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	40.1	42.1	45.6	42.6
Bohouth 22	40.23	40.87	44.8	42.0
Al-Rasheed	34.44	41.1	43.92	39.82
Abu Ghraib 3	41.50	42.5	43.7	42.56
Mean	39.06	41.62	44.50	
L.S.D	(V): NS, (K): 2.2, (VxK): 3.08			

Grain Yield (t ha^{-1})

The results presented in Table 7 indicate that there were significant differences among cultivars in grain yield. The cultivar Bohouth 22 produced the highest mean yield, reaching 7.16 t ha^{-1}, while the lowest yield was recorded for Abu Ghraib 3, at 5.21 t ha^{-1}. The superior performance of Bohouth 22 is attributed to its higher grain weight and favorable climatic conditions during the season, which enhanced the plant's ability to express its genetic potential, thereby increasing yield (Grzesiak et al., 2019, Reham et al., 2019). The table also shows that potassium fertilizer levels had a significant effect on grain yield. The application of 4000 mg K L^{-1} resulted in the highest grain yield of 6.64 t ha^{-1}, whereas the control treatment (0 mg K L^{-1}) recorded the lowest yield at 5.36 t ha^{-1}. This improvement in yield is due to the positive role of potassium in increasing the number of grains per spike, which subsequently contributed to a higher yield per unit area. These findings are consistent with those of (Hamad & Abdulhamed 2023, Saleh et al., 2024). Furthermore, a significant interaction was observed between cultivars and potassium levels. The highest yield (7.95 t ha^{-1}) was obtained from the combination of Bohouth 22 with 4000 mg K L^{-1}, while the lowest yield (4.70 t ha^{-1}) was recorded in the control treatment of Abu Ghraib 3. This supports the notion that both genetic potential and nutrient availability play essential roles in determining final yield.

Table 7. Effect of potassium foliar application and wheat cultivars on grain yield (t ha^{-1})

Cultivar	Potassium fertilizer (mg L^{-1})			Mean
	0	2000	4000	
IPA 99	5.72	6.61	7.04	6.46
Bohouth 22	5.12	6.21	6.85	6.06
Al-Rasheed	4.85	6.04	6.13	5.67
Abu Ghraib 3	4.20	5.09	5.65	4.98
Mean	4.97	5.99	6.42	
L.S.D	(V): 0.88, (K): 1.42, (VxK): 1.87			

Conclusion:

The results of the study demonstrated that the wheat cultivar IPA 99 exhibited a significant superiority in response to foliar application of 4000 mg L^{-1} potassium fertilizer, compared to the other cultivars and fertilizer levels. This indicates the efficiency of this specific combination in enhancing grain productivity.

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