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*Original Article*

# Foliar application of Potassium to Enhance Growth and Yield of Bread Wheat Cultivars Under Rainfed and supplemental Irrigation

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**ABSTRACT**

A field study was conducted during the winter season of 2023-2024 in Mosul City, Nineveh Governorate, northern Iraq, to evaluate the impact of potassium fertilizer application on the growth and productivity of wheat grown under varying irrigation conditions. The experiment was designed with a randomized complete block design (RCBD) in a split-split-plot arrangement with three replications. The main plots owned two irrigation conditions (rainfed and supplemental irrigation), the sub-plots contained three potassium fertilizer levels (0, 1.5, and 3.0 L/ha), and the sub-sub-plots involved six bread wheat cultivars (Tamoz 2, Wafia, Jihan 99, Adna 99, Aliz 66, and Aras). The findings revealed that Wafia cultivar exhibited the highest values of number of days to flowering (126.97 day), spikes number (326.2 spike/m2), grains number (51.73 grain/spike), biological yield (8165 kg/ha), grain yield (2946 kg/ha). Additionally, the application of potassium at 3 L/ha significantly improved various growth traits. Furthermore, supplemental irrigation enhanced all observed traits. To sum up, increased potassium application boosted plant drought resistance and improved growth and yield traits.



*Keywords: Foliar potassium application, Bread Wheat, Cultivars, Grain yield, Rainfed, Supplemental irrigation.*

## 1 Introduction

Bread wheat (*Triticum aestivum* L.) used as a staple food worldwide and plays a crucial role in human nutrition. Given its importance, agricultural research has extensively focused on improving wheat production to meet rising global demands. The increasing population necessitates strategies to enhance wheat yield, particularly under water-limited conditions, to determine cultivar responses to varying irrigation conditions [1]. In Iraq, the total wheat cultivation area reached approximately 8,177 thousand dunums in 2024, with 8,119 thousand dunums harvested, producing around 5,234 thousand tons. Among the wheat-producing regions, Nineveh Governorate ranked highest, contributing approximately 27% (1,394 thousand tons) of Iraq's total wheat production with the ongoing population surge and increasing wheat demand, enhancing wheat productivity has become a key global challenge. Research has indicated that potassium fertilizers significantly contribute to wheat growth and yield [2]. Potassium is a crucial macronutrient required in substantial amounts, second only to nitrogen. While it does not form part of organic compounds within plants, potassium is essential to various physiological functions, including photosynthesis activation. It also delays plant senescence, enhances nutrient and water uptake, and activates over 85 plant enzymes [3]. Foliar fertilization is considered an important method for applying diluted nutrient solutions by spraying onto the plant's vegetative parts. It plays a significant role in enhancing growth and productivity, as well as, reduces the energy required for the translocation of nutrient ions within the plant. Moreover, it meets the plant's nutrient demands during critical and sensitive growth stages, especially when the roots are unable to supply sufficient nutrients [4]. Wheat crop often depends on rainfed conditions, supplemental irrigation is vital to meet water demands during critical growth stages. Irrigation is a crucial agricultural practice that significantly affects wheat crop yield. The number of irrigations and the amount of irrigation water applied to wheat depend on soil type, climatic condition, and the irrigation method used. Irrigation is a decisive factor in determining the yield of common wheat, particularly since most of this crop is grown under rainfed conditions. This implies that, in many growing seasons, rainfall alone is insufficient to meet the crop's water needs. Therefore, supplemental irrigation becomes essential to meet the water requirements of the wheat crop throughout its growth stages in order to achieve optimal yield and quality.

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Supplemental irrigation helps improve and stabilize production and ensures uniform plant growth, especially when rainfall is inadequate during critical growth stages. The flowering and grain filling stages are the most important periods for supplemental irrigation in the life cycle of bread wheat, as adequate water supply during these stages is vital for achieving high grain yield [5]. The current study aims to identify the best-performing wheat cultivar and the optimal potassium fertilizer level to maximize yield efficiency under varying irrigation conditions.

## 2 Materials and methods

### 2. 1 Field trial design

The experiment was conducted in Nineveh Governorate, specifically in Bashiqa, Mosul district, during the 2023-2024 winter season. The study included three factors: the first was two irrigation conditions (rainfed and supplemental irrigation). The rainfed irrigation (relying solely on rainfall), while supplemental irrigation which involves providing a full irrigation dose when the plant required water during its growth stages. In over all, five full supplemental irrigations were applied only to the supplemental irrigation field during the following stages: seedling growth, tillering, stem elongation, flowering, and grain filling. Each supplementary irrigation (approximately 20 mm) was estimated based on the volume of water applied relative to the plot area, using a standard field calculation method.

The second factor was included three potassium fertilizer levels (0, 1.5, and 3.0 L/ha). The third factor was six bread wheat cultivars (Tamoz 2, Wafia, Jihan 99, Adna 99, Aliz 66, and Aras). Wheat seeds were sown at a rate of 250 seeds per square meter, with a row spacing of 17.5 cm. The wheat seeds used in this study were obtained from the College of Agriculture and Forestry, University of Mosul, Iraq. The study was conducted using a randomized complete block design (RCBD) arranged in a split-split-plot layout, with three replications for each treatment, comprising 54 experimental units (2×1 meters each). The main plots were included the two irrigation conditions, and the sub-plots were the potassium fertilizer levels, and the sub-sub-plots were bread wheat cultivars. FOLIARTAL K50, a liquid foliar fertilizer rich in potassium ($K_2O$), was applied at two important wheat growth stages (stem elongation and booting stages). This formulation is characterized by its rapid and efficient foliar absorption, ensuring effective potassium delivery to the crop during these critical developmental phases.

### 2. 2 Phenotyping and sample collection from field trial

At the end of the season, the following traits were measured: plant height (cm) was measured at full flowering by taken from the base of the plant at the soil surface to the tip of the spike on the main tiller. Flag leaf area of ten randomly selected plants at flowering stage was calculated using the equation: Flag leaf area (cm²) = Leaf length × Maximum leaf width × 0.95

Number of days to 50% flowering was recorded as the number of days from sowing to the point at which 50% of the wheat plants in each plot had flowered. Chlorophyll content (SPAD) was determined at 100% flowering using a SPAD-502 Plus Chlorophyll Meter. The average SPAD value of ten flag leaves per experimental unit was used for analysis. Number of days of vegetative growth stage (Z1–Z50**)** was calculated as the number of days from sowing to the beginning of heading stage, according to the Zadoks growth scale. Grain filling period (Z51–Z99) was determined as the duration from the beginning of flowering to physiological maturity, according to the Zadoks growth scale. Spikes number ($m^2$) was obtained by counting all the spikes within experimental unit. Grains number (spike) was calculated by counting the grains from ten randomly selected wheat spikes per experimental unit. 1000-grains weight (g) was determined by manually counting and weighing 1000 grains randomly sampled from the harvested grain yield. Biological yield and grain yield (kg/ha) was estimated by harvesting both grain and straw of each experimental unit, and the total dry weight was converted to kilograms per hectare. Harvest index (%) was determined by dividing the grain yield to the biological yield and multiplying by 100, using the following equation:

Harvest Index (%) = (Grain yield (g/m²) ÷ Biological yield (g/m²) × 100

### 2. 3 Soil and Climatic Conditions

Random soil samples were collected from various locations within the field at a depth of 0–20 cm. These samples were carefully mixed to determine the physical and chemical properties of the soil. The analysis was conducted at the Central Laboratory, College of Agriculture and Forestry, University of Mosul. The results of the soil analysis are presented in the supplementary Table (1), whereas the supplementary Table (2) shows the amount of rainfall recorded during the agricultural season.

### 2.4 Statistical analysis

Analysis of variance (ANOVA) was performed using the Genstat software (Eighteenth Edition; 18.1.0.17005, 2015, UK). Mean comparisons were performed using Duncan's Multiple Range Test, as described by [6].

## 3 Results and discussion

Significant variations were observed among wheat cultivars regarding plant height (Table 1). Aliz 66 attained the highest height (102.50 cm), while Wafia was the shortest (76.44 cm), possible due to genetic variation and adaptability to environmental conditions [7]. High potassium application (3 L/ha) resulted in increased plant height (88.17 cm), compared to the control (81.56 cm), due to improved photosynthetic efficiency and cell elongation [8]. The supplemental irrigation caused a significant increase in plant height (86.99 cm), while the rainfed field showed the lowest average at (81.85 cm). Supplemental irrigation helps sustain the photosynthesis process in irrigated wheat plants more efficiently and for a longer duration compared to wheat plants depend on only on rainfall condition. This contributes to additional plant growth, which is reflected to the plant height [9].

Regarding flag leaf area, Aras cultivar exhibited the largest leaf area (49.76 cm²), whereas Adna 99 recorded the smallest (36.98 cm²), attributed to genetic influence [3]. The 1.5 L/ha potassium level resulted in the highest leaf area (43.12 cm²), followed by 3 L/ha (42.03 cm²), while control treatment provided the lowest (38.86 cm²). Increased leaf area is linked to potassium's role in enhancing photosynthesis [10]. The supplemental irrigation also led to a significant maximized in the flag leaf area, recording the highest average value (45.29 cm²), while the rainfed field recorded the lowest average at (37.38 cm²). The increase in the flag leaf area under supplemental irrigation is attributed to the positive role of water in maintaining cell turgidity and expansion [1].

In the Table (1) showed clear significant differences in the total numbers of days to the flowering date. The wheat cultivar Wafia recorded the highest value of flowering date (126.97 days), whereas the cultivar Aras recorded the lowest value recorded (120.87 days). This could be explained by the fact that the flowering trait in wheat crop is genetically controlled. Wheat is classified as a long-day plant, where an increase in light duration accelerates flowering [11].

**Table 1:** Physical and Chemical Properties of the Field Soil.

| No | Physical and chemical properties | Location of the soil of Bashiqa |
|---|---|---|
| 1 | %Clay | 37.50 % |
| 2 | %Silt | 24.65 % |
| 3 | %Sand | 37.70 % |
| 4 | Soil Texture | Silty Clay |
| 5 | %Organic Matter | 2.6 % |
| 6 | N (PPM) | 2.7 |
| 7 | K (PPM) | 28 |
| 8 | P (PPM) | 10.60 |
| 9 | EC (us/cm) | 1400 |
| 10 | PH | 8.5 |

Central Laboratory / College of Agriculture and Forestry / University of Mosul

Regarding fertilizer levels, the application of (3 L/ha) resulted in the maximum value (130.05 days), whereas control treatment (0 L/ha) documented the minimum value (116.7 days). This effect may be due to delayed senescence in plants. Several recent studies have found that the application of different concentrations of potassium fertilizer leads to delayed senescence and extends the grain-filling period in cereal crops [12].

Additionally, the supplemental irrigation significantly increased the number of days to flowering date, with the maximum value recorded (128.18 days), while rainfed conditions resulted in the minimum value recorded (118.43 days). This might be because the low humidity in dry field, which leads to early flowering of plants and seed production to preserve the species due to high temperatures and low water in the soil [13].

In the table (1) presented that cultivar Tamoz 2 showed the highest chlorophyll content (SPAD 47.181), while Aliz 66 had the lowest (SPAD 44.640). The differences in chlorophyll content are attributed to genetic variation and environmental interactions [14]. The (3 L/ha) potassium application resulted in the highest chlorophyll content (48.535 SPAD), while the control treatment had the lowest (44.452 SPAD). Potassium plays a crucial role in enzyme activation, including those involved in chlorophyll production, which is why potassium application enhances chlorophyll content [15]. The irrigation condition also produced important increase in the chlorophyll content of flag leaf. The supplemental irrigation produced the maximum value chlorophyll content of flag leaf (49.142 SPAD), whereas the minimum value found under rainfed conditions (43.420 SPAD). The reason for the reduction in the chlorophyll content in the plant may be due to the lack of water in the soil and inside the plant, which affects the process of photosynthesis. Water stress leads to a reduction in pigment production, including chlorophyll, due to stomatal closure, decreased $CO_2$ availability, alterations in cytoplasmic composition, and dehydration of cell membranes [16].

Significant differences were observed among the wheat cultivars regarding the number of days of vegetative growth stage. The cultivar Wafia was recorded the highest number of days (121.00 days), while the cultivar Aras was recorded with the lowest average (115.45 days). This difference was attributed to the longer vegetative period of Wafia, as it is classified as a late-maturing variety. In contrast, Aras was classified as an early-maturing cultivar, generally characterized by a shorter vegetative stage [17].

Potassium fertilizer levels had a significant effect on the duration of the vegetative growth stage. The application of 3.0 L/ha resulted in the longest period, averaging (124.30 days), while the control treatment 0 L/ha showed the shortest duration, with an average (111.22 days). This increase at the higher level is likely due to improved potassium availability and elevated chlorophyll content in the leaves, which support prolonged vegetative development, which led to delay plant senescence and thus extend the vegetative period, allowing more nutrient accumulation [18]. Furthermore, supplemental irrigation significantly extended the duration of the vegetative stage, with an average of (122.75 days) compared to (112.78 days) under rainfed conditions.

Significant variation was observed among the wheat cultivars in relations grain filling period. The cultivar Wafia was recorded with the longest duration (35.67 days), whereas Adana 99 was recorded with the shortest duration (30.03 days). This difference was attributed to the delayed and slower senescence in the late-maturing cultivar Wafia compared to early-maturing cultivars, resulting in a prolonged grain filling period [3].

A significant effect was also observed for potassium fertilizer levels. The high level (3 L/ha) was associated with the highest average (34.12 days), while the control (0 L/ha) was recorded with the lowest average (28.86 days). The increase was linked to the role of potassium application during late growth stages (booting and flowering) in delaying leaf senescence, enhancing nitrogen utilization, and maintaining photosynthetic activity. This contributed to greater assimilate production and transfer to the grains, ultimately improving grain weight through increased accumulation of carbohydrates and proteins [19].

Supplemental irrigation was also found to significantly affect the number of days of the reproductive stage, with the highest average (33.75 days) being recorded under supplemental irrigation, while the lowest (29.52 days) was recorded under rainfed conditions.

The data shown in Table (2), Wafia produced the highest spikes number/m2 (326.2 spikes/m²), while Aliz 66 had the lowest (237.4 spikes/m²), potentially due to genetic differences [20]. Potassium application at 1.5 L/ha resulted in the highest spike number/m$^2$ (395.6 spikes/m²), while the control had the lowest (238.9 spikes/m²), suggesting that potassium enhances photosynthesis and carbohydrate metabolism, which influence yield components [21]. Under irrigation conditions, the supplemental irrigation condition had the highest spikes number/m$^2$, with average (284.7 spikes/m²), compared to rainfed condition (263.8 spikes/m²). A possible explanation is that both water deficiency and high temperatures reduce the number of spikes in the plant, and accelerate the leaf senescence which leads a decrease in the grain yield [22].

In terms of grains number/spike, Wafia outperformed other cultivars (51.73 grains/spike), while Aliz 66 recorded the lowest (43.97 grains/spike). The variation in the number of grains per spike among soft wheat cultivars may result from genetic differences in spike length across bread wheat cultivars, which is effectively related to the number of grains per spike [23]. The application of (3 L/ha) potassium significantly increased the grains number/spike (50.75), compared to the control treatment (45.02 grains/spike). This effect is attributed to the role of potassium in enhancing chlorophyll concentration and promoting efficient nutrient translocation. Potassium contributes to the activation of enzymes involved in chlorophyll biosynthesis, improves water uptake, and maintains cell turgor, all of which support better photosynthetic activity and sustained leaf greenness [24].

Supplemental irrigation also significantly increased grains number/spike, with the highest average recorded at (51.34 grains/spike), compared to the rainfed field condition (45.75 grains/spike). The reason may be due to that wheat is a crop sensitive to water deficiency especially at flowering stages, and related negatively pollen germination, fertilization, stigma viscosity, and grain growth, which reduces the grains number per spike [25].

Table (2) presented an important impact of thousand grains weight by studied factors. The Aliz 66 cultivar achieving the maximum value of thousand grains weight (44.91 g), whereas the Tamoz 2 cultivar gave the minimum value (37.86 g). Increasing in thousand grains weight may be attributed to the compensatory value among yield components, as Aliz 66 recorded the lowest number of grains per spike (Table 1). This reduction in grain competition for nutrients during the filling period resulted in larger grain size, which positively reflected an increase in thousand grains weight. Additionally, this cultivar exhibited a high flag leaf area, contributing to an increased remaining photosynthetic output during the grain-filling period [26].

**Table 2:** Rainfall amounts and temperatures during the agricultural season 2023/2024 in the Bashiqa location.

| No | Month | Rainfall amount (mm) | Min. Temperatures (c°) | Max. Temperatures (c°) |
|---|---|---|---|---|
| 1 | November | 66 | 12.39 | 21.53 |
| 2 | December | 51.5 | 6.5 | 14.96 |
| 3 | January | 90.5 | 7.1 | 15.93 |
| 4 | February | 87 | 8.62 | 20.43 |
| 5 | March | 130 | 17.07 | 30.76 |
| 6 | April | 58 | 18.97 | 32.04 |
| 7 | May | 84.5 | 29.87 | 43.65 |

Nineveh Agriculture Directorate / Planning Department

Regarding potassium fertilizer levels, the (3 L/ha) treatment resulted in the maximum value of thousand grains weight (42.70 g), whereas the control treatment (0 L/ha) recorded the lowest mean (37.28 g). This could be due to the influence of the role of potassium in delaying leaf senescence in soft wheat plants and maintaining leaf activity in the photosynthesis process for a longer period with higher efficiency [27].

Regarding irrigation condition, the supplemental irrigation significantly increased thousand grains weight, with the highest value recorded (41.73 g), while rainfed conditions resulted in the minimum value (38.97 g). This could because the limited availability of soil moisture, which slows down the transport of nutrients to the plant, reduces photosynthetic efficiency, and decreases the translocation of nutrients to the grains. As a result, grain filling is incomplete, leading to a decline in thousand grains weight [28].

Table (2) indicate a significant influence in the biological yield. Wafia exhibited the highest biological yield (8165 kg/ha), while Tamoz 2 had the lowest (6425 kg/ha). The variation among the cultivars in this trait could be due to differences in genetic diversity, which led to their difference in the biological yield. The clear difference in biological yield between irrigated and nonirrigated fields is attributed to a prolonged dry period due to the interruption of rainfall. As a result, the application of supplementary irrigation played a key role in enhancing biological yield [29]. The (1.5 L/ha) potassium level achieved the highest biological yield (8215 kg/ha), which was statistically similar to (3 L/ha), while the control had the lowest (6375 kg/ha), The reason for the superiority of this level of fertilizer is that it was superior in giving the highest number of spikes, which came from the highest number of branches in this characteristic, and thus increasing the dry weight of the wheat plant at this stage, and then this increase was reflected in the biological yield [21]. Supplemental irrigation condition also significantly increased the biological yield, with the highest average recorded at (8110 kg/ha), compared to (6970 kg/ha) in the rainfed condition. This may be due to the fact that supplementary irrigation treatment creates more suitable conditions for the production of late shoots, which increases the plant biomass and thus increases the dry weight of the plant [30].

In the Figure 1, the total grain yield was highest in Wafia (2946 kg/ha), while the lowest in Tamoz 2 (1833.5 kg/ha). The superiority of the Wafia variety could be due to its advantages in the components of the yield represented by the increase in the number of spikes and number of grains per spike, which positively reflected to the final grain yield [31]. Potassium application under (1.5 L/ha) resulted in the highest grain yield (2616 kg/ha), similar to (3 L/ha) (2577 kg/ha), while the control produced the minimum (1932.5 kg/ha). Increased grain yield is linked to improved spike formation and enhanced photosynthetic efficiency [3]. Supplemental irrigation condition also significantly increased total grain yield, with the highest average recorded (2524.5 kg/ha), compared to (2276 kg/ha) in the rainfed condition. Perhaps the reason is that the availability of sufficient amounts of water for the plant increases the absorption of nutrients, which stimulates the activation of the photosynthesis process in the plant, which results in an increase in the period of grain filling with dry matter and an increase in grain yield [32].

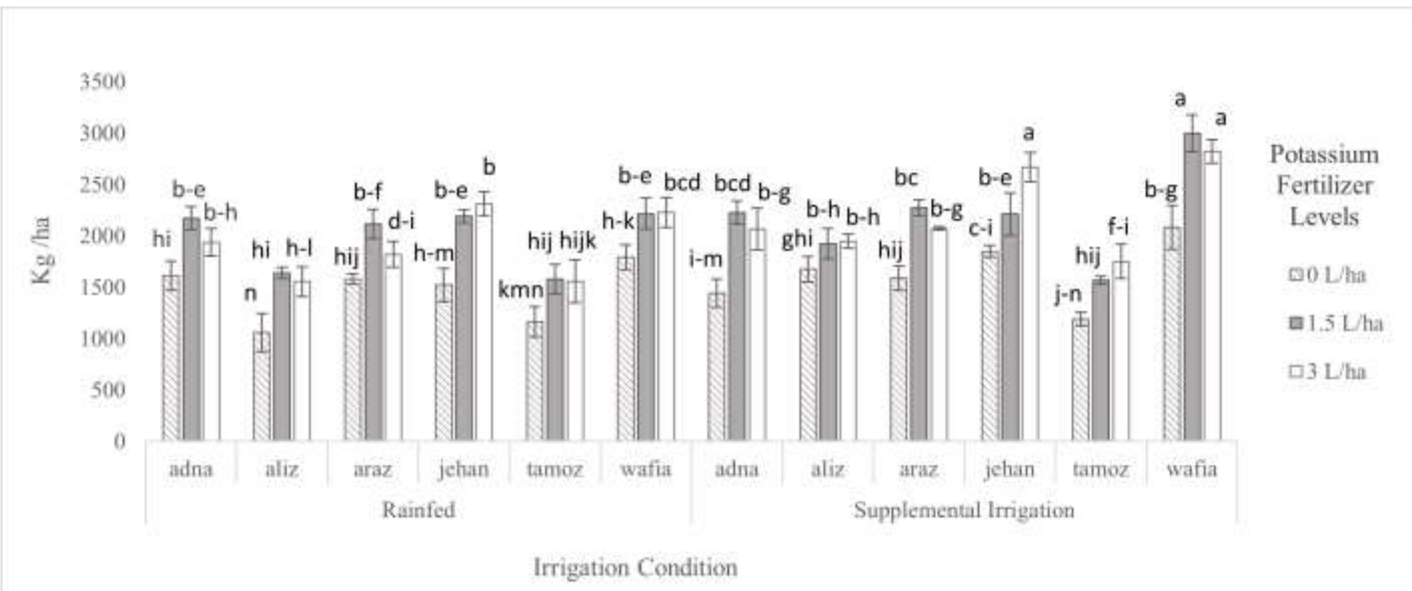


**Figure 1:** Effect of cultivars, Potassium Fertilizer Levels and Irrigation Condition on grain yield.

In regards, harvest Index, the cultivar Wafia achieving the highest value of (36.05%), whereas the cultivar Al-Ezz 66 recorded the lowest value (27.97%). This difference is attributed to the superior grain and biological yield of Wafia, as well as its efficiency in enhancing the translation of photosynthetic products and storing them in the grains [33].

The potassium fertilizer level of 3 L/ha recorded the highest value of harvest index (31.88%), while the control treatment (0 L/ha) showed the lowest value (30.29%). This improvement may be due to the enhanced potassium content in the vegetative parts and its overall absorption, which allowed the plant sufficient time to perform essential physiological activities for dry matter accumulation. Moreover, the high enzymatic activity within the plant, driven by the extended vegetative growth period, contributed to an increased grain yield per unit area, thereby reflecting positively on the percentage of harvest index [34]. There were no significant differences in harvest index in regards the application of supplemental irrigation.

## 4 Conclusions

Applying potassium fertilizer, particularly at higher levels (3 L/ha), significantly improved wheat growth traits, including plant height, leaf area, and chlorophyll content. Supplemental irrigation further enhanced growth and yield. The results suggest that increased potassium application enhances wheat drought tolerance, promoting better yield and growth under diverse irrigation conditions.

## Author Contributions

The authors collaboratively designed and performed the research plan. They carried out inclusive data analysis and merged the results into a unified manuscript. Their joint efforts and complementary skills were essential at every stage, reflecting their strong commitment to the success of this study.

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