Investigation of Foliar Spraying with Potassium and Iron on Growth and Nutrient Uptake in Cowpea (*Vigna unguiculata* L.)

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Abstract. A field experiment was conducted at the Experimental Farm of College of Agriculture, Basrah University, Iraq, to investigate the effect of foliar application of three concentrations of potassium (0,1500,3000 mg K L^{-1}), Symbolize it with symbols K0,K1, and K2,and three concentrations of Iron (0,200, 400 mg Fe.L^{-1}),F0, F1 andF2 on growth and nutrient uptake of cowpea. The experiment was laid out according to the factorial experiments with a Randomized Complete Block Design (R.C.B.D) with three replicates. Results indicated that foliar potassium and iron spray greatly improved plant growth and nutrient uptake, The second level of potassium fertilizer (3000 mg L^{-1} was superior to the highest averages for the studied traits, plant height, branches number, leaves number, leaf area, wet and dry weight of plant, % protein and potassium and Iron uptake, and it gave averages of 177.00 cm, 8.44 branch $plant^{-1}$ 46.54 leaf $plant^{-1}$, 2125.10 cm^2,172.05g, 54.92 g, 22.34% and 21.40, 6.84 mg kg^{-1} respectively. The second level of Iron fertilizer (400 mg L^{-1} was superior to the highest averages for the studied traits, plant height, branches number, leaves number, leaf area, wet and dry weight of plant, % protein and potassium and Iron uptake, and it gave averages of 190.80 cm, 10.77 branch $plant^{-1}$, 56.89 leaf $plant^{-1}$,2348.57 cm^2, 198.41 g, 73.27 g, 23.44% and 24.77, 6.44 mg kg^{-1} respectively. The interaction between the elements achieved a significant effect, as the combined higher levels of both nutrients achieved the best performance across all measured characteristics.

Keywords. Foliar fertilization, Potassium and application, Nutrient efficiency, (Vigna unguiculata L.).

1. Introduction

Cowpea (Vigna unguiculata L.) beans belong to the Leguminosae family and are a very important and versatile crop widely cultivated in arid and semi-arid tropical regions, where green pods and dry seeds are used as food because they contain high amounts of proteins, carbohydrates, and minerals; therefore, they are included in the diets of millions of people around the world. Approximately 48–56% carbohydrates, 5.1% fat, and 24–28% protein is found in bean seeds [1]. Although this crop is important, Iraq's productivity is still quite low compared to global production.

Scientists want to examine every approach that could increase the output of this crop. One of the most innovative methods is to apply the necessary nutrients, whose lack could negatively affect crop

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growth, and spraying the plant canopy with a solution containing various nutrients is the most effective method of replenishing nutrient deficiencies. Foliar application is one of the best techniques because plants can fully utilize fertilizers, which cause less environmental pollution [2]. Therefore, plants may absorb nutrients through their leaves more rapidly than through their roots, making foliar spray an effective method for nutrient delivery [3]. One of the minerals required for plant development and productivity is potassium (K), which the ability to activate approximately 75 enzymes, supports several crucial biological functions in plants, and regulates ionic balance [4]. This component is often required by plants to generate ATP, which regulates photosynthesis by moving carbohydrates from the source to the sink [5].

Iron (Fe) is vital for the activation of numerous enzymes, including cytochrome oxidase, catalase, and peroxidase, which can act as cofactors or activators in respiration. Fe plays a key role in the antioxidant defense system of plants and aids in the metabolism of nucleic acids. Nitrogen fixation is performed by the primary nitrogenase enzyme component. Consequently, it is thought to be essential for plant growth, and it lack causes problems with photosynthesis in plants. Thus, a field experiment was conducted to investigate the effect of foliar application of K and Fe on cowpea growth.

2. Materials and Methods

A field experiment was conducted at the Experimental Farm of the College of Agriculture, Basrah University, Iraq, with the aim of investigating the effect of foliar application of three concentrations of potassium (0,1500,3000 mg K L^{-1}) symbolized as K0,K1, and K2, respectively, and three concentrations of Iron (0, 200, and 400 mg Fe L^{-1}) symbolized as Fe0,Fe1, and Fe2, respectively, on the growth and nutrient uptake of cowpea.

The experiment was laid out according to the factorial design using a randomized complete block design (R.C.B.D) with three replicates. The soil texture was sandy loam with a pH of 8.35, E.C of 5.48 dSm^{-1}, organic carbon (0.30%), available nitrogen (50.71 mg kg^{-1}), phosphorus (5.47 mg kg^{-1}) and potassium (77.52 mg kg^{-1}). The plot area was 6 m2, each plot included 10 lines; and the distance between hills was 20 cm, 30 cm apart Ramshorn was sown on 7/4/2022. Nitrogen fertilizers were added as urea (46% N) at a rate of 50 kg N ha^{-1} in two doses, the first two weeks after emergence and the second dose at the flowering stage. spraying was carried out in two stages of plant growth, tillering and at the beginning of flowering stage, all foliar spraying activities were finished early in the morning due to low temperature, high relative humidity, and steady wind speed. The spraying process was performed using a backpack sprayer. Irrigation and weeding were performed whenever necessary. After the plants reached 50% flowering, the middle rows were considered to measure plant height, number of branches, number of leaves, leaf area, and wet and dry weights of the plants. Plant samples (leaves) were crushed after drying and then digested using sulfuric acid and perchloric acid in a ratio of 1:1 according to the method described previously [6]. A Kjeldahl device was used to measure nitrogen using the procedure described in [7]. The Uptake of N and K was calculated using the following equation:

$$\text{Nutrient uptake} = \text{Nutrient\%} \times \text{Dry weight}$$

A flame photometer was used to measure the potassium concentration using the procedure outlined in Eq. [8]. A di-acid mixture (HNO_3 + $HClO_4$) was used to digest a 1.0 g plant sample in a 9:4 ratio to determine the amount of Fe. The acid extract was used to measure the amount of Fe [9]. The GenStat statistical program was used for the statistical analysis of the traits. The averages were compared using the LSD ($P \leq 0.05$).

3. Results and Discussion

3.1. Plant Height (cm)

According to the analysis of variance, application of potassium and iron significantly ($p \leq 0.05$) increased cowpea plant height when compared with the control treatment. (Table 1). The higher plant height (152.33 cm) was observed with the application of Potassium K2 (1500 mg L^{-1}), which was also significantly different from K1 and control plants. K has a beneficial effect on plant height owing to its

metabolic function in activating photosynthesis and transporting its byproducts to areas of active development, in addition promoting meristematic cell division and elongation through optimal cell wall extension [10]. These findings are in agreement with [11], who reported that potassium levels significantly increased the height of mung bean plants. Results in Table 1 showed that iron had a significant effect on cowpea plant height when applied at higher concentrations. The maximum Plant height was recorded in treatment Fe2 (177.00 cm) whereas, the minimum plant height was recorded under control (104.96 cm). This increase is due to the role of Fe in oxidation and reduction processes, as well as the synthesis of chlorophyll, which increase the average rate of cell division and elongation. [12]. In addition, it was shown that the interaction of K2 with Fe2 produced the highest plant height (190.80 cm), whereas the control treatments(K0×Fe0) had the lowest plant height (89.10 cm).

Table 1. Effect of foliar application of Potassium and Iron on plant height (cm).

Treatments	K0	K1	K2	Average (Fe)
Fe0	89.10	111.90	113.90	104.96
Fe1	115.10	134.10	152.30	133.83
Fe2	161.40	178.80	190.80	177.00
Average (K)	121.86	141.60	152.33	
L.S.D. ($p \leq 0.05$)	K= 8.51 Fe=8.51 K*Fe=14.74			

3.2. Number of Branches (branch plant^{-1})

Data on the number of branches are presented in Table 2. Foliar application of Potassium and Iron and their interaction significantly **(**$p \leq 0.05$**)** affected the number of branches. The addition of both Potassium and Iron significantly increased the number of branches compared with that of the control. The maximum number of branches (8.44 branches plant^{-1}) was recorded under K1 treatment compared with the control (6.49 branches plant^{-1}). The availability of K on the leaf surfaces during most of the growth stages causes an increase in branches per plant. As a result, plant parts have a higher K content, which stimulates the formation of meristematic cells in lateral tissues and may result in more branches per plant [13]. Regarding the effect of iron application, significant differences were observed in the average number of branches per plant. The concentration of 200 mg L^{-1} (Fe2) produced the highest average number of branches (10.77 branches plant^{-1}) compared with Fe0 treatment (4.71 branches plant^{-1}). This might be due to the positive response of zinc in the production of IAA, sugar translocation, and response of Fe as a cofactor of many enzymes that help in various physiological processes, especially photosynthesis and chlorophyll synthesis, cell division, water and nutrient absorption, and ultimately help in improving various plant growth parameters. These results are corroborated by the findings of [14,15]. The interaction of K1 and K2 with Fe2 produced the highest number of branches (11.00 branch plant^{-1}),whereas the control treatment gave the lowest number of branches 4.26 branch plant^{-1}).

Table 2. Effect of foliar application of Potassium and Iron on the number of branches.

Treatments	K0	K1	K2	Average (Fe)
Fe0	3.88	6.00	4.26	4.71
Fe1	5.27	8.33	9.00	7.53
Fe2	10.33	11.00	11.00	10.77
Average (K)	6.49	8.44	8.08	
L.S.D. ($p \leq 0.05$)	K=0.854 Fe= 0.854 K*Fe=1.479			

3.3. Number of Leaves (leaf plant^{-1})

The number of leaves influenced by different concentrations of K and Fe is presented in Table 3. Foliar concentrations of both K and Fe significantly increased the number of leaves. Based on the results, the maximum number of leaves was observed after application of K2 46.54 leaf plant^{-1}, which was at par with K1 (44.89 leaf plant^{-1}), with an increase of 3.29% compared with the control. Application of Fe also improved the number of leaves per plant from 30.78 leaf plant^{-1} at control to 56.89 leaf plant^{-1} at 300 mg L^{-1}. The increase in leaves per plant with both potassium and iron foliar applications may be attributed to the associated increase in plant height and number of branches (Tables 1 and 2). In addition, the increased number of leaves produced by iron application may be

explained by the effects of iron on metabolism, biological activity, and the stimulatory effect it has on photosynthetic pigments and enzymatic activity, all of which promote plant vegetative growth. The interaction effect of K and Fe significantly increased the number of leaves in cowpea plants. The maximum number of leaves of 65.00 leaf plant^{-1} was at full dose of K and Fe (K2×Fe2) However, the minimum number leaves was found under control treatments (27.63) leaf plant^{-1}.

Table 3. Effect of foliar application of Potassium and Iron on the number of leaves.

Treatments	K0	K1	K2	Average (Fe)
Fe0	27.72	37.00	27.63	30.78
Fe1	28.77	42.67	47.00	45.48
Fe2	50.67	55.00	65.00	56.89
Average (K)	35.72	44.89	46.54	
L.S.D. (p≤ 0.05)	K=2.084 Fe=2.084 K*Fe=3.610			

3.4. Leaf Area (cm^2)

The effects of K and Fe applications and their interactions on leaf area was statistically significant (P≤0.01) (Table 4). The maximum leaf area (2125.1 cm^2) was obtained in plots that received K2 (3000 mg K L^{-1}). The minimum leaf area (1924.38 cm^2) was produced in the control plots. The stimulating effects of foliar K on the leaf area of plants could be attributed to enhance photosynthetic activity. Additionally, the number of branches and leaves on each plant increased, which provided more photosynthesis. Results of using foliar K concur with those of [16,17].

The application of Fe2 resulted in a maximum value (2348.57 cm^2), followed by Fe1 (2034.20 cm2), and the lowest value was observed in the control (1746.88 cm^2). Iron has been found to be a cofactor for about 140 enzymes that catalyze various biological events (18). Therefore, iron plays a crucial role in the growth and development of plants, including the synthesis of chlorophyll and chloroplast formation. Which is reflected in the increase in leaf area of the plant. The K2×Fe2 interaction recorded significantly higher leaf area (2401.34 cm^2) over the rest of the interactions and it was on par with K1×Fe2 (2388.34 cm^2), while the interaction of control treatments gave the lowest (1668.01 cm^2).

Table 4. Effect of foliar application of Potassium and Iron on the leaf area (cm^2).

Treatments	K0	K1	K2	Average (Fe)
Fe0	1668.01	1764.12	1808.51	1746.88
Fe1	1849.12	2088.04	2165.45	2034.20
Fe2	2256.03	2388.34	2401.34	2348,57
Average (K)	1924.38	2080.16	2125.10	
L.S.D. (p≤ 0.05)	K= 55.8 Fe=55.8 K*Fe=96.7			

3.5. Fresh Weight (g)

As shown in Table 5 fresh weight was significantly affected (P<0.05), because of the separate effects of K and Fe. Foliar application of K2 produced the maximum fresh weight (172.05 g plant^{-1}), followed by K1 (159.92 g plant^{-1}), while the minimum fresh weight (140.76 g plant^{-1}) was recorded in the control (K0). Data in Table 5 indicate that fresh weight increased with higher Fe concentrations. The data in Table 5 show that fresh weight increased with increasing Fe concentration. Thus, the highest fresh weight was obtained from Fe2 (198.41 g plant^{-1}).

The interaction between Potassium and Iron had a significant effect on fresh weight (Table 5). Potassium and Iron showed significant positive effects on all growth traits, such as plant height, number of branches, and leaf area (Table 2,3,4), which led to an increase in fresh weight, with The K2×Fe2 interaction recording the highest fresh weight (217.20 g plant^{-1}) as compared to the rest of the interactions, while the minimum fresh weight was observed in the K0×F0 treatment (98.95 g plant^{-1}).

Table 5. Effect of the foliar application of Potassium and Iron on the Fresh weight (g plant^{-1}).

Treatments	K0	K1	K2	Average (Fe)
Fe0	98.95	132.48	131.58	121.00
Fe1	135.08	157.51	167.37	153.32
Fe2	188.27	189.77	217.20	198.41

Treatments	K0	K1	K2	Average (Fe)
Average (K)	140.76	159.92	172.05	
L.S.D. (p≤ 0.05)	K=2.998 Fe=2.998 K*Fe=5.192			

3.6. Dry Weight (g plant^{-1})

Dry weight of the plant was significantly ($p<0.05$) influenced by foliar application of potassium, iron, and their interaction (Table 6). Dry weight increased with higher potassium levels. The highest dry weight was obtained in the plots that received K2 (54.92 g plant^{-1}). The minimum dry weight (41.67 g plant^{-1}) was produced in the control plots. The results showed significant differences in the dry weight with excessive concentration (Fe2) by giving it the highest dry weight (73.27 g plant^{-1}) compared to Fe0 treated plants (27.89 g plant^{-1}). The K2×Fe2 interaction recorded a significantly higher dry weight (79.73 g) than the rest of the interactions, while the minimum dry weight was found in the K0×F0 treatment (24.98 g plant^{-1}).

Table 6. Effect of the foliar application of Potassium and Iron on dry weight (g plant^{-1}).

Treatments	K0	K1	K2	Average (Fe)
Fe0	24.98	27.87	30.83	27.89
Fe1	31.02	34.23	54.20	39.81
Fe2	69.03	71.07	79.73	73.27
Average (K)	41.67	44.39	54.92	
L.S.D. (p≤ 0.05)	K=4.593 Fe= 4.593 K*Fe=7.956			

3.7. Protein Content %

The results showed statistically significant differences between foliar application concentrations of K and Fe, with significant effects of the interaction between the factors on the protein percentage of the plants (Table 7). Application of potassium at K2 treatment significantly increased protein content and uptake in the crop, which was significantly higher than all other concentrations (22.34%), whereas the lowest protein content was observed in the control. The superiority of the higher concentration of potassium fertilizer in protein concentration in the leaves can be attributed to the fact that increasing the amount of fertilizer increased its average absorption by the leaves, and thus increased its concentration within plant tissues, including the leaves. The highest protein percentage was obtained when the cowpeas were treated with Fe2 (23.44%). This is related to the role of iron in plant chlorophyll formation, respiration, photosynthesis, and symbiotic nitrogen fixation in plants. In contrast, the lowest protein percentage in seeds (20.55%) was from the Fe0 treatments. As for the interaction, K2×Fe2 showed a significantly higher protein content (24.12%) than the rest of the interactions, which was on par with K1Fe2 (24.07%).

Table 7. Effect of Potassium and Iron foliar application on the % protein.

Treatments	K0	K1	K2	Average (Fe)
Fe0	21.15	20.18	20.32	20.55
Fe1	21.34	21.76	22.58	21.89
Fe2	22.14	24.07	24.12	23.44
Average(k)	21.54	22.00	22.34	
L.S.D. (p≤ 0.05)	K= 0.13 Fe=0.13 K*Fe= 0.29			

3.8. Potassium Concentration in Leaves (mg kg^{-1})

The results presented in Table 8 show that there was a significant effect of K and Fe on the K concentration in the leaves of the plant. The K2 treatment was superior as it gave the highest concentration of potassium (21.40 mg kg^{-1} which was significantly different from that of K1 which gave 18.47 mg kg^{-1} also was significantly different from that of the control plants that gave 18.07 mg kg^{-1}. The K concentration significantly increased with an increase in the foliar application of Fe. The application at Fe2 recorded the highest potassium concentration (24.77 mg kg^{-1}), the control treatment recorded the lowest avearge of potassium concentration(12.12 mg kg^{-1}), potassium concentration record the lowest average , which might be related to increased dry matter accumulation and primary nutrient concentration; which caused the crop to remove more nutrients. The Interaction between K

and Fe had a significant effect on potassium concentration. The maximum potassium concentration of 25.97 mg kg-[1] was at the full dose of K and Fe (K2×Fe2); however, the minimum potassium concentration was found under control treatments (10.90 mg kg^{-1}).

Table 8. Effect of the foliar application of Potassium and Iron on Potassium concentration (mg kg^{-1}).

Treatments	K0	K1	K2	Average(Fe)
Fe0	10.90	12.80	12.67	12.12
Fe1	16.10	22.50	25.57	21.39
Fe2	28.23	20.13	25.97	24.77
Average (K)	18.41	18.48	21.40	
L.S.D. ($p \leq 0.05$)	K= 2.59 Fe= 2.59 K*Fe=.4.49			

3.9. Iron Concentration in Leaves (mg kg^{-1})

The results presented in Table 9 showed that there is a significant effect of K and Fe on Iron concentration in the leaves of the plants. The K2 treatment was superior as it gave the highest concentration of Iron 6.84 mg kg^{-1} which was significantly different from K1 which gave 5.56 mg kg^{-1}which also was significantly different from that of the control plants that gave 4.61 mg kg^{-1}. The Iron concentration significantly increased with an increase in the foliar application of Fe. The application at Fe2 recorded the highest Iron concentration (6.44 mg kg^{-1}), The control treatment recorded the lowest mean for the trait, which was (4.85 mg kg^{-1}). Potassium and Iron application increased the iron concentration, which might be related to increased dry matter accumulation and primary nutrient concentration, which caused the crop to remove more nutrients. The interaction between K and Fe had a significant effect on the iron concentration. The highest interaction value resulted from the second level of potassium with the second level of iron. ($K_2 \times Fe_2$) which reached (7.61 mg kg^{-1}); however, the minimum iron concentration was found under control treatments (3.89 mg kg^{-1}).

Table 9. Effect of Potassium and Iron foliar application on Iron concentration (mg kg^{-1}).

Treatments	K0	K1	K2	Average (Fe)
Fe0	3.89	4.57	6.11	4.85
Fe1	4.66	5.70	6.81	5.73
Fe2	5.29	6.42	7.61	6.44
Average(k)	4.61	5.56	6.84	
L.S.D. ($p \leq 0.05$)	K=0.405 Fe= 0.405 K*Fe=0.702			

Conclusion

To enhance the growth of Cowpea, Potassium and Iron must be applied in sufficient amounts, particularly through foliar spraying, which has the benefits of rapid and effective nutrient use, preventing losses from leaching and fixing, and controlling plant nutrient uptake. The results of this study clearly show that the best fertilizer dose to enhance growth and nutrient uptake was foliar feeding a concentration of 3000mg $K.L^{-1}$ and 400 mg $Fe.L^{-1}$.

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