Effect of potassium fertilizer and foliar feeding with boron on growth and yield of safflower

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Abstract

During winter 2022–2023, a field experiment was conducted at College of Agriculture and Forestry affiliated with University of Mosul and Badush Dam area to ascertain the effects of three boron concentrations (0, 30, 60 mg B/L) and three potassium fertilizer levels (0, 75, 150 kg K2O/ ha) on traits of safflower growth and yield. The design was randomized complete block with three repetitions. Potassium fertilizer level of 150 kg/ ha produced the highest averages for plant height (80.53 , 81.86 cm), branches number per plant (6.51 , 7.01 branch/plant), leaf area (1964.33 , 1977.66 cm2), heads number per plant (30.96 , 31.85 head/plant), seeds number per head (30.61 , 30.94 seed/head), weight of a thousand seed (44.03 , 44.81 gm), seed yield (1097.06 , 1100.40 kg/ha), content of seed from oil (32.38 , 33.05%, and oil yield (356.00 , 364.41 kg/ha), in both study sites. Significant effects of boron concentrations were observed in both study sites; the highest average plant height (82.02 , 83.37cm) was found at 30 mg/ L, while the highest values for a branches number per plant (6.21 , 6.87 branch/plant), leaf area (2054.00 , 2067.33cm2), heads number per plant (31.78 , 33.12cm2), seeds number per head (31.94 , 32.27head/plant), weight of a thousand seed (44.73 , 45.40gm), seed yield (1125.33 , 1128.66 kg/ha), content of seed from oil (32.95 , 33.73%), and oil yield (371.09 , 380.96kg/ha) were found at 60 mg/ L. There was a substantial interaction between potassium levels and boron concentrations in the two characteristics of leaf area (2147.66 , 2161.00cm2) in both research sites and seed yield (1152.26kg/ha) in the Badush Dam site. The greatest values for leaf area and seed output were obtained with a boron concentration of 60 mg/L and a potassium fertilizer level of 175 kg/ ha.

Keywords: Potassium, boron, growth, yield, safflower.

Introduction

One of the most significant oil crops that contribute significantly to producing vegetable oils worldwide is safflower (Carthamus tinctorius L.). It is cultivated to extract oil from its seeds, having a high percentage of non-essential fatty acids and a low percentage of essential fatty acids. This crop offers many health advantages besides its industrial, oil, and feed applications, such as decreasing cholesterol and treating liver illnesses [15.[
Compared to other oil crops, safflower is still farmed in comparatively limited quantities, with an area of 850 thousand hectares planted, according to data from the United Nations Food and Agriculture Organization. India, Ethiopia, Mexico, and the United States of America are the top safflower-growing nations [22.[

Safflower production is enhanced by appropriate cultural methods, and it is a strong contender for winter cereal crops due to its resilience to drought and adverse circumstances [4.[
The growth and production of safflower crops are significantly influenced by crop service operations, with fertilization with major and

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minor elements being the most crucial component.

By activating over 80 enzymes, opening and closing stomata, controlling the osmotic potential of plant cells, increasing their permeability, aiding in photosynthesis, product transfer, cell division, and plant resistance to lodging and plant diseases, potassium fertilizer is important for plant development and yield. Additionally, it aids in the synthesis of proteins, enzymes, and nucleic acids [9.[

When sprayed on plants or given directly to the soil, boron foliar feeding also contributes significantly to pollination, fertilization, and seed setting in field crops, especially oil crops. According to [21], boron also promotes the synthesis of ATP and functions as a substance that facilitates the transfer of sugars to the plant's active growth regions during the reproductive stages.

In their investigation of three different potassium levels (0 , 100 , 200 , 300 , 400 kg K/ ha), [13] discovered that the 400 kg K/ha potassium level outperformed heads number per plant, seeds number per head, 300 seeds' weight, and seed yield.

Among four potassium rates (0 , 50 , 100 , 150 kg/ ha), [1] discovered that the 150 kg/ha level greatly increased seed yield and oil yield. The 400 kg/ha level was superior in terms of seeds number/ head, One hundred seeds' weight, seed yield, One hundred seeds' weight, and oil production, according to [24] who investigated 3 different potassium levels (0, 60, 120 kg/ha.(

[19]found that the potassium level of 30 kg K/ha outperformed the seed and oil yields in their investigation of 4 different potassium rates (0 , 10 , 20 , 30 kg K/ha.(

[11]demonstrated that the third treatment (60 kg K2O/ha) was significantly superior in terms of plant height, branches number per plant, leaf area, pods number /plant, weight of a thousand seed, and seed yield when they studied effects of various potassium treatments (0, 30, 45, 60 kg/K2O ha, spraying 2% K2O, 30 kg/K2O ha with spraying 2% K2O, 45 kg/K2O ha with spraying 2% K2O.(

In [14] investigation of three potassium rates (0, 50, 75 kg K /ha), results indicated that potassium level of 75 kg K/ha outperformed plant height, branches number per plant, seed production, seed oil content, and oil production.

[12]discovered that adding boron at a concentration of 1% considerably raised plant height, branches number per plant, seeds number per head, and seed yield, study employed three different concentrations of boron (0, 0.5, and 1%). Using four different boron concentrations (0, 50, 100, and 150 mg B/ha), [7] found that the third concentration (100 mm/L) considerably outperformed the third concentration in plant height, leaf area, seed yield, seed oil content, oil yield. In their investigation of three boron concentrations (0, 350, and 700 ppm), [23] found that the concentration of 350 ppm considerably outperformed heads number per plant, weight of a thousand seed, and seed production.

[17]found that the treatment of adding boron to soil by 2 kg/ha + spraying the leaves with 0.2% boron was significantly better than plant height, branches number per plant, heads number per plant, weight of a hundred seed, seed yield. This is evident from the results of their study of various boron additions.

The study is to ascertain the ideal quantity of potassium fertilizer with the proper boron concentration and its impact on raising safflower crop productivity.

Materials and Methods

During winter 2022–2023, a field experiment was conducted at College of Agriculture and

Forestry affiliated with University of Mosul and Badush Dam area to ascertain the effects of three boron concentrations (0, 30, 60 mg B/L) and three potassium fertilizer levels (0, 75, 150 kg K2O/ ha) on traits of safflower growth and yield. The design was randomized complete block with three repetitions.

A total of 27 experimental units, or 3×3×3, will be used. The experimental unit comprises four lines, each measuring two meters in length. The gap between lines is fifty centimeters, while the distance between plants is twenty-five centimeters. We took readings from the plants of the two center lines and left guard lines consist of two extreme lines. Experimental units in each sector received the treatments at random. One meter separated the experimental units from one another, and one and a half meters separated each sector.

As deep as 0 – 30 cm, a few of soil's physical and chemical characteristics were examined (Table 1). A rotary-blade plough was used to plow the experimental field perpendicularly, and subsequently procedures such as leveling, dividing, and smoothing were performed. On November 1, 2022, three to four seeds were sown in the ground. Three weeks following planting, the plants were trimmed by leaving one plant in the hole once the seedlings had fully sprouted. Weeding and other crop service tasks were completed as needed.

Arithmetic means were compared using Duncan's multiple range test at the 5% and 1 probability levels [6], and the data were statistically analyzed using the analysis of variance method with the statistical software [20.[

Table 1. The experimental soil's physical and chemical traits.

Physical properties	**planting location**	
	College site	**dam site**
Sand (%)	20.85	55.45
Silt (%)	38.35	26.25
Clay (%)	40.80	18.3
Texture	clay	sandy loam
Chemical properties		
Nitrogen (ppm)	52	60
Phosphorus (ppm)	5.0	1.4
Potassium (ppm)	175	116.5
Electrical conductivity (dS/cm)	0.56	0.13
Soil acidity	7.1	7.6

Results and Discussion

Height of plant (cm(

The 150 kg/ha fertilizer treatment produced the highest average for this trait, reaching 80.53 and 81.86 cm, according to the data in Table (2). This treatment did not differ significantly of 75 kg/ha fertilizer treatment, whose produced an value of 79.16 and 80.50 cm, while the treatment without addition produced the lowest average for the trait, reaching 77.53 and 78.80 cm for both sites, respectively. This may be because potassium plays a crucial function in the activity of enzymes that build the structural integrity of cells that enter the plant structure. In order to boost plant height, potassium also helps to regulate hormones and improve the effectiveness of growth regulators [16]. This outcome aligns with the findings of [11] and [14.[

The third boron concentration produced the highest average plant height of 82.02 and 83.37 cm, indicating that boron concentrations had a substantial impact on plant height in both research sites (Table 3). For both sites, the comparison treatment had the lowest average plant heights, measuring 75.42 and 76.77 cm, respectively. This might be a result of boron's function in assuring or speeding up the delivery of produced nutrients to the plant's meristematic tissues, which promote more cell division and elongation. According to [7], [12], and [17], this result is consistent with what they discovered.

Table (4) shows that the interaction between boron and potassium treatments in plant height did not change significantly.

Branches number/plant

The 150 kg/ha fertilizer treatment produced the highest average number of branches (6.51 and 7.01 branches/plant) for both sites, according to Table (2), while the treatment without addition produced the lowest average plant height (4.82 and 5.48 branches/plant). This could be because potassium helps the main stem's vegetative buds grow and supports and develops the branches that emerge. [11] and [14] obtained similar results to this one.

Since a boron concentration of 60 mg/L produced the greatest number of branches (6.21 and 6.87 branches/plant) and a boron concentration of 0 mg/L produced the lowest number of branches (4.90 and 5.56 branches/plant) for both sites, respectively, Branches number per plant varies significantly depending on boron content, as shown in Table (3). This may be explained by boron's beneficial and efficient physiological function in facilitating the movement of carbohydrates from the source to the outlet and their prompt availability to the new growth centers, which provides a favorable environment for the development of plant branches [3]. This outcome is in line with the findings of [11] and [17.[

Table 4's findings show that branches number per plant does non significantly change in response to the interaction between boron and potassium treatments.

Leaf area (cm2(

It is evident from Table (2), 150 kg/ha fertilizer treatment was the most effective in producing the highest amount of this trait, reaching 1964.33 and 1977.66 cm2, while the treatment that did not include it produced the lowest amount, reaching 1768.66 and 1782.00 cm2 for both sites, respectively. It might be because the plant needs potassium to grow, especially in terms of its function in promoting cell division and expansion by attaining optimal cell wall expansion and enhancing the activity of growth regulators that directly affect cell growth and expansion [8]. That is why the plant needs potassium in adequate amounts. This outcome is in line with [11] assertions.

With the highest average for the leaf area trait (2054.00 and 2067.33 cm2) at a boron concentration of 60 mg/ha and the lowest average for the trait (1724.55 and 1737.88 cm2) for both sites, respectively, the results presented in Table (3) demonstrate notable variations in boron concentrations. The beneficial action of boron in promoting leaf cell division and expansion is what causes the increase in leaf area as boron levels rise. This is reflected in the growing leaf area. This outcome is in line with [7] findings.

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According to the information in Table (4), highest amount of this trait was obtained with fertilizer 150 kg/ha and a boron concentration of 60 mg/L, reaching 2147.66 and 2161.00 cm2, while the lowest amount was obtained with neither potassium fertilizer with boron, reaching in each case 1659.00 and 1672.33 cm2.

Heads number/plant

According to Table 2's results, the 150 kg/ha fertilizer treatment significantly outperformed the 75 kg/ha fertilizer level, which produced an average of 28.15 and 29.82 heads/plant, in terms of producing the most heads (30.96 and 31.85 heads/plant), while the treatment without addition produced the fewest heads (26.97 and 28.97 heads/plant) for both sites, respectively. Potassium may play a part in this by activating enzymes that promote cell division, elongation, and branching, all of which increase the number of heads in the plant [5]. This outcome is in line with the conclusions drawn by [13.[

The number of heads per plant varies significantly depending on the boron concentration, as shown in Table (3). The highest boron concentration for the trait was 60 mg/L, reaching 31.78 and 33.12 heads/plant, while the lowest amount was recorded by the comparison treatment, reaching 25.61 and 27.05 heads/plant for both sites, respectively. This could be explained by the function of pectin in the cell wall, which prepares the absorbed boron for the fruits by acting as a drain for it. Therefore, a boron deficiency may cause the fruits to abort since there will be less competition for the materials that the boron deficiency represents [10]. This outcome is in line with the conclusions made by [17] & [23.[

Table (4)'s findings indicate that the number of heads per plant does not significantly change in response to the interaction between boron concentrations and potassium treatments.

Seeds number/head

According to Table 2's results, the 150 kg/ha fertilizer treatment produced the most seeds (30.61 and 30.94 seeds/head) across both sites, while the treatment that did not apply fertilizer produced the fewest seeds (26.67 and 27.01 seeds/head). In addition to its superiority in leaf area, potassium may also improve the percentage of fertilization and fruit set in flowers, which could explain why there are more seeds in the head when it is added (Table 2). This increases the quantity of seeds in the head by increasing the supply of developing flowers and their need for produced food to boost their vitality and raise the proportion of fertilization and fruit set in them. This outcome is in line with [11] findings.

As shown in Table (3) and in both study sites, zinc concentrations significantly impacted the trait of number of seeds per head. The highest mean for the trait was obtained with a boron concentration of 60 mg/L, reaching 31.94 and 32.27 seeds/head, while the lowest mean was obtained with a comparison treatment of 0 mg/L, reaching 25.78 and 26.12 for both sites, respectively. Because reproductive parts require high levels of boron to grow healthily, particularly the development of callus in the cell walls of pollen tubes, which is accomplished by the production of the callus-borate complex, this could be because boron has a direct physiological effect on reproductive part growth. Since the female parts of flowers become more vital with adequate boron, borates in this case perform an extra physiological role in the formation of the pollen tube through the reproductive tissues. The pollen tube requires high

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concentrations of boron in the ovary [18]. This outcome is in line with the findings of [12.[

Table (4) indicates that the feature of the number of seeds per head does not exhibit any discernible variations in the interaction between boron and potassium fertilizer.

1000seeds' weight (g(

Table (2) demonstrates that the 150 kg/ha fertilizer treatment was superior in providing the highest value for the weight of 1000 seeds, equivalent to 44.03 and 44.81 g. It was not substantially different from the 75 kg/ha fertilizer treatment, whose produced an value of 43.21 and 43.76 g. The treatment without addition provided the lowest value for the weight of 1000 seeds, equal to 42.16 and 42.94 g for both sites, respectively. Because of its superior leaf area (Table 2), photosynthesis is more efficient and produces more products, which may be the cause of the 1000 seed weight increase caused by the 150 kg/ha level. This outcome is in line with [11] findings.

According to Table (3), the boron concentration of 60 mg/L produced highest weight of a thousand seeds, 44.73 and 45.40 g, while the comparison treatment produced lowest weight of a thousand seeds, 41.65 and 42.32 g, for both sites, respectively. One possible explanation is that the crop's flowering stage was aided by the proper amount of boron being available, which improved growth, flowering, flower bud formation, and grain filling. This, in turn, is positively reflected in the weight of 1000 seeds. According to [17] and [23], this outcome is in line with their findings.

The 1000-seed weight trait's interaction between boron concentrations and potassium fertilizer levels does not differ significantly, according to Table (4)'s findings.

Yield of seed (kg/ha(

In light of information in Table (2), treatment with 150 kg/ha of fertilizer was the best at producing the highest amount of this trait (1097.06 and 1100.40 kg/ha), while the treatment without it produced the lowest amount (1052.73 and 1056.06 kg/ha) for both sites, respectively. Potassium's contribution to the yield's components—heads number, seeds number per head, and Weight of a thousand seed (Table 2)—was favorable reflection in rise in yield of seed, particularly at the 150 kg/ha level. The results of [11] and [14] are consistent with this finding.

When the comparison treatment for both sites was conducted sequentially, the largest quantity of this feature reached (1125.33 and 1128.66 kg/ha) at a boron concentration of 60 mg/L, while the lowest amount reached (1035.27 and 1038.61 kg/ha), as indicated by findings in Table (3). It could be because of the superiority of the same concentration (60 mg/L) in terms of heads number per plant, seeds number per head, Weight of a thousand seed (Table, 3), all of whose were favorable reflection with the seed output. According to [12], [17], & [23], this outcome is in line with their findings.

The interaction between potassium fertilizer treatments and boron concentrations in the seed yield trait varies significantly for the Badush Dam site, as indicated by Table (4). The fertilizer level of 150 kg/ha and the boron concentration of 60 mg/L produced the highest amount of seed yield, which was 11152.26 kg/ha. In contrast, the treatment without adding potassium fertilizer and the treatment without adding boron produced the lowest average for this trait, which was 1021.76 kg/ha. In the college site, however, the interaction did not reach the significant limit.

Content of seed oil(%)

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The 150 kg/ha fertilizer treatment led to the highest average oil content of 32.38 and 32.05% for both sites, according to the data in Table (9). Conversely, addition-free treatment yielded lowest value oil content for both sites, at 29.37 and 30.15 percent. Safflower is a crop that puts stress on the soil because of the oil that is produced in its seeds. This oil is an organic material that needs a number of nutrients that must be present in the soil, including potassium, which is essential for the vital functions of the plant and helps move products of photosynthesis from their source to areas for effective growth and storage. It also improves the plant's ability to form carbohydrates, which give it the energy it needs to make fats and for transport and storage processes [16]. This outcome is in line with the conclusions made by [14] and [24.[

The boron concentration of 60 mg/L give highest amount for trait, reaching 32.95 & 33.73% for both sites, and comparison treatment give lowest amount for trait, reaching 29.17 and 29.84% for both sites, respectively, Table (3) demonstrates notable distinctions between boron concentrations in seed oil content. This can be explained by the fact that boron plays a crucial part in the critical functions of plants and helps move products of photosynthesis from their source to areas of active development and storage [2]. This outcome aligns with the findings of [7.[

According to Table (4), the interaction between the levels of potassium fertilizer and the boron concentrations in the seed oil content did not differ significantly between the two study sites.

Yield of oil (kg/ha(

Based on the data presented in table (10) makes it clear that the fertilizer application of 150 kg/ha was the most effective in producing the highest amount of this trait, which was 356.00 and 364.41 kg/ha for both sites, while the treatment without addition produced the lowest amount, which was 309.75 and 319.03 kg/ha for both sites, respectively. One possible explanation for the rise is that oil production increased as a outcome of the superiority of the 150 kg/ha level in yield of yield and seed oil content (Table, 2). This conclusion is consistent with the research conducted by [1] and [14.[

According to Table (10) and both research sites, zinc concentrations significantly impacted the oil yield trait. The highest average for the trait was obtained with a boron concentration of 60 mg/L, reaching 371.09 and 380.96 kg/ha, while the treatment without addition produced the lowest average for this trait, reaching 302.21 and 310.11 kg/ha for both sites, respectively. The superiority of the same concentration in terms of oil percentage and seed production could be the cause (Table 3). This outcome aligns with the findings of [7.[

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Table 2. Potassium effect on a few safflower traits.

potassium (kg/ha)	Plant height (cm)	Branches number/ plant	Leaf area (cm^2)	Heads number/ plant	Seeds number/ head	Weight of a thousand seed (g)	Yield of seed (kg/ha)	Content of seed oil (%)	Yield of oil (kg/ha)
college site									
0	77.53b	4.82c	1768.66c	26.97b	26.67c	42.16b	1052.73c	29.37c	309.75c
75	79.16ab	5.51b	1892.00b	28.15ab	28.61b	43.21ab	1073.00b	30.60b	328.94b
150	80.53a	6.51a	1964.33a	30.96a	30.61a	44.03a	1097.06a	32.38a	356.00a
Dam site									
0	78.80b	5.48c	1782.00c	28.97b	27.97c	42.94b	1056.06c	30.15c	319.03c
75	80.50ab	6.17b	1905.33b	29.82ab	28.94b	43.76ab	1076.33b	31.26b	337.13b
150	81.86a	7.01a	1977.66a	31.85a	30.94a	44.81a	1100.40a	33.05a	364.41a

Values in the same column that are indicated by different letters are significantly different from each other.

Table 3. Boron effect on a few safflower traits.

Boron (mg/l)	Plant height (cm)	Branches number/ plant	Leaf area (cm^2)	Heads number/ plant	Seeds number/ head	Weight of a thousand seed (g)	Yield of seed (kg/ha)	Content of seed oil (%)	Yield of oil (kg/ha)
college site									
0	75.42c	4.90c	1724.55c	25.61c	25.78c	41.65c	1035.27c	29.17c	302.21c
30	82.02a	5.56b	1846.44b	28.70b	28.16b	43.02b	1062.18b	30.23b	321.39b
60	79.78b	6.21a	2054.00a	31.78a	31.94a	44.73a	1125.33a	32.95a	371.09a
Dam site									
0	76.77c	5.56c	1737.88c	27.05c	26.12c	42.32c	1038.61c	29.84c	310.11c
30	83.37a	6.23b	1859.77b	30.47b	28.50b	43.80b	1065.52b	30.90b	329.51b
60	81.01b	6.87a	2067.33a	33.12a	32.27a	45.40a	1128.66a	33.73a	380.96a

Values in the same column that are indicated by different letters are significantly different from each other.

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Table 4. Interaction effect between potassium and boron on a few safflower traits.

Potassium (kg/ha)	Boron (mg/l)	Plant height (cm)	Branches number/ plant	Leaf area (cm^2)	Heads number/ plant	Seeds number/ head	Weight of a thousand seed (g)	Yield of seed (kg/ha)	Content of seed oil (%)	Yield of oil (kg/ha)
college site										
0	**0**	74.36	4.26	1659.00i	23.83	23.03	41.06	1018.43	28.23	287.51
	30	80.16	4.73	1736.33g	26.83	26.30	41.96	1036.06	28.53	295.59
	60	78.06	5.46	1910.66d	30.26	30.70	43.46	1103.70	31.36	346.15
75	**0**	75.40	4.83	1716.00h	24.96	25.70	41.80	1033.93	28.63	296.08
	30	82.10	5.43	1856.33e	28.10	28.06	43.30	1061.70	30.46	323.44
	60	80.00	6.26	2103.66b	31.40	32.06	44.53	1123.36	32.70	367.31
150	**0**	76.50	5.60	1798.66f	28.03	28.63	42.10	1053.46	30.66	323.06
	30	83.80	6.53	1946.66c	31.16	30.13	43.80	1088.80	31.70	345.14
	60	81.30	6.90	2147.66a	33.70	33.06	46.20	1148.93	34.80	399.82
Dam site										
0	**0**	75.76	4.93	1672.33h	25.83	23.36	41.73	1021.76h	28.90	295.31
	30	81.56	5.40	1749.67g	29.16	26.63	42.96	1039.40g	29.20	303.52
	60	79.06	6.13	1924.00d	31.93	31.03	44.13	1107.03c	32.36	358.27
75	**0**	76.73	5.50	1729.33g	26.63	26.03	42.46	1037.26g	29.30	303.93
	30	83.43	6.10	1869.67e	30.43	28.40	43.63	1065.03e	31.13	331.55
	60	81.33	6.93	2117.00b	32.40	32.40	45.20	1126.70b	33.36	375.92
150	**0**	77.83	6.26	1812.00f	28.63	28.96	42.76	1056.80f	31.33	331.10
	30	85.13	7.20	1960.00c	31.83	30.46	44.80	1092.13d	32.36	358.27
	60	82.63	7.56	2161.00a	35.03	33.40	46.86	1152.26a	35.46	408.68

Values in the same column that are indicated by different letters are significantly different from each other.

Conclusions

We conclude this investigation that, in the two study sites, safflower productivity increased significantly when plants were fertilized with 150 kg/ha of potassium fertilizer and sprayed with a boron concentration of 60 mg B/L.

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