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GROWTH AND PHYSIOLOGICAL PROPERTIES OF FABA BEAN GENOTYPES AFFECTED BY ZINC

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SUMMARY

The presented experiment on faba bean (*Vicia faba* L.) began in the winter of 2022–2023 at the College of Agriculture, University of Anbar, Anbar, Iraq. The study aimed to determine the effects of foliar application of zinc on the growth and physiological traits of the faba bean genotypes. The experiment had a randomized complete block design (RCBD) with a split-plot arrangement and three replications. The prime plots included three concentrations of zinc, i.e., 0, 30, and 60 mg Zn L^{-1}, while the subplots comprised three different genotypes (American, Dutch, and Spanish) of faba beans. The results revealed that the faba genotypes significantly displayed their latent potential in growth and physiological parameters. The American faba bean genotype proved superior in plant height (37.52 cm), leaf area (1413 cm^2 $plant^{-1}$), and zinc concentration in leaves (113.30 mg kg^{-1} dry matter). However, the Spanish faba bean genotype led to an average leaf chlorophyll content (56.59 SPAD). The zinc foliar application with the highest concentration (60 mg L^{-1}) provided the least number of days to flowering (60.89 days) and also excelled in obtaining the tallest plants (41.13 cm), branches per plant (3.85), leaf area (1337.6 cm^2 $plant^{-1}$), the chlorophyll content (52.23 SPAD), and the zinc concentration in leaves (116.58 mg kg^{-1} dry matter). The interaction of the American faba bean genotype and the highest zinc foliar application (60 mg L^{-1}) significantly affected the plant height, leaf area, and zinc concentration in leaves. The interaction between the Spanish genotype and zinc concentration (60 mg L^{-1}) gave the highest average for leaf chlorophyll content, and the interaction of the Dutch genotype with the highest zinc concentration exhibited a shorter period from planting to flowering.

Keywords: *Vicia faba* L., exotic genotypes, vegetative growth traits, micro-nutrients

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Key findings: Zinc foliar application significantly impacted faba bean genotypes for growth and physiological traits. The superiority of the high concentration of zinc (60 mg L^{-1}) in maturation and physiological features might be due to its positive role in stimulating various physiological processes and improving plant performance. In addition to delaying the leaf senescence by preserving the chlorophyll content, it positively affected the increase in photosynthesis process efficiency.

INTRODUCTION

The faba bean (*Vicia faba* L.) crop is one of the valuable winter crops belonging to the legume family Fabaceae. The crop's importance refers to it being a vital food source for millions of hungry mouths, especially in low-income communities, because its seeds contain the highest protein (20%–36%), ultimately addressing the lack of animal protein in those communities (Dhull *et al.,* 2021). Faba beans also contain carbohydrates, some mineral elements, and vitamins (Karkanis *et al.,* 2018). Additionally, it improves soil properties by fixing atmospheric nitrogen in the soil through root nodes coexisting with rhizobium bacteria and benefits crop rotation (Alsalimm *et al.,* 2018).

In Iraq, the faba bean productivity is low covering a small percentage of the local production due to the genotypes' variations in the nature of their growth and morphological shape, leading to different responses to the environmental conditions affecting its economic yield (Kamal *et al.,* 2016; Abead *et al.,* 2018). However, in faba bean (*V. faba* L.) a good yield can happen with appropriate compatibility among the cultivars, environmental conditions, and the agricultural operations required for the said crop (Kubure *et al.,* 2016).

The faba bean crop also suffers other prime problems, particularly the highest percentage of fallen flowers, considerably declining its productivity (Ali *et al.,* 1990; Ali, 2012). For managing this problem, one of the treatments is using mineral nutrition with micronutrients, especially zinc, crucial in forming and developing pollen grains and enhancing the percentage of fertility and knots in flowers and seeds (Anand *et al.,* 2008). These micronutrients also effectively contribute to increasing the efficient transfer of photosynthetic products from the leaves to the rest of the plant parts and their vital role in producing energy (ATP) and chlorophyll formation due to their direct impact on the construction processes of amino acids and carbohydrates (Al-Essawi, 2010). Therefore, foliar feeding with nutrients is very influential, especially zinc, in improving crop growth and tolerance to prevailing environmental stresses.

These micronutrients are also requirements for crop plants in fabricating the amino acid tryptophan, composed of the growth hormone Indole Acetic Acid (IAA), which was necessary for plant tissue development (Cakmak *et al.,* 1998). The practical study sought to determine the extent to which faba bean genotypes respond to foliar feeding with zinc and the interaction between these two factors, improving the growth and physiological characteristics of faba beans.

MATERIALS AND METHODS

Plant material and procedure

The experiment on the faba bean (*V. faba* L.) commenced in the winter of 2022–2023 at the College of Agriculture, University of Anbar, Anbar, Iraq. The study aimed to recognize the effects of zinc foliar application on the growth and physiological traits of faba bean genotypes. Accomplishing the experiment used the randomized complete block design (RCBD) with a split-plot arrangement and three replications. The chief plots comprised the three concentrations of zinc (30 and 60 mg Zn L^{-1}), with zero zinc dose for comparison treatment (Control) spraying only with water. The subplots included three exotic genotypes (American, Dutch, and Spanish) of the faba bean. Each foliar application of zinc ensued until the plant leaves were totally wet, performed early in the morning using a manual sprinkler with an eight-liter capacity at the beginning of flowering for each faba bean cultivar.

Plastic boxes with a capacity of 30 kg, prepared and filled with soil, had the seeds sown in them on November 20, 2020, with two seeds per hole at a depth of 3–5 cm, then covering the seeds with a light layer of soil. Immediately after planting, the experiment received light irrigation, continuing the process according to soil moisture and plant needs until complete seedling emergence. The holes with failed germination bore replanting, with the plants thinned and one plant kept per hole. Nitrogen fertilizer addition had a rate of 160 kg N ha^{-1} in the form of urea (46% N) in two batches, with the first at the planting time and the second at the beginning of the flowering stage. Phosphate fertilizer application also occurred at the rate of 80 kg P_2O_5 ha^{-1} through DAP fertilizer (P_2O_5 46%), which was entirely used at the planting time (Ali, 2012).

Data recorded

Recording the data on the growth and physiological traits continued on randomly selected plants and was then averaged before the analysis. The studied traits were the number of days from planting to the beginning of flowering (days), plant height (cm), branches per plant, leaf area (cm^2 $plant^{-1}$), and the leaf's chlorophyll content (SPAD) and zinc concentration in leaves (mg kg^{-1} dry matter).

Statistical processes

The experimental data investigation proceeded according to the analysis of variance (ANOVA) required for the RCBD using the GenStat program (Version 11). The arithmetic means of the treatments for various traits' comparison and separation employed the least significant difference ($LSD_{0.05}$) test (Steel and Torrie, 1980; Kadem and Abed, 2018).

RESULTS AND DISCUSSION

Days to flowering

The results indicated a significant effect of faba bean genotypes, zinc concentrations, and their interactions on the number of days from planting to the beginning of flowering (Table 1). The Dutch genotype recorded the lowest average number of days from planting to flowering (62.44 days), followed by the American genotype (63.33 days), which was also not significantly different from the Spanish genotype (64.00 days). In the faba bean genotypes, these variations in the number of days to flowering are attributable to the difference in the genotypes' genetic makeup, as reflected in their differing responses to the existing soil and environmental conditions. The findings of Singh *et al.* (2017) and Al-Rawi (2020) also revealed significant differences among the faba beans for earliness traits.

The outcomes in Table 1 also showed that the zinc concentration of 60 mg L^{-1} resulted in the minimum average period from planting to flowering (60.89 days), compared with the control treatment recorded with the extended duration (65.33 days). A reason might be due to the beneficial role of zinc in increasing the efficient transfer of photosynthetic products from the leaves to the rest of the plant parts (Al-Essawi, 2010). A significant interaction between the Dutch

Table 1. Effect of faba bean genotypes, zinc concentrations, and their interaction on the days to flowering.

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (days)
	0	30	60	
American	65.00	64.00	61.00	63.33
Dutch	65.00	61.67	60.67	62.44
Spanish	66.00	65.00	61.00	64.00
Means (days)	65.33	63.56	60.89	
$LSD_{0.05}$	G = 0.85	Z = 1.94	G x Z = 2.01	

Table 2. Effect of faba bean genotypes, zinc concentrations, and their interaction on the plant height (cm).

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (cm)
	0	30	60	
American	33.67	36.90	42.00	37.52
Dutch	30.67	35.42	41.89	35.99
Spanish	29.67	35.22	39.50	34.80
Means (cm)	31.33	35.85	41.13	
$LSD_{0.05}$	G = 0.60	Z = 0.78	G x Z = 1.02	

Table 3. Effect of faba bean genotypes, zinc concentrations, and their interaction on the branches per plant.

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (#)
	0	30	60	
American	2.89	3.11	4.56	3.52
Dutch	2.67	3.75	4.00	3.47
Spanish	2.78	3.22	3.00	3.00
Means (#)	2.78	3.36	3.85	
$LSD_{0.05}$	G = ns	Z = 0.75	G x Z= ns	

genotype and zinc concentration (60 mg L^{-1}) appeared, recording the shortest period from planting to flowering (60.67 days). The micronutrients are also necessary for the production of energy (ATP), the activation of numerous enzymes, and the formation of amino acids and carbohydrates (Cakmak *et al.,* 1998), stimulating plant growth, including the flowering parts, and, eventually, reducing the planting to flowering period.

Plant height

The observed results specified a significant effect of the genotypes, zinc concentrations, and their interactions on plant height (Table 2)**.** The American faba bean genotype excelled in this trait, recording the tallest plants (37.52 cm), with an increase of 4.25% and 7.82% over the Dutch and Spanish genotypes, respectively**.** The cause of the differences may be due to the genetic nature of these genotypes and the extent of their response to the existing soil and field operations, which reflected positively on their response to the environmental conditions, increasing cell division and elongation, and thus, an increase in plant height**.** These results were in analogy with the findings of Kubure *et al.* (2016) and Saleh (2020), as they reported that the faba bean genotypes significantly differed for growth traits, including plant height.

Application of zinc with the highest concentration (60 mg L^{-1}), on average, provided the tallest plants (41.13 cm), followed by the zinc concentration (30 mg L^{-1}), incurring an average plant height of 35.85 cm (Table 2). The comparison treatment emerged with the lowest average for this trait (31.33 cm). The interaction effect between the American faba bean genotype and the zinc concentration (60 mg L^{-1}) significantly produced taller plants (42.00 cm). An explanation may be because the role of zinc in forming the amino acid tryptophan and the growth hormone indole acetate, comprising heteroauxin (IAA), was necessary for elongating cells, including stem cells, increasing plant height (Hafeez et al., 2013).

Branches per plant

Results enunciated that zinc concentrations substantially affected the number of branches per plant, while the faba bean genotypes and their interaction with zinc concentrations have a nonsignificant effect on the said trait (Table 3). The zinc concentration (60 mg L^{-1}) showed the highest average number of branches per plant, reaching 3.85 branch $plant^{-1}$; however, it

Table 4. Effect of faba bean genotypes, zinc concentrations, and their interaction on the leaf area.

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (cm^2 $plant^{-1}$)
	0	30	60	
American	1044.4	1591.8	1602.8	1413.0
Dutch	1098.9	1058.3	1341.7	1166.3
Spanish	1108.4	1072.6	1068.2	1083.1
Means (cm^2 $plant^{-1}$)	1083.9	1240.9	1337.6	
$LSD_{0.05}$	G = 46.5	Z = 86.6	G x Z = 94.9	

did not differ significantly from the zinc concentration (30 mg L^{-1}), producing an average of 3.36 branch $plant^{-1}$. The non-spraying and control treatment exhibited the minimum average number of branches per plant (2.78 branch $plant^{-1}$). Zinc contributes effectively to increasing the efficient transfer of the products of the photosynthesis process from their manufacturing sites to the rest of the plant parts, improving the growth of plant parts, including the number of branches (Hamad, 2018; Jaafar *et al*., 2022). In addition, the high zinc concentration excelled in plant height (Table 2), raising the number of branches.

Leaf area

The faba bean genotypes significantly enhanced the leaf area (Table 4). The American genotype was superior in giving the highest average leaf area (1413.0 cm^2 $plant^{-1}$), with an increase rate of 21.15% and 30.46% over the Dutch and Spanish faba bean genotypes, respectively. The superiority of the American genotype for this trait may refer to the existing differences in the genetic and physiological characteristics of the genotypes, which often appear in growth traits, including leaf area**.** These results aligned with the findings of Al-Ani (2017) and Abid *et al.* (2017), who found considerable variances in leaf area among the faba bean genotypes.

The results further indicated that the leaf area enlarged with increasing zinc concentration (60 mg L^{-1}) and recorded an average of 1337.6 cm^2 $plant^{-1}$ (Table 4). The said zinc concentration notably varied from the other concentrations (30 mg L^{-1}) (1240.9) and the control treatment with the lowest average (1083.9 cm^2 $plant^{-1}$). The increase in leaf area by spraying zinc on the plant is indicative of the importance of forming the amino acid tryptophan, necessary to extend and augment cell division and expansion, thus a boost in leaf area; zinc insufficiency in leaves leads to a decrease in leaf area for plants (Alrawi and Aljumaili, 2018; Abed *et al*., 2022; Herman *et al*., 2023).

The interaction among the faba bean genotypes and zinc concentrations was notable for leaf area. Moreover, the interaction between the American genotype and the concentration of 60 mg L^{-1} gave the highest leaf area (1602.8 cm^2 $plant^{-1}$). The increase in leaf area achieved through increased foliar application of zinc may be due to the constructive role of zinc in increasing cell division and expansion in growth traits (Mousavi, 2011). Additionally, the superior concentration of zinc (60 mg L^{-1}) in plant height and the number of branches in the plant (Tables 2 and 3) reflected positively in increasing the number of leaves and the leaf area in faba bean plants.

Leaf chlorophyll content

The outcomes showed a remarkable influence of the faba bean genotypes and zinc concentrations and their interaction on the chlorophyll content of leaves (Table 5). The Spanish genotype excelled in this trait, recording the highest mean (56.59 SPAD), with an increase of 28.18% and 10.51% over the American and Dutch faba bean genotypes, respectively. The differences in faba bean genotypes in their chlorophyll content may be due to their genetic makeup variations, environmental factors, and their impact on vegetative growth traits. These results were similar to those of Al-Ani (2017) and Al-

Table 5. Effect of faba bean genotypes, zinc concentrations, and their interaction on the leaves chlorophyll content.

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (SPAD)
	0	30	60	
American	45.25	44.37	42.83	44.15
Dutch	49.00	52.77	51.87	51.21
Spanish	52.00	55.77	62.00	56.59
Means (SPAD)	48.75	50.97	52.23	
$LSD_{0.05}$	G = 1.14	Z = 2.10	G x Z =2.31	

Table 6. Effect of faba bean genotypes, zinc concentrations, and their interaction on zinc concentration in leaves.

Genotypes (G)	Zinc concentrations (mg L^{-1}) (Z)			Means (mg kg^{-1} dry matter)
	0	30	60	
American	101.93	118.90	119.07	113.30
Dutch	90.18	115.69	116.62	107.49
Spanish	85,33	92.05	114.06	97.14
Means (mg kg^{-1} dry matter)	92.48	108.88	116.58	
$LSD_{0.05}$	G = 4.26	Z = 5.00	G x Z = 7.01	

Fahdawi (2018), who also observed relevant differences among the faba bean genotypes for leaf chlorophyll content.

The zinc concentration (60 mg L^{-1}) showed the highest mean of chlorophyll content in the faba bean leaves (52.23 SPAD) but did not differ significantly from the second zinc concentration (30 mg L^{-1}), which recorded an average of 50.97 SPAD (Table 5). The comparison and control treatment provided the lowest average for the trait (48.75 SPAD). A significant interaction between the faba bean genotypes and the zinc concentrations appeared for the chlorophyll content of the leaves. The Spanish genotype with a zinc concentration of 60 mg L^{-1} emerged with the maximum chlorophyll content (62.00 SPAD). The enhanced zinc concentration (60 mg L^{-1}) played an augmenting role in the formation of chlorophyll in the plant due to its direct effect on the processes of amino acids and carbohydrates formation and the synthesis of numerous enzymes, positively reflecting in the increased chlorophyll content in leaves (Anand *et al.,* 2008).

Leaf zinc concentration

Study findings revealed a remarkable influence of the faba bean genotypes on the zinc concentration in the leaves (Table 6). The American genotype excelled in this trait, producing the highest average of zinc in the leaves (113.30 mg kg^{-1} dry matter), followed by the Dutch genotype (107.49 mg kg^{-1} dry matter) and the Spanish genotype with the lowest average (97.14 mg kg^{-1} dry matter). The reason for the superiority of this genotype (American) is due to the genetic nature of the variety, linking to the physiological and biological processes that affect the ability to exploit carbon assimilation products and increase their accumulation in plant parts, such as leaves and seeds (Mohammed and Faris, 2021). An explanation for this could be due to the American genotype giving the highest leaf area (Table 4), increasing the surface area exposed to the foliar application with the zinc element, with an increased amount absorbed by the leaves, and positively raising its concentration in the faba bean leaves (Samreen *et al.,* 2017).

The foliar application of increased zinc concentration (60 mg L^{-1}) on the faba bean leaves also enhanced the leaves' zinc concentration element (Table 6). The highest zinc concentration (60 mg L^{-1}) displayed the highest mean (116.58 mg kg^{-1} dry matter), while the control treatment incurred the lowest mean for the trait (92.48 mg kg^{-1} dry matter). The interaction between the American faba bean genotype and the zinc concentration (60 mg L^{-1}) recorded the utmost average for zinc concentration in the leaves (119.07 mg kg^{-1} dry matter). Explaining the increase in zinc concentration in the leaves may refer to the elevated concentration of the element in the spray solution, and the component is slow-moving in the plant, which increases its accumulation in the leaves. These results were consistent with past observations indicating that increased zinc concentration in the spray solution also increases its concentration in the leaves (Raed, 2011; Al-Fahdawi, 2018, 2023; Kausar *et al.*, 2023).

CONCLUSIONS

The superiority of the highest zinc concentration (60 mg L^{-1}) in the growth traits might be due to its essential role in improving faba bean (*Vicia faba* L.) plants' performance by stimulating various physiological processes. In addition to its effect in delaying the leaf senescence by preserving the chlorophyll content, it also positively affected the increase in the photosynthesis process efficiency, causing superiority in growth and physiological characteristics of the faba bean plants, especially the American genotype, which gave the best indicators for most growth traits. Therefore, this genotype could be better raw genetic material for future breeding programs.

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