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EFFECT OF FOLIAR SPRAYING WITH NANO-ZINC ON GROWTH AND PRODUCTIVITY SOME FABA BEAN VARIETIES

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Abstract

This fieldwork was conducted in the North of Babil Governorate, Iraq, to test the foliar fertilization influence with nano zinc on growth, yield, and its elements of some faba bean varieties during the 2022/2023 season. The field trial was designed using a split-plot and organized in haphazard complete blocks with triple replications. The study specifies the core plots with the kinds of field beans, *i.e.*, Aquadlge (Turkish origin) V_1, Aquaduice a longue cross (American origin) V_2, Luz de otono (Spanish origin) V_3 and Otono star (Holand origin) V_4, and the sub-plots were specified with foliar fertilization with nano zinc (0, 150, and 200 mg L^{-1}). The development of the investigated faba bean types, yield, and components varied significantly, with V_3 (Luz de otono, Spanish origin) being the highest character. There was a significant spraying impact with nano zinc levels on growth, yield, and its elements, as the 200 mg nano zinc L^{-1} had the maximum average for these characteristics, with a significant difference from the 150 mg nano zinc L^{-1} and control treatment. Foliar spraying V_3 plants with 200 mg nano zinc L^{-1} two times is recommended at the first part of the flowering phase, and the second is at the 75% flowering phase in the ecological conditions of the research area.

Keywords: Field bean, Vicia faba, Varieties, Foliar Fertilization, Nano zinc, Growth yield and components.

تأثير الرش الورقي بالزنك النانوي على نمو وإنتاجية بعـــض أصناف الباقلاء Vicia faba L.

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الخلاصة

نفذت تجربة حقلية في قضاء الكوثي (جبلة) شمال محافظة بابل – العراق، تأثير التسميد الورقي بالزنك النانوي على النمو ومحصول البذور ومكوناته لبعض أصناف الباقلاء (*Vicia faba* L.) في تربة مزيجة طينية غرينية خلال الموسم 2023/2022. نفذت التجربة الحقلية في تصميم القطع المنشقة المرتبة في قطاعات كاملة العشوائية في ثلاث مكررات. تم تخصيص القطع الرئيسية لأصناف الباقلاء وهي؛ التركي V_1 (aquadlge)، الأمريكي V_2 (aquaduice a longue coss)، الإسباني V_3 (luz de otono) والهولاندى V_4 (otono star). بينما خصصت القطع الفرعية للتسميد الورقي بالنانو زنك (0، 150، 200 ملغم لتر$^{-1}$) كانت هناك فروق معنوية بين أصناف الباقلاء المدروسة في صفات النمو وحاصل البذور ومكوناته، حيث أعطى الصنف الإسباني V_3 (luz de otono) أعلى قيم لهذه الصفات. كان للرش بمستويات النانو زنك تأثير معنوي على صفات النمو ومحصول البذور ومكوناته، حيث سجل التركيز 200 ملغم نانو زنك لتر$^{-1}$ أعلى متوسطات لهذه الصفات، بفارق معنوي عن تركيز 150 ملغم نانو زنك لتر$^{-1}$ ومعاملة المقارنة. من نتائج هذه الدراسة يوصى بالرش الورقي لنباتات الصنف الإسباني (luz de otono) بـ 200 ملغم نانو زنك لتر$^{-1}$ مرتين، الأولى عند بداية مرحلة التزهير والثانية عند 75% من مرحلة التزهير تحت الظروف البيئية لمنطقة الدراسة.

كلمات مفتاحية: الباقلاء، الأصناف، التسميد الورقي، الزنك النانوي، النمو، حاصل البذور ومكوناته.

Introduction

Faba bean (*Vicia faba* L.) is the first crop that humans have ever produced. It is a significant commercial crop that is cultivated primarily for its high-protein seed, which reaches 25-40% and 56% carbohydrates, in addition, fibers, oils, minerals, and vitamins, such as B, and a large amount of phytic acid (15). It is, therefore, employed in diets as a protein, particularly in impoverished nations. In addition to being food, field beans may be grown for animal feed and forage and to increase the amount of nitrogen accessible in the biosphere. It is common knowledge that achieving high

agricultural yield requires several components and activities. The importance of agronomical processes such as using promising varieties and foliar fertilization with zinc fertilizer ineffective form (nanoparticles) significantly affect growth, yield, and its faba bean elements. Many researchers in different countries stated that faba bean varieties noticeably varied in growth, seed yield, and other elements. According to (1), the Sakha 1 cultivar outperformed others under study (Sakha 2 and Giza 3 enhanced), achieving the greatest values for growth, seed production, and related factors overall. However, the cultivar Sakha 2 had the greatest percentage of shedding. The Giza 3 cultivar produced the tallest plants. As demonstrated by (14), the greatest values for seed yield fed^{-1}, weight per 100 seeds, and seeds pod^{-1} number for Giza 716. Nevertheless, the longest faba bean pods were produced by Giza 3. Plant height and the pod number in a plant were highest for the Syrian variation, whereas pod length, the seeds pod^{-1} number, and the seeds per plant weight were highest for the Spanish type. According to (2 and 18), the Taqa variety had the most branches, plants, and a total weight of 100 seeds; it also had the shortest time to 50% blooming and the production of the first pod. According to (6 and 7), the Spanish cultivar outperformed the Turkish cultivar regarding leaf area, pod number, seed production, and harvest index. In contrast, the Turkish cultivar considerably outperformed the other three traits studied (plant height, number of branches and biological yield). (10) demonstrated that the Spanish Genotype was better in height, branches in a plant, chlorophyll, the seeds pod^{-1}, and seed output. On the other hand, the Turkish Genotype outperformed in terms of biological yield, 100-seed weight, and pod count per plant.

An important micronutrient for people, animals, and plants is zinc (Zn). Plants mostly absorb zinc as a divalent cation (Zn^{++}). Plant functions are significantly impacted by zinc. The synthesis of proteins and the metabolism of carbohydrates regulates the effects of auxin by controlling the synthesis of tryptophan, functions as a cofactor for redox enzymes, namely dehydrogenases and superoxide dismutase, and is crucial for the gene expressions linked to environmental problems (17 and 20). Even though plants need zinc for healthy metabolism, the effectiveness of this microelement is dependent on both absorption and translocation (20). Zinc may be applied topically to increase plant absorption. However, mobility Zn speciation within plants, lack of understanding, and the creation of novel materials all pose challenges to developing Zn-based foliar fertilizers. A new technology known as nanotechnology has found its place and uses in agriculture and has solved several challenging issues in various scientific and industrial domains. Nanotechnology is critical in manufacturing, processing, storing, packaging, and transporting agricultural products (21). Since zinc oxide nanoparticles (ZnO NPs) effectively suppress disease, promote plant growth, and protect plants from infection, they are biosecure material for biological species (22). In contrast to sulfur concentrations and the control, (13) found that zinc nanoparticles (50 ppm) significantly increased the overall bean length, leaf number, and branches. (2) research demonstrated how nano fertilizers enhanced several growth and yield qualities. The results of B-nano fertilizer showed the greatest values for pod weight, pods in a plant, length, and seeds in a pod, whereas Zn-nano fertilizer enhanced plant height and total yield of seeds. In their 2022 study,

(16) investigated the reaction of faba to foliar spraying at ZnO NPs (0, 50, and 100 mg L^{-1}). They discovered an enhancement of foliar treatment with ZnO NPs at 50 and 100 mg L^{-1}. In contrast to the alternative control, plants receiving 50 mg L^{-1} ZnO NPs had the biggest pigments, carotenoids, and chlorophyll a, b. (20) showed that foliar spraying faba bean with ZnONPs promoted growth parameters, photosynthetic pigments, proline, and mineral elements relative to controls. (10) concluded that the Spanish genotype with different responses to spraying with nano-chelated zinc fertilizer and zinc fertilizer positively correlated with their concentration. The current investigation determined the foliar fertilization impact with zinc fertilizer in the nano form on growth, production, and its constituents of faba bean (*Vicia faba* L.) in the North of Babylon.

Materials and Methods

This work was performed as a field experiment in the southern part of Baghdad in the Kothi (Jableh) Al-Hamiri area, North of Babylon, Iraq, in the successive winters of 2022/2023 to study the foliar fertilization impact with zinc fertilizer in the nano form on growth, produce and its constituents of faba bean (*Vicia faba* L.) varieties. The field trial was made using a split-plot design organized in the haphazard comprehensive block with triple replications. The experiment included twelve treatments, comprising four faba bean varieties and three foliar fertilizations with nanozinc. The study specified the main plots with faba bean varieties, *i.e.,* Aquadlge (Turkish origin) V_1, Aquaduice a longue cross (American origin) V_2, Luz de otono (Spanish origin) V_3 and Otono star (Holand origin) V_4. The faba bean varieties used were from specialized agents in the Iraq Republic. However, the sub-plots were apportioned with foliar fertilization with nano zinc at two rates (150 and 200 mg L^{-1} in each spray) and control treatment (spraying with irrigation water only). Zinc nanoparticles were eco-friendly and were synthesized following (19), with a small change by (8). Deionized water was used to create zinc sulfate and ascorbic acid aqueous solutions (150 and 200 mg L^{-1}) for each solution. To prevent a fast reaction that may lead to greater particle size and precipitate formation, 20 ml of ascorbic acid at each concentration was gently dropped into a 20 ml metal salt solution, stirring the mixture for 120 ml at room temperature. (12) report that the resultant nanoparticles were manufactured at an equimolar ratio 1:1. To wet the plant thoroughly, a drop of Al-Zahi detergent was added to the solution to reduce tension and complete the spraying treatment. The first spraying treatment was applied to the vegetative group in the early morning at the beginning of the flowering, and the second stage at 75%.

The four ridges that comprised each empirical basic unit (sub-plot) were every 60 cm wide and 2.0 m long, resulting in 4.8 m^2. Before preparing the seedbed, the soil study sampled from the field of experiment at 0 to 30 cm deep below the soil surface was used to test the soil's physics and chemistry, Table 1.

Table 1: Physics and chemistry of the soil of the empirical area in 2022/2023.

Physical properties	Sand (g kg^{-1} soil)	582	**Chemical properties**	pH soil paste		7.1
				EC dS m^{-1}		3.29
				Organic matter (g kg^{-1} soil)		6.1
	Silt (g kg^{-1} soil)	330		Available nutrients (mg kg^{-1} soil)	N	25.04
					P	7.84
					K	79.81
	Clay (g kg^{-1} soil)	88		Soluble cations (meq L^{-1})	Ca^{++}	17.76
					Mg^{++}	11.5

Upon the field experiment, 4.8 m^2 of experimental units were thoroughly prepared using two plows to level, compact, and ridge. During the soil preparation, 475 kg ha^{-1} of calcium superphosphate (15.5% P_2O_5) was added. An overnight soak in water was given to faba bean seeds before planting to increase germination. The seed was sown on both sides of ridges on November 15, 2022, with a spacing of 25 cm between hills and 60 cm between ridges and two seeds on each hill. The complete germinating plant was adjusted by resowing the missing hills. It can also be modified by thinning the over plants three weeks after sowing two healthy plants on a hill. Hand hoeing was conducted every three weeks to suppress weeds (prior to irrigation season). Before the initial irrigation, nitrogen was provided as ammonium nitrate (33.1%) at a 35 kg N ha^{-1} starting dosage. Before the first and second irrigations, the soil was treated with potassium sulfate (48% K_2O) at 120 kg ha^{-1} in two equal parts. The irrigation was as required. However, other agricultural practices were followed. Every experimental unit gave three plants after the plants from the middle ridges).

Studied traits:

Growth characters: The following growth characters were measured; height of the plant (in cm), number of branches, number of leaves $plant^{-1}$, plant leaf area (cm^2), the total chlorophyll (SPAD).

Seed yield and its elements: The following seed yield and its elements were measured; pod length (cm), number of pods $plant^{-1}$, number of seeds pod^{-1}, 100-seed weight (g). Total yield (ton ha^{-1}) of seeds. After harvesting the plants in each of the two internal ridges of the plot and letting them air dry, the seeds, which had 12% moisture, were threshed, weighed in kilograms, and the result was rendered to tons per hectare.

For the split-plot design, statistical examination was used for the analysis of variance (ANOVA) approach, as described by (9), adopting "MSTAT-C" software. The Least Significant Difference (LSD) approach was adopted to examine the discrepancies at 5 % probability by (24).

Results and Discussion

Plant height (cm): Table 2 revealed that the varieties of faba bean and foliar fertilization with nano zinc levels significantly affected plant height. The V3 variety (Luz de otono, Spanish origin) had the maximum average height of the bean tree 91.35 cm, with a substantial difference from the V1 variety (Aquadlge, Turkish origin), which had the least average height 78.79 cm. Spraying the field of bean

florae with 200 mg nano zinc L^{-1} considerably contributed to increasing the height of the plant, and it had the highest mean 89.61 cm in comparison to the controls (0 nano zinc) that had the lowest mean 76.99 cm. The genetic variations and heredity among broad bean cultivars may cause plant height variations. These results were confirmed by (2, 4, 7, 10 and 14).

Zinc has a significant role in biomass formation, which might explain the rise in the height caused by foliar spraying with nanozinc at different proportions (17). Moreover, when compared to standard fertilizer forms, applying nano-fertilizers such as zinc increased chlorophyll production, photosynthesis rate, growth parameters, and dry matter. This increased photosynthesis and photosynthetic translocation to other plant parts (23). These findings agree with (2, 5, 13 and 20).

The interaction between the faba bean varieties and foliar fertilization with nano-zinc levels substantially affected height, and the perfect treatment was spraying with foliar V3 variety with 200 mg nano-zinc L^{-1}, which had 98.40 cm. However, the shortest (70.36 cm) resulted from V1 plants with no nano zinc foliar fertilization.

Table 2: Effect of varieties and foliar fertilization with nano zinc levels on plant height (cm) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	**150**	**200**	
V_1. Aquadlge (Turkish)	70.36	81.80	84.23	**78.79**
V_2. Aquaduice a longue cros(American)	72.74	82.78	87.50	**81.00**
V_3. Luz de otono (Spanish)	84.67	91.00	98.40	**91.35**
V_4. Otono star (Holand)	80.22	84.11	88.32	**84.21**
Means of (F)	**76.99**	**84.92**	**89.61**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	3.01	2.10	4.25	

Number of branches $plant^{-1}$: Table 3 revealed significant variances among the faba bean varieties in branches in 2022/2023. The V_3 variety (Luz de otono, Spanish origin) had the maximum average of 6.41 branch $plant^{-1}$, whereas the V_1 (Aquadlge, Turkish origin) had the lowest average of 5.06 branch $^{-1}$ during the 2022/2023 season.

The findings in Table 3 revealed significant differences owing to foliar fertilization with nano zinc levels on several branches per the plant during the 2022/2023 season, where the nano zinc concentration 200 mg L^{-1} had the maximum mean of 6.13 branch $^{-1}$, in comparison to the no-spraying treatment, that had the least average of 5.05 branch $plant^{-1}$ during 2022/2023 season.

The previous outcomes may have resulted from the plant's expanded branches due to reasons related to its genetic composition. These findings align with what (2, 7, 10 and 18) found. The increased number of branches per plant following foliar application of a zinc nano-fertilizer solution might be the consequence of this technique, which has shown to be successful in providing plants with nutrients in a regulated and progressive way (17). Thus, it enhances nutritive plant status, meristematic activity, and branches per plant, relating to (2, 13 and 20).

The faba bean variety interaction with foliar fertilization with nano zinc levels significantly affected the number of branches, and the most perfect dealing was foliar spraying V_3 with 200 mg nano zinc L^{-1}, which had 7.02 branch $plant^{-1}$. However, the

least number of branches (4.23 branch plant^{-1}) resulted from V_1 plants with no nano zinc foliar fertilization.

Table 3: Effect of varieties and foliar fertilization with nano zinc levels on number of branches plant^{-1} of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	4.23	5.31	5.65	**5.06**
V_2. Aquaduice a longue cros(American)	4.46	5.12	5.77	**5.11**
V_3. Luz de otono (Spanish)	5.88	6.33	7.02	**6.41**
V_4. Otono star (Holand)	5.64	5.87	6.11	**5.87**
Means of (F)	**5.05**	**5.65**	**6.13**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	0.10	0.30	0.45	

Number of leaves plant^{-1}: Based on Table 4, faba bean varieties significantly differed from foliar fertilization with nano zinc levels in the number of leaves per plant. The V_3 variety significantly outperformed the other varieties for the leaves plant^{-1}, which had 98.00 leaves plant^{-1}, whereas the V_1 variety had the least mean number of leaves plant^{-1} as 70.20 leaves plant^{-1}. The Table reveals that the spraying treatment with 200 mg L^{-1} of nano zinc for the number of leaves plant^{-1} is superior, showing a substantial difference from the other treatments, which had the maximum mean of 84.30 leaves plant^{-1}, yet the control (with water only) had the lowest 78.10 leaves plant^{-1}. The variables related to genetic composition may have caused the earlier outcomes. These outcomes correspond with what (1) found. This increase in number of leaves plant^{-1} because of applying foliar with nano zinc as nanotechnology helps enhance agricultural yield through raising the input efficiency, reducing related damages and more extensive specific surface area to fertilizers (23), for raising growth and elongating the plant parts showing more leaves plant^{-1} confirming (2, 13 and 20).

The faba bean varieties' interaction and foliar fertilization with nano zinc insignificantly impacted the number of leaves per plant.

Table 4: Effect of varieties and foliar fertilization with nano zinc levels on number of leaves plant^{-1} of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	67.50	70.10	73.20	**70.20**
V_2. Aquaduice a longue cros(American)	63.70	65.80	69.70	**66.40**
V_3. Luz de otono (Spanish)	93.10	98.40	102.60	**98.00**
V_4. Otono star (Holand)	88.40	90.30	92.00	**90.20**
Means of (F)	**78.10**	**81.10**	**84.30**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	5.10	3.60	N.S	

Leaves area plant^{-1} (cm^2): According to Table 5, the Luz de Otono, Spanish origin (V_3 variety) considerably exceeded the other faba bean varieties under research (Aquadlge, Turkish origin, Aquaduice a longue cross, American origin and Otono star, Holand origin) in leaves area plant^{-1}, as it recorded 8080.8 cm^2, while the V_1

variety (Aquadlge, Turkish origin) had the least average of 7448.0 cm^2. According to Table 5, spraying with nano zinc for the leaves area $plant^{-1}$ during the 2022/2023 season significantly impacted the concentration of 200 mg L^{-1} with a maximum mean of 8654.5 cm^2, lowest for control treatment of leaves area $plant^{-1}$ of 6366.0 cm^2. The genetic composition elements may have contributed to the previous outcomes proving (1 and 7). This increase in leaves area $plant^{-1}$ by applying zinc foliar is due to the exact causes impacting the elongating plant parts and nutritive status of faba bean plants, proving (2 and 20). The interaction among the varieties of faba bean and foliar fertilization with nano zinc levels had a significant effect on leaves area $plant^{-1}$, and foliar spraying V_3 variety with 200 mg nano zinc L^{-1} was the most effective at 9187.9 cm^2 during the 2022/2023 season. Even though the lowest mean of leaves area $plant^{-1}$ (6143.7 cm^2) gave rise from V_1 plants without nano zinc foliar fertilization during the 2022/2023 season.

Table 5: Effect of varieties and foliar fertilization with nano zinc levels on leaves area $plant^{-1}$ (cm^2) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	6143.7	7996.1	8204.3	**7448.0**
V_2. Aquaduice a longue cros(American)	6210.1	8217.0	8430.4	**7619.1**
V_3. Luz de otono (Spanish)	6784.1	8870.5	9187.9	**8080.8**
V_4. Otono star (Holand)	6326.3	8454.2	8795.4	**7858.6**
Means of (F)	**6366.0**	**8384.4**	**8654.5**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	578.0	832.0	1022.5	

The total chlorophyll in the leaves (SPAD): Table 6 demonstrated significant differences among the varieties of field beans in the total chlorophyll content in the leaves, as the variety V_3 provided the maximum average of 43.20 SPAD, whereas the variety V_2 had the lowest 39.80 SPAD in the study period.

Table 6 revealed that spraying with nano zinc had a significant effect on the content of total chlorophyll in the leaves, as the 200 mg nano zinc/liter had the greatest average for the whole chlorophyll in the leaves of 45.50 SPAD, with a significant difference from 150 mg nano zinc L^{-1}, and the controls (with no spraying with nano zinc) had the least mean of 36.40 SPAD during 2022/2023 season. This is due to the genetic makeup confirming (1 and 10). This may be explained by the increased nutrient content in the leaves, which begins in the stage just before flowering and continues through the holding of the pods. One such nutrient is nanozinc, which is crucial for promoting vegetative growth, increasing the amount of chlorophyll in the leaves, and, ultimately, increasing photosynthesis efficiency. These findings partially conform to those provided by (2, 16 and 20).

The interaction among the varieties of faba bean and foliar fertilization with nano zinc levels had a significant impact on the leaf total chlorophyll, in which the finest was foliar spraying V_3 variety with 200 mg nano zinc L^{-1}, that had 47.50 SPAD during 2022/2023 season. The lowest averages of the total chlorophyll (33.80 SPAD) were from V1 plants with no nano-zinc foliar fertilization.

Table 6: Effect of varieties and foliar fertilization with nano zinc levels on the total chlorophyll (SPAD) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	35.80	40.10	44.70	**40.20**
V_2. Aquaduice a longue cros(American)	33.80	41.50	44.30	**39.80**
V_3. Luz de otono (Spanish)	38.60	43.60	47.50	**43.20**
V_4. Otono star (Holand)	37.70	42.60	45.70	**42.00**
Means of (F)	**36.40**	**41.90**	**45.50**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	2.30	3.25	5.13	

Pod length (cm): Table 7 revealed a significant effect of faba bean varieties and foliar fertilization with nano zinc levels on pod length during the 2022/2023 season. The V_3 variety (Luz de otono, Spanish origin) recorded the greatest average pod length 24.00 cm, being significantly different from the V_1 variety (Aquadlge, Turkish origin), which had the minor average pod length 21.40 cm during 2022/2023 season.

Spraying the field of bean plants with 200mg nano zinc L^{-1} considerably improved pod length, which had the maximum mean 24.10 cm in comparison with control treatment (without nano zinc foliar fertilization), which had the least mean 20.80 cm during 2022/2023 season. These results could be caused by genetic makeup proving (2 and 14).

The increased use of nano zinc spraying may be because of its significant contribution to boosting photosynthetic efficiency and producing dry substances that promote pod lengthening. This result agrees with the results of (2).

The interaction among the faba bean varieties and foliar fertilization with nano zinc levels significantly influenced pod length, with perfect foliar spraying V3 as an ideal treatment for a variety with 200 mg nano zinc L^{-1}, which had 25.30 cm. On the other hand, the shortest faba bean pods 19.30 cm rose from V_1 plants with no nano zinc foliar fertilization during the 2022/2023 season.

Table 7: Effect of varieties and foliar fertilization with nano zinc levels on pod length (cm) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	19.30	22.30	22.80	**21.40**
V_2. Aquaduice a longue cros(American)	21.20	23.50	24.00	**22.90**
V_3. Luz de otono (Spanish)	22.10	24.70	25.30	**24.00**
V_4. Otono star (Holand)	20.60	23.70	24.60	**22.70**
Means of (F)	**20.80**	**23.50**	**24.10**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	2.10	2.20	3.25	

Number of pods $plant^{-1}$: It is noticed from Table 8 that there is a significant difference among the varieties of field beans in several pods $plant^{-1}$ during the 2022/2023 season. The V_3 variety (Luz de otono, Spanish origin) provided the most significant average of 18.50 pods $plant^{-1}$, whereas the V_2 variety (Aquaduice a longue cross, American origin) gave the lowest 16.40 pods $plant^{-1}$ during the 2022/2023 season.

The findings in Table 8 also revealed significant differences due to foliar fertilization with nano zinc levels on several pods plant^{-1} during the 2022/2023 season, where the nano zinc concentration 200 mg L^{-1} provided the maximum mean of 18.40 pods plant^{-1}, in comparison to the lowest average of 15.60 pods plant^{-1} of the no-spraying treatment during 2022/2023 season.

The earlier findings may have been caused by genetic variables arising from the relationships between the cultivars' genetic composition, which confirm (2, 7, 10, 11 and 14).

The rise might be attributed to the significant function that nano zinc plays in pollination. By promoting biological processes and fertilization during the development and blooming stages, nano zinc stimulates more fertilization, increasing the number of pods each plant produces. These results conform to the results attained by (2).

The interaction among the varieties of faba bean and foliar fertilization with nano zinc levels significantly influences several pods plant^{-1}, and the paramount treatment was foliar spraying V_3 with 200 mg nano zinc L^{-1}, which had 19.80 pods plant^{-1} during the 2022/2023 season. However, the lowest number of pods plant^{-1} (14.60 pods plant^{-1}) rose from with no nano zinc foliar fertilization in the same period.

Table 8: Effect of varieties and foliar fertilization with nano zinc levels on number of pods plant^{-1} of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	14.60	17.80	18.40	**16.90**
V_2. Aquaduice a longue cros(American)	15.40	16.90	17.00	**16.40**
V_3. Luz de otono (Spanish)	16.70	19.20	19.80	**18.50**
V_4. Otono star (Holand)	15.70	17.60	18.70	**17.30**
Means of (F)	**15.60**	**17.80**	**18.40**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	1.70	2.20	2.85	

Number of seeds pod^{-1}: Based on Table 9, the faba bean varieties and foliar fertilization differed significantly with nano zinc levels in several seeds pod^{-1} in the study period. The V_3 variety was significantly superior to the other types in the number of seeds pod^{-1}, which had 5.60 seeds pod^{-1}. Still, the V_2 variety had the lowest average number of seeds pod^{-1} at 4.90 and seeds pod^{-1} in the period under consideration.

Statistics in Table 9 indicate that the spraying treatment with 200 mg L^{-1} of nano zinc for the number of seeds pod^{-1} is superior and is considerably different from the other treatments, which had the maximum mean of 5.80 seeds pod^{-1}, while the control (spraying with water only) had the least mean of 4.60 seeds pod^{-1} during 2022/2023 season.

The earlier findings may have been caused by genetic variables arising from the relationships between the cultivars' genetic composition, restating what (2 and 10) reported.

The stimulatory impact on several seeds pod^{-1} because applying foliar of nano zinc could be ascribed to the same reasons that led to increasing plant height, number of branches plant^{-1}, number of pods plant^{-1}, and pod length partially proving (2).

The interaction among the varieties of faba bean and foliar fertilization with nano zinc levels had a significant effect on several seeds pod^{-1}, where the perfect treatment was foliar spraying V_3 variety with 200 mg nano zinc L^{-1}, which had 6.20 seeds pod^{-1} during 2022/2023 season. The least number of seeds pod^{-1} (4.30 seeds pod^{-1}) resulted from V_1 plants without nano zinc foliar fertilization during the 2022/2023 season.

Table 9: Effect of varieties and foliar fertilization with nano zinc levels on number of seeds pod^{-1} of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	4.30	5.10	5.80	**5.00**
V_2. Aquaduice a longue cros(American)	4.50	4.80	5.60	**4.90**
V_3. Luz de otono (Spanish)	5.00	5.80	6.20	**5.60**
V_4. Otono star (Holand)	4.90	5.30	5.90	**5.30**
Means of (F)	**4.60**	**5.20**	**5.80**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	0.50	0.55	0.85	

100-seed weight (g): The findings in Table 10 illustrated that the Luz de Otono, Spanish origin (V_3 variety) considerably exceeded the other faba bean varieties under research (Aquadlge, Turkish origin, Aquaduice a longue cross, American origin and Otono star, Holand origin) in 100-seed weight, as it recorded 138.30 g. In contrast, the V_2 variety (Aquaduice a longue cross, American origin) recorded the lowest average of 129.80 g during the 2022/2023 season. The findings in Table 10 revealed a significant effect of spraying with nano zinc for 100-seed weight during the 2022/2023 season, and the concentration of 200mg/liter provided the maximum mean of 139.80 g, whereas the control treatment had the least 100-seed weight of 125.90 g during 2022/2023 season. The previous results are possibly due to genetic factors for the types partially proving (2, 10, 14 and 25). It is possible to explain this increase in 1000-grain weight due to foliar applying nanozinc because of their effects on translocated metabolites to seeds, dry matter accumulation, and increased plant development. These findings align with those reported by (2). The interaction among the varieties of faba bean and foliar fertilization with nano zinc levels had a significant effect on 100-seed weight, and the perfect treatment was foliar spraying V_3 variety with 200mg nano zinc L^{-1}, which had 146.00 g during the 2022/2023 season even though the least mean of 100-seed weight (122.40 g) arose from V_4 plants without nano zinc foliar fertilization during 2022/2023 season.

Table 10: Effect of varieties and foliar fertilization with nano zinc levels on 100-seed weight (g) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	124.30	133.60	136.50	**131.50**
V_2. Aquaduice a longue cros(American)	125.20	128.60	135.60	**129.80**
V_3. Luz de otono (Spanish)	130.10	138.80	146.00	**138.30**
V_4. Otono star (Holand)	122.40	132.60	141.40	**132.10**
Means of (F)	**125.90**	**133.40**	**139.80**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	4.60	5.55	6.10	

Total seed yield (ton ha^{-1}): The findings in Table 11 revealed significant varieties' total seed yield ha^{-1}, as the variety V_3 was significantly different, giving the highest average of 5.329 ton ha^{-1}, while the V_2 had the lowest 4.488 ton ha^{-1} during the 2022/2023 season.

The findings in Table 11 revealed a significant impact of nano zinc-spraying with levels on total seed yield ha^{-1}, as 200 mg nano zinc/L had the maximum range for total seed yield ha^{-1} amounted to 5.574 ton ha^{-1}, with a significant difference from 150 mg nano zinc L^{-1}, and the controls (with no spraying with nano zinc), which had the least mean of total seed yield ha^{-1} as 4.305 ton ha^{-1} during 2022/2023 season. These effects on the yield of grains per unit area may have resulted from applying zinc chelated or nanoforms through foliar treatment. The earlier findings could be related to genetic factors resulting from the genetic composition of the varieties agreeing with (2, 3, 7 and 14). This is because chelated zinc influences plant processes, including nitrogen metabolism, protein quality, nitrogen uptake, photosynthesis, chlorophyll synthesis, carbon anhydrase activity, resistance to biotic and abiotic stresses, and protection against oxidative damage (17). Moreover, zinc used in nano form rather than conventional form is given to plants gradually and under control, which improves application efficiency and lowers hazards and pollution (23). According to the preceding, improved early development, increased accumulation of dry material, and stimulation of the synthesis of metabolic processes would increase the number of seeds produced per unit area. These findings partially agree with (2). The faba bean varieties and foliar fertilization interact with nano zinc levels, showing a significant effect on total seed yield ha^{-1}, and the better treatment was foliar spraying V_3 with 200 mg nano zinc L^{-1}, which had 6.212-ton ha^{-1} during the 2022/2023 season. Meanwhile, the lowest averages of total seed yield ha^{-1} (4.111 ton ha^{-1}) came from V_1 plants without nano zinc foliar fertilization during the 2022/2023 season.

Table 11: Effect of varieties and foliar fertilization with nano zinc levels on Total seed yield (ton ha^{-1}) of faba bean during the 2022/2023 season.

V. Faba bean varieties	F. Foliar (mg L^{-1})			Means of (V)
	0	150	200	
V_1. Aquadlge (Turkish)	4.111	4.899	5.588	**4.866**
V_2. Aquaduice a longue cros(American)	4.233	4.366	4.865	**4.488**
V_3. Luz de otono (Spanish)	4.566	5.211	6.212	**5.329**
V_4. Otono star (Holand)	4.312	4.651	5.632	**4.865**
Means of (F)	**4.305**	**4.781**	**5.574**	
	V	**F**	**V × F**	
LSD $_{(0.05)}$	0.676	0.965	1.030	

Conclusions

Based on the research results, it is recommended that foliar spraying V_3 variety (Luz de otono, Spanish origin) plants with nano zinc at a concentration of 200 mg L^{-1} for two times, the first at the beginning phase of flowering and the second at 75% flowering phase in situations of the environment in the study area.

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No Supplementary Materials.

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