Bionatura
Latin American Journal of Biotechnology and Life Sciences

Bionatura Issue 1 Vol 8 No 1 2023

Article

Response of Seed Yield and Its components of Several Genotypes of *Vicia faba* L. to Spraying of Zinc Nanoparticle Fertilizer

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Available from: http://dx.doi.org/10.21931/RB/CSS/2023.08.01.98

Abstract: A field experiment was conducted at a College of Agriculture research station at - the University of Anbar during the winter season of 2021-2022 to study the response of seed yield and its components of several genotypes of *Vicia faba* L. to spraying of zinc nanoparticle fertilizer. The experiment was carried out by Split Plots arrangement according to the Randomized Complete Block Design (R.C.B.D.) at three replications. The main plots included four concentrations of zinc nanoparticle fertilizer (0, 60, 12 and 180mg L^{-1}), whereas the sub-plots included four faba bean genotypes (Local, American, Dutch and Italian). The results showed that the American genotype was significantly superior in the number of pods per plant (21.40 pod $plant^{-1}$), fertility percentage per pod (88.80%), seed yield (6.57 Mg ha^{-1}) and biological yield (11.01 Mg ha^{-1}). In contrast, the Dutch genotype achieved the highest mean of the number of seeds per pod (5.64 seed pod^{-1}) and weight of 100 seeds (107.68 g). Also, the spraying of zinc nanoparticles at 180 mg L^{-1}were significantly superior in the number of pods per plant (22.35 pod $plant^{-1}$), weight of 100 seeds (111.40 g), fertility percentage per pod (90.30%), seed yield (6.23 Mg ha^{-1}) and biological yield (10.78 Mg ha^{-1}), while the spraying of zinc nanoparticle at a 120 mg L^{-1} gave the highest mean of the number of seeds per pod (5.66 seed pod^{-1}). The interaction between two factors had a significant effect on the most studied traits; the American genotype with the spraying of zinc nanoparticle at 180 mg L^{-1} gave the highest values of the number of pods per plant (25.23 pod $plant^{-1}$), fertility percentage in a pod (91.14%) and seed yield (7.88 ton ha^{-1}).

Keywords: *Viciafaba* L., nano-zinc, seed yield, yield components.

Introduction

Faba bean is one of the legume family's main and essential winter crops (Fabaceae). The importance of this crop comes from being one of the rich sources of protein and its role in improving soil properties through the process of nitrogen fixation by Rhizobium bacteria [1]. Despite the importance of this crop, its productivity rate in Iraq needs to meet the needs of local consumption compared with global production because of many problems it suffers from, including low productivity per unit area. This is due to several reasons, including the inappropriateness of the genotype to the environmental conditions in which it is cultivated and failure to apply soil and crop service operations correctly according to scientific principles, which requires studying all possible means to improve its vegetative traits, thus increasing its production, including the introduction of

highly productive genotypes and adapted with local conditions to expand the cultivation area of this crop and raise its productivity.

In order to use the potential energy of these genotypes to the maximum extent, modern agricultural technologies must be applied, including the use of nano fertilizers, as nano fertilizers are a modern technology in Iraq, which can be added as an element or a group of elements leading to increased growth, quantity and quality of yield and increased use efficiency of nutrients and less environmental pollution. Also, micronutrients are essential in human and plant life, including zinc, which is an essential nutrient in the formation of nucleic acids, cell growth, and protein building, stimulates brain cells, and supports the function of the healthy immune system in humans, as it was noted that zinc deficiency weakens the resistance of the human body to pathogens, which increases the risk of infection with colds and the Coronavirus COVID-19 [2]. In addition, the plant needs it in small amounts. Its deficiency affects the plant growth, seed yield and the quality of the seeds produced, as it participates in the metabolic reactions of both carbohydrates and proteins and enters into the construction of tryptophan, which enters into the production of auxin necessary for cell elongation. Its decrease causes changes in growth, thus the production of dwarfed plants [3]. This study aims to study the response of seed yield and its components of several genotypes of Vicia faba L. to spraying of zinc nanoparticle fertilizer.

Materials and Methods

A field experiment was conducted at a College of Agriculture research station - at the University of Anbar during the winter season of 2021-2022 to study the response of seed yield and its components of several genotypes of Vicia faba L. to spraying of zinc nanoparticle fertilizer. The experiment was carried out by Split Plots arrangement according to the Randomized Complete Block Design (R.C.B.D.) at three replications. The main plots included four concentrations of zinc nanoparticle fertilizer (0, 60, 12 and 180mg L^{-1}), whereas the sub-plots included four faba bean genotypes (Local, American, Dutch and Italian). The spraying was carried out after 40 and 80 days of planting in the early morning using a 15-liter dorsal sprinkler until the leaves were completely wet. Soil management was carried out, and the experiment land was divided into 48 experimental units. Phosphorous fertilizer was added at 100 Kg ha^{-1} as a triple super phosphate (46% P_2O_5) at one dose before the planting.

In contrast, the nitrogen fertilizer was added at 60 kg N ha^{-1} as urea (46% N) at two equal doses, the first at the planting time while the second at the flowering stage [4]. The seeds of faba bean genotypes were sown on 15 October 2020. Crop management was carried out as needed, and the plants were harvested after the appearance of maturity signs

Studied traits

1. Number of pods per plant (cm): The number of pods per five plants was randomly taken from each experimental unit at the harvest stage, and their mean was extracted.

2. Number of seeds per pod: The number of seeds per 25 pods was randomly taken from each experimental unit at the harvest stage, and their mean was extracted.

3. Weight of 100 seeds (g): One hundred seeds were randomly taken from the grain yield of each experimental unit, weighed and the mean of 100 seeds weight was extracted.

4. Fertility percentage per pod (%): Fertility percentage of 25 pods was calculated at the harvest stage by the following equation:

$$\text{Fertility percentage } (\%) = \frac{\text{No. of total seeds per pods}}{\text{No. of total ovules per pod}} x\ 100$$

5. Seed yield (Mg ha^{-1}): Five plants were randomly harvested from each experimental unit, then the seed yield was calculated by multiplying the mean of seed yield of the five plants by the plant density, and the results were converted to a mega gram per hectare.

6. Biological yield (Mg ha^{-1}): Five plants were randomly harvested from each experimental unit, air-dried and weighed by a sensitive scale, then the biological yield was calculated by multiplying the mean of plant dry weight of the five plants by the plant density, and the results were converted to mega gram per hectare.

The data were statistically analyzed using the Genstat program, and the least significant difference (L.S.D.) test at 0.05 probability level was used to compare the treatment means.

Results

Number of pods per plant

The results in Table 1 show that the faba bean genotypes were significant differences in the number of pods per plant; the American genotype achieved the highest mean (21.40 pod $plant^{-1}$) compared with the Local genotype, which achieved the lowest mean (17.68pod $plant^{-1}$). The reason may be due to the ability of the American genotype to exploit the surrounding environmental conditions and use them in the photosynthesis process, which was reflected in the increase in the transfer of metabolic products from the sources to the sinks and then increase in the number of pods per plant [31]. The results in Table 1 reveal that the spraying of zinc nanoparticles at 180 mg L^{-1} was significantly superior and gave the highest mean of the number of pods per plant (22.35 pod $plant^{-1}$) compared with the control treatment (spraying of distilled water only) which gave the lowest mean (14.95pod $plant^{-1}$). The increase may be due to the role of zinc nanoparticles in increasing the activity of many enzymes related to the growth and development of pollinated flowers and then increasing the number of pods per plant. The interaction between two factors had a significant effect on the number of pods per plant Table 1; the American genotype with the spraying of zinc nanoparticles at 180 mg L^{-1} gave the highest value (25.23 pod $plant^{-1}$), while the Local genotype with control treatment (spraying of distilled water only) gave the lowest value (13.37 pod $plant^{-1}$).

Zinc nano-particle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	13.37	16.84	15.94	13.65	14.95
60	17.52	20.89	18.55	16.65	18.40
120	19.81	22.64	20.75	19.13	20.58
180	20.03	25.23	21.77	22.37	22.35
Mean	17.68	21.40	19.25	17.95	
LSD 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.83		0.68		1.37

Table 1. Effect of genotypes and zinc nanoparticle concentrations on the number of pods per plant.

Number of seeds per pod

The results in Table 2 indicate that the faba bean genotypes were significant differences in the number of seeds per pod; the Dutch genotype gave the highest mean (5.64 seed pod^{-1})with a non-significant difference in the American genotype (5.62 seed pod^{-1}), whereas the Italian genotypegavea lowest mean (4.60 seed pod^{-1}). The reason for superiority may be attributed to the fact that the American and Dutch genotypes exploited the surrounding environmental conditions, as well as their efficiency in transferring the photosynthesis products to the flowers and emerging seeds, which led to an increase in the fertility rate of pods Table 1, and then increase the number of seeds per pod. The results in Table 2 reveal that the spraying of zinc nanoparticles at 120 mg L^{-1} was significantly superior and achieved the highest mean number of seeds per pod (5.66 seed pod^{-1}) compared with the control treatment, which achieved the lowest mean(4.72 seed pod^{-1}).

Zinc nano-particle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	4.59	5.26	5.04	4.01	4.72
60	4.87	5.72	6.01	4.52	5.28
120	5.79	5.89	5.91	5.04	5.66
180	5.50	5.60	5.62	4.83	5.38
Mean	5.19	5.62	5.64	4.60	
Lsd 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.11		0.27		N.S.

Table 2. Effect of genotypes and zinc nanoparticle concentrations on the number of seeds per pod.

Weight of 100 seeds (g)

The results in Table 3 reveal that the faba bean genotypes had significant differences in the weight of 100 seeds; the Dutchgenotypehada had the highest mean (*107.*68 g) while the Local genotype had the lowest mean (104.95 g). The reason for the variation of faba bean genotypes in this trait may be their difference in the size of the seeds. These results agree with [13] who reported that the faba bean genotypes significantly differed in the weight of 100 seeds. The results in Table 3 show that the spraying of zinc nanoparticles at 180 mg L^{-1} was significantly superior and gave the highest mean weight of 100 seeds (111.40 g) compared with the control treatment, which had the lowest mean(103.33 g). The reason for the increase may be attributed to the role of zinc in improving the various biochemical processes within the plant, activating many essential enzymes in the photosynthesis process, transferring their products to the reproductive parts, including seeds, and then increasing the duration of their filling and increasing their weight. The interaction between two factors had a significant effect on the weight of 100 seeds Table 3; the Italian genotype with the spraying of zinc nanoparticles at 180 mg L^{-1} recorded the highest value (*113.49* g), whereas the Local genotype with control treatment recorded the lowest value (101.19 g).

Zinc nano-particle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	101.19	105.52	104.99	101.62	103.33

60	101.35	105.80	106.97	104.76	104.72
120	106.28	107.39	108.12	108.18	107.49
180	110.98	110.47	110.64	113.49	111.40
Mean	104.95	107.30	107.68	107.01	
Lsd 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.59		0.81		1.48

Table 3. Effect of genotypes and zinc nanoparticle concentrations on weight of 100 seeds (g).

Fertility percentage per pod (%)

According to the research data, the results in Table 4 show that the American genotype was significantly superior and achieved the highest fertility percentage per pod (88.80%) compared with the Local genotype, which achieved the lowest percentage (83.44%). The superiority of the American genotype may be due to its genetic structure in exploiting the surrounding environmental conditions and its high efficiency in transferring photosynthesis products to ovules, which led to an increase in their fertility percentage. The results in Table 4 reveal that the spraying of zinc nanoparticles at 180 mg L^{-1} was significantly superior and gave the highest percentage of fertility per pod (90.30%) compared with the control treatment, which gave the lowest mean (82.11%). The reason for the high concentration of zinc nanoparticles may be due to the role of this element in increasing the activity of more than 300 enzymes in the plant, including the enzymes responsible for the formation of pollen and fertilization, and then increasing the fertility percentage of ovules [29], in addition to the role of zinc in improving most growth traits, which led to an increase the photosynthesis process efficiency and the transfer of its products to the reproductive parts (pods), which was positively reflected in increase the fertility percentage per pod. The increase may be due to the role of zinc nanoparticles in increasing the activity of many enzymes related to the growth and development of pollinated flowers and then increasing the number of pods per plant. The interaction between the two factors significantly affected the number of pods per plant. Table 4, the American genotype with the spraying of zinc nanoparticles at 180 mg L^{-1} gave the highest value (91.14%). In contrast, the Local genotype with control treatment gave the lowest value (71.21%).

Zinc nano-particle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	71.21	87.44	83.02	86.78	82.11
60	85.63	88.34	84.11	86.93	86.25
120	86.83	88.27	85.46	87.76	87.08
180	90.07	91.14	89.75	90.26	90.30
Mean	83.44	88.80	85.59	87.93	
Lsd 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.71		0.64		1.25

Table 4. Effect of genotypes and zinc nanoparticle concentrations on fertility percentage per pod(%).

Seed yield (Mg ha^{-1})

According to the research data, the results in Table 5 reveal that the American genotype was significantly superior and achieved the highest mean of seed yield (*6.*57 Mg ha^{-1}) compared with the Dutch genotype, which achieved the lowest

mean (4.71 Mg ha^{-1}). The superiority of the American genotype may be attributed to the superiority in the number of pods in the plant Table 1 and fertility percentage per pod Table 4. These results agree with [30] and [13], who reported that the faba bean genotypes significantly differed in the seed yield. The results in Table 5 show that the spraying of zinc nanoparticles at 180 mg L^{-1} was significantly superior and gave the highest mean of seed yield (6.23 Mg ha^{-1}) compared with the control treatment, which gave the lowest mean (3.84 Mg ha^{-1}). The increase may be due to the superiority of spraying zinc nanoparticles at 180 mg L^{-1} in the number of pods in the plant Table 1, weight of 100 seeds Table 3 and fertility percentage per pod Table 4. This is in line with the results of Raed (2011) and Saleh (2012), who indicated a significant increase in the seed yield of different leguminous crops due to spraying different zinc concentrations. The interaction between two factors had a significant effect on the seed yield (Table 5); the American genotype with the spraying of zinc nanoparticle at 180 mg L^{-1} gave the highest value (*7.88*Mg ha^{-1}), whereas the Italian genotype with control treatment gave the lowest value (3.57 Mg ha^{-1}).

Zinc nanoparticle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	3.65	4.51	3.62	3.57	3.84
60	4.92	6.61	4.72	5.03	5.32
120	5.47	7.28	5.09	5.53	5.84
180	6.24	7.88	5.41	5.40	6.23
Mean	5.07	6.57	4.71	4.88	
Lsd 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.20		0.22		0.42

Table 5. Effect of genotypes and zinc nanoparticle concentrations on seed yield(Mg ha^{-1}).

Biological yield (Mg ha^{-1})

The results in Table 6 indicate that the American genotype was significantly superior and recorded the highest mean of biological yield (*11.*01 Mg ha^{-1}) compared with the Dutch genotype, which recorded the lowest mean (9.66 Mg ha^{-1}). The reason for the variation of faba bean genotypes in this trait may be their difference in growth traits and seed yield and its components Tables 1, 2, 3, 4 and 5. These results agree with [8] and [9]who noted that the faba bean genotypes significantly differed in the biological yield. The results in Table 6 reveal that the spraying of zinc nanoparticles at 180 mg L^{-1} was significantly superior and achieved the highest mean of biological yield (10.78Mg ha^{-1}) compared with the control treatment, which achieved the lowest mean(9.51 Mg ha^{-1}). The increase may be due to the superiority of spraying zinc nanoparticles at 180 mg L^{-1} in the number of pods in the plant Table 1, fertility percentage per pod Table 4 and seed yield Table 5.

Zinc nanoparticle (mg L^{-1})	Genotypes				Mean
	Local	American	Dutch	Italian	
0	9.57	10.35	8.83	9.27	
60	10.01	10.57	9.15	9.59	9.51
120	10.18	11.27	10.31	9.94	9.83
180	10.88	11.84	10.34	10.08	10.42

Mean	10.16	11.01	9.66	9.72	10.78
Lsd 0.05	Zinc nanoparticle		Genotypes		Interaction
	0.34		0.27		N.S.

Table 6. Effect of genotypes and zinc nanoparticle concentrations on biological yield(Mg ha^{-1}).

Discussion

This result agrees with [25] and [26], who reported that the faba bean genotypes significantly differed in the number of pods per plant.

The result is consistent with other studies that indicated the positive effect of mineral nutrition in increasing the number of pods per plant Raed, 2011; Saleh, 2012 and [27]

These results agree with Mahidi et al. (2018) and [9], who indicated that the faba bean genotypes significantly differed in the number of seeds per pod.

The increase in the number of seeds per pod could be attributed to the significant effect of zinc in improving the biochemical processes in the plant, which leads to an increase in the transfer of photosynthetic products to the fertilized ovules, which reduces their abortion and increases their number per pod (IPI, 2000). This result is consistent with [24] and [22]. The interaction between the two factors had a non-significant effect on the number of seeds per pod.

In this regard, Issa (1990) mentioned that the weight of a seed is a function of the average photosynthesis and the transfer of its products. This result is consistent with Raed (2011) and Saleh (2012), who indicated that the weight of 100 seeds was significantly increased when spraying zinc at different concentrations.

This result is with [19] who reported that the faba bean genotypes significantly differed in the fertility percentage per pod.

The results also agree with Saleh (2012) and [27], who found that the biological yield of legume crops was significantly affected when spraying different concentrations of mineral fertilizers. The interaction between the two factors had a non-significant effect on the biological yield.

Conclusion

We can conclude that the faba bean genotypes varied in all the studied traits, and the American genotype was the best and gave the highest means of most studied traits compared with other genotypes, as well as its higher response to the high concentration of zinc nanoparticle fertilizer. Also, the response to spraying of zinc nanoparticle fertilizer was progressive with increased zinc nanoparticle concentrations, and the high concentration was significantly superior in most of the studied traits.

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Received: May 15, 2023/ Accepted: June 10, 2023 / Published: June 15, 2023
Citation: Mahdi, S.A..; Kafoor, A.A. Response of Seed Yield and Its Components of Several Genotypes of Vicia faba L. to Spraying of Zinc Nanoparticle Fertilizer. Revis Bionatura 2023;8 (1) 98. http://dx.doi.org/10.21931/RB/CSS/2023.08.01.98