Original Article

Effect of Mycorrhizae and Rhizobia Inoculation and Spraying Sorbitol and Microelements on The Growth and Yield of Pea Plants

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Abstract

This field experiment was conducted during winter 2023 at the Al-Buaitha research station of the College of Agriculture, University of Anbar using a randomized complete block design (RCBD) and employing two factors. The first was the addition of biofertilizers (full fertilizer connection, mycorrhizae+½ connection, rhizobia + ½ connection, mycorrhizae+ rhizobia+ ½ fertilizer connection) and the second involved leaching with sorbitol and larger elements and four treatments (no spraying, sugar alcohols, zinc, boron, sugar alcohols + zinc + boron). The results showed that adding biofertilizers (mycorrhizae + rhizobia) led to a significant increase in plant length (113.29 cm), number of branches (8.51 plant branch-1), pod length (9.10 cm), pod weight (7.41 g), number of seeds per pod (6.63 pod seed-1), number of pods (31.87 pod plant-1), plant yield (237.14 g plant-1), hectare yield (12.65 ton ha-1), seed nitrogen content (3.15%), seed phosphorus content (0.422%), seed TSS ratio (14.08%), and seed protein percentage (19.69%). There was also a significant effect from the sorbitol and microelements spraying treatments on plant length (117.70 cm), number of branches (9.35 plant branch-1), pod length (9.63 cm), pod weight (7.60 g), number of seeds per pod (6.99 pod seed-1), number of pods (31.61 pod Plant-1), plant yield (240.27 g plant-1), hectare yield (12.81 t ha-1), seed nitrogen content (3.17%), seed phosphorus content (0.427%), seed TSS ratio (14.36%), and seed protein percentage (19.81%).

Keywords: Peas, Mycorrhizae, Rhizobia, Sorbitol, Microelements.

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Introduction

The pea (*Pisum sativum* L.) is among the leguminous herbaceous plants that rank second in economic significance, following the Poaceae family, and they are recognized after tomatoes as a key ingredient for canning purposes. It is classified as an annual herbaceous species with restricted or unrestricted growth, and it complements the prevailing climatic conditions (16). Peas are cultivated for their edible green seeds, and can be eaten cooked, canned, or frozen. They are regarded as plant-based components high in protein and other essential nutrients. Their protein content ranges from 21–25%, and they are rich in essential amino acids like lysine and tryptophan, making them a valuable source of plant-based protein (24).

Although mineral fertilizers are essential, efforts are being made to reduce their use while maintaining the same yields and quality of the final agricultural product (25). Legumes (Fabaceae) are of particular interest in this

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regard, as they can be free of mineral nitrogen sources due to mutualistic endosymbiosis with nitrogen-fixing nodule bacteria (rhizobia) and arbuscular mycorrhizal (AM) fungi (17 and 20). Regarding these plant–microbial interactions, rhizobia supply plants with metabolically accessible nitrogen, whereas AM fungi provide water and hardly soluble phosphates. On the other hand, the microorganisms gain access to plant photosynthetic assimilates and find a well-balanced habitat within the plant rhizosphere. Multiple studies have confirmed that these symbioses can improve the overall fitness of the plant and, ultimately, positively impact seed productivity and quality (15 and 22). Sugar alcohols are carbohydrate compounds that occur naturally in plants as products of photosynthesis and move quickly within the plant. The aldehyde group (CH2OH-CHO) is reduced to form a sugar alcohol. One of these is sorbitol, which is a natural sugar alcohol produced within plants and contributes to increasing the efficiency of foliar fertilization by penetrating nutrients through the cuticle layer, taking advantage of its tiny molecular size (3 and 11).

As for nutrients or microelements, plants need low concentrations or small amounts of them to enhance growth and increase productivity, which is indispensable in plant production (6). Microelements are important for healthy plant growth and play an important role in shaping the shape and anatomy of the plant. They are termed microelements because their dry matter content does not exceed 0.01%, and the bioavailability of these elements depends on the extent of soil interaction and fertility, in addition to the presence of other ions (synergic or antagonistic) (13). Based on the above, this study investigated the effect of adding mycorrhizae and rhizobia and spraying a combination of sugar alcohols (sorbitol) and trace elements on the growth, yield, and qualitative and quantitative characteristics of peas.

Materials and Methods

The experiment was conducted at the research station of the College of Agriculture, University of Anbar, Al-Buaitha, Iraq, located at latitude 33.28 and longitude 43.21 during the 2023-2024 agricultural season from October 15, 2023, to February 25, 2024. It examined the effects of inoculation with mycorrhizae and rhizobia and spraying with alcohol sugars and microelements on the growth and yield of peas. The experiment was conducted using a randomized complete block design (RCBD), and the means of the treatments were compared using the least significant difference (LSD) test at a 5% significance level (19). The results were analyzed using the Genestat program.

The experiment included three replicates with 20 treatments. The length of the experimental unit was 5 m, and the distance between one line and another was 75 cm. Each terrace was considered an experimental unit giving a total area of 3.75 m^2. A drip irrigation system was installed consisting of polyethylene pipes with a diameter of 1.5 inches (approximately 3.81 cm) for the main pipe and 16 mm for the distribution network of the GR type. Each plant was planted 25 cm apart. NPK fertilizer was added to the soil according to the fertilizer recommendation for pea plants (4). Field soil samples were taken from different locations before the start of the experiment and at a depth of 0-0.5 m to analyze the physical and chemical properties of the soil (Table 1). The pea seeds were planted on October 15, 2023, at a rate of three seeds per hole. After that, thinning operations were carried out, and one plant was retained. Service operations were carried out, including irrigation, weeding, fertilization, and weed and insect control, equally for all experimental units.

Table 1. Some physical and chemical properties of the soil.

Attributes	Unit	Value
Soil reaction Ph	ــــــ	7.2
Electrical conductivity EC	Desi Siemens M^{-1}	3.17
Organic matter	١kg soil	5.78
Nitrogen available in soil	malgam kg^{-1} soil	55.0
Phosphorus available in soil	malgam kg^{-1} soil	9.7
Potassium available in soil	malgam kg^{-1} soil	123.5
Zn	malgam kg^{-1} soil	8.50
Fe	malgam kg^{-1} soil	3.81
B	malgam kg^{-1} soil	0.2
Sand	malgam kg^{-1} soil	672
Clay	malgam kg^{-1} soil	126
Silt	malgam kg^{-1} soil	202
Soil texture	Sandy loam	

Study Factors:

The experiment involved two factors.

1. Application of biofertilizers with the following treatments: full fertilizer recommendation, adding mycorrhizae 10g + 1/2 fertilizer recommendation, rhizobia 5g + 1/2 fertilizer recommendation, mycorrhizae + rhizobia + 1/2 fertilizer recommendation.
2. Spraying with combinations of sugar alcohols and trace elements: without addition, spraying with sugar alcohols at a concentration of 30 g L^{-1}, spraying with zinc 100 mg L^{-1}, spraying with boron 100 mg L^{-1}, spraying with sugar alcohols + zinc + boron.

Mycorrhizae were added at 10 g $plant^{-1}$ (6) before planting, and rhizobia were added at 5 g $plant^{-1}$. Spraying operations were carried out three times, the first month after planting the seeds, and conducted every 15 days. A 20-liter hand sprayer was used with a spreading material (20-Tween) at a rate of 0.1 ml L^{-1} to reduce the surface tension of the spraying solution particles and to achieve complete wetting of the green parts and thus the plant's ability to benefit from it.

Readings were taken from ten plants per experimental unit and each replicate, and the following traits were examined:

1. Plant length (cm)
2. Number of branches (branch $plant^{-1}$)
3. Pod length (cm)
4. Pod weight (gm)
5. Number of seeds in pod (seed pod^{-1})
6. Number of pods (pod $plant^{-1}$)
7. Plant yield (gm $plant^{-1}$)
8. Yield (ton ha^{-1})
9. Nitrogen content in seeds (%)
10. Phosphorus content in seeds (%)
11. TSS ratio in seeds (%)
12. Protein percentage in seeds (%).

Results and Discussion

As shown in Table 2, plant height was significantly affected by the addition treatments, with B3 recording the highest plant height at 113.29 cm, outperforming the other treatments with the lowest height for B1 at 103.34 cm. The combination treatments also showed a significant difference with S4 recording the highest plant height at 117.70 cm over the other treatments, with the lowest height of 96.54 cm for treatment S0. The interaction treatments also showed marked differences with B3S4 recording the highest plant height at 126.32 cm, significantly outperforming the others, while the lowest height was for B0S0 at 93.24 cm.

Table 2. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on plant height (cm).

	B_0	B_1	B_2	B_3	Average S
S_0	93.24	94.06	95.45	103.42	96.54
S_1	104.77	105.23	106.59	112.24	107.21
S_2	109.01	106.79	114.70	118.10	112.15
S_3	102.68	100.14	106.56	106.36	103.93
S_4	115.07	110.51	118.91	126.32	117.70
Average B	104.95	103.34	108.44	113.29	
LSD B			1.79		0.05
LSD S			2.00		
LSD B*S			4.01		

Table 3 shows significant differences between the additions (biofertilizers). Treatment B3 (inoculation with mycorrhizae+ rhizobia + 1/2 fertilizer recommendation) produced the highest value of 8.51 branch plant^{-1}, while B0 recorded the lowest at 8.12 branch plant^{-1}. For the combination treatments, S4 excelled by giving the highest number of branches at 9.35 branch plant^{-1} while S0 recorded the lowest (7.47 branch plant^{-1}). As for the interaction between the two study factors, the results showed significant differences with the B3S4 interaction being superior, recording the highest value at 9.64 plant branches^{-1} compared to B0S0 which had the lowest value at 7.26 plant branches^{-1}.

Table 3. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on the number of branches (plant branch^{-1}).

	B_0	B_1	B_2	B_3	Average S
S_0	7.26	7.44	7.51	7.68	7.47
S_1	8.13	8.26	8.59	8.89	8.47
S_2	8.11	8.26	8.45	8.79	8.40
S_3	7.80	7.71	7.54	7.56	7.65
S_4	9.29	9.20	9.29	9.64	9.35
Average B	8.12	8.17	8.28	8.51	
LSD B			0.16		0.05
LSD S			0.18		
LSD B*S			0.37		

Table 4 shows that the average pod length differed significantly when treated with the additions. Treatment B3 recorded the highest average pod length of 9.10 cm, significantly outperforming the others while B1 had the lowest (8.12 cm). As for the combination treatments, S4 significantly outperformed by recording the longest pod length of 9.63 cm, while the lowest pod length was in S0 at 7.59 cm. Significant differences appeared when the two study factors interacted as seen in treatment B3S4 which registered the longest pod length (10.67 cm) compared to B1S0 which had the shortest length (7.07 cm).

Table 4. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on pod length (cm).

	B_0	B_1	B_2	B_3	Average S
S_0	7.73	7.07	7.67	7.90	7.59
S_1	8.43	8.33	8.30	9.00	8.52

S_2	8.33	8.17	8.13	8.40	8.26
S_3	8.63	8.45	8.47	9.53	8.77
S_4	10.60	8.60	8.63	10.67	9.63
Average B	8.75	8.12	8.24	9.10	
LSD B			0.40		0.05
LSD S			0.45		
LSD B*S			0.90		

The results obtained in Table 5 show that the additional treatments significantly affected pod weight with B3 recording the highest weight at 7.41 gm and B2 the lowest at 7.02 gm. For the combination treatments, S4 significantly outperformed the others at 7.60 gm while S0 recorded the lowest pod weight of 6.58 gm. The data in the table show insignificant interaction between the two study factors.

Table 5. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on pod weight (gm).

	B_0	**B_1**	**B_2**	**B_3**	**Average S**
S_0	6.60	6.52	6.55	6.65	6.58
S_1	7.18	7.16	7.20	7.55	7.27
S_2	6.98	6.81	6.83	7.27	6.97
S_3	7.20	7.15	7.00	7.63	7.25
S_4	7.33	7.59	7.53	7.96	7.60
Average B	7.06	7.04	7.02	7.41	
LSD B			0.14		0.05

When comparing the data in Table 6, it can be seen that the number of seeds per pod differed significantly, with treatment B3 giving the most at 6.63 seeds pod^{-1}, outperforming the other treatments, and B0 producing the least at 6.32 seeds pod^{-1}. As for the combination treatments, treatment S4 recorded the highest number of seeds per pod, reaching 6.99 seeds pod^{-1}, while S0 had 5.78 seeds pod^{-1}. As for the interaction between the addition and combination factors, treatment B3S4 significantly outperformed the rest at 7.50 seeds pod^{-1} while the lowest number of seeds in one pod was for B3S0 (5.54 seeds pod^{1}).

Table 6. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on the number of seeds per pod (seeds pod^{-1})

	B_0	**B_1**	**B_2**	**B_3**	**Average S**
S_0	5.64	5.94	6.01	5.54	5.78
S_1	6.49	6.57	6.49	6.33	6.47
S_2	5.85	6.31	6.25	6.64	6.26
S_3	6.71	6.86	6.95	7.17	6.92
S_4	6.88	6.98	6.60	7.50	6.99
Average B	6.32	6.53	6.46	6.63	
LSD B			0.22		0.05
LSD S			0.25		
LSD B*S			0.50		

The results in Table 7 indicate significant differences in the number of pods in the addition treatment, as treatment B3 recorded the highest number reaching 31.87 pod plant-1, while the lowest was in B2 at 28.38 pod plant-1. For the combination treatments, the results also show significant differences as evident in S4 giving a superior number of pods over the other treatments (31.61 pod plant-1), while the lowest was for S0 at 25.68 pod plant-

1. As for the two-factor interactions, treatment B3S4 recorded the highest number of pods (34.41 pod plant-1) significantly superior to the other treatments but not differing much from B0S4, B3S3, and B3S2. The lowest number of pods was in treatment B0S0, amounting to 23.29 pod plant-1.

Table 7. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on the number of pods (pod plant^{-1}).

	B_0	B_1	B_2	B_3	Average S
S_0	23.29	24.16	26.78	28.47	25.68
S_1	29.08	29.61	30.38	31.06	30.03
S_2	27.50	29.29	27.00	32.18	28.99
S_3	29.04	30.60	29.08	33.21	30.48
S_4	33.12	30.29	28.64	34.41	31.61
Average B	28.41	28.79	28.38	31.87	
LSD B			1.26		0.05
LSD S			1.40		
LSD B*S			2.81		

Table 8 shows significant differences between the additions (biofertilizers). Treatment B3 (inoculation with mycorrhizae+rhizobia+1/2 fertilizer recommendation) distinguished by giving the best plant yield value at 237.14 g plant^{-1} while treatment B2 (rhizobia + 1/2 fertilizer recommendation) recorded the lowest at 199. g plant^{-1}. Also, for the combinations, treatment S4 (spraying with sugar alcohols + boron + zinc) excelled by giving the best value at 240.27 g plant^{-1}, while S0 (no spraying) recorded the lowest (168.93 g plant^{-1}). Statistical analysis show no significant differences between the two study factors.

Table 8. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on plant yield (g plant^{-1}).

	B_0	B_1	B_2	B_3	Average S
S_0	153.64	157.25	175.29	189.52	168.93
S_1	208.82	211.95	218.77	234.43	218.49
S_2	191.65	199.94	184.10	234.37	202.51
S_3	209.05	218.74	203.36	253.49	221.16
S_4	242.83	229.53	214.84	273.89	240.27
Average B	201.20	203.48	199.27	237.14	
LSD B			11.12		0.05
LSD S			12.43		
LSD B*S			NS		

The statistical results in Table 9 indicate significant superiority between the additives (biofertilizers). Treatment B3 (inoculation with mycorrhizae + rhizobia + 1/2 fertilizer recommendation) dominated by giving the best value in plant yield, amounting to 12.65 tons ha^{-1}, while B2 (rhizobia + 1/2 fertilizer recommendation) recorded the lowest value, amounting to 10.63 tons ha^{-1}. For the combinations, treatment S4 (spraying with sugar alcohols + boron + zinc) was superior by giving the best value, amounting to 12.81 tons ha^{-1} while S0 (no spraying) recorded the lowest at 9.01 tons ha^{-1}. The table shows no significant differences for this trait when the two study factors overlap.

Table 9. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on yield per hectare (tons ha^{-1}).

	B_0	B_1	B_2	B_3	Average S
S_0	8.19	8.39	9.35	10.11	9.01
S_1	11.14	11.30	11.67	12.50	11.65
S_2	10.22	10.66	9.82	12.50	10.80
S_3	11.15	11.67	10.85	13.52	11.80
S_4	12.95	12.24	11.46	14.61	12.81
Average B	10.73	10.85	10.63	12.65	
LSD B			0.59		0.05
LSD S			0.66		
LSD B*S			NS		

Data comparison in Table 10 reveal seed nitrogen content differing significantly, with treatment B3 producing highest content at 3.15%. This outperformed the other treatments with the lowest rate recorded for B0 at 2.72%. As for the combination treatments, S4 recorded the highest rate, reaching 3.17%, and the lowest number was in treatment S0 (2.58%). Data in the same table show the interaction between the two study factors as not being significant.

Table 10. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on nitrogen content in the seeds (%).

	B_0	B_1	B_2	B_3	Average S
S_0	2.41	2.49	2.59	2.84	2.58
S_1	2.69	2.85	2.87	3.06	2.87
S_2	2.61	2.73	2.76	3.07	2.79
S_3	2.83	3.08	3.00	3.33	3.06
S_4	3.05	3.09	3.10	3.45	3.17
Average B	2.72	2.85	2.86	3.15	
LSD B			0.23		0.05
LSD S			0.26		
LSD B*S			NS		

As evident from the data in Table 11, seed phosphorus content was significantly affected by the addition treatments, with B3 recording the highest value, reaching 0.422%, thus outperforming the other treatments, while the lowest percentage was in treatment B‧ at 0.384%. As for the combination coefficients, they also recorded significant differences. This was clearly evident in treatment S4 which recorded the highest percentage (0.427%) and differed significantly from the other treatments. The lowest percentage at 0.380% was for treatment S0. No significant effect is seen in the interaction between the two study factors.

Table 11. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on phosphorus content in the seeds (%).

	B_0	B_1	B_2	B_3	Average S
S_0	0.370	0.387	0.380	0.383	0.380
S_1	0.380	0.400	0.390	0.417	0.397
S_2	0.363	0.403	0.390	0.420	0.394
S_3	0.400	0.413	0.400	0.433	0.412
S_4	0.407	0.433	0.410	0.457	0.427
Average B	0.384	0.407	0.394	0.422	
LSD B			0.027		0.05

LSD S	0.030	
LSD B*S	NS	

The results in Table 12 show significant differences between the additives. Treatment B3 excelled by giving the highest TSS ratio (14.08%) while B0 recorded the lowest (13.17%). For the combinations, S4 led with the highest rate at 14.36% compared to the lowest for S0 (12.79%). As for the interaction between the two study factors, significant differences appeared with the B3S4 leading with the highest value of 14.63% while the B0S0 recorded the lowest at 12.62%.

Table 12. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on TSS content in the seeds (%).

	B_0	**B_1**	**B_2**	**B_3**	**Average S**
S_0	12.62	12.79	12.62	13.12	12.79
S_1	12.79	13.34	13.27	13.59	13.25
S_2	12.80	13.57	13.22	14.47	13.52
S_3	13.44	14.13	13.51	14.60	13.92
S_4	14.23	14.30	14.30	14.63	14.36
Average B	13.17	13.63	13.38	14.08	
LSD B			0.21		0.05
LSD S			0.24		
LSD B*S			0.47		

The addition treatments as depicted in Table 13 had a significant effect on seed protein content with B3 recording the highest value at 19.69% and B0 the lowest at 16.98%. For the combination coefficients, treatment S4 at 19.81% had a significantly higher value than the others with S0 scoring the lowest rate at 16.15%. The data table also show no significant effect in the interaction between the two study factors.

Table 13. Effect of inoculating mycorrhizae and rhizobia and spraying sugar alcohols and trace elements on protein content in the seeds (%).

	B_0	**B_1**	**B_2**	**B_3**	**Average S**
S_0	15.04	15.58	16.21	17.75	16.15
S_1	16.83	17.83	17.92	19.10	17.92
S_2	16.31	17.04	17.23	19.21	17.45
S_3	17.69	19.27	18.75	20.83	19.14
S_4	19.04	19.29	19.35	21.54	19.81
Average B	16.98	17.80	17.89	19.69	
LSD B			1.43		0.05
LSD S			1.60		
LSD B*S			NS		

As seen in Tables 2 – 13, there was a significant increase in plant length, number of branches, pod length, pod weight, number of seeds per pod, number of pods, plant yield, hectare yield, seed nitrogen content, seed phosphorus content, seed TSS ratios, and seed protein content.

The increase in the number of pods and seeds per pod (Tables 6 and 7) from zinc, boron, and sugar alcohols foliar spraying may be due to the role of the element boron and its importance in the germination of both pollen grains and pollen tubes. It could also be attributed to the increase in the level of carbohydrates transferred to the growth areas and an increase in the length of the pods (Tables 5 and 8).

Improvements in the vegetative growth characteristics is positively reflected in the components of the crop, as increasing the

carbon representation led to a higher production of carbohydrates in the leaves. These are transferred to the fruits, increasing the number, weight and yield of pods, enhancing crop quality, increasing the number and weight of the seeds, and stimulating the role of sugars in transferring nutrients to the seeds quickly (1). These results are consistent with (14 and 23) when spraying boron and sugar alcohol mannitol on pea plants.

The results in Tables 2 - 13 show a significant increase in the yield characteristics represented by pod length, number of seeds per pod, yield per plant, and total yield when adding mycorrhizae and rhizobia bacteria. This may be attributed to bacterial inoculation in the formation of root nodules, which has a major role in the efficiency of fixation thus increasing nitrogen in the vegetative part of the plant, as it reflects an increase in protein in the plant, leading to improved plant growth and yield. These results are consistent with (9) on the cowpea plant and with (12 and 14) on the broad bean plant.

The moral superiority of plant length shown in Table 9 is attributed to the production of plant growth regulators by bacteria that stimulate cell elongation and thus stimulate root growth by fixing nitrogen, resulting in higher and better absorption of nutrients from the soil and thus increasing the length of the plant (10).

The increase in the number of pods (Table 5) may be due to the ability of rhizobia to fix nitrogen and the ability of the plant to benefit from it, in addition to the increased ability of the roots to absorb nutrients, as good nitrogen supply is necessary for the absorption of nutrients. This result is consistent with (21) on the mung bean plant and (6) on the broad bean plant. Mycorrhizae causes elongation of the roots in the early stages, which leads to the absorption of a larger amount of elements. In the later stages, the growth of the plant's vegetative group is higher than that of the roots, which causes an increase in the number of pods in the plant.

Conclusion

Adding biofertilizers, glomus mosseae fungus, and Rhizobium and spraying with sorbitol, zinc, and boron on the vegetative group of the plant led to improved characteristics in plant growth and yield. It produced a significant increase in the characteristics of plant height, number of pods, number of seeds per pod, pod length, plant yield, and total yield per hectare in the pea plants.

Supplementary Materials
No Supplementary Materials.

Author Contributions
Saad A. Mahmoud: methodology, writing-original draft preparation; Israa H. Sarhan: writing-review and editing. Both authors have read and agreed to the published version of the manuscript.

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No Data Availability Statement.

Conflicts of Interest
The authors declare no conflict of interest.

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References

1. Abu Dahi, Y. M., and Al-Younis, M. A. (1988). Plant nutrition guide. Baghdad University. Ministry of Higher Education and Scientific Research. Iraq.
2. Rashid, N. S. (2023). Effect of foliar application of boron and mannitol on growth and yield of pea (Pisum sativum L.). Master's thesis, College of Agriculture, University of Diyala, Iraq.
3. Rathore, R., Meghwal, M. L., Regar, O. P., & Sahu, G. (2025). Influence of foliar spray of micronutrients on growth and yield of cauliflower (Brassica oleracea var. botrytis L.). Journal of Advances in Biology & Biotechnology, 28(7), 967–974. https://doi.org/10.9734/jabb/2025/v28i72613
4. Ali, N. S., Rahi, H. S., and Shaker, A. W. (2014). Soil fertility. Scientific Books House for Printing, Publishing and Distribution. Baghdad, Iraq.
5. Ali, N. S., Allawi, M. M., and Majeed, N. H. (2022). Rhizosphere management and agricultural sustainability. University of Bagdad, 324.
6. Al-Khafaji, M. H. (2018). Effect of rhizobia and mycorrhiza inoculants and concentrations of vitamin B-complex on the growth and yield of (Vicia faba L.) (Doctoral dissertation, Ph. D. Thesis, College of Agriculture, Al-Muthanna University).
7. Al-Omrani, H. H. A. (2018). The effect of inoculation with mycorrhizae and spraying with ferrous sulphate and Armurox solution on the growth and yield of okra. MSc. Thesis, University of Baghdad, College of Agriculture.
8. Al-Sahaf, F. H. (1989). Applied Plant Nutrition, Dar Al. In Hikma Press. Ministry of Higher Education and Scientific Research. Iraq. IOP Conf. Series: Earth and Environmental Science1371, 82053: 1755-1315.
9. Al-Samarrai, N. S. (2021). Evaluation of the vaccine prepared from the local isolation of the molecularly characterized Bradyrhizobium vignae and plant growth-promoting bacteria on the growth and yield of cowpea. MSc. Thesis, Tikrit University, College of Agriculture.
10. Al-Shabani, H. R. J. (2021). The effect of bacterial inoculation of Rhizobium leguminosarum and fungal inoculation of Trichoderma harzianum and levels of organic fertilizer on the growth and yield of mung bean (Vigna radiata) and the availability of iron and molybdenum in the soil. MSc. Thesis, University of Al-Qadisiyah, College of Agriculture.
11. Al-Shammari, M. F. M. (2018). The role of spraying boron and sugars (sorbitol and mannitol) on the growth, yield and seeds of pepper plants. PhD. Thesis, University of Baghdad, College of Agriculture.
12. Amin, E. A. M. (2022). The effect of inoculation with Rhizobium leguminosarum and compost on the growth and yield of broad beans in gypsum soil. MSc. Thesis, Tikrit University, College of Agriculture.
13. Barker, A. V., and Pilbeam, D. J. (2015). Handbook of plant nutrition. 2nd ed.. CRC Press. https://doi.org/10.1201/b18458.
14. Fayyad, L. S. H., & Al Shaheen, M. A. S. (2022). Effect of root inoculation with Mycorrhizal fungus and foliar spraying with Moringa leaf extract on some vegetative characteristics and concentration of the active substance in Citrullus colocynthis fruits. International Journal of Health Sciences, 6(S5), 10977–10989. https://doi.org/10.53730/ijhs.v6nS5.11362
15. Harman, G., Khadka, R., Doni, F., and Uphoff, N. (2021). Benefits to plant health and productivity from enhancing plant microbial symbionts. Frontiers in plant science, 11: 610065. https://doi.org/10.3389/fpls.2020.610065.
16. Hassan, A. A. M. (2002). Production of legume vegetables. 1st ed. Arab House for Publishing and Distribution.
17. Herridge, D. F., Peoples, M. B., and Boddey, R. M. (2008). Global inputs of biological nitrogen fixation in agricultural systems. Plant and soil, 311(1): 1-18. https://doi.org/10.1007/s11104-008-9668-3.
18. Iqbal, S., Riaz, U., Murtaza, G., Jamil, M., Ahmed, M., Hussain, A., and Abbas, Z. (2021). Chemical fertilizers, formulation, and their influence on soil health. In: Microbiota and Biofertilizers. Springer, 1-15. https://doi.org/10.1007/978-3-030-48771-3_1.
19. Kazem, F. A., and Abdul, N. Y. (2017). Applications in statistics and analysis of agricultural experiments (practical part). Department of Crops, College of Agriculture, University of Baghdad, Iraq.
20. Liu, A., Ku, Y. S., Contador, C. A., and Lam, H. M. (2020). The impacts of domestication and agricultural practices on legume nutrient acquisition through symbiosis with rhizobia and arbuscular mycorrhizal fungi. Frontiers in Genetics, 11: 583954. https://doi.org/10.3389/fgene.2020.583954.
21. Muftin, S. T., and Jabbar, S. (2014). Effect of inoculation with Rhizobium leguminosarum and different levels of phosphate rock on the growth and yield of mung bean (Vigna radiata). Al-Muthanna Journal of Agricultural Sciences, 2(1): 123-128.
22. Noceto, P. A., Bettenfeld, P., Boussageon, R., Hériché, M., Sportes, A., van Tuinen, D., ... and Wipf, D. (2021). Arbuscular mycorrhizal fungi, a key symbiosis in the development of quality traits in crop production, alone or combined with plant growth-promoting bacteria. Mycorrhiza, 31(6): 655-669. https://doi.org/10.1007/s00572-021-01054-1.
23. Rashid, N. S. R. (2022). Effect of foliar spraying with boron and mannitol on the growth and yield of pea plants. MSc. Thesis, University of Diyala, College of Agriculture.
24. Shreida, Insam Shalal; Khalifa, Hamoud Gharbi. Effect of Root Cutting, Secondary Branch Thinning, and Spraying with Boron on the Seed Yield and

Quality of Carrot (Daucus carota L.). Journal of Life Science and Applied Research 6(2):p 31-37, Jul–Dec 2025. | DOI: 10.4103/JLSAR.JLSAR_8_25.

25. Yu, X., Li, H., and Doluschitz, R. (2020). Towards sustainable management of mineral fertilizers in China: An integrative analysis and review. Sustainability, 12(17): 7028. https://doi.org/10.3390/su12177028.

مقالة أصيلة

تأثير التلقيح بالمايكورايزا والرايزوبيا والرش بالسوربيتول العناصر الصغرى في نمو وحاصل البزاليا

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الخلاصة

اجريت التجربة الحقلية خلال لموسم الشتوي (2023–2024) في المحطة البحثية (البوعيثة) التابعة لكلية الزراعة جامعة الانبار، اجريت التجربة الحقلية تحت تصميم القطاعات العشوائية (RCBD) واشتملت الدراسة عاملين، الاول: اضافة المخصبات الحيوية (توصية سمادية كاملة، مايكوريزا +½توصية، رايزوبيا+½ توصية، مايكورايزا+ رايزوبيا+ ½ توصية سمادية). والعامل الثاني: الرش بالسوربيتول والعناصر الصغرى وتضمنت اربع معاملات (بدون رش، السكريات الكحولية، زنك، بورون، سكريات كحولية + زنك + بورون). بينت النتائج: ان الإضافة بالمخصبات الحيوية (المايكورايزا+ الرايزوبيا) أدى الى زيادة معنوية في طول النبات 113.29 (سم)، عدد الافرع 8.51 (فرع نبات$^{-1}$)، طول القرنة 9.10 (سم)، وزن القرنة 7.41 (غم)، عدد البذور في القرنة 6.63 (بذرة قرنة$^{-1}$)، عدد القرنات 31.87 (قرنة نبات$^{-1}$)، حاصل النبات 237.14 (غم نبات$^{-1}$)، حاصل الهكتار 12.65 (طن هكتار$^{-1}$)، كما بينت النتائج التأثير المعنوي لمعاملات الرش بالسوربيتول والعناصر الصغرى في طول النبات 117.70 (سم)، عدد الافرع 9.35 (فرع نبات$^{-1}$)، طول القرنة 9.63 (سم)، وزن القرنة 7.60 (غم)، عدد البذور في القرنة 6.99 (بذرة قرنة$^{-1}$)، عدد القرنات 31.61 (قرنة نبات$^{-1}$)، حاصل النبات 240.27 (غم نبات$^{-1}$)، حاصل الهكتار 12.81 (طن هكتار$^{-1}$)، نسبة النتروجين في البذور (٣.١٧٪)، نسبة الفسفور في البذور (٠.٤٢٧٪)، نسبة المواد الصلبة الذائبة الكلية TSS (١٤.٣٦٪)، نسبة البروتين في البذور (١٩.٨١٪).

كلمات مفتاحية: البزاليا، المايكورايزا، الرايزوبيا، السوربيتول، عناصر صغرى.

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