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Influence of Mycorrhizal Inoculation and Different Phosphorus Levels on Broad Bean (*Vicia faba* L.) Growth, Nutrient Uptake and Yield.

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ABSTRACT
During 2022/2023 growing season, the plastic pot experiment was conducted at the College of Agricultural Engineering Sciences, University of Sulaimani, Sulaymaniyah city, Kurdistan Region, Iraq to identification the effect of application 20 g kg^{-1} soil Arbuscular Mycorrhizal Fungi (*Glomus intraradices*) once time before planting, also application five levels of phosphors (0, 40, 80, 120 and 160) kg ha^{-1} once time before planting on broad bean plant growth, nutrient uptake and total yield. The experiment performed in completed randomized design (CRD) with three replications in silty clay soil. Before harvested the plant height and chlorophyll intensity was measured and then the plants were harvested to measured shoot dry weight, root dry weight, root colonization, pods numbers per plant and yield per plant and after the N, P, K, Fe, and Zn were measured in shoot plant. The results showed that the 160 kg phosphors per hectare with mycorrhiza caused significantly increase, chlorophyll intensity, shoot and root dry weight, nitrogen, phosphor and potassium content in shoot system with the value of (82.67 cm, 48.90 SPAD, 16.90 g, 7.70 g , 53.10 g kg^{-1}, 14.77 g kg^{-1}, and 39.50 g kg^{-1}) respectively, while the interaction treatment of P level 80 kg P ha^{-1} with mycorrhizal inoculation gave the highest values of root colonialization, Fe and Zn content which were (68.00%, 378.33 µg g^{-1} and 293.00 µg g^{-1}) respectively. On another hand, mycorrhizal inoculation with 120 kg ha^{-1} phosphorus recorded the significantly highest values for number of pods per plant and plant yield were (30.90 pods $plant^{-1}$ and 721.17 g $plant^{-1}$) compared with control.
***Keywords*:** Biostimulators, *Glomus intraradices*, Nutrient uptake, Rock phosphate, *Vicia faba*.

INTRODUCTION

Broad bean (*Vicia faba* L.) is one of the winter crops in the Fabaceae family, it is marked as one of an important protein source for human and animals' utilization of the world, and also conceded as perfect source of protein, carbohydrate, minerals, fiber and vitamins, and it is also sours of nutrients such as K, Mg, Ca, Cu, and Zn [1]. They can also play a vital role in sustainable agriculture practices due to their ability to fix atmospheric N through nitrogen fixation, which increases the amount of nitrogen in the environment. One of the best methods to achieve economic yield and higher productivity is selecting suitable cultivars [2].

Agricultural technology advancement requires improvement and development, such as using different types of biofertilizer which are environmentally safe, which are considered suitable sources of nutrients for plants, also play a significant role in boosting soil nutrient content, which leads to enhancing the soil fertility, and finally reflects positively in crop yield [3]. Also, releasing plant hormones, and stimulating plant development by production antibiotics [4]. Using mycorrhiza inoculating in sustainable agriculture attracted for improving plant growth, water uptake, soil health, soil fertility and yield [5]. There are many ways to increase available nutrients to the plant and to decline environmental pollution such as (water, soil and air). The most paramount method is the symbiotic between mycorrhizal fungi and legume plants which play positive role to improve soil fertility, also progress plant growth and yield [3].

Most soils in the Iraq- Kurdistan region area are calcareous with a high amount of Caco3, which fixes available phosphorus. While phosphorus playing a significant role in several physiological and biological plant activities. It is involved in several key plant functions such as photosynthesis, respiration, energy metabolism, transformation of sugar and component of DNA, RNA, ATP, and phospholipids, and it affects root development, stalk and stem strength, crop maturity, and nitrogen fixation in legumes [6]. Since there are a few exhaustive studies that have been conducted to describe the application of mycorrhiza fungi, such as biofertilizer, for broad bean plants for this purpose, it is necessary to focus on these areas of study in our region.

The objectives of the study:

1. To evaluate the impacts of Arbuscular Mycorrhizal Fungi (AMF) on broad bean growth at various phosphorus levels.

2- To study the impacts of different phosphorous levels on broad bean plant growth, nutrient uptake and yield.

Materials and Methods

This experiment was started on October 2022 to March 2023 at the research plastic house of Horticulture Department, College of Agricultural Engineering Sciences, University of Sulaimani, located at (35º 53' 7.9" N, 45º 36' 4.5" E), to study the effect of mycorrhizal fungi (Glomus intraradices), and different levels of phosphors on some broad bean plant growth characteristics and yield in Calcareous soil. The plant's growth in plastic pots contains soil collected from surface soil at a depth of 15-30 cm from the agricultural farm of the college. The collected soil is air-dried, then crushed completely to pass through a sieve with a 4 mm diameter. The soil classified as vertosols based on the US soil taxonomy with silty clay texture. Then (5 kg) of sieved soil was added to each pot 15 cm diameter with 30 cm depth. The phosphorus in the form rock phosphate was added in each pots inoculated and non- inoculated at followed levels (0, 40, 80, 120 and 160 kg P ha-1) and 100 g of mycorrhiza inoculum (Glomus intraradices) was added to a pot before planting only for each mycorrhiza treatments in (October. 01, 2022) eight seeds of broad been Batlle variety were sown in each pots inoculated and non-inoculated and the pots irrigated to preserve 70% of soil field capacity by orderly weighting of pots during the growing season. The plants in each pot thinned to four plants after two weeks of growth.

Factorial Completed Randomized Design (C.R.D) experiment was conduct and three replications used for each treatment all plants were grown for 75 days under plastic house. Before harvesting in (12 Dec. 2022) plant height (cm) was measured from the soil surface to the top of plant by a ruler, and chlorophyll intensity (SPAD) was measured by portable chlorophyll meter instrument (Minolta Corporation, Osaka, Japan). Then in (14 Mar. 2023) the plants harvested, then shoot was cut off from the root, samples of roots took and colonization percentage was measured according to [7], both shoot and root weighted and oven dried at 65 Co for 72 hours, then dried shoot and root reweighted to calculate the shoot and root dry weight (g). The pod weight (g plant-1) and the number of pods (pod plant-1) were measured.

In (17 Mar. 2023) the dried shoot ground by grinder till to pass through a sieve with 0.5 mm to determine the nutrients concentration, the macro nutrients, nitrogen (g kg-1) was determined by the Kjeldahl method as described in [8] phosphorus (g kg-1) was determined by using Spectrophotometer as described in [8], Potassium (g kg-1) was determined by using Flame-Photometer as described in [9], about the micro nutrients Fe, and Zn (µg g-1)concentration, determined by using atomic absorption as described in [11].

The data statistically analyzed by utilizing (XL-STAT 2019) biostatistics application analysis of variance (ANOVA) performed to determine the significant differences among the treatments by using Duncan's multiple range test at $P \leq 0.05$. The meteorological data under the high tunnel during the experiment time were summarized in the Table 1. explains some physical and chemical properties of the soil used in the experiment that tested and the results are shown in the Table 2

Table 1. Certain meteorological information collected within the high tunnel throughout the duration of the study.

Months	Temperature (0 C)		Relative humidity (%)		Avg. Sunshine Duration (Hours)
	Min.	Max.	Min.	Max.	
Oct.	10.25	32.32	15.83	69.15	9.0
Nov.	7.53	30.91	17.68	75.50	7.0
Dec.	6.21	24.02	20.59	91.11	5.4
Jan.	2.75	24.44	19.93	92.13	4.2
Feb.	3.46	28.27	19.89	90.30	5.8
Mar.	8.84	32.09	16.01	86.21	6.7
Apr.	10.41	34.27	13.76	72.02	6.9
May	16.46	38.53	11.18	60.53	8.3

Table 2. Some soil physical and chemical properties which utilized in this experiment

Soil property	Value	Unit
Sand	44.60	
Clay	480.20	(g kg-1)
Silt	475.20	
Soil Texture	Silty clay	
Soil pH	7.21	
EC	0.36	(dSm-1)
O.M.	9.10	
CaCO3	245	
Total N	0.10	(g kg-1)
Available P	3.15	
Soluble K	0.38	
Fe	3.10	(mg kg-1)
Zn	0.45	

Results and Discussions

Plant height (cm)

The data in table (3) exhibit that when the soil inoculated with AMF and p significantly increase broad bean plant height compared to control. The maximum value (82.67 cm) obtained at maximum P level (160 kg ha-1) compared with control which was (41.33 cm), and the plant which inoculated only with mycorrhiza the height value was observed at P level 0 kg ha-1 with mycorrhizal inoculation was (48.33cm) while the lowest value gave by control treatment (41.33 cm). The increase of plant height in inoculated with AMF plants can returned to the ability of mycorrhiza to increase availability of nutrient such as (N, P, K) to plant, helping them to absorb more of these essential nutrients, this synergy typically results in increasing plant height [11].

Chlorophyll intensity (SPAD)

The data that shown in table (3) shows that inoculation broad bean with mycorrhiza and phosphorus applications had a significantly effect on the chlorophyll intensity compared to control, this results in line with the results which recorded by [11] and chlorophyll intensity grow by rising P levels. The highest chlorophyll intensity value recorded was (48.90 SPAD) obtained in maximum P level, while the minimum value obtained by control treatment which was (32.17 SPAD). But when the plants inoculated with only mycorrhiza the best value for chlorophyll intensity was (38.00 SPAD) in the treatment (0 kg p ha-1 with mycorrhizal inoculation), and the smallest value was (32.17 SPAD) in the control treatment (0 kg P ha-1 with mycorrhizal inoculation). The increasing of chlorophyll intensity when plant inoculated with mycorrhiza can be returned to the function of mycorrhiza symbiotic association with broad bean roots, extending their reach through fungal hyphae this enhances the uptake of essential nutrients, particularly phosphorus and nitrogen which are critical for chlorophyll synthesis and photosynthesis and mycorrhiza increases availability P in the soil by solubilizing unavailable P into available P which enhanced nitrogen fixation and increased chlorophyll content [12].

Shoot dry weight (g)

Table (3) shown that the broad bean shoot inoculation by mycorrhiza significantly affected on increasing shoot dry weight under phosphorus level compared to control. The highest shoot dry weight value (16.90 g) recorded in maximum value of phosphorus (160 kg P ha-1), while the minimum value (11.86 g) observed from control. the data show that shoots dry weight boosts with raise the rate of P adding. The maximum value of shoot dry weight recorded in interaction treatment of 0 kg P ha-1 with mycorrhiza inoculation) was (12.08 g) while the minimum value observed in treatment control was (11.86 g). This result is agreed with results which recorded by [13] the increasing of broad bean shoot dry weight may be due to the mycorrhiza symbiosis cause benefit for plants due to nutrients and water uptake from the soil rhizosphere to plants then increased plant shoot dry weight [14].

Root dry weight (g)

Table (3) shows that broad bean plant which inoculated with mycorrhizal with phosphorus cased increasing in root dry weight compart with control treatment. The highest root dry weight was (7.00g) observed from application of (160 kg P ha-1) and minimum root dry weight was (3.00 kg P ha-1) obtained from control zero kg P. The treatment supply only mycorrhizal inoculation, they gave the maximum value (5.00 g), while the lowest value obtained from control treatment which was (3.00

g). The most important role of mycorrhizal fungi had lengthy the plant root system beside increases root characteristics such as root surface, extended, diameter, density, and also branching, all former enhancing in plants to ability to uptake more nutrients causing the plants have more ability to growth with high root biomass and rise root dry weight [14].

Root colonization %

Data in Table (3) clearly show the percentage of root colonization by mycorrhizal fungi inoculation significantly influenced the percentage of root colonization compared to the plants that non-inoculated by mycorrhiza and root colonization affected by the rate of P compared to control. These results in line with the results which recorded by [15]. The resalt clearly shown that the maximum root colonization achieved (68.00%) in treatment maximum P level (80 kg P ha-1), and minimum value recorded (16.00 %) observed at (0 kg P ha-1). Where the plants inoculated with only mycorrhiza the maximum root colonization was (25.00%) obtained at (80 kg P ha-1 with mycorrhizal inoculation), the minimum recorded value (25.67%) obtained from interaction treatment of zero P with mycorrhiza inoculation. These results were agreed with which observed by [13]. The upraise of plant root colonizing with inoculating plant by mycorrhiza at low phosphorus, may be due to increase root infection significantly and mycorrhiza sensitivity to phosphorous is less or may be not sensitive to phosphorous in low colonization of phosphorous rise the activity of mycorrhiza [16]. The declining of plant root colonization by mycorrhiza with growing P levels because of inhibition the growth of hyphal that subsequently decline the spared of mycorrhiza fungi colonization and the plant root be impervious to colonization in high soil phosphorous concentration and inhibition of spore germination [17].

Table (3) Impact of mycorrhizal inoculation and phosphorus levels on broad bean plant height (cm), chlorophyll intensity (SPAD), shoot dry weight (g), root dry weight (g), and root colonization (%)

Treatments	Plant height (cm)	Chlorophyll intensity (SPAD)	Shoot dry weight (g)	Root dry weight (g)	Root Colonization (%)
P 0	41.33 cd	32.17 c	11.86c	3.00 e	16.00 e
P 40	45.00 cd	37.50 b	12.86c	3.70 c	18.67 d
P 80	55.00 c	39.67 c	13.39b	4.00 bc	24.67 c
P 120	68.00 b	42.80 b	14.12b	5.00 b	17.67 d
P 160	70.67 b	43.43 b	15.50a	6.00 a	15.67 e
P 0 + AMF	48.33 cd	38.00 c	12.08b	5.00bc	25.67 c
P 40 + AMF	55.33 c	44.57 b	14.54b	4.50 bc	42.33 b
P 80 + AMF	59.67 c	45.77 b	15.61a	5.00 b	68.00 a
P 120 + AMF	76.00 a	46.70 ab	16.05a	6.50 a	47.47 b
P 160 + AMF	82.67 a	48.90 a	16.90a	7.70 a	39.00 b

(AMF) mycorrhizal inoculated, P0 (0 kg P ha-1), P40 (40 kg P ha-1), P80 (80 kg P ha-1), P120 (120 kg P ha-1) and P160 (160 kg P ha-1). Values of the same dependent variable followed by the same letter(s) are not significantly different according to Duncan's multiple range test ($p \leq 0.05$).

Number of pod (pod plant^{-1})

As shown in table (4) the data relating in number of pods per broad bean plant. were beneficially affected by mycorrhiza and phosphorus application. The number of pods were the highest (30.90 pods plant-1) in case of application 120 kg P ha-1, and minimum value (13.39 pods plant-1) obtained from control (zero P kg ha-1). And when plant inoculated with only mycorrhiza the better result was from control (0 kg P ha-1) with mycorrhizal inoculation was (17.49 pods plant-1) compared with control zero P kg ha-1 control was (13.19 pods plant-1)

Mycorrhizal inoculation by phosphorus application led to increasing of number of pods per broad bean plants which may be as a result of combination et mycorrhiza and phosphorus improves the number of pods in broad bean plants by synergistically enhancing nutrient availability plant health, and reproductive growth and mycorrhiza execrate different organic acids which change unavailable P to available P form which directly affected the formation of flowers and pods leading to higher pod counts per plant [18].

Plant yield (g plant $^{-1}$)

The result in Table (4) clearly indicates that inoculation broad bean by mycorrhiza increase the yield significantly compared with control (non-inoculated) plants and yield of plants increase by rising phosphorus level. The result show that the highest value for yield was (721.17 g plant-1) obtained at P level (120 kg P ha-1) with mycorrhiza, and the smallest yield

(292.20 g plant-1) observed in control non-applied P (0 kg P ha-1). In plants which inoculated with only mycorrhiza the maximum yield was (305.97 g plant-1) in P levels 0 kg P ha-1 compared to control (292.20 g plant-1) in treatment control 0 kg P ha-1.
The increasing of yield of broad bean when inoculated with mycorrhiza can be returned to important of mycorrhiza fungi extends their hyphae into the soil increasing the roots absorption for P, acritical nutrients for flowering and seed production and better P available by mycorrhiza leads to more produce pod and seed formation per plant [19, 20]

Table (4) Impact of mycorrhizal inoculation and phosphorus levels on broad bean number of pods per plant and plant yield (g plant-1)

Treatments	Number of pods (pod plant-1)	Plant yield (g plant-1)
P 0	13.39 b	292.20 d
P 40	18.39 c	413.34 cd
P 80	20.67 b	455.07 cd
P 120	16.50 d	463.29 cd
P 160	16.89 c	561.24 bc
P 0 + AMF	17.49 cd	305.97 d
P 40 + AMF	18.99 c	550.59 bc
P 80 + AMF	22.11 b	543.09 bc
P 120 + AMF	30.90 a	721.17 a
P 160 + AMF	24.90 b	612.57 b

(AMF) mycorrhizal inoculated P0 (0kg P ha-1), P40 (40kg P ha-1), P80 (80kg P ha-1), P120 (120kg P ha-1) and P160 (160kg P ha-1). Values of the same dependent variable followed by the same letter(s) are not significantly different according to Duncan’s multiple range test ($p \leq 0.05$).

Nitrogen content (g kg^{-1})

The arranged data in figure (1) demonstrate that application of mycorrhiza with phosphorus significantly increased nitrogen content in broad bean plant. The results show that the maximum nitrogen contents value (53.10 g kg-1) observed in highest level of P application, while the control give the lowest value (13.47 g kg-1), the results show that the concentration of nitrogen in broad bean increase with rising the levels of P. These results in line with the results which recorded by [21]. In the mycorrhizal inoculation treatment, the maximum value (14.77 g kg-1) obtained by treatment (0 kg P ha-1) with mycorrhiza, while smallest vale (13.47 g kg-1) obtained in control treatment.
The rising of nitrogen content in broad bean plant inoculated by mycorrhiza can be returned to the rule of mycorrhiza that promoted plant biomass production with increased nitrogen uptake by the plant [22], or may be due to mycorrhizal association increased root surface area and mycorrhiza hypha network significantly extends the root system which increasing the effective surface area for nitrogen absorption which increased the concentration of nitrogen content in plant [14, 15].

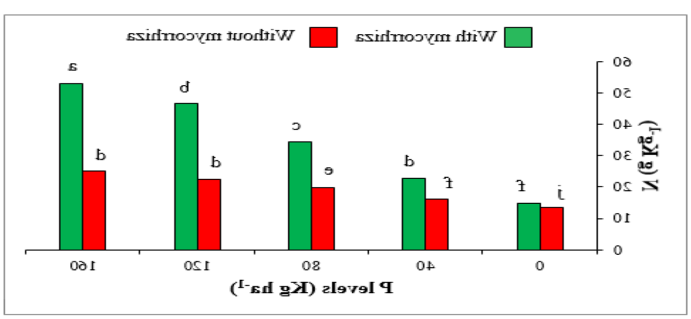

Figure 1. Impact of mycorrhiza inoculating and non-inoculating on broad bean nitrogen at various phosphors levels.

phosphorus concentration (g kg^{-1})

The broad bean shoots P concentration is shown in (figure 2) the result reveal that the phosphorus concentration in mycorrhiza treatments with medium p significantly influenced in broad bean p concentration compared to the untreated treatment. This result was in inline which illustrated by [23].

The maximum value for shoot phosphorus concentration in broad bean plant (14.977 g kg^{-1}) obtained at highest phosphorus level with mycorrhiza which were 160 kg P ha-1 compart with control treatment (0 kg P ha^{-1}) was (6.84 g kg^{-1}), on the other hand inoculated plants by only mycorrhiza, the maximum value for plant shoot phosphorus concentration equal to (7.55 g kg^{-1}) in treatment 0 kg P ha^{-1} with mycorrhizal inoculation compared to control (0 kg P ha^{-1} treatment was (6.84 g kg^{-1}). The rising of phosphorus contend in those plants which inoculated by mycorrhiza on hand the reason may be because mycorrhiza play a critical role in enhancing plant for uptake phosphorus which is essential nutrient for plant growth which increase the phosphors concentration in plant and mycorrhiza network extends far beyond the plant root system and transport phosphors outside the root zone of P and increase the more uptake of P and accumulated more P in plant [24], on another hand may be returned to the capability of mycorrhiza to enhanced P solubilization by secreting different organic acids and enzymes such phosphatase that release bound P in the soil which making it more soluble and available to plant uptake [25].

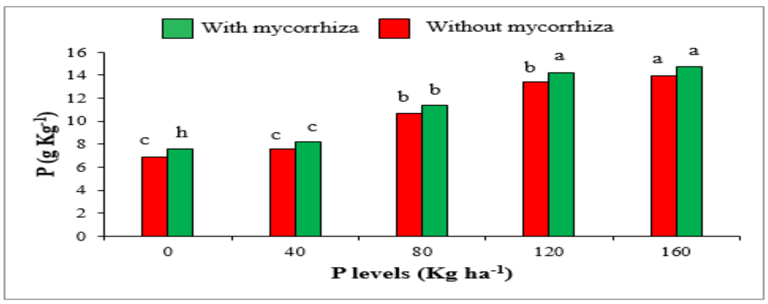

Figure 2. Impact of mycorrhiza inoculating and non-inoculating on broad bean Phosphors at various phosphors levels.

Potassium concentration (g kg^{-1})

The date obtained in the study were determined to develop better potassium concentration significantly increased in mycorrhizal treatments with phosphorus compared to non- mycorrhizal treatment. The result in figure 3 show that the highest potassium concentration for shoot of broad bean plants was (39. 50 g kg^{-1}) recorded at maximum level of P, while the smallest value for potassium concentration was (14.71 g kg^{-1}) which recorded at control 0 kg P ha-1. The result show that the brood bean potassium concentration increased by increasing phosphorus supply. The highest values of potassium in plant which inoculated only with mycorrhiza obtained application of 0 kg P ha-1 with mycorrhizal inoculation was (16.96 g kg^{-1} with mycorrhiza inoculation, while the lowest value obtained in 0 kg P ha-1 was (14.71 g kg^{-1}). The increasing of potassium concentration by mycorrhizal inoculation in broad bean plants may be returned to the ability at mycorrhiza to solubilizing K in the soil and make it available for plant by secret different organic acids by mycorrhiza which charge unavailable K to available form which more uptake by plants [24].

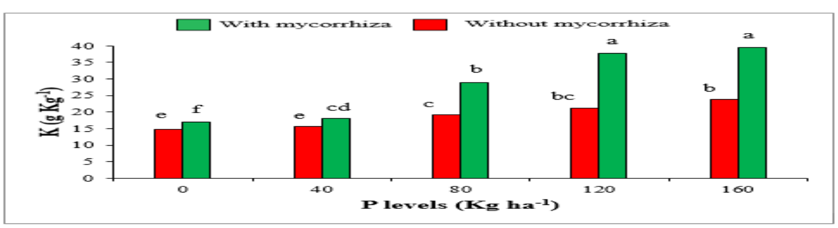

Figure 3. Impact of mycorrhiza inoculating and non-inoculating on broad bean Potassium at various phosphors levels.

Iron concentration (µg g^{-1})

The listed data in the (figure 4) illustrate that iron concentration of broad bean plant shoot was impacted by application mycorrhiza with phosphorus significantly compart with uninoculated plant with mycorrhiza. The maximum Fe concentration was obtained in (80 kg P ha-1) was (378.33 µg g-1) and the lowest Fe uptake was obtained in (0 kg P ha-1) control was (159.33 µg g-1). The result show that the levels of phosphorus application significantly affected on Fe uptake by broad bean plant. In the inoculated plants only with mycorrhiza, the highest uptake of Fe was (182.00 µg g-1) obtained in 0 kg P ha-1 plus mycorrhizal inoculation. compared with non-application of phosphors with mycorrhizal inoculation was (159.33v cx µg g^{-1}. The rising of Fe contend in mycorrhiza plants can be returned to the ability of mycorrhiza fungi to release different organic acids which help to dissolved unavailable Fe from the soil minerals making it more soluble and available to plant and, organic acids release by mycorrhiza which also change the rhizosphere pH, which can help solubilize Fe that is more available to plant [26, 27].

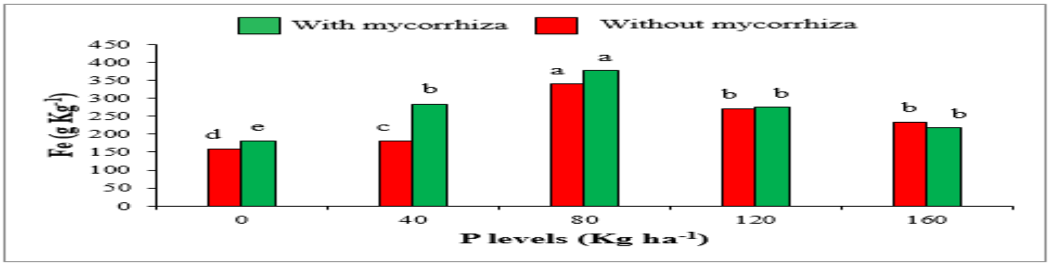

Figure 4. Impact of mycorrhiza inoculating and non- inoculating on broad bean iron at different various levels.

Zinc concentration (µg g -1)

The effect of mycorrhiza and phosphorus application on Zn uptake of broad bean was presented in the (figure 5). The results show that when the plants inoculated with mycorrhiza and p the maximum Zn concentration was obtained in P level 80 ka P ha-1 was (293.00 µg g^{-1}) compared with control (83.00 µg g^{-1}) obtained at zero p control. The result show that the mycorrhiza application significantly increased Zn uptake of shoot broad bean plant compart with control, the maximum value for Zn uptake was obtained in 0 kg Pha-1 with mycorrhizal inoculation was (93.00 µg g-1), and the smallest value (83.00 µg g-1) observed in control.

The rising of Zn concentration in arial parts of plant that inoculated by mycorrhiza may be returned to the root infected with mycorrhiza enhance the growth of plants through uptake nutrients from soil by more hyphae on plant root. The radical hyphae have ability to elongate several centimes from the root can strongly bridge over the Zn depletion zone surround the roots and able to absorb Zn element from around soil [28].

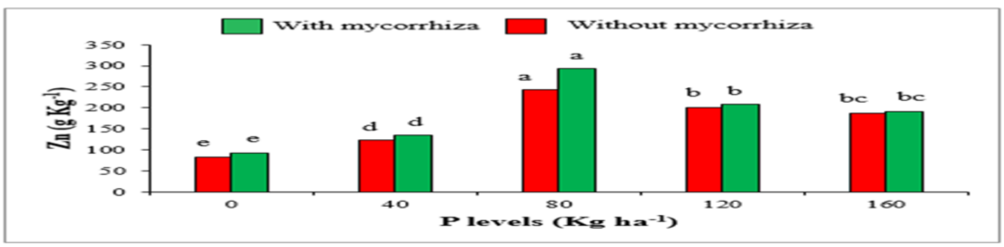

Figure 5. Impact of mycorrhiza inoculating and non- inoculating on broad bean zinc at different phosphors levels.

Conclusion

The broad bean plant inoculation with arbuscular mycorrhiza fungi along or beside different Phosphorus level and non-inoculated plant.

The morphology broad bean plant characteristic plant height, chlorophyll intensity, root dry weight, shoot dry weight gave the maximum value when broad bean inoculated with mycorrhiza and maximum level of phosphorus. And inoculation the mycorrhizal with fourth level of phosphorus recorded the significantly maximum values for number of pods per plant and plant yield. Minerals composition such as N, P, and K were affected by mycorrhiza with the highest phosphorus concentration. However, root colonization, Fe, and Zn proved better in plant inoculated with mycorrhiza and second P level. On other side, the minimum value of all parameters in this study was achieved from non-inoculated plant with AMF and phosphorus levels.

References:

[1]. Labba, I. C. M., Frøkiær, H., & Sandberg, A. S. (2021). Nutritional and antinutritional composition of fava bean (Vicia faba L., var. minor) cultivars. Food Research International, 140: 110038. https://doi.org/10.1016/j.foodres.2020.110038.

[2]. Soumare, A., Diedhiou, A. G., Thuita, M., Hafidi, M., Ouhdouch, Y., Gopalakrishnan, S., & Kouisni, L. (2020). Exploiting biological nitrogen fixation: a route towards a sustainable agriculture. Plants, 9(8): 1011. https://doi.org/10.3390/plants9081011.

[3]. Pal, S., Singh, H. B., Farooqui, A., & Rakshit, A. (2015). Fungal biofertilizers in Indian agriculture: perception, demand and promotion. Journal of Eco-friendly Agriculture, 10(2): 101-113. http://ecoagrijournal.com/wp-content/uploads/2019/10/Full-Paper-102.pdf.

[4]. Mitra, D., BE, G.S., Khoshru, B., De Los Santos Villalobos, S., Belz, C., Chaudhary, P., Shahri, F.N., Djebaili, R., Adeyemi, N.O., El-Ballat, E.M. and El-Esawi, M.A. (2021). Impacts of arbuscular mycorrhizal fungi on rice growth, development, and stress management with a particular emphasis on strigolactone effects on root development. Communications in Soil Science and Plant Analysis, 52(14): 1591-1621.mailtohttps://doi.org/10.1080/00103624.2021.1892728

[5]. Mohamed, M. G., EL-Mahdy, A. F., Kotp, M. G., & Kuo, S. W. (2022). Advances in porous organic polymers: Syntheses, structures, and diverse applications. Materials Advances, 3(2): 707-733. https://doi.org/10.1039/D1MA00771H.

[6]. Sharma, S.B., Sayyed, R.Z., Trivedi, M.H., and Gobi, T.A. (2013) Phosphate solubilizing microbes: sustainable approach for managing phosphorus deficiency in agricultural soils. Springer Plus 2: 587. https://doi.org/10.1186/2193-1801-2-587

[7]. Alrajhei, K., Saleh, I., & Abu-Dieyeh, M. H. (2022). Biodiversity of arbuscular mycorrhizal fungi in plant roots and rhizosphere soil from different arid land environment of Qatar. Plant Direct, 6(1): e369. https://doi.org/10.1002/pld3.369

[8]. Rowell DL (1996). Soil science: methods and applications. Addison Wesley Longman Ltd. UK.

[9]. Temminghoff, E. E., & Houba, V. J. (Eds.). (2004). Plant analysis procedures. Dordrecht: Springer Netherlands.

[10]. A.O.A.C. (1984) 'Association of Official Analytical Chemistry '. 14th Edition William Horwitz. Editor, P.O. Box 540. Franklin Station, Washington, D.C.

[11]. Ahmed, M., Hasanuzzaman, M., Raza, M.A., Malik, A., Ahmad, S. (2020). Plant nutrients for crop growth, development and stress tolerance. In: Roychowdhury, R., Choudhury, S., Hasanuzzaman, M., Srivastava, S. (eds) Sustainable agriculture in the era of climate change. Springer, Cham. https://doi.org/10.1007/978-3-030-45669-6_3.

[12]. Wahab, A., Muhammad, M., Munir, A., Abdi, G., Zaman, W., Ayaz, A., Khizar, C. and Reddy, S.P.P. (2023). Role of arbuscular mycorrhizal fungi in regulating growth, enhancing productivity, and potentially influencing ecosystems under abiotic and biotic stresses. Plants, 12(17): 3102. https://doi.org/10.3390/plants12173102

[13]. Mohammed, S. Z. (2017). The effect of mycorrhiza, phosphorus solubilizing bacteria and rock phosphate on (Vicia faba L.). Master of Science, College of Agricultural Engineering Sciences, University of Sulaimani. Iraq.

[14]. Banni, M., Hajer, A., Sforzini, S., Oliveri, C., Boussetta, H. and Viarengo, A. (2014). Transcriptional expression levels and biochemical markers of oxidative stress in Mytilus galloprovincialis exposed to nickel and heat stress, Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 160: 23-29. https://doi.org/10.1016/j.cbpc.2013.11.005

[15]. Harso, W. (2016). The Mycorrhizal Plant Root System: Foraging Activities and Interaction with Soil Bacteria in Heterogeneous Soil Environments. (Doctoral dissertation, Dissertation, Berlin, Humboldt Universität zu Berlin).

[16]. Soleimanzadeh, H. (2010). Effect of VA-Mycorrhiza on growth and yield of Sunflower (Helianthus annuus L.) at different phosphorus levels. International Journal of Agricultural and Biosystems Engineering, 4(11): 820-823.

[17]. Sardans, J., Lambers, H., Preece, C., Alrefaei, A. F., & Penuelas, J. (2023). Role of mycorrhizas and root exudates in plant uptake of soil nutrients (calcium, iron, magnesium, and potassium): has the puzzle been completely solved? The Plant Journal, 114(6): 1227-1242. https://doi.org/10.1111/tpj.16184

[18]. Youssef, S. M., Riad, G. S., & Abd Elhady, S. A. (2017). Effect of phosphorus sources and arbuscular mycorrhizal inoculation on growth and productivity of snap bean (Phaseolus vulgaris L.). Gesunde Pflanzen, 69(3): 139-148. https://DOI 10.1007/s10343-017-0398-4

[19]. Dubova, I., Šenberga, A., & Alsiņa, I. (2015). The effect of double inoculation on the broad beans (Vicia faba L.) yield quality. Research for Rural Development, 1: 34-39.

[20]. Zhang, W., Yu, L., Han, B., Liu, K., & Shao, X. (2022). Mycorrhizal inoculation enhances nutrient absorption and induces insect-resistant defense of Elymus nutans. Frontiers in plant science, 13: 898969. https://doi.org/10.3389/fpls.2022.898969

[21]. Abrahim, A. H., Mustafa, A. A., Abdulahi, J., & Mume, A. J. (2023). Differential Response of Common bean (Phaseolus vulgaris L.) Varieties to Mixed NPS Fertilizer Rates: An Analysis of Growth and Yield. research square, 2023: 1-30. https://doi.org/10.21203/rs.3.rs-3656130/v1

[22]. Jimenez-Lopez, J. C., & Clemente, A. (Eds.). (2022). Legumes Research: Volume 1. BoD–Books on Demand.

[23]. Ali, M.M., Sani, N.H., Arifunnahar, M. Aminuzzaman, F.M. and Mridha, M. (2018). Influence of arbuscular mycorrhizal fungi on growth, nutrient uptake and suppression of some selected vegetable crop. Azarian Journal of Agriculture, 5(6): 190-196.

[24]. Öztürk, F., Aksahin, V., Khan, Y., & Ortas, I. (2023). The effect of different mycorrhizal fungi inoculation and biochar application on the growth of broad bean plant and carbon sequestration under different irrigation levels. International Journal of Agricultural and Applied Sciences, 4(1): 150-158. https://doi.org/10.52804/ijaas2023.4125.

[25]. Sun, X., Xu, Z., Xie, J., Hesselberg-Thomsen, V., Tan, T., Zheng, D., Strube, M.L., Dragoš, A., Shen, Q., Zhang, R. and Kovács, Á.T. (2022). Bacillus velezensis stimulates resident rhizosphere Pseudomonas stutzeri for plant health through metabolic interactions. The ISME Journal, 16(3): 774–787.

[26]. Smith, S. and Read, D. (2008). Colonization of roots and anatomy of arbuscular mycorrhiza', Mycorrhizal Symbiosis. Academic Press: London: 42-90.
[27]. Andrino, A., Guggenberger, G., Kernchen, S., Mikutta, R., Sauheitl, L., & Boy, J. (2021). Production of organic acids by arbuscular mycorrhizal fungi and their contribution in the mobilization of phosphorus bound to iron oxides. Frontiers in plant science, 12: 661842. https://doi.org/10.3389/fpls.2021.661842.
[28]. Bhantana, P., Rana, M. S., Sun, X. C., Moussa, M. G., Saleem, M. H., Syaifudin, M., and Hu, C. X. (2021). Arbuscular mycorrhizal fungi and its major role in plant growth, zinc nutrition, phosphorous regulation and phytoremediation. Symbiosis, 84: 19-37. https://doi.org/10.1007/s13199-021-00756-6.

تأثير التلقيح بالمايكورايزا ومستويات مختلفة من الفسفور على نمو وامتصاص العناصر الغذائية وإنتاجية الباقلاء (*Vicia faba* L.)

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الخلاصة
تم تنفيذ تجربة في سنادين بلاستكية في كلية علوم الهندسة الزراعية /جامعة السليمانية محافظة السليمانية اقليم كوردستان العراق خلال موسم النمو 2023/2022 لدراسة تأثير اضافة 20غم كغم تربة-1 من المايكورايزا ***(Glomus intraradices)*** لمرة واحدة الى التربة قبل الزراعة مع اضافة خمس مستويات مختلفة من الفسفور (0 و40 و80 و120 و160) كغم هكتار-1 المضافة الى التربة قبل الزراعة و لمرة واحدة على نمو و امتصاص العناصر الغذائية و انتاج نبات الباقلاء. أجريت التجربة وفق تصميم العشوائي الكامل (***CRD***) في تربة غرينية طينية وبثلاث مكررات لكل المعاملة، قبل الحصاد التجربة تم قياس ارتفاع النباتات وشدة الكلوروفيل وبعد ذلك تم حصاد النباتات وبعدها تم قياس نسبة المئوية للإصابة بالمايكورايزا والوزن الجاف للمجموع الخضري والجذري للنباتات وعدد القرنات وحاصل نبات الواحد ثم تم قياس تركيز عناصر النيتروجين والفوسفور والبوتاسيوم والحديد والزنك في المجموع الخضري للنباتات. وأظهرت النتائج أن 160 كغم هكتار$^{-1}$ فوسفور مع اللقاح المايكورايزا اعطي زيادة معنوية في ارتفاع النباتات وشدة الكلوروفيل ووزن الجاف للمجموع الخضري و الجذور ومحتوى النبات من النيتروجين والفوسفور والبوتاسيوم في المجموع الخضري مقارنة بمعاملة لمقارنة و اعلى القيم كانت (82.67 سم، 48.90 ***SPAD***، 16.90 غم، 7.70 غم، 53.10 غم كغم-1، 14.77 غم كغم-1، و***39.50*** غم كغم-1) على التوالي، كما اضهرت النتائج ان مستوى 80 كغم هكتار-1 فوسفور مع التلقيح بالمايكورايزا أعطى أعلى القيم لنسب الاصابة بالمايكورايزا، ومحتوى الحديد والزنك وبلغوا (68.00٪، 378.33 ميكروغرام غم$^{-1}$ و293.00 ميكروغرام غم$^{-1}$) على التوالي. على الجهة الاخرى سجلت معاملة تلقيح النباتات بالماكورايزا مع 120 كغم هكتار-1 فسفور. زيادة معنوية لعدد القرون لكل نبات وإنتاج نبات الواحد وبلغت (30.90 قرنة نبات$^{-1}$ و 721.17 غم نبات$^{-1}$) مقارنة بمعاملة المقارنة.

الكلمات المفتاحية: الحفزات الحيوية، ***Glomus intraradices***، فوسفور، ***Vicia faba***.