PAPER • **OPEN ACCESS**

Impact of *T. harzianum* and *G. mosseae* Inoculum and Phosphate Rocks on the NPK Content in Barley Crop (*Hordium Valgari* L.)

To cite this article: Salah Mahdi Laibi and Jawad Abdul Kadhim Kamal 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1060** 012017

Impact of *T. harzianum* and *G. mosseae* Inoculum and Phosphate Rocks on the NPK Content in Barley Crop (*Hordium Valgari* L.)

Salah Mahdi Laibi[1] and Jawad Abdul Kadhim Kamal[2]

[1,2] College of Agriculture, University of Al-Qadisiyah, Iraq.

E-mail: salah20119010@gmail.com

Abstract. The effect of fungal fertilizers with isolates of *T. harzianum* and *G. mosseae* and levels of phosphate rock on NPK content in the barley plant was investigated. A field trial was conducted on clay loamy soil to produce a variety of barley crops named (Samir 1) during the autumn agricultural season in 2021 in the Al-Qadisiyah Governorate. The factorial experiment was designed according to a Randomized Complete Block Design (RCBD) with three replications. The factors of the experiment included two levels of *T. harzianum* inoculum (T0, control and T1, fungal inoculation), two levels of *G. mosseae* inoculum (G0, control and G1 fungal inoculation), and four levels of phosphate rock (P0, P1, P2, and P3) with an amount (0,1000,1500, and 2000) t/ha^{-1}. The results present that the interaction treatment (*G. mosseae* + *T. harzianum* and phosphate rock of 1000 t/ha^{-1}) resulted in a significant increase in the content of nitrogen, phosphate, and potassium (NPK) in the plant 1.977, 0.437, and 2.603 %, respectively, compared to the control.

Keywords. *T. harzianum, G. mosseae*, Phosphate rocks, Barley plant, NPK.

1. Introduction

Barley is one of the crops of the Gramineae family and is the fourth most strategic crop after wheat, rice, and maize. Its productivity is estimated at 160 million tons, and the areas cultivated with this crop are estimated at 70 million hectares worldwide. Russia, France, Canada, Germany, and Spain lead in the quantities produced from this crop [1]. This crop is resistant to harsh growing conditions in arid and semi-arid regions such as cold, drought, and alkalinity. It is competitive with shrubs and herbs because of its faster growth and ripens faster than wheat.

Biogenic nutrients are a group of organisms or microbes that promote the growth of host plants and play an essential role in maintaining soil fertility. They can be used in conjunction with mineral and organic fertilizers. It is environmental protection, low cost, and reduced fertilizer use. Biofertilizers can also play a role and are essential for developing integrated systems for managing soil nutrients and maintaining ecosystems [2]. A study by [3] highlighted the role of biofertilizers in increasing the solubility of phosphorous and other nutrients, enhancing stress resistance, increasing soil agglomeration to improve the soil environment, increasing organic matter content, and preventing plant infection from some diseases.

Mycorrhizae are a type of soil organism that lives in the roots of plants. The importance of these fungi is that they grow partly in the root system and partly in the soil of the roots and are biologically different from the other organisms in the soil. Several sources report that rhizosphere fungi increase the absorption of macronutrients, especially phosphorous, in low-elemental nutrient media [4,5].

Weindlling discovered the importance of Trichoderma in natural resistance after a successive series of research that extended from the thirties and forties of the last century [6,7].
Trichoderma fungus inactivates the pathogen's enzymes by secreting enzymes into the pathogen's environment, such as the protease enzyme, which inhibits the pathogen's susceptibility to the pathogen and its ability to cause infection as well as prevents the toxic effect on the host [8,9,10]
Phosphate rock is a raw material containing 20-40% phosphorous in the form of P2O5 [11,12]. It is extracted from phosphate deposits scattered worldwide, especially in Iraq, where phosphates are unavailable to plants unless dissolved naturally. Either with the help of microorganisms naturally or synthetically by using them in the manufacture of phosphate fertilizers. One of the benefits of using phosphate rock as a fertilizer is that it is inexpensive compared to the phosphate manufacturing process and can be used on many soil types. Phosphate rocks have different properties [13,14], although their compounds are calcium phosphate or fluoride phosphate, with slight water solubility. When added to the soil, some of the phosphorous becomes ready for the plant due to the soil solution's acidity and the various chemical reactions with the soil components in which microorganisms play an indirect role.
Through the preceding, the objectives of the study include the following:

- Investigating the effect of T. harzianum on the content of NPK in barley plants.
- Investigating the effect of G. mosseae on the content of NPK in barley plants.
- Investigating the interaction between T. harzianum and G. mosseae on on the content of NPK in barley plants.
- Investigating the effect of phosphate rocks on the content of NPK in barley plants at different application levels.

2. Materials and Methods

2.1. Experimental Site
The experiment was conducted on clay loamy soil to produce barley plant variety (Samir 1) during the fall agricultural season of 2021 in the Al-Qadisiyah Governorate / Al-Nouriah region / in one agricultural land belonging to the Al-Nouriah Forest Department. First, soil samples were taken from the field from all areas of the field and mixed to make a composite sample representing the field soil. Then the sample was dried pneumatically and crushed well, and then it was sieved through a sieve with an a-holes diameter of 2 mm to perform physical, chemical, and biological tests, as shown in Table (1).

2.2. Experience Design
The experiment was designed according to the Complete Randomized Block Design (RCBD). The field was divided into three replicates, 48 experimental units, and each sector included 16 treatments distributed randomly. The area of each experimental unit is 9 $m^{2,}$ and its dimensions are 3x3 m.

2.3. Experience Factors
The first factor of this study was the application of fungus (*T. harzianum*) on two levels:

- T0 = without *T. harzianum* application (control)
- T1 = with the application of T. harzianum

The second factor of this study was the application of fungus (*G. mosseae*) on two levels

- G0 = without *G. mosseae* application (control)
- G1 = with the application of *G. mosseae*

The third factor of this study was the application of phosphate rocks at four levels

- P0 = 0 t/h^{-1} without phosphate rocks applications (control)
- P1 = phosphate rocks applications at 1000 0 t/h^{-1}
- P2 = phosphate rocks applications at 1500 0 t/h^{-1}
- P3 = phosphate rocks applications at 2000 0 t/h^{-1}

Table 1. Physical, chemical, and biological characteristics of the soil of the field soil.

Trait		Value	Unit
PH		7.7	
EC		2.7	DesiSmens.M^{-1}
Soil texture		Clay Loam	
Soil Separators	Sand	215	
	Clay	375	
	Silt	410	g.kg-^{1}Soil
Organic matter		8.4	
Available ions	N	32.12	Mg.kg^{-1} Soil
	P	8.3	
	K	196.14	
Dissolved positive ions	Ca^{+2}	9.6	
	Mg^{+2}	10.2	
	Na^{+}	13.9	
	K^{+}	0.2	$mmol_c$. L -^{1}
Dissolved negative ions	SO_4^{-2}	11.3	
	HCO_3	12.4	
	CO_3^{-2}	Nill	
Total fungi		1.83 X 10^3	Soil/g^{-1}/CFU

3. Results and Discussion

3.1. Plant Nitrogen Content (%)

Table (2) showed the significant impact of applying *G.mosseae* fungus on increasing the average plant nitrogen content by 1.886% compared to the control treatment of 1.815%. This increase is attributed to the fungus *G. mosseae* in increasing the density of the root system and thus increasing nitrogen uptake and preparing the plant with it, and these results are consistent with [15,16]. The results also showed that *T. harzianum* significantly increased the average plant nitrogen content 1.910 %, compared to the control treatment, 1.791%. The reason for this increase is attributed to the role of the fungus *T. harzianum*, which works to promote root growth and the formation of a dense and deep root system for the plant, which leads to an increase in the amount of nitrogen uptake by the plant, thus increasing its content in the plant [17,18]

The use of phosphate rock resulted in a significant increase in the average nitrogen content in the plant, 1.868%, compared to the control treatment, 1.831%. The reason is due to the role of phosphorous freed from phosphate rock in forming a solid and dense radical group that helps absorb nutrients, including nitrogen [19].

The results of the Table indicated that the bilateral interaction between the fungi, *G.mosseae, and T. harzianum,* resulted in the highest significant increase in the average nitrogen content in the plant, 1.953 %, compared to the treatment of 1.763%. The reason is attributed to the positive interaction between the biological (fungal) inoculation, which is reflected positively in providing the nutrients these microorganisms need for growth and reproduction. Through various mechanisms, the mycorrhizal fungus is one of the most effective soil microbes on its plant hosts. It affects the absorption of nutrients, increases resistance to drought, and protects against pathogens.

The results confirmed that the triple interaction between *G.mosseae and T. harzianum* and the phosphate rock resulted in the highest significant increase in the nitrogen content of the plant, 1.977%, compared to the control treatment of 1.740%.

Table 2. Impact of fungal inoculums (*T. harzianum* and *G. mosseae)* and phosphate rock on nitrogen content in the plant.

Fungal (G)	**Fungal (T)**	**Phosphorus (P)**				**Mean of Binary overlap G x T**
		0	**1**	**2**	**3**	
0	0	1.740	1.760	1.770	1.783	1.763
	1	1.850	1.850	1.897	1.870	1.867
1	0	1.800	1.810	1.847	1.820	1.819
	1	1.933	1.977	1.960	1.943	1.953
LSD 0.05		0.011				0.005
Bi-interaction G x P						
Fungal (G)		P				Mean
0		1.795	1.805	1.833	1.827	1.815
1		1.867	1.893	1.903	1.882	1.886
LSD 0.05		0.007				0.004
Bi-interaction T x P						
Fungal (T)		P				Mean
0		1.770	1.785	1.808	1.802	1.791
1		1.892	1.913	1.928	1.907	`1.910
LSD 0.05		0.007				0.004
P mean		1.831	1.849	1.868	1.854	
L.S.D. 0.05		0.005				

3.2. The Phosphorous Content in Plants (%)

Table (3) showed the significant influence of using *G.mosseae* on the average plant phosphorous content, 0.383%, compared to the control of 0.285%. The reason is attributed to the fungus *Glomus mossea* increasing the surface area for absorption [20]. On the other hand, the application of *T. harzianum* fungus significantly increased the average plant content of phosphorous by 0.358% compared to the control treatment of 0.310%. The reason is attributed to the role of the *T. harzianum* in dissolving phosphorous and transforming it from the form that is not available for absorption by the plant to the form available for absorption and its role in forming a dense root system that results in the efficient absorption of nutrients [21].

The application of phosphate rock made a significant increase in the average phosphorous content in the plant, 0.348%, compared to the control, 0.313%. The reason is attributed to the released phosphorous from phosphate rock in the formation of the root group, which in turn supplies the plant with nutrients [22]. The results indicated that the bilateral interaction between *G. mosseae* and *T. harzianum* made the highest significant increase in the average phosphorous content in the plant, 0.416%, compared to the control treatment of 0.268%. The reason is due to the interference role of the two organisms in secreting growth-promoting substances and the role of VAM fungi in increasing the readiness and uptake of phosphorous and its transfer to the plant [23,24]. The triple interaction between the fungus (*G.mosseae and T. harzianum*) and the phosphate rock made the highest significant increase in the phosphorous content in the plant, 0.437%, compared to the control treatment of 0.240%.

Table 3. Impact of fungal inoculums, *T. harzianum* and *G. mosseae*, and phosphate rock on phosphorous content in the plant.

Fungal (G)	**Fungal (T)**	**Phosphorus (P)**				**Mean of Binary overlap G x T**
		0	**1**	**2**	**3**	
0	0	0.240	0.260	0.277	0.297	0.268
	1	0.280	0.290	0.323	0.310	0.301
1	0	0.340	0.353	0.363	0.347	0.351
	1	0.390	0.437	0.430	0.407	0.416
LSD 0.05		0.014				0.007
Bi-interaction G x P						
Fungal (G)		P				Mean
0		0.260	0.275	0.300	0.303	0.285
1		0.365	0.395	0.397	0.377	0.383
LSD 0.05		0.010				0.005
Bi-interaction T x P						
Fungal (T)		P				Mean
0		0.290	0.307	0.320	0.322	0.310
1		0.335	0.363	0.377	0.358	0.358
LSD 0.05		0.010				0.005
P mean		0.313	0.335	0.348	0.340	
L.S.D. 0.05		0.007				

3.3. Potassium Content in The Plant (%)

Table (4) presents the significant effect of applying *G.mosseae* on the average plant potassium content of 2.476% compared to the control treatment of 2.185%. The reason is attributed to the role of the fungus in *Glomus mossea* in increasing the solubility and absorption of nutrients, including potassium [23,24]. The application of *T. harzianum* gave a significant increase in the average plant potassium content of 2.405% compared to the control treatment of 2.257%. The reason for this increase is attributed to the ability of the *T. harzianum* to increase the availability of nutrients in the soil and make it more ready for plants, including potassium [25]

The use of phosphate rock significantly increased the average potassium content in the plant by 2.369% compared to the control by 2.261%. The reason is attributed to the role of phosphorous liberated from phosphate rock in forming a solid and deep root group that absorbs nutrients, including potassium [27]. The treatment of bilateral interaction between fungi (G.mosseae and T.harzianum) gave the highest significant increase of potassium content in the plant, 2.553%, compared to the control 2.114%. The reason is attributed to the interference of the work of the two organisms by increasing their absorption of nutrients, including potassium [27]. The Table results confirmed that the triple interaction between *G.mosseae and T. harzianum* and the phosphate rock gave the highest significant increase in potassium content in the plant, 2.603%, compared to the comparison treatment, which amounted to 1.997%.

Table 4. Impact of fungal inoculum of *T. harzianum* and *G. mosseae* and phosphate rock on potassium content in the plant.

Fungal (G)	Fungal (T)	Phosphorus (P)				Mean of Binary overlap G x T
		0	1	2	3	
0	0	1.997	2.120	2.150	2.190	2.114
	1	2.210	2.250	2.297	2.267	2.256
1	0	2.353	2.383	2.440	2.420	2.399
	1	2.483	2.603	2.590	2.537	2.553
LSD 0.05		0.016				0.008
Bi-interaction G x P						
Fungal (G)		P				Mean
0		2.103	2.185	2.223	2.228	2.185
1		2.418	2.493	2.515	2.478	2.476
LSD 0.05		0.011				0.006
Bi-interaction T x P						
Fungal (T)		P				Mean
0		2.175	2.252	2.295	2.305	2.257
1		2.347	2.427	2.443	2.402	2.405
LSD 0.05		0.011				0.006
P mean		2.261	2.339	2.369	2.353	
L.S.D. 0.05		0.008				

References

[1] Grando, S. (2002). Food barley grains long-overdue attention. ICARDA, Caravan 16.
[2] Mishra D.j., Singh Rajvir, MishraU.K.and Shahi Sudhir Kumar.2013.Role of Bio-fertilizer in organic Agriculture: A Review.Research Journal of Recent Sciences.2(ISC-2012),39-41(2013).
[3] Naveen K.; Samina m. R .2016.Bioformlation: for sustainable Agriculture. Springer India.
[4] Sylvia, D. M.; A. K Alageiy; D. O. Chellemi and Demchendo. 2001. Arbuscular mycorrhizal fungi influence tomato competition with *Bahia Grass*. Biology and Fertility of soil. 34(6): 448-452.
[5] Khaeim, Hussein M., Bushra A. Jeber, and Mahmood A. Ali. "Winter Wheat Genotypes Response to Different Water Quality." Int. J. Agricult. Stat. Sci 15, no. 2 (2019): 669-676.
[6] Wells, H.D. (1988). Trichoderma as a biocontrol agent in Biocontrol of Plant Disease. Vol. 1, Mukerki, K.G. and Grag, K.L., Eds., CRC Press. Boca Raton, Fl. 71.
[7] Khaeim, Hussein, Zoltán Kende, István Balla, Csaba Gyuricza, Adnan Eser, and Ákos Tarnawa. 2022. "The Effect of Temperature and Water Stresses on Seed Germination and Seedling Growth of Wheat (Triticum aestivum L.)" Sustainability 14, no. 7: 3887. https://doi.org/10.3390/su14073887.
[8] Elad, Y.; David, D.R.; Levi, T.; Kapat, a.; Kirshmer, B.; Guvrin, E. and Levine, A. (1999). Trichoderma harzianum T39-mechanism of biocontrol of foliar pathogens. Pages 459-467.
[9] Harman, G.E. (2000). Myths and dogmas of biocontrol-plant Disease 84 (4): 377-393.
[10] D Aljawasim, Baker, Hussein M Khaeim, and Mustafa A Manhood. "Assessment of arbuscular mycorrhizal fungi (Glomus spp.) as potential biocontrol agents against damping-off disease Rhizoctonia solani on cucumber." Journal of Crop Protection 9, no. 1 (2020): 141-147.
[11] Terry L. R. (1997). Rock phosphate … should we use it in the prairie? Potash and phosphate Institute of Canada.
[12] Alawsy, W. S. A., Alabadi, L. A. S., & Khaeim, H. M. (2018). Effect of sewage water irrigation on growth performance, biomass, and nutrient accumulation in maize and barley. International Journal of agricultural and statistical sciences, 14(2), 519-524.
[13] Antonio, P. M. & David R. (1997). Evaluation of superphosphate and rock phosphate for a Corn-Oat-Forage rotation. LSRF, 22: 6-8.

[14] Drebee, H.A.; Razak, NAA Measuring the efficiency of colleges at the university of al-qadisiyah-Iraq: A data envelopment analysis approach. J. Ekon. Malays. 2018, 52, 163–179.
[15] Al-Husseini, Muhammad Ajami Salman. 2020. Effect of biological fertilization and potassium fertilizer on the growth and yield of yellow maize (Zea mays L.) and copper, iron, and zinc compounds. Master Thesis. Faculty of Agriculture. Al-Qadisiyah University.
[16] Khaeim, Hussein, Zoltán Kende, Márton Jolánkai, Gergő P. Kovács, Csaba Gyuricza, and Ákos Tarnawa. 2022. "Impact of Temperature and Water on Seed Germination and Seedling Growth of Maize (Zea mays L.)" Agronomy 12, no. 2: 397. https://doi.org/10.3390/agronomy12020397.
[17] Abdullah, Noor Adnan, Abdul Karim Oraibi, Sabaa Al-Kartani. (2017) Effect of inoculation with *Pseudomonas fluorescens*, *Brasiliense azospirillum*, and Trichoderma Harzianum on some maize crop growth traits and plant hormones. Tikrit University Journal of Agricultural Sciences. Volume 17, Issue (1).
[18] Jeber, B. A., & Khaeim, H. M. (2019). Effect of foliar application of amino acids, organic acids, and naphthalene acetic acid on growth and yield traits of wheat. Plant Archives, 19(2), 824-826.
[19] Al-Zubaidi, Ahmed Haider, Ayman Hussein Abdel-Hadi Al-Janabi and Mowaffaq Saeed Naoum. 2004. Study of the efficacy of phosphate fertilizers in calcareous soils using chemical kinetics. Journal of Agricultural Sciences: 35(3):6-1.
[20] Tufenkci, S., S. Demir, S. Şensoy, S. Ünsal, E. Demirer, C. Erdinc, S. Bicer, A. Ekincial and A. Kincialp. 2012. The effects of arbuscular mycorrhizal fungi on the seedling growth of four hybrid cucumbers (*Cucumis sativus* L.) cultivars. Turk J . Agric. For., 36: 317–327.
[21] Marlina , N., N. Amir, R.I . S. Aminah, G. Abdul Nasser, Y.Purwanti, L. Nisfuriah and Asmawati. 2017. Organic and Inorganic Fertilizers Application on NPK Uptake and Production of Sweet corn in inceptisol soil of Lowland Swamp Area. MATEC Web of Conferences 97, 01106.
[22] Thorns, Arkan Mohammed. 1988. Diagnosing the behavior of calcium phosphate formed by adding phosphorous to the soil. Proceedings of the first conference for technical education. Institution of Technical Institutes.
[23] Al-Husseni, A. K. A., Alabadi, L. A. S., Khaeim, H. M., & Al-Jutheri, H. W. (2021, April). Chemical and Mineralogical Nature of The Sediments of Sawa Lake in Muthanna Governorate, Southwestern Iraq. IOP Conference Series: Earth and Environmental Science (Vol. 735, No. 1, p. 012054). IOP Publishing.
[24] Al-Shaibani, Jawad Abdul-Kazim Kamal. 2005. Effect of adding organic matter (compost) and the biocide Trichoderma harzianum to the bio fertilization of Glomus mossea and Azotobacter on the growth and yield of the tomato plant. Ph.D. thesis. College of Agriculture - University of Baghdad.
[25] Dewan, M. H. 1989. Identity and frequency of occurrence of fungi in roots of wheat and ryegrass and their effect on take-all wheat and its growth. Ph.D. Thesis. Univ. of Western Australia. 210 pp.
[26] Havlin, J. L; ,J. D. Beaton ; S. L. Tisdal and W. L. Nelson .2005. Soil fertility and fertilizers. 7 th Ed. An introduction to nutrition management.Upper Saddle River, New Jersey.
[27] Azcon, R. El., and F. Atrash. 1997. Influence of arbuscular mycorrhizae and phosphorus fertilization on growth, nodulation, and N2 fixation (N15) in Medicago sativa at four salinity levels. Biology and Fertility of soils 24: 81-86.
[28] Barea, J.M.; M. E. Brown and B., Mosse .1973. Association between VA mycorrhiza and Azotobacter. Rothamsted Exp. Stn. Annu. Rep. For (1972).