Impact of Mycorrhizal Inoculation Efficiency and Levels of Potassium Fertilizer on Available Potassium, Growth, and Yield of Potatoes

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Abstract

A field experiment was conducted for autumn season 2023-2024 to grow the Arizona potato crop in one of the private fields in the Abu Gharq district – Babylon province, in a clay loam soil classified to the level of great aggregates (TypicTorrifluvent). The study included determining the effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer on potassium available, growth and yield. Potatoes included three levels of mycorrhizal inoculation , namely 0, 10, and 20 g. plant-1, and were symbolized as M0, M1, and M2, respectively. This applies to the first factor, while the second factor represented the addition of potassium fertilizer in the form of potassium sulfate in the ground, at three levels, namely (0, 125, and 250) kg.ha. -1 and symbolized by K0, K1 and K2 sequentially. The experiment was conducted in a randomized complete block design (RCBD). At maturity, the traits were measured total yield. Samples of leaves and tubers were taken to measure the concentrations of K, P, and N in the tubers. The results showed that the The mycorrhizal inoculation treatment (M2) of 20 grams per plant achieved the highest potato tuber yield of 1142. Mg per plant.The treatment of adding potassium fertilizer K2 (250 kg ha-1) achieved the highest concentrations of N, P and K nutrients in the tubers, which were 1.69% N, 0.320% P and 2.86% K.The K2 M2 treatment gave the highest indicators for the traits studied. Compared to control treatment M0K0.

Keywords: mycorrhizal, potassium, Potatoes, tubers.

Introduction

Potato, Solanum tuberosum L., is one of the important vegetable crops in the world and belongs to the Solanaceae family. It is characterized by containing a high percentage of energy (carbohydrates), and is considered an important food source, making it ranked fourth after wheat, rice, and yellow corn in terms of importance [19] . Fertilizers are known. Biofertilizers are living organisms that are mixed with seeds or added to the soil in the rhizosphere region that work to stimulate plant growth through many chemical and biological roles through which they stabilize or activate and increase the available of some important nutrients for absorption by the plant. Mycorrhizal fungi are considered biofertilizers. Because they live in the rhizosphere region and inside plant root

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tissues in a symbiotic manner, the fungi that belong to this group are called Plant Growth Promoting Fungi, abbreviated PGPF. They are known as vaccines that include a group of organisms added individually or in mixtures that inhabit the rhizosphere region and the internal surfaces of the plant and perform different functions and mechanisms. for plants [21[

Some studies have found that inoculation with mycorrhizal fungi improves the absorption of nutrients such as phosphorus, nitrogen, and potassium. This is due to the role of the fungus' hyphae, as they act as an additional network for the root system, as they have the ability to penetrate between the soil particles and reach areas that the root hairs cannot reach, and thus absorb the elements. The nutrient is less mobile, thus improving plant growth and increasing yields [17[

Potassium is an important factor for increasing the economic yield and improving its quality, especially for the potato crop, as it affects the process of division and expansion of meristematic cells through its role in ensuring and achieving ideal swelling of the cell wall. It also regulates water and the mechanism of closing and opening stomata [7] as potassium is present. In large quantities in the soil, a small percentage of it is available for absorption, and its available in the soil can increase when potassium fertilizers are added. This is done by dissolving the potassium in the soil solution first, and shortly after that most of it turns into the non-exchanged form, and when the potassium is absorbed, it is more readily available and available . By the plant, the reactions go in reverse, as the exchanged potassium turns into dissolved potassium in the soil solution, and this leads to continuous stabilization and release of potassium in the soil [4]Due to the lack of studies that clarify the role of biofertilizer (mycorrhiza) and its role in increasing the availability of most nutrients, including potassium, and to reach an appropriate combination with biofertilizer to contribute to the natural growth of the plant and thus increase agricultural production in quantity and quality, this study aimed to find out:

.1The effect of the efficiency of mycorrhizal inoculation and ground potassium fertilizer on some growth indicators and potato yield.

.2Interaction effect of biofertilizer and potassium fertilizer on potassium available, growth and yield of potatoes.

Materials and methods

A field experiment was conducted for autumn season 2023 - 2024 to grow the Arizona potato crop in one of the private fields in the Abu Gharq district - Babylon provainc, in a clay mixture soil classified to the level of great aggregates (TypicTorrifluvent). Several samples were randomly taken, representing the field soil before plowing, at a depth of (0-30 cm). The soil samples were mixed, a composite sample was obtained from them, air-dried, then ground and sieved with a sieve with a hole diameter of 2 mm. It was used to estimate some of the physical and chemical properties of the field soil , The experiment was conducted in a field with an area of 602 m2, its dimensions being 39.5 m x 15.25 m. The experiment site was plowed using a rotary plow to a depth of 0.25 m for two perpendicular plowing times, where adjustment and leveling operations were conducted . The field was divided into three main plot, each sector containing 9 experimental units, the area of the

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experimental unit It was 10.5 m2, its dimensions were 3 x 3.5 m, and in two rows the length of the row was 5.3 m. Planting was done with two lines for each row, that is, on two sides. The width of the row was 80 cm and the distance between one row and another was 60 cm, according to [15] Separations of 2 m were left between the sectors. Separations of 1 m were left between treatments for the purpose of controlling fertilization processes and not transferring potassium fertilizer between treatments. The experiment included a study of the effect of two factors: the first is inoculation with mycorrhizal fungi at three levels: M0, control treatment, M1, inoculation at a level of 10, and M2, inoculation at a level of 20 grams per plant. The second factor is the addition of potassium fertilizer (potassium sulfate) at three levels: K0, control treatment, and K1, an addition at a level of 125 kg ha-1. And K2 is an addition at the level of 250 kg ha-1, so the number of treatments became 3 x 3 = 9 treatments and in three sectors, so that the number of experimental units became 3 x 3 x 3 = 27 experimental units.

The seeds were cultivated on October 5, 2023-2024 for the fall season in the upper third of the garden, at a depth of 10-12 cm. The distance between one tuber and another was 25 cm, at a rate of 10 tubers. They were inoculated with mycorrhizal fungi at planting, and according to the experimental levels, potassium sulfate fertilizer (51% K2O) was added. , S 18%) in two batches below the planting line with a groove and at a depth of 0.2 m and covering the fertilizer with a layer of soil, where the first batch was 20 days after planting with half the recommended amount and the second batch was 40 days after planting and according to the experimental levels.

Results and discussion

Tuber yield (Mg ha-1(

The results of the statistical analysis indicated in Table (1) that the effect of inoculation with mycorrhizae and levels of potassium fertilizer and the interaction between them had a significant effect in increasing the total yield of tubers for treatment M2 compared to treatments M1 and M0, as the average for each of them reached (35.22 and 25.11) Mg ha-1, with an increase rate of (19.56) and 67.70% for each of them, respectively. It is also noted from the same table that adding potassium fertilizer had a significant effect on giving The highest total yield of tubers was an average of 41.56 Mg ha-1for the K2 treatment compared to the K1 and K0 treatments, as the average for each of them reached (36.21 and 24.58) Mg ha-1, with an increase rate of 14.77 (14.77) and 69.08% for each of them, respectively. It is also noted that the effect of the interference of inoculation With mycorrhizae and adding levels of potassium had a significant effect on increasing the total yield of tubers (Mg ha-1), and its highest value was in the intervention treatment (M2K2), which amounted to 49.15 Mg ha-1, which did not differ significantly from the interaction treatment (M2K1), which amounted to Its value was 47.07 Mg ha-1, while the control treatment (M0K0) gave the lowest value for the total tuber yield, amounting to 19.67 Mg ha-1.

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Table 1. The effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer and their interaction on total tuber yield (Mg ha^{-1})

	Potassium fertilization			
average	K_2	K_1	K_0	Mycorrhiza Inoculation levels
25.11	31.37	24.31	19.67	M_0
35.22	44.17	37.56	23.95	M_1
42.11	49.15	47.07	30.13	M_2
	41.56	36.31	24.58	average
Potassium levels	interaction		Mycorrhiza Inoculation	L.S.D(0.05)
K	K*M		M	
0.68	1.19		0.68	

Number of tubers (tuber plant-1(

The results of the statistical analysis in Table (2) indicated that for all study indicators, namely inoculation with mycorrhizae and the addition of different levels of potassium fertilizer and their interactions, had a significant effect on the trait of the number of tubers (tuber plant-1). Inoculation with mycorrhizae had a significant effect in giving the highest average for this trait, amounting to 6.37 tubers. Plant-1 at treatment M2 compared to treatments M1 and M0, as the average for each of them reached (4.91 and 4.00) tubers. Plant-1. It is also noted from the table that the effect of adding different levels of potassium fertilizer also had a significant effect in increasing the number of tubers as represented by the treatment. (K2) gave the highest average of 6.22 tubers. Plant-1, while the (K1) treatment gave an average of 5.47 tubers. Plant-1. As for the effect of treatment (K0) of not adding potassium fertilizer, it gave the lowest average for this trait, amounting to 3.58 tubers. Plant-1. The results of the statistical analysis in the same table also indicated that the effect of the interaction with mycorrhizal inoculation and the addition of different levels of potassium fertilizer on the number of tubers for the experimental unit, and that its highest value was in the double interaction treatment (M2K2), which amounted to 7.59 tubers. Plant-1, which did not differ significantly from the treatment. Bi- interaction (M2K1) had a value of 7.12 tubers. Plant-1, while the lowest value for this trait was in control treatment (M0K0), which had a value of 3.12 tubers. Plant-1.

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Table 2. The effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer and their interaction on the number of tubers (tuber plant-1)

average	Potassium fertilization K_2	K_1	K_0	Mycorrhiza Inoculation levels
4.00	5.04	3.84	3.12	M_0
4.91	6.04	5.47	3.23	M_1
6.37	7.59	7.12	4.41	M_2
	6.22	5.47	3.58	average
Potassium levels	Interaction		Mycorrhiza Inoculation	L.S.D(0.05)
K	K*M		M	
0.45	0.78		0.45	

The percentage of nitrogen in tubers

The results of the statistical analysis in Table (3) indicated that inoculation with mycorrhizae and the addition of different levels of potassium fertilizer and the interaction between them had a significant effect on the concentration of nitrogen in the tubers. The effect of inoculation with mycorrhizae had a significant effect in increasing the concentration of nitrogen in the tubers, as the M2 treatment was significantly superior in increasing the concentration of nitrogen. In tubers, it gave the highest average of 1.66% compared to the M1 and M0 treatments, as the average of each of them reached 1.53 (1.33)%, with an increase rate of (8.49 and 24.81)% for each of them, respectively. It is also noted that the treatment of adding K2 potassium fertilizer was superior in giving the highest average concentration. Nitrogen in tubers reached 1.69% compared to the K1 and K0 treatments, as the average for each of them reached (1.57 and 1.26)%, with an increase rate of 7.64) and 34.12% for each of them, respectively. It is also noted from the same table that the effect of the intervention had a significant effect in increasing Nitrogen concentration in tubers and its highest value was with bi-interaction treatment M2K2, which amounted to 1.90%, which did not differ significantly from bi-interaction treatment for inoculation with mycorrhizal fungi and the addition of potassium fertilizer to the M2K1 treatment, which amounted to 1.80%, while control treatment M0K0 gave the lowest value. The value of nitrogen concentration in tubers reached 1.20%, with an increase of 58.33%.

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Table 3. The effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer and their interaction on the percentage of nitrogen concentration in tubers

average	Potassium fertilization K_2	K_1	K_0	Mycorrhiza Inoculation levels
1.33	1.46	1.33	1.20	M_0
1.53	1.73	1.60	1.28	M_1
1.66	1.90	1.80	1.30	M_2
	1.69	1.57	1.26	average
Potassium levels	Interaction		Mycorrhiza Inoculation	L.S.D(0.05)
K	K*M		M	
0.07	0.13		0.07	

The percentage of phosphorus in tubers

The results of the statistical analysis in Table (4) indicated that all study indicators represented by inoculation with mycorrhizal fungi and the addition of different levels of potassium fertilizer and the interaction between them had a significant effect in increasing the concentration of phosphorus in the tubers. It is noted that inoculation with mycorrhizal fungi had a significant effect in increasing the concentration of phosphorus in the tubers. The second level treatment, M2, gave the highest average concentration of phosphorus in tubers, amounting to 0.324%, compared to the M1 and M0 treatments, as the average for each of them reached (0.290 and 0.267)%, with an increase rate of (11.72 and 21.34)% for each of them, respectively. Also, the effect of adding different levels Of potassium fertilizer significantly increased the concentration of phosphorus in tubers by giving its highest average in the K2 treatment, which reached 0.320%, compared to the K1 and K0 treatments, where the average of each reached (0.292 and 0.270)%, with an increase rate of (9.58 and 18.51)% for each of them, respectively. It is also noted from the same table that the effect of bi-interaction had a significant effect in increasing the concentration of phosphorus in the tubers, and that its highest value was in bi-interaction treatment M2K2, which amounted to 0.375%, while bi-interaction treatment gave the lowest value for the concentration of phosphorus in the tubers for the M0K0 treatment, which Its value reached 0.261%, an increase of 43.67%.

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Table 4. The effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer and their interaction on the percentage of phosphorus concentration in tubers

	Potassium fertilization			
average	K_2	K_1	K_0	Mycorrhiza Inoculation levels
0.267	0.273	0.269	0.261	M_0
0.290	0.313	0.290	0.269	M_1
0.324	0.375	0.319	0.280	M_2
	0.320	0.292	0.270	average
Potassium levels	Interaction		Mycorrhiza Inoculation	L.S.D(0.05)
K	K*M		M	
0.010	0.017		0.010	

The percentage of potassium in tubers

The results of the statistical analysis in Table (5) indicated that the effect of inoculation with Microrhiza had a significant effect on increasing the concentration of potassium in the tubers, and that its highest value was in the M2 treatment, which gave the highest concentration of this trait with an average of 2.96% compared to the M1 and M0 treatments, as the average for each of them reached 2.50. And 2.22%, with an increase rate of 18.40 and 33.3% for each of them, respectively. Also, the effect of adding potassium fertilizer at different levels had a significant effect in increasing the potassium concentration in the tubers as a percentage, as the K2 treatment gave the highest average potassium concentration in the tubers of 2.86% compared to the K1 and K0 treatments, as the average for each of them reached 2.59 and 2.23%, with an increase rate of 10.42 and 28.25% for each of them, respectively. It is also noted from the same table that the combined effect of mycorrhizal inoculation and the addition of different levels of potassium fertilizer had a significant effect. In increasing the concentration of potassium in the tubers, its highest value was with bi-interaction treatment (M2K2), which reached a value of 3.65%, which did not differ significantly from bi-interaction treatment (M2K1), which had a value of 2.90%, while bi-interaction treatment of control treatment, M0K0, gave the lowest value. The potassium concentration in tubers reached 2.15%, with an increase of 69.76%.

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Table 5. The effect of mycorrhizal inoculation efficiency and levels of potassium fertilizer and their interaction on the percentage of potassium concentration in tubers

average	Potassium fertilization K_2	K_1	K_0	Mycorrhiza Inoculation levels
2.22	2.23	2.29	2.15	M_0
2.50	2.71	2.60	2.21	M_1
2.96	3.65	2.90	2.34	M_2
	2.86	2.59	2.23	average
Potassium levels	Interaction		Mycorrhiza Inoculation	L.S.D(0.05)
K	K*M		M	
0.051	0.089		0.051	

It is noted from Tables 1 and 2 that the effect of inoculation with mycorrhizae and the addition of different levels of potassium fertilizer and their interactions had a significant effect on increasing the total yield (meg-1) and the number of tubers (plant tuber-1). The effect of inoculation with mycorrhizae on the number of tubers and their yield may be due to its role. In increasing photosynthesis by increasing chlorophyll in the plant, which is reflected in an increase in yield growth and the number of tubers of the potato crop [20]. Also, inoculating the potato crop with mycorrhizae led to a significant increase in the dry weight of the shoot and root system and the water use efficiency of the inoculated plants compared to non-inoculated plants. These results are consistent with [10]. Mycorrhizae also increase the percentage of growth factors produced in the growth medium, such as auxins, gibberellins, and cytokines that stimulate the growth of root hairs and thus increase the surface area for nutrient absorption [5]. Inoculation with mycorrhizal fungi also helps in stimulating root growth and increasing their density, which works to increase the shoot and this is reflected in the number of tubers and their yield. Many studies have shown the important role of mycorrhizal fungi in the fertility and physical characteristics of the soil by improving the structure of the soil by means of fibers that bind soil particles and support From its construction, it works to increase the stability of soil aggregates and retain soil organic matter, as well as by strengthening water relations, retaining water even in sandy soils, increasing the resistance of the host plant to drought, and improving soil aeration and pore permeability, as all of these factors improve soil conditions. It is reflected positively on the characteristics of the yield and the number of tuber. These results are consistent with [14, and Youssef and Eissa, 2014). Adding

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different levels of potassium has a significant effect on the number of tubers and potato yield by increasing the size of the tubers [19]. Adding potassium also increases the resistance of the tubers to the mechanical damage they are exposed to as a result of the transportation process and prolongs the storage period [12]. The reason for adding potassium may also be attributed to the activation of a very large number of enzymes, which may reach more than 90 enzymes, such as the enzymes responsible for reducing nitrates, which work to complete vital processes such as photosynthesis, protein formation, etc. It also has a major role in activating the process of carbon metabolism. Then it affected the manufacture of carbohydrates in the leaves and their transport and storage in the tubers, as it contributed to increasing the number of tubers per plant and this was reflected in an increase in the total yield [11]. Adding potassium to the soil also led to an increase in the available of nutrients in the soil solution and their absorption by Plants, and this demonstrates the importance of potassium fertilization in increasing the total yield and number of tubers. These results are consistent with what [6] reached, in which the reason for the increase in the number of tubers and total yield may be attributed to the functional role of potassium in the growth and emergence of the plant, starting with the division and expansion of meristematic cells until the end of growth. The plant by controlling the mechanism of opening and closing stomata, which is linked to the accumulation of sugars in the guard cells [3], and potassium can move against a change in chemical concentration into the plant cells, and it is considered a mobile element within the plant and the main direction of its transport is towards the meristematic tissues and leaves. Newly formed, which contributes to increasing the yield of one plant and the number of tubers, and this is reflected in the total yield of the potato crop [1]. It is also noted in Tables 3, 4 and 5 that the effect of mycorrhizal inoculation and the potassium levels and their interactions have significantly affected the increase in the concentrations of nitrogen, phosphorus and potassium nutrients in the tubers. The reason for this may be due to the fact that biofertilizers play a major role in increasing the permeability of cell membranes, photosynthesis and growth. Roots, in addition to its indirect role in increasing the efficiency of added fertilizers in improving all biological activities [16[

Mycorrhizae also have a great ability to increase the concentrations of N, P, and K in tubers by increasing the activity of enzymes that decompose organic compounds and work to liberate elements from them, which increases their available and in turn increases plant growth rates. Free amino acids are also an essential source of nitrogen in building proteins. And enzymes and energy processing that encourage vegetative and root growth and thus the transfer of nutrients from the plant to the tubers and increase the concentrations of N, P, and K in the tubers. These results are consistent with [13] and the reason is also due to increasing the available of plant nutrients through regulating development. Suitable for plant growth and also leads to soil enrichment and compatibility with agriculture, thus increasing the available of these nutrients and their transfer from leaves to potato tubers [9]. Inoculation with mycorrhizal biofertilizer also results in the secretion of some important

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enzymes and plant growth regulators, and their importance in increasing the concentrations of these nutrients in tubers [3], and adding different levels of potassium fertilizer has had a significant effect on increasing the concentrations of N, P, and K in the tubers. With an increase in the level of addition, which indicates the role of this nutrient in raising the efficiency of the root system in absorbing nutrients and increasing its concentration in the plant, including tubers. The reason for the increase in the concentrations of these nutrients in the tubers may also be attributed to adding different levels of potassium fertilizer to the soil, which led to the activation of biological processes, as potassium participates with the rest of the nutrients, including phosphorus and nitrogen, in the formation of some enzymatic attachments that support enzymatic activity in starch formation. It also participates in Potassium in the enzymatic activities responsible for transporting and storing starch in tubers, and this works to increase the concentrations of these nutrients in them. These results are consistent with what was found [1,2] and adding different levels of potassium fertilizer helps build a good root and vegetative system and thus increases The amount of these nutrients increases and the absorption of them increases and they accumulate in the vegetative part, which helps the plant to carry out vital activity, which results in the amount of synthetic materials in the leaves. With the availability of transport factors for this plant to the tubers, the concentration of nitrogen, phosphorus and potassium in them increases. This is consistent with [8]. The reason may also be attributed to Increasing the concentrations of nitrogen, phosphorus, and potassium in the tubers exceeded the addition of a high level of potassium fertilizer, which played a major role and rapid processing. The reason for this may be due to the availability of this nutrient, which leads to an increase in the concentrations of these nutrients in the tubers. The potassium fertilizer also stimulated the plant to produce auxins. Which increased the plant's effectiveness in carrying out the process of carbon metabolism and thus increasing the absorption of nutrients, in addition to the role of potassium in regulating the osmotic potential of plant cells and controlling the mechanism of opening and closing stomata [3] . The reason may also be attributed to the fact that biofertilization with potassium achieved an important balance for the potato crop, as adding potassium fertilizer makes the nutrients more available for the biofertilizer to contain organic acids and encourages the absorption of N, P, and K elements, and this is consistent with everything they found [1,6]. The reason may also be attributed to the fact that adding potassium fertilizer in the presence of mycorrhizae led to an increase in the preparation of nutrients such as available potassium in the soil, and then an increase in their absorption by the plant, and this was reflected in an increase in the concentrations of N, P, and K in the tubers. These results are consistent with what they found. [18.[

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