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RESEARCH ARTICLE

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The role of Soaking and spraying with some micronutrients in the qualitative characteristics of potato yield (*Solanum tuberosum* L.)

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ABSTRACT

A field experiment was conducted during the fall season 2023-2024 in a soil sandy clay texture to study soaking potato tubers and spraying plants with micro elements (iron, zinc and copper) in two separate experiments and their effect on plant growth and yield. The experiment was conducted at the Agricultural Research and Experiment Station affiliated to the College of Agriculture / University of Kirkuk /Iraq according to the Randomized Complete Block Design (R.C.B.D) with three replicates for the spraying and soaking experiment. The spraying experiment included spraying potato plants twice, once during the vegetative growth stage and the second 30 days after the first spray. As for the soaking experiment, potato tubers were soaked for 8 hours before planting. The results of the study showed the Treatment T7 gave the best results in increasing the qualitative characteristics of the crop in the average percentage of dry matter in tubers, which reached (21.830%) and outperformed all other treatments. In contrast, treatment T2 gave the best results, outperforming by giving the highest average protein, which reached 8.470%. In contrast, treatment T3 outperformed by giving the highest average percentage of dry matter in tubers, which reached (20.630%), which outperformed its counterparts of individual additions in these characteristics, and treatment T6 gave the best results by giving the highest percentage of average dry matter in tubers, which reached 21.470%, and outperformed its counterparts of dual additions. As for the results of the soaking experiment, they were as follows Treatment D7 gave the best results for the average percentage of dry matter in tubers, which reached 19.533%, as it outperformed its counterparts of individual additions, and treatment D6 gave the best results in the average percentage of dry matter in tubers reached 20.400%, thus outperforming similar dual additives.

***Keywords*:** microelements, spraying, soaking, quality attributes, potato.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a strategic crop ranked second after grains. It is a soil-stressing crop due to its greed for nutrient absorption. This is due to the large green mass of the plant and the number of tubers it produces during its growth period, which extends between 90-120 days. In addition, it is considered one of the most important vegetable crops in the Arab world and in many countries worldwide, especially the Americas and Europe [1]. It is an annual herbaceous plant that reaches a height of 100 cm and produces potato tubers, which are very rich in starch. It is one of the most widespread vegetable crops in the world. It contains vitamins such as C and B, a high percentage of potassium, and other mineral salts such as phosphorus and magnesium [2].

Therefore, researchers have resorted to using some methods to reduce pollution with chemical fertilizers and reduce the accumulation of nutrients in the soil that cause soil degradation to use better, more successful and less expensive methods by adopting applications and concepts of strategies including fertilization programs by spraying on the plant, as the use of foliar spraying to treat the deficiency of micronutrients in order to provide the plant with all its needs by conducting more than one spray with solutions of their salts on the vegetative part of the plant, foliar fertilization with microelements was used in the foliar nutrition of the plant, including iron, zinc and copper, due to their importance in activating vital activities in the plant and their rapid absorption by the vegetative part of the plant and compensating for the deficiency in nutritional elements [3].

The researchers' results showed that soaking seeds in micro- or macro-nutrients increases the efficiency of water absorption and accelerates the rate of seed germination and seedling growth [4].

Iron is one of the essential micronutrients for the growth and completion of the plant life cycle. Its importance comes from the fact that it enters into the composition of the basic components of the plant cell, such as cytochromes, and its contribution to the formation of chlorophyll, in addition to its role in the composition and activity of many enzymes responsible for the vital processes of oxidation and reduction, such as the enzymes Reductase number 2, 3 and nitrogenases [5]. Zinc is an important component of many different enzymes and ribosomes and plays an important role in the formation of carbohydrates, chlorophyll and root growth, which enhances the process of nutrient absorption and increases its content in the soil and plant [13]. Copper enters into enzymes that help in reactions that reduce the oxygen molecule. These enzymes include Cytochrome oxidase and a number of other enzymes such as Lactase, Tyrosinase, which is also called Polyphenol oxidase, Diamine oxidase, and Ascorbic acid oxidase. These enzymes contribute to the oxidation and reduction processes that occur in plant tissue cells and lead to vital processes such as respiration, chloroplast and protein formation, nitrate reduction, and vitamin C formation [18]. The study aimed to increase the efficiency of using micronutrient fertilizers (iron, zinc and copper) through soaking and foliar spraying and its reflection on the qualitative characteristics of potatoes.

Materials and methods:

A field experiment was conducted in the autumn agricultural season of 2023 at the Agricultural Research and Experiment Station affiliated with the College of Agriculture, University of Kirkuk, Located at latitude (12 23°35) north, and longitude (35 20°44) east, to study soaking potato tubers and spraying plants with some trace elements (zinc, iron, and copper) and their interaction in two separate experiments and the effect of this on the concentration of some nutrients in tubers and its reflection on the qualitative characteristics of the crop in a soil with a mixed sandy clay texture, some of whose characteristics and properties are estimated in Table 1 according to [6].

Table (1) Some chemical and physical properties of soil before planting

The attribute		Unity	Value
pH soil reaction		-----	7.82
(ECe) Electrical conductivity		dS m^{-1}	1.42
organic soil material		g kg^{-1} soil	10.31
Bulk density		Mega g m^{-3}	1.45
N			37
P			7.2
K		mg kg^{-1} soil	125.12
Zn			0.21
Cu			2.1
Fe			3.71
CaCO3			227
Soil separators	Sand		590
	Green	g kg^{-1} soil	170
	Clay		240
Textural name		Sandy Clay	

Treatments at a rate of 120 kg P_2O_5 ha^{-1} in the form of triple superphosphate fertilizer (45% P_2O_5) was mixed with the soil before planting. Fertilizers were added according to the fertilizer recommendation [7]. Potato tubers were soaked before planting for 8 hours [8] in a solution of 100 mg L^{-1} ($ZnSO_4.H_2O$) and symbolized by D1, in a solution of 50 mg L^{-1} ($CuSO_4.7H_2O$) and symbolized by D2, in a solution of 200 mg L^{-1} ($FeSo_4.7H_2O$) and symbolized by D3, 50 mg L^{-1} copper and 100 mg L^{-1} zinc and symbolized by D4, in a solution of 200 mg L^{-1} iron and 100 mg L^{-1} zinc and symbolized by D5, in a solution of 200 mg L^{-1} iron and 50 mg L^{-1} copper and symbolized by D6, in a solution of 200 mg L^{-1} iron and 50 mg L^{-1} copper and 100 mg L^{-1} zinc and symbolized by D7 and finally without soaking and symbolized by D0. As for the spraying experiment, potato plants were sprayed twice, once at the dense branching during the vegetative growth stage and 30 days after the first spray. The experimental treatments were as follows: spraying with zinc at a rate of 50 mg L^{-1} ($ZnSO_4.H_2O$) and symbolized by T1, spraying with iron at a rate of 100 mg L^{-1} ($FeSo_4.7H_2O$) and symbolized by T2, spraying with copper at a rate of 25 mg L^{-1} ($CuSO_4.7H_2O$) and symbolized by T3. Spraying with iron and zinc at a rate of 100 mg L^{-1} iron and 50 mg L^{-1} zinc, symbolized as T4, spraying with copper and zinc at a rate of 25 mg L^{-1} copper and 50 mg L^{-1} zinc, symbolized as T5, spraying with copper and iron at 25 mg copper L^{-1} and 100 mg iron L^{-1}, symbolized as T6, spraying with copper, iron and zinc at 25 mg copper L^{-1} and 100 mg iron L^{-1} and 50 mg zinc L^{-1}, symbolized as T7, and a final treatment that was not sprayed with water, symbolized as T0. Potato seeds were planted on 9/5/2023. The irrigation process was carried out according to the crop's need, using the fixed sprinkler irrigation method and relying on compensating for what is lost from the evaporation basin. Plants were harvested and samples were taken from plants and soil to study the following characteristics: NPK concentration in tubers, percentage of dry matter, percentage of protein and percentage of starch. According to the randomized complete block design (R.C.B.D) and with three replicates for the spraying and soaking experiment. The results were statistically analyzed using the analysis of variance (ANOVA) method at a probability level of 0.05 using the GenStat V. 12.1 program.

Results and discussion:

Nitrogen:

The results of the statistical analysis in Table 2 show that soaking with the three micronutrients individually or in combination led to a different response to nitrogen concentration in tubers, depending on the soaking treatments that contained one or more of the three nutrients. The iron D3 soaking treatment outperformed by giving a nitrogen concentration of 1.42%, with an increase rate of 8.3% compared to the comparison treatment D0, which gave 1.31%. In contrast, the zinc D1 soaking treatment and the copper D2 soaking treatment gave an average nitrogen concentration of 1.41%, respectively, achieving an increase rate of 7.9% and 7.38%, respectively, compared to the comparison treatment. As for the effect of the interaction possibilities for these three elements, we note that the D6 treatment, soaking with iron + copper, led to a significant increase in the average nitrogen concentration, which reached 1.48%, achieving an increase rate of 12.9% compared to the comparison treatment. Followed by treatment D4 soaking with zinc + copper and finally treatment soaking with iron + zinc D5, which gave an average nitrogen concentration of 1.47% and 1.41% respectively, recording an increase rate of 12.9% and 7.3% compared to the comparison treatment. On the other hand, the results of the same table confirm that treatment D7 soaking with the three microelements in combination gave the highest average nitrogen concentration in tubers of 1.55%, thus outperforming all other study treatments and achieving an increase rate of 18.2% compared to the comparison treatment.

Phosphorus:

Soaking potato tubers with micronutrients iron, zinc and copper before planting led to significant differences in the average concentration of phosphorus, as shown in Table 2, as the treatment of soaking with iron D3 was significantly superior by giving an average concentration of phosphorus of 0.28% and an increase of 38.7% compared to the comparison treatment D0, which gave the lowest average concentration of phosphorus of 0.20%, while the treatment of soaking with zinc D1 and the treatment of soaking with copper D2 gave an average concentration of phosphorus of 0.28% and 0.26%, achieving an increase of 35.4% and 25.7% compared to the comparison treatment. As for the effect of the interaction possibilities of these three elements, we note that the treatment D6 soaking with iron + copper led to a significant increase in the average concentration of phosphorus, which reached 0.30%, achieving an increase of 46.7% compared to the comparison treatment, followed by the treatment of soaking D4 Zinc + copper and D5 treatment soaking with iron + zinc, which gave an average phosphorus concentration of 0.29% and 0.24% respectively, recording an increase rate of 34.5% and 19.3% compared to the comparison treatment. On the other hand, the results of the same table confirm that D7 treatment soaking with the three microelements in combination gave the highest average phosphorus concentration of 0.31%, thus outperforming all other study treatments and achieving an increase rate of 53.2% compared to the comparison treatment.

Potassium:

The results in Table (2) show that soaking with the three micronutrients individually or in combination led to a different response to the potassium concentration in tubers, depending on the soaking treatments that contain one or more of the three nutrients. The iron D3 soaking treatment outperformed by giving an average potassium concentration of 2.20% and an increase rate of 14.5% compared to the comparison treatment D0, which gave the lowest average potassium concentration of 1.92%, while the copper D2 soaking treatment and the zinc D1 soaking treatment gave an average potassium concentration of 2.043% and 1.983%, respectively, recording increase rates of 6.4% and 3.2%. As for the effect of the interaction possibilities for these three elements, we note that treatment D6, soaking with iron + copper, led to a significant increase in the average potassium concentration of 2.29%, achieving an increase rate of 19.2% compared to the comparison treatment, followed by treatment D4 soaking zinc + copper and D5 soaking iron + zinc, which gave an average potassium concentration of 2.28% and 2.22% respectively, recording an increase of 19.1% and 15.7% compared to the comparison treatment. On the other hand, the results of the same table confirm that D7 soaking with the three microelements in combination gave the highest average potassium concentration of 2.37%, thus outperforming all other study treatments and achieving an increase of 23.5% compared to the comparison treatment.

This is attributed to the fact that soaking the tubers may have stimulated the enzymatic activity, photosynthesis, chlorophyll formation, and metabolic pathways involved in carbon metabolism, which had a positive impact on improving the roots and their branching, which contributed to the absorption of some nutrients (nitrogen, phosphorus, and potassium), thus increasing their concentration in the tubers [9].

Table 2 Effect of soaking with microelements (iron, zinc, copper) on the concentration of NPK nutrients in the yield of potato tubers%

Transactions	N	P	K
D0	1.31	0.20	1.92
D1	1.41	0.28	1.98
D2	1.41	0.26	2.04
D3	1.42	0.28	2.20
D4	1.47	0.29	2.28
D5	1.41	0.24	2.22
D6	1.48	0.30	2.29
D7	1.55	0.31	2.37
$L.S.D_{0.05}$	0.197	0.079	0.173

Effect of soaking with micronutrient fertilizers (iron, zinc and copper) on the qualitative characteristics of potato yield Percentage of dry matter in tubers:

The results in Table 3 show that soaking with the three micronutrients individually or in combination led to a different response in the percentage of dry matter in tubers, depending on the soaking treatments that contain one or more of the three nutrients. The soaking treatment with iron D3 was significantly superior, giving an average of 19.53% and an increase of 37.8% compared to the comparison treatment D0, which gave the lowest average percentage of dry matter, reaching 14.16%. While the copper D2 and zinc D1 soaking treatments gave an average percentage of dry matter of 18.43% and 17.36%, respectively, recording increase rates of 30.1% and 22.5%. As for the effect of the interaction possibilities of these three elements, we note that the treatment D6, soaking with iron + copper, led to a significant increase in the average percentage of dry matter, reaching 20.40%, achieving an increase rate of 43.9% compared to the comparison treatment, followed by Treatment D4 soaking zinc + copper and treatment D5 soaking iron + zinc gave an average percentage of dry matter of 20.23% and 19.70% respectively, recording an increase of 42.8% and 39.05% compared to the comparison treatment. On the other hand, the results of the same table confirm that treatment D7 soaking with the three microelements in combination gave the highest average percentage of dry matter in tubers of 21.36%, thus outperforming all other study treatments and achieving an increase of 50.8% compared to the comparison treatment**.**

Protein percentage in tubers:

Soaking potato tubers with micronutrients iron, zinc and copper before planting led to significant differences in the average percentage of protein in tubers, as shown in Table 3. The iron soaking treatment D3 was significantly superior, giving an average protein percentage of 8.89%, with an increase of 8.4% compared to the comparison treatment D0, which gave the lowest average protein percentage of 8.2%. In comparison, the zinc soaking treatment D1 and the copper soaking treatment D2 gave an average protein percentage of 8.85% and 8.81%, respectively, recording an increase of 7.9% and 7.4%. As for the effect of the interaction possibilities of these three elements, we note that the treatment D6, soaking with iron + copper, led to a significant increase in the average protein percentage of 9.27%, achieving an increase of 13.04% compared to the comparison treatment, followed by the treatment D4, soaking with zinc + copper, and the treatment D5, soaking With iron + zinc, which gave an average protein percentage of 9.22% and 8.81% respectively, recording an increase of 12.4% and 7.4% compared to the comparison treatment. On the other hand, the results of the same table confirm that the D7 treatment, soaking with the three microelements in combination, gave the highest average protein percentage in tubers, reaching 9.70%, thus outperforming all other study treatments and achieving an increase of 18.2% compared to the comparison treatment.

Percentage of starch in tubers:

Soaking potato tubers with micronutrients iron, zinc and copper before planting led to significant differences in the average percentage of starch in tubers, as shown in Table (3). The iron soaking treatment D3 was significantly superior, giving an average of 13.40%, with an increase of 55.4% compared to the comparison treatment D0, which gave the lowest average starch of 8.62%. In comparison, the copper soaking treatment D2 and zinc soaking treatment D1 gave an average percentage of starch of 12.42% and 11.47%, respectively, recording an increase of 44.07% and 33.05%. As for the effect of the interaction possibilities of these three elements, we note that treatment D6, soaking with iron + copper, led to a significant increase in the average percentage of starch of 14.18%, achieving an increase of 64.3% compared to the comparison treatment, followed by treatment D4, soaking with zinc + copper. The D5 treatment, soaking with iron + zinc, gave an average starch percentage of 14.03% and 13.55% respectively, recording an increase of 62.6% and 57.1% compared to the comparison treatment. On the other hand, the results of the same table confirm that the D7 treatment, soaking with the three microelements in combination, gave the highest average starch in tubers of 15.04%, outperforming all other study treatments and achieving an increase of 74.3% compared to the comparison treatment.

Table 3 shows that soaking potato tubers with micronutrient fertilizers (iron, copper and zinc) before planting had a significant effect on the quality characteristics, percentage of dry matter, and percentage of protein and starch in tubers. On the other hand, the increase in protein and starch concentration in tubers may be due to the role of zinc in improving nitrogen absorption, which is a significant component of amino acids and proteins, and thus increasing protein synthesis in tubers [10]. Zinc also participates in the synthesis of carbohydrates and helps in converting starch into sugar, which may increase the starch content in tubers [11]. The increase in the percentage of starch and protein in tubers may be due to the role of iron, which participates in many metabolic processes, including the synthesis of chlorophyll and enzymes necessary for the production of starch and protein in tubers [12].

Table 3 Effect of soaking with microelements (iron, zinc, copper) on the qualitative characteristics of potato tubers

Transactions	Dry matter%	Protein%	Starch%
D0	14.16	8.20	8.62
D1	17.36	8.85	11.47
D2	18.43	8.81	12.42
D3	19.53	8.89	13.40
D4	20.23	9.22	14.03
D5	19.70	8.81	13.55
D6	20.40	9.27	14.18

D7	21.36	9.70	15.04
L.S. $D_{0.05}$	0.421	1.237	0.376

The effect of spraying with microelements (iron, zinc and copper) on the concentration of nutrients (NPK) in the yield of potato tubers%:

Nitrogen:

The results of the statistical analysis in Table 4 show that spraying with the three micronutrients individually or in combination led to a different response to nitrogen concentration in tubers depending on the spray treatments that contained one or more of the three nutrients. The iron addition treatment 2T outperformed by giving an average nitrogen concentration of 1.36% and an increase rate of 10.5% compared to the comparison treatment T0, which gave an average nitrogen concentration of 1.23%. In comparison, the zinc addition treatment T1 and the copper addition treatment 3T gave an average nitrogen concentration of 1.34% and 1.34% respectively, achieving an increase rate of 8.9% and 8.9% compared to the control treatment. As for the effect of the interaction possibilities of these three elements, we note that the T6 treatment, spraying iron + copper, led to a significant increase in the average nitrogen concentration, which reached 1.39%, achieving an increase rate of 13% compared to the comparison treatment, followed by the T4 treatment, spraying iron + zinc, and finally the T5 treatment, spraying zinc + copper, which gave an average nitrogen concentration of 1.37% and 1.35%, respectively, recording an increase rate of 11.3% and 9.7% compared to the comparison treatment. On the other hand, the results of the same table confirm that the T7 treatment, spraying with the three microelements in combination, gave the highest average nitrogen concentration of 1.40%, thus outperforming all other study treatments and achieving an increase rate of 13.8% compared to the comparison treatment.

Phosphorus:

The statistical data in Table 4 indicate that spraying with the three micronutrients individually or in combination led to a different response to the phosphorus concentration in tubers, depending on the spray treatments that contain one or more of the three nutrients. The iron addition treatment 2T outperformed by giving a phosphorus concentration of 0.30% and an increase rate of 9.8% compared to the comparison treatment T0, which gave a phosphorus concentration of 0.27%, while the zinc addition treatment T1 and the copper addition treatment T3 gave an average phosphorus concentration of 0.28% and 0.28%, achieving an increase rate of 2.5% and 2.5% compared to the comparison treatment. As for the effect of the interaction possibilities of these three elements, we note that T6 spraying iron + copper led to a significant increase in the average concentration of phosphorus in tubers, as it reached 0.33%, achieving an increase rate of 21.9% compared to the comparison treatment, followed by T4 spraying iron + zinc. Finally, T5 spraying zinc + copper gave an average concentration of phosphorus of 0.31% and 0.28%, respectively, recording an increase rate of 16.1% and 3.6% compared to the control treatment. On the other hand, the results of the same table confirm that the treatment of spraying with the three microelements T7 in combination gave the highest average concentration of phosphorus of 0.34%, thus outperforming all other study treatments and achieving an increase rate of 25.6% compared to the comparison treatment.

Potassium:

The results of the statistical analysis in Table (4) show that spraying with the three micronutrients individually or in combination led to a different response to the potassium concentration in tubers depending on the spray treatments that contain one or more of the three nutrients. The copper addition treatment 3T outperformed by giving a potassium concentration of 2.19% and an increase rate of 3.4% compared to the comparison treatment T0, which gave a potassium concentration of 2.123%. In comparison, the iron addition treatment 2T and the zinc addition treatment T1 gave an average potassium concentration rate of 2.17% and 2.16%, achieving an increase rate of 2.5% and 1.7% compared to the comparison treatment. As for the effect of the interaction possibilities of these three elements, we note that the T6 treatment of spraying iron + copper led to a significant increase in the average potassium concentration, which reached 2.32%, achieving an increase rate of 9.2% compared to the comparison treatment, followed by the T4 treatment of spraying iron + zinc, and finally the T5 treatment of spraying zinc + copper, which gave an average potassium concentration of 2.29% and 2.25%, respectively, recording an increase rate of 8.007% and 6.1% compared to the comparison treatment. On the other hand, the results of the same table confirm that the T7 treatment of spraying with the three microelements in combination gave the highest average potassium concentration of 2.34%, thus outperforming all other study treatments and achieving an increase rate of 10.5% compared to the comparison treatment.

Table (4) Effect of spraying with microelements (iron, zinc and copper) on the concentration of nutrients (NPK) in the yield of potatoes from tubers%

Transactions	N	P	K
T0	1.23	0.27	2.12
T1	1.34	0.28	2.16
T2	1.36	0.30	2.17
T3	1.34	0.28	2.19
T4	1.37	0.31	2.29
T5	1.35	0.28	2.25
T6	1.39	0.33	2.32
T7	1.40	0.34	2.34
L.S.D $_{0.05}$	0.075	0.053	0.173

Effect of spraying with microelements (iron, zinc and copper) on the qualitative characteristics of tubers Percentage of dry matter in tubers:

The results of the statistical analysis in Table 5 show that spraying the three micronutrients individually or in combination led to a different response to the percentage of dry matter in tubers, depending on the spray treatments that contained one or more of the three nutrients. The copper addition treatment 3T outperformed by giving an average percentage of dry matter of 20.63% and an increase of 52.4% compared to the comparison treatment T0, which gave a percentage of dry matter of 13.53%, while the iron addition treatment 2T and the zinc addition treatment T1 gave an average percentage of dry matter of 19.03% and 17.43%, achieving an increase of 40.6% and 28.8% compared to the comparison treatment. As for the effect of the interaction possibilities of these three elements, we note that treatment T6 spraying iron + copper led to a significant increase in the average dry matter, reaching 21.47%, achieving an increase rate of 58.6% compared to the comparison treatment, followed by treatment T5 spraying zinc + copper, and finally treatment T4 spraying iron + zinc, which gave an average dry matter percentage of 20.33% and 20.07%, respectively, recording an increase rate of 50.2% and 48.3% compared to the comparison treatment. On the other hand, the results of the same table confirm that the spraying treatment with the three microelements T7 in combination gave the highest average dry matter percentage of 21.83%, thus outperforming all other study treatments and achieving an increase rate of 61.3% compared to the comparison treatment**.**

Protein percentage in tubers:

The results of the statistical analysis in Table 5 show that spraying with the three micronutrients individually or in combination led to a different response to the protein percentage in tubers, depending on the spray treatments that contained one or more of the three nutrients. The iron addition treatment 2T outperformed by giving a protein percentage of 8.47% and an increase of 10.2% compared to the comparison treatment T0, which gave a protein percentage of 7.68%, while the zinc addition treatment T1 and the copper addition treatment 3T gave an average protein percentage of 8.39% and 8.37%, achieving an increase of 9.2% and 8.9% compared to the comparison treatment. As for the effect of the interaction possibilities of these three elements, we note that the T6 treatment, spraying iron + copper, led to a significant increase in the average protein percentage, which reached 8.68%, achieving an increase rate of 13.02% compared to the comparison treatment, followed by the T4 treatment, spraying iron + zinc, and finally the T5 treatment, spraying zinc + copper, which gave an average protein percentage of 8.54% and 8.43%, respectively, recording an increase rate of 11.1% and 9.7% compared to the comparison treatment. On the other hand, the results of the same table confirm that the T7 treatment, spraying with the three microelements in combination, gave the highest average protein percentage of 8.75%, thus outperforming all other study treatments and achieving an increase rate of 13.9% compared to the comparison treatment.

Percentage of starch in tubers:

The statistical data in Table 5 show that spraying with the three micronutrients individually or in combination led to a different response to the percentage of starch in tubers, depending on the spray treatments that contained one or more of the three nutrients. The copper addition treatment 3T outperformed by giving a percentage of starch of 14.39% and an increase of 78.5% compared to the comparison treatment T0, which gave a percentage of starch of 8.06%, while the iron addition treatment 2T and the zinc addition treatment T1 gave an average percentage of starch of 12.96% and 11.54%, achieving an increase of 60.7% and 43.1% compared to the comparison treatment. We note that treatment T6 spraying iron + copper led to a significant increase in the average starch percentage, reaching 15.13%, achieving an increase rate of 87.7% compared to the comparison treatment, followed by treatment T5 spraying zinc + copper, and finally treatment T4 spraying iron + zinc, which gave an average starch percentage of 14.12% and 13.88%, respectively, recording an increase rate of 75.1% and 72.2% compared to the comparison treatment. On the other hand, the results of the same table confirm that the treatment of spraying with the three microelements T7 in combination gave the highest average starch percentage of 15.46%, thus outperforming all other study treatments and achieving an increase rate of 91.8% compared to the comparison treatment.

The results of Tables 4 and 5 show an improvement in the qualitative yield indicators. Zinc has an important role in building proteins through its important role in nitrogen metabolism and converting it into essential amino acids, as well as building

DNA and RNA and contributing to their regulation. In addition, zinc is an important component of many different enzymes and ribosomes. It plays an important role in the formation of carbohydrates, chlorophyll and root growth, which enhances the process of nutrient absorption to a greater extent and increases its content in the soil and plant [13]. Spraying with iron and zinc led to a significant increase in the percentage of dry matter, starch and protein in tubers, as these nutrients play an important role in a number of physiological activities, the most important of which is activating enzymes involved in the carbon metabolism process and increasing the amount of absorbed nitrogen. This was reflected in the percentage of protein in the formed tubers and in increasing the amount of manufactured carbohydrates and their accumulation in the tubers, which leads to an increase in the qualitative characteristics of the potato tubers. This is consistent with what was found by [14, 15]. Also, the plant's possession of a strong and active vegetative group has an important role in increasing the level of natural gibberellin inside the plant, which increases the formation of DNA and RNA nucleic acids, which results in an increase in the amount of protein [16], [17].

Table 5: Effect of spraying with microelements (iron, zinc and copper) on the qualitative characteristics of potato crop:

Transactions	Percentage of dry matter in tubers	Protein percentage in tubers	Starch percentage
T0	13.53	7.68	8.06
T1	17.43	8.39	11.54
T2	19.03	8.47	12.96
T3	20.63	8.37	14.39
T4	20.07	8.54	13.88
T5	20.33	8.43	14.12
T6	21.47	8.68	15.13
T7	21.83	8.75	15.46
$L.S.D_{0.05}$	1.292	0.469	1.151

Conclusion:

1 .Iron spraying and soaking treatment gave the highest results in the qualitative characteristics of potato yield in the concentration of nutrients NPK in tubers and the percentage of protein, dry matter and starch.

2 .The treatment of spraying and soaking of dual elements was superior, as the treatment of spraying and soaking with iron and zinc gave the highest results in the studied characteristics and the concentration of some nutrients NPK in leaves and tubers. Also, the treatment of spraying and soaking with iron and copper gave the best results in some nutrients in tubers and qualitative characteristics of the yield.

3. The treatment of spraying and soaking with the three elements iron, zinc and copper gave the best results in the studied characteristics.

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دور النقع والرش ببعض العناصر الغذائية الصغرى في الصفات النوعية لمحصول البطاطا (*Solanum tuberosum* L.)

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الخلاصة

أجريت تجربة حقلية خلال الموسم الخريفي 2023–2024 في تربة رملية طينية لدراسة نقع درنات البطاطا ورش النباتات بالعناصر الصغرى (الحديد والزنك والنحاس) في تجربتين منفصلتين وتأثيرهما على صفات النمو والحاصل. أجريت التجربة في محطة البحوث والتجارب الزراعية التابعة لكلية الزراعة / جامعة كركوك / العراق وفق تصميم القطاعات العشوائية الكاملة (*R.C.B.D*) بثلاث مكررات لتجربة الرش والنقع. تضمنت تجربة الرش رش نباتات البطاطا مرتين إحداهما عند التفرع الكثيف خلال مرحلة النمو الخضري والثانية بعد 30 يوم من الرشة الأولى. أما تجربة النقع فقد تم نقع درنات البطاطا قبل الزراعة لمدة 8 ساعات. اظهرت نتائج الدراسة ان المعاملة *T7* أعطت افضل النتائج في زيادة الصفات النوعية للحاصل في متوسط النسبة المئوية للمادة الجافة في الدرنات بلغ (21.830 %) وتفوقت على جميع المعاملات الاخرى، بينما المعاملة *T2* اعطت افضل النتائج حيث تتفوق باعطائها اعلى متوسط بروتين بلغ 8.470%، فيما تفوقت المعاملة *T3* باعطائها اعلى متوسط للنسبة المئوية للمادة الجافة في الدرنات بلغ (20.630%) والتي تفوقت على مثيلاتها من الاضافات الفردية بهذه الصفات، والمعاملة *T6* اعطت افضل النتائج باعطاها اعلى نسبة لمتوسط المادة الجافة في الدرنات وبلغت 21.470%، وتفوقت على مثيلاتها من الاضافات الثنائية .اما نتائج تجربة التنقيع فكانت كالاتي ان المعاملة *D7* اعطت افضل النتائج لمتوسط نسبة المادة الجافة في الدرنات بلغت 19.533% ، حيث تفوقت على مثيلاتها من الاضافات الفردية، وان المعاملة *D6* اعطت افضل النتائج في متوسط نسبة المادة الجافة في الدرنات بلغ 20.400% ، وبهذا تفوقت على مثيلاتها من الاضافات الثنائية.

الكلمات المفتاحية: العناصر الصغرى ، الرش ، النقع ، الزنك ، النحاس ، الحديد ، البطاطا.