Effect of different fertilizer treatments on the chemical content of tubers of three spring potato cultivars

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Abstract

The field experiment was carried out in the Musayyib project area, which is located 35 km north of Babylon Governorate, during the fall growing season of 2023 according to a randomized complete block design (RCBD), to determine the effect of biofertilization four levels (0 without adding + full fertilizer recommendation, addition 10g of a mixture of four types of bacterial fertilizer + half the fertilizer recommendation, addition 10g of fungal biofertilizer (mycorrhizal) + half the fertilizer recommendation and addition 10g of a mixture of bacterial and fungal biofertilizers + half the fertilizer recommendation) which is symbolized by (B0, B1, B2 and B3 respectively) and nanofertilizer at two levels (0 + full fertilizer recommendation and 2g L^{-1}+ half the fertilizer recommendation) and denoted by the symbol (N0 and N1, respectively) in the growth and yield of three potato varieties (Rashida, Sifra and Arizona), denoted by the symbol (V1, V2 and V3 respectively). The results showed Arizona variety excellence the rest of the other varieties in the tubers' content of nitrogen, phosphorus, potassium, protein, and starch. The biofertilization treatment (adding 10g of a mixture of bacterial and fungal biofertilizers) also had a positive effect on the tubers' content of nitrogen, phosphorus, potassium, protein, and starch compared to the control treatment. The nano-fertilizer addition treatments also had a clear effect on the tubers' content of nitrogen, phosphorus, potassium, protein, and starch compared to the control treatment. As for the interaction between the study factors, there were significant differences in most of the study traits.

Keywords: Potato, Mycorrhiza fungi, Nanofertiliser.

Introduction

Potato (*Solanum tuberosum* L.) is one of the plants of the Solanaceae family, which includes 90 genera and about 200 species. It is considered one of the important vegetable crops in the world and tops the list of tuber crops [1]. The area cultivated with potatoes in iraq amounted to 12645 ha^{-1}, with a productivity of 270,591 ton, and a yield

of 21399.2 kg ha^{-1} [2]. Potato cultivation is affected by many genetic and environmental factors, the most important of which is soil salinity and irrigation water, as they are among the factors that negatively affect the growth and productivity of the potato crop [3].

Biofertilization (bacterial and fungal) improves soil properties, lowers pH, and increases the readiness of nutrients for absorption by secreting organic acids that dissolve nutrients that are not ready for the plant [4]. Recent studies have indicated that biofertilizers play an important and significant role in increasing the growth and yield of potatoes, as the mycorrhizal fungus Gloms led to an increase in yield and its components by up to 33% [5]. Other studies also showed that the use of bacterial biofertilizer (Azobacter) on potato plants led to an increase in yield compared to the control treatment [6].

Nanotechnology has recently appeared in the agricultural field to increase the efficiency of the use of chemical fertilizers by increasing the surface area, leading to an increase in the surface area of the reaction and increasing its speed, which has resulted in an increase in the efficiency of the use of traditional chemical fertilizers. Some key nutrients (NPK) have been incorporated into different nanoparticles in order to A significant effect is obtained and the rate of absorption by the plant increases in larger quantities than non-nano fertilizers. Nanotechnology is considered a good treatment of matter at the molecular or atomic level. This technology is promising in improving ongoing agricultural operations by improving agricultural production management [7,8]. It should be noted here that the current agricultural system in many countries of the world is characterized by declining productivity over time. Therefore, it is recommended to use modern methods with chemical fertilizers for the purpose of increasing yields and improving their quality. Therefore, the study aimed to determine the effect of bacterial and fungal biofertilizers and nanofertilizers of three cultivars in the chemical content of tubers.

Materials and Methods

The field experiment was carried out in the Musayyib project area, which is located on 35 km north of Babylon, during the 2022 autumn growing season, to determine the role of bio- and nano-fertilizers in the quality yield characteristics of three varieties of potato. The land was prepared for cultivation and divided into three replicates, where cultivation was done on furrows with a length of 2m and a width of 1m, with 3 furrows for each experimental unit with an area of 6 m^2 (2*3 m^2). Tubers were planted for each furrow 8 tubers on one side of the furrow, with a distance of 24 cm between one tuber and another. The number of tubers per experimental unit reached 24 tuber, with 72 experimental units.

Bacterial and fungal biofertilizer (a mixture of types of bacteria (Azotobacter chroocaccum, Bacillus mucilage nosus, and Pseudomonas fluorescens) and the mycorrhizae fungi) loaded on peat moss was added to the tubers in the soil when planting. The NPK fertilizer recommendation was added to the potato plant at a rate of 300 kg

ha^{-1} (0.20.20) and 300 kg ha^{-1} 46N%, and the first fertilizer was added before planting after preparing the soil, add urea fertilizer in two batches, the first after emergence and the second a month after the first batch [9]. Planting took place in the spring session, 1/15/2023, and foliar spraying with nanofertilizer was carried out twice, the first when the leaves appeared completely (45 days after planting) and the second 14 days after the first spraying before flowering. The treatments were randomly distributed within each replicate and the potato tubers were planted in the soil. The factorial experiment was carried out with three factors according to a randomized complete block design (RCBD). The experiment included 24 treatments and three replicates, and each experimental unit had 24 plants.

Data recorded

Nitrogen content of tubers (%): The nitrogen content in leaves and tubers was estimated according to the method described by [10], sing a device micro kjeldahl.

Phosphorus content of tubers (%): The phosphorus content of tubers was determined using a spectrophotometer according to the method described by [11].

Potassium content of tubers (%): The percentage of potassium was determined using a flamephotometer according to the method mentioned [12].

Protein percentage in tubers (%): The protein percentage was calculated based on the percentage of total nitrogen according to the method of [13], and as follows:

Protein percentage in tubers (%) = percentage of nitrogen * 6.25

The percentage of starch in tubers (%): was also estimated according to what was stated in [14] (1970), based on the following equation:

Percentage of starch = 17.55 + 0.89 * (percentage of dry matter in tubers - 24.18).

Statistical analysis

The data were collected from the field experiment and the results were statistical-ly analyzed according to the analysis of variance (ANOVA) as per the RCBD design [15]. The least significant difference (L.S.D 0.05) test was used to compare and separate the means . The statistics software GenStat12 was employed.

Results and Discussion

Nitrogen content of tubers (%)

The results of Table (1) showed that there were significant differences between the varieties, as the Arizona V3 variety recorded the highest percentage of 2.073%, followed by the Sifra V2 variety, while the Rashida V1 variety recorded the lowest percentage of 1.851%. Biofertilization also had a positive effect, as treatment recorded B3. (Bacterial and fungal biofertilizer) had the highest percentage of 2.068%, which did not differ significantly from treatment B1 (bacterial biofertilizer), while the control treatment B0 recorded the lowest percentage of 1.872%. Also, there were significant differences between the nanofertilization treatments, as treatment N1 recorded the highest percentage of 2.016%, while the control treatment N0 recorded the lowest percentage of 1.932%.

As for the interaction between the varieties and biofertilization, there were significant differences between the treatments, as treatment V3B3 recorded the highest percentage of 2.227%, while the control treatment V1B0 recorded the lowest percentage of 1.694%. The results of the same table also showed that there were significant differences in the interaction between the varieties and nanofertilization. Treatment V3N1 recorded the highest percentage of 2.176%, while the lowest percentage of 1.821% was recorded in treatment V1N0. Also, the interaction between biofertilization and nanofertilization treatments had significant differences, as treatment B3N1 recorded the highest percentage of 2.089%, while treatment B0N0 recorded the lowest percentage of 1.757%. As for the interaction treatments between the varieties, biofertilization, and nanofertilization, there were significant differences in the percentage of nitrogen in the tubers, as treatment V3B3N1 recorded the highest percentage, of 2.230%, while treatment V1B0N0 recorded the lowest percentage of 1.576%.

Table (1): Effect of bio and nano-fertilization, cultivars and their interaction on the percentage of nitrogen in tubers (%)

Treatments		Cultivars			Means	
Nano Fertilization N	**Bio Fertilization B**	**Rashida**	**Sifra**	**Arizona**	**N*B**	**Average N**
N_0 (0g L^{-1})	B_0	1.576	1.949	1.745	1.757	1.932
	B_1	2.065	2.004	2.060	2.043	
	B_2	1.780	2.012	1.850	1.881	
	B_3	1.861	2.057	2.223	2.047	
N_1 (2g L^{-1})	B_0	1.812	1.941	2.209	1.987	2.016
	B_1	1.812	2.136	2.083	2.010	
	B_2	1.812	1.941	2.181	1.978	
	B_3	2.093	1.944	2.230	2.089	
LSD 0.05		0.157			0.090	0.045
N*V		N_0	N_1		Average V	
	V_1	1.821	1.882		1.851	
	V_2	2.005	1.991		1.998	
	V_3	1.969	2.176		2.073	
LSD 0.05		0.078			0.055	
B*V		V_1	V_2	V_3	Average B	
	B_0	1.694	1.945	1.977	1.872	
	B_1	1.939	2.070	2.072	2.027	
	B_2	1.796	1.977	2.015	1.929	
	B_3	1.977	2.001	2.227	2.068	
LSD 0.05		0.111			0.064	

Phosphorus content of tubers (%)

The results of Table (2) confirm that there are significant differences between the varieties, as the Arizona V3 variety recorded the highest percentage of 0.460%, followed by the Sifra V2 variety, while the Rashida V1 variety recorded the lowest percentage of 0.403%. As for the biofertilization treatments, there were significant differences between the treatments, as treatment B3 (bacterial and fungal biofertilizer) recorded the highest percentage of 0.460%, which did not differ significantly with treatment B1 (bacterial biofertilizer) for the second season, while treatment B0 recorded the lowest percentage of 0.405. %. The nanofertilization treatments also had a significant effect, as treatment N1 recorded the highest percentage of 0.447%, while the control treatment N0 recorded the lowest percentage of 0.423%.

As for the interaction between the varieties and biofertilization, there were significant differences between the treatments, as treatment V3B3 recorded the highest percentage of 0.502%, while treatment V1B0 recorded the lowest percentage of 0.347%. The interaction between the varieties and nanofertilization also had a moral superiority, as treatment V3N1 recorded the highest percentage of 0.484%, while treatment V1N0 recorded the lowest percentage of 0.389%. Also, the interaction treatments between biofertilization and nanofertilization had a positive effect, as treatment B3N1 recorded the highest percentage of 0.466% while treatment B0N0 recorded percentage of 0.370%. As for the interaction between varieties, biofertilization, and nanofertilization, there were significant differences between the treatments, as treatment V3B3N1 recorded the highest percentage of 0.507%, while the lowest percentage was recorded percentage of 0.295%, in treatment V1B0N0.

Table (2): Effect of bio and nano-fertilization, cultivars and their interaction on the percentage of phosphorus in tubers (%)

Treatments		Cultivars			Means	
Nano Fertilization N	Bio Fertilization B	Rashida	Sifra	Arizona	N*B	Average N
N_0 (0g L^{-1})	B_0	0.295	0.430	0.385	0.370	0.423
	B_1	0.456	0.443	0.455	0.451	
	B_2	0.395	0.445	0.409	0.416	
	B_3	0.411	0.454	0.497	0.454	
N_1 (2g L^{-1})	B_0	0.400	0.429	0.488	0.439	0.447
	B_1	0.400	0.472	0.460	0.444	
	B_2	0.401	0.429	0.482	0.437	
	B_3	0.462	0.430	0.507	0.466	
LSD 0.05	0.037				0.021	0.010
N*V		N_0	N_1		Average V	
	V_1	0.389	0.416		0.403	
	V_2	0.443	0.440		0.441	
	V_3	0.437	0.484		0.460	
LSD 0.05	0.018				0.013	

B*V		V_1	V_2	V_3	Average B
	B_0	0.347	0.430	0.437	0.405
	B_1	0.428	0.457	0.458	0.448
	B_2	0.398	0.437	0.445	0.427
	B_3	0.437	0.442	0.502	0.460
LSD $_{0.05}$	0.037				0.015

Potassium content of tubers (%)

The results in Table (3) indicate that there are significant differences between the varieties, as the Arizona V3 variety recorded the highest percentage of 1.853%, which did not differ significantly from the Sefra V2 variety, while the Rashida V1 variety recorded the lowest percentage of 1.631%. As for the biofertilization treatments, they had a positive effect on the percentage of potassium in the tubers, as treatment B3 (bacterial and fungal biofertilizer) recorded the highest percentage of 1.944%, which did not differ significantly from treatment B2 (fungal biofertilizer), while the lowest percentage was recorded of 1.587%. When comparing transaction B0. The nanofertilization treatments also had a significant effect, as the N1 treatment recorded the highest percentage of 1.917%, while the lowest percentage of 1.590% was recorded in the control treatment N0.

As for the interaction coefficients between the varieties and biofertilization, there was a significant effect between the treatments, as treatment V3B3 recorded the highest percentage of 2.068%, while the lowest percentage of 1.147% was recorded in treatment V1B0. The interaction between the varieties and nanofertilization treatments also had a moral effect, as the treatment recorded V3N1 had the highest percentage of 2.069%, while the lowest percentage of 1.552% was recorded in the V2N0 treatment, while there were no significant differences between the biofertilization treatments and nanofertilization treatments in the percentage of potassium in the tubers. As for the interaction between the three study factors, there were no significant differences between the treatments in the percentage of potassium in tubers.

Table (3): Effect of bio and nano-fertilization, varieties and their interaction on the percentage of potassium in tubers (%)

Treatments		Cultivars			Means	
Nano Fertilization N	Bio Fertilization B	Rashida	Sifra	Arizona	N*B	Average N
N_0 (0g L^{-1})	B_0	1.117	1.678	1.622	1.472	1.590
	B_1	1.650	1.238	1.644	1.511	
	B_2	1.788	1.487	1.515	1.597	
	B_3	1.767	1.807	1.770	1.781	
N_1 (2g L^{-1})	B_0	1.177	1.966	1.963	1.702	1.917
	B_1	1.905	1.880	1.933	1.906	
	B_2	1.886	1.963	2.012	1.954	

	B_3	1.761	2.197	2.366	2.108	
LSD 0.05	**NS**				**NS**	**0.124**
N*V		**N_0**	**N_1**		**Average V**	
	V_1	1.580	1.682		1.631	
	V_2	1.552	2.002		1.777	
	V_3	1.638	2.069		1.853	
LSD 0.05	**0.216**				**0.152**	
B*V		**V_1**	**V_2**	**V_3**	**Average B**	
	B_0	1.147	1.822	1.793	1.587	
	B_1	1.777	1.559	1.788	1.708	
	B_2	1.837	1.725	1.764	1.775	
	B_3	1.764	2.002	2.068	1.944	
LSD 0.05	**0.305**				**0.176**	

Protein content in tubers (%)

It is noted from Table (4) that there are significant differences between the varieties, as the Arizona V3 variety recorded the highest percentage, amounting to 12.95%, followed by the Sifra V2 variety, while the Rashida V1 variety recorded the lowest percentage of 11.57%. As for the biofertilization treatments, there were significant differences between the treatments, as treatment B3 (bacterial and fungal biofertilizer) recorded the highest percentage of 12.92%, which did not differ significantly from treatment B1 (bacterial biofertilizer), while the control treatment B0 recorded the lowest percentage of 11.70. %. The nanofertilization treatments also had a positive effect on the protein percentage in the tubers, as treatment N1 recorded the highest percentage of 12.60%, while the control treatment N0 recorded the lowest percentage of 12.07%.

As for the interaction coefficients between the varieties and biofertilization, there were significant differences, as treatment V3B3 recorded the highest rate of 13.91%, while treatment V1B0 recorded the lowest percentage of 10.58%. The interaction coefficients between varieties and nanofertilization also had a positive effect, as treatment V3N1 recorded the highest percentage of 13.59%, while the lowest percentage of 11.37% recorded in the V1N0 treatment for the two study seasons, respectively. Also, there were significant differences for the interaction treatments of biofertilization and nanofertilization, as treatment B3N1 recorded the highest percentage percentage of 13.05%, while the lowest percentage was recorded of 10.97%, in treatment B0N0. As for the interaction between varieties, biofertilization, and nanofertilization, there were significant differences between the treatments, as treatment V3B3N1 recorded the highest percentage of 13.93%, while the lowest percentage of 9.85% was recorded in treatment V1B0N0.

Table (4): Effect of bio and nano-fertilization, cultivars and their interaction on the percentage of protein in tubers (%)

Treatments		Cultivars			Means	
Nano Fertilization N	Bio Fertilization B	Rashida	Sifra	Arizona	N*B	Average N
N_0 (0g L^{-1})	B_0	9.85	12.17	10.90	10.97	12.07
	B_1	12.90	12.52	12.87	12.76	
	B_2	11.12	12.57	11.56	11.75	
	B_3	11.63	12.85	13.89	12.79	
N_1 (2g L^{-1})	B_0	11.32	12.13	13.80	12.42	12.60
	B_1	11.33	13.34	13.02	12.56	
	B_2	11.32	12.13	13.63	12.36	
	B_3	13.08	12.15	13.93	13.05	
LSD 0.05		0.98			0.56	0.28
N*V		N_0	N_1		Average V	
	V_1	11.37	11.76		11.57	
	V_2	12.53	12.44		12.48	
	V_3	12.30	13.59		12.95	
LSD 0.05		0.49			0.34	
B*V		V_1	V_2	V_3	Average B	
	B_0	10.58	12.15	12.35	11.70	
	B_1	12.11	12.93	12.94	12.66	
	B_2	11.22	12.35	12.59	12.05	
	B_3	12.35	12.50	13.91	12.92	
LSD 0.05		0.69			0.40	

Starch content in tubers (%)

The results of Table (4) confirmed the presence of significant differences between the varieties, as the Arizona V3 variety recorded the highest percentage of 9.810%, followed by the Sifra V2 variety, while the lowest percentage of 8.210% was recorded by the Rashida V1 variety. Biofertilization treatments also had a significant effect on the percentage of starch in Tubers, as the highest percentage was recorded at 9.670% in treatment B3 (bacterial and fungal biofertilizer), which did not differ significantly from treatment B1 (bacterial biofertilizer), while the control treatment B0 recorded the lowest percentage of 8.090%. There were also significant differences between the fertilization treatments. Nano, as treatment N1 recorded the highest percentage of 9.440%, while the lowest percentage of 8.600% was recorded in control treatment B0.

As for the interaction coefficients between the varieties and biofertilization, there were significant differences, as treatment V3B3 recorded the highest rate of 11.110%, while treatment V1B0 recorded the lowest percentage of 6.730%. The interaction coefficients between varieties and nanofertilization also had a positive effect, as treatment V3N1 recorded the highest percentage of 10.790%, while the lowest rate was 8.060% recorded in treatment V1N0. As for the interaction between biofertilization and nanofertilization treatments, there were also significant differences between the treatments, as treatment B3N1 recorded the highest percentage percentage of 10.050%,

while the lowest percentage was recorded percentage of 7.120%, in treatment B0N0. As for the interaction between varieties, biofertilization, and nanofertilization, there were significant differences, as treatment V3B3N1 recorded the highest percentage of 11.520%, while treatment V1B0N0 recorded the lowest percentage percentage of 5.800%.

Table (5): Effect of bio and nano-fertilization, cultivars and their interaction on the percentage of starch in tubers (%)

Treatments		Cultivars			Means	
Nano Ferti-lization N	Bio Fertili-zation B	Rashida	Sifra	Arizona	N*B	Average N
N_0 (0g L^{-1})	B_0	5.800	8.440	7.130	7.120	8.600
	B_1	9.730	9.20	9.540	9.490	
	B_2	8.620	8.890	7.970	8.490	
	B_3	8.100	9.090	10.690	9.290	
N_1 (2g L^{-1})	B_0	7.670	8.700	10.820	9.060	9.440
	B_1	7.670	9.700	9.790	9.060	
	B_2	8.210	9.550	11.030	9.900	
	B_3	9.900	8.720	11.520	10.050	
LSD 0.05	**1.477**				**0.853**	**0.427**
N*V		**N_0**	**N_1**		**Average V**	
	V_1	8.060	8.360		8.210	
	V_2	8.900	9.170		9.040	
	V_3	8.830	10.790		9.810	
LSD 0.05	**0.739**				**0.522**	
B*V		**V_1**	**V_2**	**V_3**	**Average B**	
	B_0	6.730	8.570	8.980	8.090	
	B_1	8.700	9.450	9.670	9.270	
	B_2	8.410	9.220	9.500	9.050	
	B_3	9.000	8.900	11.110	9.670	
LSD 0.05	**1.045**				**0.603**	

The results of tables (1, 2, 3, 4, 5) show that there is a significant superiority of the Arizona variety over the rest of the other varieties in the chemical content of the tubers represented in the tubers content of nitrogen, phosphorus, potassium, and the percentage of protein and starch in the tubers, this may be the reason for the increase in the chemical content the difference in yields between varieties in indicators of the chemical content of tubers is due to the differences in genetic characteristics and the extent of the plant's adaptation to the conditions surrounding it and the appropriate conditions available to it for growth and carrying out metabolic processes [16,17 ,18].

As for the biofertilization treatments (bacterial and fungal), there was a significant increase in the indicators of the chemical content of the tubers. The reason for the increase may be due to the continuous preparation of the nutrients necessary for growth that the plant needs in the area around the root, in addition to the growth-stimulating substances resulting from the vital activities of microorganisms. Or resulting from the

decomposition of organic matter (plant growth hormones), such as auxins, gibberellins, cytokinins, and chelating compounds that work to prepare micronutrients, which leads to an increase in the content of leaves and tubers of nutrients such as nitrogen, phosphorus, and potassium, and an increase in the efficiency of the photosynthesis process [19]. Or perhaps the reason is due to the role of biofertilizer in providing nutrients in a form ready for absorption by the plant, in addition to its secretion of growth stimulants, sugars, and vitamins, which are considered a source of energy and carbon, which have a positive role in influencing the root system and increasing its surface area, and thus this leads to an increase in Absorption of nutrients and their transfer to the leaves and thus transfer to the tubers, which are a source for making plant food for the production of carbohydrates [20,21].

As for nanofertilizer treatments, there was a significant increase in the indicators of the chemical content of tubers (1, 2, 3, 4, 5) the reason for the increase may be attributed to an increase in the rate of the photosynthesis process, an increase in the production of carbohydrates, and the amount of dry matter, which is reflected in the increase in the percentage of materials. chemicals in tubers [22]. The reason may be attributed to the increased absorption of nutrients, which in turn works to increase the efficiency of the photosynthesis process in the leaves as a result of their expansion, and thus works to increase the manufactured carbohydrate materials, the surplus of which is transferred to the tubers and stored in the form of starch, and this explains the reason for the increase in the percentage of starch [23,24]. The nanofertilization treatments showed significant superiority in all qualitative characteristics of the yield. The reason may be attributed to the role of the nitrogen element contained in the nanofertilizer in increasing vegetative growth, which leads to a speedy process of photosynthesis and then an increase in manufactured sugars, thus increasing the percentage of total solid soluble substances in the tubers, in addition to the role The potassium element stimulates the materials resulting from the photosynthesis process and transfers them to tubers [8,25].

We conclude that the Arizona variety was significantly superior to the rest of the varieties in all the traits studied. As for the biofertilizer, it had a positive effect in increasing the chemical content of the tubers when treated with 10g of a mixture of bacterial biofertilizer and fungal biofertilizer. As for the treatments of adding NPK nanofertilizer, it was superior. Spraying treatment at a concentration of 2g L^{-1} led to a significant increase in the chemical content indicators of tubers.

References

1) Hassan, A. A. (2003). *Potatoes*. Al-Dar Alarabia for Publishing and Distribution. Alqahira, the Egyptian Arabic Republic, pp. 281.
2) CSO (2022). *Annual Statistical Collection*. Ministry of Planning-Directorate of Agricultural Statistics. Department of Publishing and Public Relations, Baghdad, Iraq, pp. 44-46.

3) Hassan, A. A. (2017). *Principles of Vegetable Crop Breeding*. First edition. College of Agriculture, University of Alqahira, The Egyptian Arabic Republic, p. 258.
4) Youssef, R. A. (2011). *Biofertilizers (Types, Classification, Marketing)*. King Saud University Publications, Saudi Arabia, pp. 201-355.
5) Douds, D. D., Nagahashi, G., Reider, C., & Hepperly, P. (2007). Inoculation with AM fungi increases the yield of potatoes in a high pH soil. *Biological Agriculture and Horticulture, 25*, 67-78.
6) Singh, K. (2000). Effect of inoculation with Azotobacter and phosphobactrin on potato (*Solanum tuberosum* L.) in North East Hills. *Indian Journal of Agricultural Sciences*, *70*(6), 385-386.
7) Abdel Rahman, L. S., Anjal, S. A., & Badr, B. R. (2018). The effect of chemical fertilizer and spraying with nanofertilizer on cauliflower yield characteristics. *Journal of Agricultural, Environmental and Veterinary Sciences, 10*(2), 4-6.
8) Almohammedi, O. M., Sekhi, Y. S., & Ismail, M. H. (2023). A review of nano-fertilization and its role on growth, yield, and quality characteristics of fruit trees. *Tikrit Journal for Agricultural Sciences*, *23*(1), 158-167.
9) Hassan, A. A. (2016). *Fertilization of Vegetable Crops*. First edition. Dar Al-Kutub Al-Ilmiyyah for Publishing and Distribution, p. 600.
10) Jackson, M. L. (1958). *Soil Chemical Analysis*. Prentice Hall Inc. Soil Sci. Englewood Cliffs, N.J. USA, pp. 318.
11) Olsen, S. R., & Sommers, L. E. (1982). Phosphorus. In A. L. Page (Ed.), *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties* (2nd ed.). Madison, USA: Am. Soil Sci., pp. 289.
12) Haynes, R. J. (1980). A comparison of two modified Kjeldahl digestion techniques for multi-element plant analysis with conventional wet and dry ashing methods. *Communications in Soil Science and Plant Analysis*, *11*(5), 459-467.
13) Cresser, M. S., & Parsons, J. W. (1979). Sulphuric-perchloric acid digestion of plant material for determination of nitrogen, phosphorus, potassium, calcium, and magnesium. *Analytical Chimica Acta*, *109*, 431-436.
14) AOAC (1970). *Official Methods of Analysis* (11th ed.). Washington, D.C.: Association of Official Analytical Chemists, Arlington, USA, pp. 1015.
15) Al-Mohammadi, S. M., & Al-Mohammadi, F. M. (2012). *Statistics and Experimental Design*. Dar Osama for Publishing and Distribution, Oman, Jordan, pp. 355.
16) Bashi, Z. B. Z. (2018). The effect of mulching tubers and fertilizing with humic acid on the growth and fall season yield of two varieties of potato (*Solanum tuberosum* L.). Master's Thesis. College of Agriculture and Forestry, University of Mosul, Iraq, pp. 112.

17) Tigist, M., Workneh, T. S., & Woldetsadik, K. (2013). Effects of variety on the quality of tomato stored under ambient conditions. *Journal of Food Science, 50*(3), 477–486.

18) Al-Dulime, M. L. A., & Al-Mohammedi, O. H. M. (2023). Effect of spraying with growth regulators brassinolide and thidiazuron on the chemical content of leaves and pods of three okra hybrids under protected cultivation conditions. *IOP Conference Series: Earth and Environmental Science, 1252*, 1-7.

19) Yang, J., Kloepper, J. W., & Ryu, C. M. (2009). Rhizosphere bacteria help plants tolerate abiotic stress. *Trends in Plant Science*, *14*, 1-4.

20) Prasad, H., Sajwan, P., Kumari, M., & Solanki, S. (2016). Effect of organic manures and biofertilizer on plant growth, yield, and quality of horticultural crops. *International Journal of Chemical Studies, 5*(1), 217-221.

21) Jnawali, A. D., Ojha, R. B., & Marahatta, S. (2015). Role of *Azotobacter* in soil fertility and sustainability. *Advances in Plant and Agriculture Research*, *2*(6), 69.

22) Qureshi, A., Singh, D. K., & Dwivedi, S. (2018). Nano-fertilizers: A novel way for enhancing nutrient use efficiency and crop productivity. *7*(2), 3325-3335.

23) Agrawal, S., & Rathore, P. (2014). Nanotechnology pros and cons to agriculture: A review. *International Journal of Current Microbiology and Applied Sciences, 3*(3), 43-55.

24) Al-Nuaimi, J. J. J., Mohammed, M. R., & Alnuaimi, O. J. (2021). Genetic action heritability rate, expected genetic improvement, and coefficient of difference for four varieties of upland cotton (*Gossypium hirsutum* L.) by nano fertilizer effect. *International Journal of Agricultural and Statistical Sciences, 17*, 2145–2151.

25) Mariyoush, A. H. K. (2020). Effect of fertilization and adding amino acids on the growth and production of broccoli. Master's Thesis. College of Agriculture, University of Baghdad, Iraq, pp. 120.