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The role of the biofertilizer *P. fluorescens* in the interaction with nanoparticles and cow manure in growth of radish (*Raphanus sativus* L.) and some active Ingredients

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ABSTRACT

A field experiment was conducted in Al-Qadisiyah, Al-Badir, on radish crops during the 2024 autumn season to study the effect of three factors. The first factor was the bacterial bioinoculation *Pseudomonas fluorescens* at two levels (no inoculation and inoculation). The second factor was three levels of phosphate rock nanoparticles (no addition, 30, and 60 kg.ha⁻¹). The third factor consisted of three levels of composed cow manure (3, 5, and 6 t.ha⁻¹). The treatments were distributed in a factorial experiment according to an R.C.B.D. design. mono bio-inoculation of *P. fluorescens* , mono addition of nanoparticles and mono composed organic matter, and both the double interaction (S₁*O bacterial inoculum + organic matter), (S₁*Rn bacterial inoculum + nanoparticles), and (O*Rn nanoparticles + composed organic matter) significantly affected plant height (cm), leaves carbohydrate content (g.100g⁻¹ F.W), total phenol (mg EAG.100g⁻¹ D.W), pholvedes (mg quercetin 100g⁻¹ D.w) at 40 days post planting, and root phosphorus content (%) after 70 days from planting. The highest significant increase in the studied characteristic was observed in the triple interaction of (S₁*Rn*O *P. fluorescens* + nanoparticles + composed organic matter), which amounted to 42 (cm), 4.15 g. 100 (g⁻¹ D.M), 668 (mg EAG 100 g⁻¹ D.M), 1011.67 (mg quercetin 100 g⁻¹) dry matter for a period of 40 days of planted , 0.52 p% in the root after 70 days of planted, respectively, compared to the control, which gave the lowest means in all of the above characteristic , which amounted to 30.33 (cm), 3.27(g. 100g⁻¹ D.M), 573.33(mg EAG 100g⁻¹ D.M), 735.33(mg quercetin 100g⁻¹ D.M) for 40 days of planting 0.38 p % in the root at 70 days post planting.

Keywords: *Pseudomonas fluorescens*, active ingredients, radish.

Introduction

Radish is an economically important vegetable with numerous health benefits because of their high content of active ingredients such as alkaloids and amino acids, which can reach up to 5% of the dry matter [1]. The total protein content in radish is 6.5% [2]. It contains many enzymes, oils, phenolic compounds, sulfur-containing compounds, and others [3]. The fast-growing radish plant needs soil containing readily available nutrients to complete its life cycle, the most important of which are nitrogen, phosphorus, potassium, magnesium, and iron [4]. Composted organic matter, such as cow manure, is characterized by being rich in nutrients such as phosphorus, organic nitrogen, magnesium, and other nutrients. It also improves chemical and physical soil conditions and increases its quality, which is reflected in plant growth and productivity [5]. Organic matter represents an energy reservoir for microorganisms, including bacteria that decompose this organic matter and release different nutrients. In addition, it produces many organic acids that work to dissolve phosphate compounds, including natural phosphate rock, improve soil CEC, and increase soil water retention [6]. *Pseudomonas fluorescens* are among the most important types of bacteria that dissolve phosphate compounds, as they increase the available nitrogen, they also secrete many enzymes and organic acids that dissolve the nanoparticles of phosphate rock, thus increasing the availability of phosphorus, which is very important for increasing root growth, and elements found in phosphate rock such as potassium and calcium [7]. The nanotechnology of natural compounds found in the local environment, such as phosphate rock, and their converted into nanoparticles, contributes to the interaction of organisms with organic matter in increasing the speed of supplying the plant with the necessary nutrients to increase plant metabolism, thus accumulating the nutrient in the plant and improving quality [8]. Field experiments have confirmed that phosphate-solubilizing bacteria release phosphate from phosphorus-containing mineral compounds, and also work to decompose organic matter and release nutrients to contribute to the biological cycle of elements in the soil under field conditions [9]. A field experiment was conducted to study the effect of composted organic fertilizers ($15 \text{ t}\cdot\text{ha}^{-1}$) in combination with bio-fertilizer made up of bacteria that dissolve phosphate compounds ($15 \text{ kg}\cdot\text{ha}^{-1}$) to study the effect of this combination on the growth and yield of radish. The experiment gave a significant increase in plant height of 43.43 (cm) and vitamin C of 2.87 ($\text{mg}\cdot\text{ml}^{-1}$) [10]. The reason is attributed to the fact that phosphate-solubilizing bacteria supplied the plant with nutrients such as phosphate ions by secreting many organic acids, including Malic and Citric acids with low molecular weight, which led to an increase in phosphorus, which is important in building vital compounds such as ADP, ATP, phospholipids, nucleic acids, coenzymes, phosphoproteins, and phytic acid, which combines with calcium and magnesium to form phytin, which is stored in the seeds and is necessary in the germination process [9]. The results of the study [11] showed that fertilizing radish plants with $2 \text{ t}\cdot\text{ha}^{-1}$ of organic matter, combined with copper oxide nanoparticles (60 ppm) and zinc nanoparticles (50 ppm), led to a significant increase in the measured characters, plant height (cm), leaves area, dry root weight, chlorophyll, leaves carbohydrate content, total phenols, tannins, total polyphenols, total protein, and total carbohydrates, (8, 5.5, 6, 14, 5, 19, 22, 25, and 24%) respectively, compared to the control. Sustainable agriculture encourages the use of natural resources to preserve the environment and reduce economic costs to achieve the best production in characters of quantity and quality. Our study uses the natural resources available in the local environment to achieve this goal. This study aims to explore the potential use of environmentally friendly natural resources, such as bio-fertilizers and cow manure, in addition to Nano-phosphate fertilization, to improve the growth, yield, and active compound content of radish plants.

Materials and Methods

Preparation of the Bacterial Inoculum

Pseudomonas fluorescens 1 kg inoculation loaded on peatmoss was obtained from the Biotechnology Laboratory - Department of Agricultural Research - Ministry of Science and Technology. This inoculation was propagated by mixing it well with 100 kg of composed cow manure, moistening the organic mixture to 60%, and incubating it in an incubator at a temperature of 28°C for five days. The manure was turned over twice daily to ensure the spread of the bacteria in the manure.

Preparation of composed Organic Fertilizer

Large quantities of organic cow manure are available in the local environment. On 1/6/ 2024, 100 kg of cow manure was ground into small pieces (2 mm) and placed on polyethylene, 3 kg of urea, 2 kg of superphosphate, 3 kg of potassium sulfate, and 10 kg of lime (CaO) were added at a rate of 10 (kg 100 kg⁻¹) of ground organic matter. The mixture was thoroughly mixed and moistened to 60%, which is the optimal moisture content for microbial decomposition [12]. The material was then transferred to a pit 1.5 m wide and 1 m deep, lined with two layers of polyethylene. It was placed in the pit, covered with, and polyethylene kept at ground level for 16 weeks. The material was turned every two weeks, and the lost water was replenished to ensure continued microbial decomposition. 1/10/ 2024, the organic fertilizer was fully composed and stored in tightly sealed 50 kg polyethylene bags. It was then used in the field experiment.

Preparation of Phosphate Rock Nanoparticles

After obtaining natural phosphate rock from the Akashat in western Iraq, it was ground and sieved. Some of the rock's chemical properties were measured and found to be as follows: pH (8.21), phosphorus (10.12)%, sulfates (0.25)%, calcium (28)%, and potassium (710) mg.kg⁻¹. Subsequently, the nanoparticles were prepared using a two stage mechanical grinding method (Jet Mill and Ball Mill) for 72 hours. The process was repeated three times. The particle size range (40–100 nm) was then confirmed using (SEM) scanning electron microscopy [13].

Field Soil and Planting

The field experiment was conducted in Diwaniyah - Afak - Al-Thuraimah. The field was plowed, the soil was smoothed and leveled, and it was divided into experimental units with dimensions of (1.5*3m²) with 54 experimental units distributed randomly across three replicates. Spaces were left between each plot and between each section. The bioinoculant was mixed with the soil. A quarter of the recommended fertilizer was added (50 N + 25 P₂O₅ + 125 K)kg.ha⁻¹.

composed cow manure loaded with bacteria was added, and levels of nanoparticles phosphate rock were added at a distance of 4 cm around the seeds in the holes. Radish seeds of a local were planted on 15/11/2024 in rows within the plots, with 5 rows in each plot and a distance of 20 cm between rows, and the number of plants in each row was 50 plants, with a distance of 22 cm between plants. The number of plants in each experimental unit was 250 plants, and crop service operations were carried out, including fertilization and pest control.

Factors of the Field Experiment and Experimental Design

Factor 1: *Pseudomonas fluorescens* bacterial inoculum at two levels, addition and non-addition (S₀ and S₁). Factor 2: Organic matter, composed cow manure (O₁), at three different levels (O₁, O₂, O₃) of 5, 3,

and $6 \text{ t} \cdot \text{h}^{-1}$. Factor 3: Phosphate rock nanoparticles (R_n) at three different levels (R_{n1} , R_{n2} , R_{n3}) of 0, 30, and $60 \text{ kg} \cdot \text{h}^{-1}$. The factorial experiment was conducted according to the R.C.B.D. design and then statistically analyzed using GenStat (2010). Means were compared using the least significant difference (LSD) at a probability level of 0.05 to determine the type of significance between the means of the different treatments.

Field Experiment Measurements

Plant height (cm) was measured 40 days after planting using a measuring tape

Carbohydrate content was measured (100 g^{-1} of F.W) on leaves 40 days after planting.

Nitrogen was calculated using the Kjeldal method, and protein was extracted by multiplying the percentage by a convert factor of (6.25), as described in [14].

Phenol content in the leaves was measured 40 days after planting (mg of GAE equivalents 100 g^{-1} .(D.W)

The total phenol content (TPC) of the leaves was determined colorimetrically according to Vega-Gálvez et al. [15]. A mixture of 0.5 mL of horseradish extract, 0.5 mL of foline-cyocaltiou reagent, and 2 mL of (20)% from Na_2CO_3 solution was added, along with (10) mL of deionized water. The mixture was centrifuged for 5 minutes at (4000×1000) rpm, and the precipitate was removed. The absorbance was measured using a spectrophotometer at (725) nm and then calibrated using a titration curve in gallic acid equivalents (GAE). The results were expressed in mg of GAE equivalents 100 g^{-1} D.M.

Measurement of total pholvedes content in the leaves after 40 days of planted

Mix (1.0) ml of methanolic extract of radish leaves with (2.4) ml of deionized water. Add (0.15) ml of NaNO_2 at a concentration of ($50 \text{ mg} \cdot \text{ml}^{-1}$) and allow to react for 5 minutes. Then add (0.15) ml of AlCl_3 at a concentration of ($100 \text{ mg} \cdot \text{ml}^{-1}$) and allow to react for (6) minutes. Finally, add (1.0) ml of NaOH at a concentration of ($1 \text{ mol} \cdot \text{L}^{-1}$) and (1.2) ml of deionized water. Measure the absorbance using a spectrophotometer at a wave length of (510) nm. The results were then calibrated using the quercetin titration curve and expressed in (mg quercetin. 100 g^{-1} of D.W), according to [16].

Root content of phosphorus % after 70 days of planted

The roots were digested at (70) days of age, using the wet digestion method with a mixture of sulfuric and perchloric acids, and were then available for phosphorus determination using a spectrophotometer [17].

Results

(Tables 1, 2, 3, and 4) show that the bacterial biofertilization with *Pseudomonas fluorescens* alone, the addition of phosphate rock nanoparticles, and the addition of decomposed cow manure alone also resulted in a significant increase in plant height (cm), leaf carbohydrate content ($\text{g}100\text{g}^{-1}$ dry matter), total phenol (mg EAG 100g^{-1} D.M), and phoulvedes (mg quercetin. 100g^{-1} matter) after 40 day period planted. Phosphorus content (%) in the root was also increased after 70 days of planted . Treatment with *Pseudomonas fluorescens* (S_1) bacterial inoculation resulted in a significant increase in plant height, 35.15 cm compared to the control of 32.15(cm). The treatment also significantly increased leaf carbohydrate content, $3.77 \text{ } 100 \text{ g}^{-1}$, compared to the control of $3.41 \text{ } 100 \text{ g}^{-1}$ D.M. Furthermore, the

treatment significantly increased leaves total phenol content, reaching 591 mg EAG/100 g⁻¹ D.M, compared to the control of 654 mg EAG 100 g⁻¹ D.M. The treatment also resulted in a significant increase in pholvedes content in the leaves, 885.30 mg quercetin 100 g⁻¹D.W compared to the control of 773.74 mg quercetin 100 g⁻¹D.W Similarly, the treatment significantly increased phosphorus content in the roots, 0.43%, compared to the control of 0.48%.

The treatment of adding phosphate rock nanoparticles resulted in a significant increase in plant height, 35.50 cm compared to the control of 30.61 cm. This treatment also significantly increased the leaves carbohydrate content to 3.40 g.100 g⁻¹ D.W, compared to the control treatment of 3.75 g 100 g⁻¹ D.W. Furthermore, the treatment significantly increased the leaves total phenol content to 611.11 mg EAG/100 g D.W, compared to the control treatment of 639.9 mg EAG 100 g⁻¹D.W The treatment also resulted in a significant increase in pholvedes content in the leaves, 788.39 mg quercetin 100 g⁻¹ D.W , compared to the control treatment of 886.33 mg quercetin 100 g⁻¹ D.W. Similarly, the treatment significantly increased phosphorus content in the roots, 0.48%, compared to the control of 0.42%.

The treatment of adding composed cow manure resulted in a significant increase in plant height, 35.50 cm compared to the control of 30.61 cm. This treatment also significantly increased the leaves carbohydrate content to 3.63 g.100 g⁻¹D.W, compared to the control of 3.53 g.100 g⁻¹. D.W Furthermore, the treatment significantly increased the leaves total phenol content to 626.6 mg EAG.100 g⁻¹ D.W , compared to the control of 618.0 mg EAG.100 g⁻¹ D.W . The treatment also achieved a significant increase in the pholvedes content in the leaves, 886.33 mg quercetin 100 g⁻¹ D.W, compared to the control of 788.49 mg quercetin 100 g⁻¹ D.W. As for the phosphorus content in the root, the treatment achieved a significant increase of 0.46%, compared to the control treatment of 0.42%.

As shown in (Tables 1, 2, 3, and 4), the double interactions of the study factors (S₁*O), (S₁*Rn), and (O*Rn) resulted in a significant increase in plant height (cm), leaves carbohydrate content (g.100g⁻¹ F.W), total phenol (mg EAG.100g⁻¹ D.W), and pholvedes (mg Cuercetin.100g⁻¹D.W) over a 40 day period after planting. The phosphorus content in the root was also significantly increased after 70 days of planting.

The interaction of the(S₁*O) double (*P. fluorescens* + composed cow manure) resulted in the highest significant increase in plant height, 37.56 cm compared to the control of 32.00 cm. This treatment also significantly increased **leaves** carbohydrate content to 3.86 g.100 g⁻¹F.W, compared to the control of 3.40 g.100 g⁻¹F.W. Furthermore, the treatment significantly increased **leaves** total phenol content to 658.0 mg EAG.100 g⁻¹D.W, compared to the control of 584.1 mg EAG.100 g⁻¹D.W. The treatment also achieved a significant increase in the pholvedes content in the leaves, 905.89 mg quercetin 100g⁻¹ D.W, compared to the control of 760.11 mg quercetin .100 g⁻¹W.D. As for the phosphorus content in the root, the treatment achieved a significant increase, 0.49%, compared to the control of 0.43%.

The interaction of (S₁*Rn) with *P. fluorescens* and phosphate rock nanoparticles resulted in the highest significant increase in plant height, 40.33 cm compared to the control of 29.00 cm. This treatment also significantly increased leaves carbohydrate content to 4.07g.100g⁻¹F.W, compared to the control of 3.32 g⁻¹100 F.W. Furthermore, it significantly increased leaf total phenol content to 670.4 mg EAG 100 g⁻¹D.W, compared to the control of 577.1 mg EAG.100 g⁻¹D.W. The treatment also achieved a significant increase in the pholvedes content in the leaves, reaching 959.44 mg quercetin 100 g⁻¹ D.W, compared to the control of 734.56 mg quercetin 100 g⁻¹D.W As for the phosphorus content in the root, the treatment achieved a significant increase, 0.51%, compared to the control of 0.40%.

The interaction (O*Rn) of the double (composed cow manure + phosphate rock nanoparticles) resulted in the highest significant increase in plant height, 36.67 cm compared to the control treatment of 27.50 cm. This treatment also significantly increased the leaves carbohydrate content, g.100 g⁻¹D.W, compared to the control of g.100 g⁻¹D.W. Furthermore, the treatment significantly increased the leaves total phenol content, reaching 645.7 mg EAG.100 g⁻¹D.W, compared to the control of 609.0 mg EAG.100 g⁻¹D.W. The treatment also achieved a significant increase in the pholvedes content in the leaves, reaching 926.33 mg quercetin 100 g⁻¹D.W, compared to the control of 782.67 mg quercetin 100 g⁻¹ dry matter. As for the phosphorus content in the root, the treatment achieved a significant increase, 0.47%, compared to the control of 0.41%.

Tables(1, 2, 3, and 4 show) that the triple interaction (S₁*Rn*O) of the study agents (*P. fluorescens* + phosphate rock nanoparticles + composed cow manure) resulted in the highest significant increase in plant height in the field experiment, 42.00 cm compared to the control of 30.33 cm. The treatment also significantly increased leaves carbohydrate content to 4.15 g.100 g⁻¹D.W, compared to the control of 3.27 g.100 g⁻¹W.D. Furthermore, the treatment significantly increased leaves total phenol content to 668.0 mg EAG.100 g⁻¹W.D, compared to the control treatment of 573.3 mg EAG.100 g⁻¹D.W. The treatment also achieved a significant increase in the pholvedes content in the leaves, 1011.67 mg quercetin 100 g⁻¹W.D, compared to the control of 735.33 mg quercetin 100 g⁻¹D.W. As for the phosphorus content in the root, the treatment achieved a significant increase, 0.52%, compared to the control of 0.38%.

(Table 1) Effect of Fertilization with Mycorrhizal Fungus in Interaction with Phosphate Rock Nanoparticles and Poultry Manure on Plant Height (cm)

Bio-fertilizer (S)	Nanoparticle levels Rn kg.ha ⁻¹	Organic matter levels (O) T.ha ⁻¹			Mine S*Rn
		3	5	6	
Inoculation without S ₀	0	30.33	32.33	34.00	29.00
	30	35.00	33.67	32.00	30.67
	60	30.67	30.00	31.33	32.22
Inoculation S ₁	0	24.67	29.00	33.33	33.56
	30	34.67	36.33	37.33	36.11
	60	38.67	40.33	42.00	40.33
LSD= S*O* Rn 4.753					LSD= S*Rn 3.589
Interaction S*O		32.00	32.11	32.44	Mine S=
		32.67	35.22	37.56	32.15
LSD S*O =2.335					35.15
Interaction O*Rn	0	27.50	30.67	33.67	LSD _S =2.358
	20	34.83	35.00	34.67	LSD O*Rn =3.660
	40	34.67	35.17	36.67	
Mine O		32.55	33.61	35.00	LSD O=1.735
Mine Rn		30.61	34.83	35.50	LSD Rn=3.005

(Table 2). Effect of Mono fertilization and the interaction of double and Tribal factors study on leaf content of carbohydrates g. 100 g⁻¹FW

Bio-fertilizer (S)	Nanoparticle levels Rn kg.ha ⁻¹	Organic matter levels (O) T.ha ⁻¹			Mine S*Rn
		3	5	6	
Inoculation without S ₀	0	3.27	3.34	3.34	3.32
	30	3.42	3.52	3.51	3.48
	60	3.53	3.43	3.34	3.43
Inoculation S ₁	0	3.50	3.34	3.63	3.49
	30	3.75	3.72	3.80	3.76
	60	3.95	4.11	4.15	4.07
LSD= S*O* Rn 0.124					LSD= S*Rn 0.112
Interaction S*O		3.40	3.41	3.41	Mine S=
		3.72	3.73	3.86	3.41
LSD S*O =0.101					3.77
Interaction O*Rn	0	3.30	3.42	3.48	LSD _S =0.134
	20	3.59	3.62	3.65	LSD O*Rn =0.073
	40	3.74	3.77	3.74	
Mine O		3.58	3.56	3.63	LSD O=0.049
Mine Rn		3.40	3.62	3.75	LSD Rn=0.027

(Table3). Effect of Mono fertilization and the interaction of double and Tribal factors study in leaves of total phenol mg EAG 100g⁻¹ D.W

Bio-fertilizer (S)	Nanoparticle levels Rn kg.ha ⁻¹	Organic matter levels (O) T.ha ⁻¹			Mine S*Rn
		3	5	6	
Inoculation without S ₀	0	573.3	577.3	580.7	577.1
	30	583.3	586.0	590.7	586.7
	60	595.7	609.0	623.3	609.3
Inoculation S ₁	0	644.7	646.7	644.0	645.1
	30	646.0	649.0	652.7	649.2
	60	665.0	678.3	668.0	670.4
LSD= S*O* Rn 16.64					LSD= S*Rn 10.38
Interaction S*O		584.1	590.8	598.2	Mine S=
		651.9	653.0	658.0	591.00
LSD S*O =11.22					654.00
Interaction O*Rn	0	609.0	312.0	612.3	LSD _S =13.46
	20	614.7	617.5	621.7	LSD O*Rn =11.12
	40	630.3	643.7	675.7	
Mine O		618.0	624.0	626.6	LSD O=7.27
Mine Rn		611.1	617.9	639.9	LSD Rn=5.09

(Table 4). Effect of Mono fertilization and dual and triple interaction of the study factors in leaves of pholvedes mg quercetin 100g⁻¹ D.W for a period of 40 days of planted .

Bio-fertilizer (S)	Nanoparticle levels Rn kg.ha ⁻¹	Organic matter levels (O) T.ha ⁻¹			Mine S*Rn
		3	5	6	
Inoculation without S ₀	0	725.33	732.67	745.67	734.56
	30	764.00	773.67	782.67	773.44
	60	791.00	807.67	841.00	813.22
Inoculation S ₁	0	840.00	839.00	877.67	842.22
	30	852.67	851.67	858.33	854.22
	60	875.33	991.33	1011.67	959.44
S*O* Rn 8.791 LSD=					LSD= S*Rn 6.021
Interaction S*O		760.11	771.33	789.78	Mine S=
		856.00	894.00	905.89	773.74
LSD S*O =4.11					885.30
Interaction O*Rn	0	782.67	785.83	796.67	LSD S=1.46
	20	808.33	812.67	820.50	LSD O*Rn =6.793
	40	833.17	899.50	926.33	
Mine O		808.06	832.67	847.83	LSD O=3.52
Mine Rn		788.39	813.83	886.33	LSD Rn=5.20

(Table 5). Effect of Mono fertilization and dual and triple interaction of the study factors on the phosphorus content in the root after 70 days of planting.

Bio-fertilizer (S)	Nanoparticle levels Rn kg.ha ⁻¹	Organic matter levels (O) T.ha ⁻¹			Mine S*Rn
		3	5	6	
Inoculation without S ₀	0	0.38	0.40	0.41	0.40
	30	0.43	0.44	0.44	0.44
	60	0.47	0.44	0.43	0.45
Inoculation S ₁	0	0.43	0.46	0.46	0.45
	30	0.46	0.48	0.49	0.48
	60	0.50	0.51	0.52	0.51
LSD= S*O* Rn 0.031					LSD= S*Rn 0.026
Intrraction S*O		0.43	0.43	0.43	Mine S=
		0.47	0.48	0.49	0.43
LSD S*O =0.026					0.48
Intrraction O*Rn	0	0.41	0.43	0.43	LSD S=0.034
	20	0.45	0.46	0.47	LSD O*Rn =0.019
	40	0.49	0.47	0.47	
Mine O		0.45	0.45	0.46	LSD O=0.011
Mine Rn		0.42	0.46	0.48	LSD Rn=0.012

Discussion of results

The composed organic matter of cow manure used in the field experiment contains many nutrients, including nitrogen, phosphorus, magnesium, and micronutrients such as iron and zinc. It also helps relation water, thus improving the plant's water relations. Generally, it improves the chemical, physical, and biological properties of the soil. Furthermore, it is rich in enzymes, vitamins, and proteins, thereby improving the plant's root environment. This leads to nutrient accumulation in the plant [18], resulting in increased photosynthesis, which was reflected in the increased characteristics studied in radish plants, including plant height [19] Moreover, the radish plant is fast growing and requires large quantities of different nutrients. Increasing nitrogen in the cytoplasm ensures good vegetative growth, carbohydrate accumulation, and increased root size [9, 20].

As for nanoparticles, they are characterized by a large surface area relative to their size. This provides a very large chemical reaction area, which microorganisms can benefit from it , and the ions present in the soil solution can react with them, as well as the plant roots. Through the plant's much secretions, part of the phosphorus of these nanoparticles is converted into the soil solution [21]. The plant roots absorb it, and thus these nanoparticles used in the field experiment provide the phosphorus necessary for building biomolecules in the plant. Phosphorus affects root growth and helps cells divide, photosynthesize, and metabolize carbohydrates. It is also important in activating enzymes and defiant of metabolism in the radish plant [22 , 2]

During its life cycle, *P. fluorescens* bacteria secrete enzymes and acids that dissolve apatite by breaking down the ester bonds that link phosphate. These enzymes include phosphatase and formic, acetic, oxalic, citric, and other acids. This same process applies to the interaction of bacteria with phosphate rock nanoparticles [23].The substances released from phosphate rock are numerous, including potassium, which improves crop quality, thus increasing total soluble solids (TSS), vitamin C, and sugars in radish leaves and roots [24 , 8].

The interaction between *fluorescens* bacteria (P) and nanoparticles (Rn) is very important for the plant, as the bacteria increase the availability of phosphorus by secreting several organic acids that make the medium more acidic, thus increasing the availability of phosphorus from the nanoparticles, as well as secreting phosphatase enzymes responsible for converting phosphorus into the available form [7].

The double interaction between *P. fluorescens* and organic matter is the breakdown of organic matter and the increased availability of nutrients, particularly nitrogen, phosphorus, zinc, and others, through the secretion of organic and inorganic acids by the bacteria [8].

P. fluorescens bacteria release defiant nutrients, especially nitrogen, phosphorus, and potassium, which are involved in the synthesis of many active Ingredients in radish plants [25, 26]. These compounds include colloids, amino acids, total protein, different enzymes, and oils [27].

The interaction of composed organic matter, and nanoparticles can have a positive, effect. Organic matter serves as a reservoir for energy sources for microorganisms and also contains numerous enzymes, vitamins, and acids that help release nutrients from nanoparticles. Furthermore, it increases the number of active soil components [10]. Phosphate rock contains several nutrients, including P₂O₅ (21.47%), MgO (0.60%), F (2.88%), Cl (0.13%), and Zn (150 ppm). [28]. Nutrients whose concentration increases due to this interaction, such as phosphorus, potassium, zinc, magnesium, and iron, are essential for cell health and quality improvement. Consequently, nutrient accumulation increases, which is reflected in the building of carbohydrates, the primary source of energy in plants. The photosynthesis process is improved due to the increase in magnesium, which is also involved in

building the chlorophyll molecule along with other nutrients such as iron and calcium resulting from the decomposition of phosphate rock. These substances also contribute to the building of other compounds such as phenols, pholvedes , and vitamin C [6]. All the study indicators in the triple interaction were greater than in mono interaction and double additions. This field experiment reflects the effectiveness of the fertilizers used and also reflects the positive interaction of the three study factors in the radish Rhizosphere.

Conclusion

The triple interaction showed significant variation ($p < 0.05$) in all characters on study. The triple interaction (*P. fluorescens* phosphate rock nanoparticles and composed cow manure) It was observed that it gave the greatest significant increase in characters on study.

Therefore, the use of (*P. fluorescens* + 60 kg .ha⁻¹ nanoparticle + 6 t.h⁻¹ of composed cow manure) can be suggested for radish growers in the study area. This experiment needs to be conducted with other factors to clarify the role of interactions in radish growth and other plant active Ingredients.

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