International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

Effect of Bacillus megaterium, Vermicompost, and Phosphate on the yield of sunflower (Helianthus annuus L.) on N.P.K. content of the leaf.

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Abstract: Aiming to investigate the interaction between Bacillus megaterium and vermicompost and three levels of phosphate rock fertilizer 0, 100, and 200 kg.K.ha^{-1} on the growth and yield of sunflowers, this field experiment was carried out. The results present that inoculation with Bacillus megaterium and vermicompost bacteria singly or double produced a significant increase in (nitrogen, phosphorous, and potassium in the plant and total yield) compared to the control. The application of bacterial and organic inoculum and rock phosphate fertilizer at the level of 100 kg.K.ha^{-1} (3.112, 0.459, 3.528, and 2808) resulted in the highest values of the studied traits, respectively, compared to the control.

Keywords: Bacillus, vermicompost, phosphate rock, total yield

1. INTRODUCTION

Sunflower crop, *Helianthus annuus* L., is one of the most important oil crops in the world. Its seeds give a large amount of oil, up to (55)%. It is one of the high-quality oils that are used in the human diet. Its seeds' coat is good fodder for farm animals since it contains (36) % protein and 20-22% carbohydrates, with up to (6)% oil and other nutrients[1]. This crop ranks third, after soybeans and colza, in the amount of oil produced. Sunflower oil is among the best-consumed vegetable oils globally due to its health and economic distinction. It is characterized by a high proportion of essential unsaturated fatty acids (90)% [2]. Despite the great importance of the crop, its productivity per unit area locally is still low compared to global production, as the yield rate did not exceed (310.7) kg.d^{-1}, with a production amount of (5.2) thousand tons and an area of (16.8) thousand dunums[3]. The global production rate was (1.426) tons.h^{-1}, with a production amount of (33.77) million tons and an area of (23.68) million hectares[4].

One of the reasons for the crop's low productivity is the lack of its supply of the necessary nutrients because the oil formed in its seeds as organic matter depletes the ready elements in the soil significantly, especially phosphorus, which the plant cannot grow and develop naturally without it. Phosphorous is one of the primary and essential elements needed by plants in relatively large quantities and cannot be replaced by another element because of its significant role in many physiological processes. For example, it is included in the composition of energy-rich compounds and enzymatic attachments, without which the plant cannot carry out its vital functions and the decomposition of carbohydrates resulting from the photosynthesis process. In addition, Phosphorous helps in the division of plant cells and stimulates the growth and development of roots, maturation of plants, and seeds and fruits' formation. Therefore, its presence in sufficient quantities during the growth stages is essential for increasing productivity and improving quality[5]. Phosphate rock can be used as a source of phosphorous. It contains a fair percentage of phosphorous (10-15)% P. The phosphate rock efficiency in phosphorus preparation can be increased by grinding it and sifting it into small (0.5) mm or smaller[6]. Thus, it has importance in plant nutrition and increases the root group's growth and size, improving its resistance to diseases and encouraging organisms' growth in the root zone.

Many types of bio-inoculations can apply to the soil, including bacteria of atmospheric nitrogen fixation. These fertilizers provide (35)% of the applied nitrogen fertilizer. Its availability may be higher or lower than that, depending on its efficiency, improving crop yields, and raising soil fertility. As for the other type, it contains phosphate-dissolving bacteria such as (*Bacillus megaterium*) that contribute to reducing the rate of phosphate chemical fertilization by up to (50)% and thus saving its costs and also reducing the rate of soil and environmental pollution with increasing production in quantity and quality. These biofertilizers are environmentally friendly and contribute to increasing agricultural production by up to (30)%. It replenishes the fertile state of the soil and protects plants against drought and some pathogens. They expand the root system and increase seed germination. Following the correct method of serving the crop, especially when using vital vaccines, is the key to successful operations management for good crop performance. Therefore, biofertilizers are among the necessary growth requirements for their importance in preparing the plant's nutritional needs and its positive effect in increasing the yield in quantity and quality on the one hand and improving the physical, chemical, and biological properties of the soil on the other hand.

There are many fertilizers, including compost produced from earthworms, great dissolvers of various organic residues, and temperate and tropical regions. The presence of these ring organisms in the soil makes them fertile and rich in organic matter through the production of Vermicompost (CAST), which is rich in nutrients such as nitrogen, magnesium, iron, and other nutrients and helps the growth of the plant through its good absorption of the elements essential for its growth.

Vermicompost also contains several enzymes that enhance the activities of living organisms[8]. The presence of earthworms in the soil affects its physical properties, improves its structure, water, and nutrients' movement through it, and enhances its porosity by digging channels while performing its various biological activities. These channels help spread pesticides and fertilizers to different soil layers. Also, earthworm products are excellent nutritional fertilizer that helps plant growth[9].

Based on the importance of the preceding, the field experiment was conducted to study:

1) The effect of *Bacillus megaterium* on sunflower growth and yield.

2) The effect of *vermicompost* on the growth and yield of the sunflower plant.

3) The effect of phosphate rock on the growth and yield of the sunflower plant.

4) The interaction between *Bacillus megaterium*, *vermicompost*, and phosphate rock on the sunflower plant's growth and yield.

2. METHODS AND METHODS

The field experiment was conducted in the fall season of 2020. The field soil was prepared by conducting critical field operations, including orthogonal tillage, smoothing, and leveling. Three main drivers were constructed along the field, including sub-markets for each experimental unit. As the field was divided into three main sectors, each sector contains (12) experimental units, and each experimental unit contains (5) rows. The distance between a row and another is (75) cm, and between planting seedbed and the other is (25) cm. The experimental unit dimensions were (4 × 4) $m^{2,}$ and (1) m was left between each experimental unit and another. Thus, the total number of experimental units is (36) units.

Sunflower seeds, *Helianthus annuus* L, and the local variety (Aishaqi 1) were planted on July 28, 2020. Seeds were planted in rows, and the distance between a row and another was (75) cm, and between a seedbed and another is (25) cm as the experimental unit contains five rows in a unit, with a plant density of (53333) $plants.ha^{-1}$. Three seeds were placed in each seedbed hole, and after (10) days of planting, the plant was rouge out to one plant in each seedbed. Thus, the number of plants in each unit is (64) plants. Urea fertilizer (46% N) was used as a nitrogen source at a rate (200) $kg.N.ha^{-1}$. The first application was applied three times at the six-leaf stage, the second application after 30 days of the first one, and the third application was a month after the second one. Potassium sulfate fertilizer K2SO4 (45) % K was applied as a source of potassium element at the rate (225) kg $K.ha^{-1}$. Phosphate rock was applied in three levels (0-100-200) P.kg. $.ha^{-1}$as a phosphorus source once before planting.

Bush control was carried out manually throughout the growing season and whenever needed. The experiment was irrigated with a regular flow of irrigation water according to the plant's water needs.

Soil's chemical and physical analyzes

Soil samples were taken from the field soil before planting, and samples were taken at a depth ranging between (0-30) cm. A compound sample was taken from it after mixing it well to ensure the sample's homogeneity between them and air-dried. It was ground with a wooden hammer and then sifted with a sieve with a diameter of (2) mm holes to complete chemical, physical, and biological analyses.

1- Degree of reaction (pH): The degree of soil reaction in a 1: 1 soil: water suspension was measured using an E.C. meter according to [10 and 11].
2- Electrical conductivity (E.C.): Soil: water was measured in suspension 1: 1 using an E.C. meter as stated in[11].
3- Cation exchange capacitance (C.E.C.): It was measured using sodium acetate and ammonium acetate as reported[10].
4- Soil texture: It was measured by the international pipette method, according to (29).
5- Organic matter (O.M): The organic matter was determined by the wet digestion method using 1N of (K2Cr2O7) as mentioned in[10].
6- Available nitrogen: Nitrogen was measured using potassium chloride KCl, and nitrogen was estimated using a keldal device as mentioned in[11].
7- Available phosphorous: The available phosphorus was measured by NaHCO3 sodium bicarbonate, the color was developed with ascorbic acid and ammonium molybdate, and the Spectrophotometer was used to estimate the available phosphorus as mentioned in[11].
8- Available potassium: Soil potassium was measured using (0.5) Molar calcium chloride and was estimated using a Flame Photometer, according to to[11].
9- Sodium Ione: Sodium was measured using NaCl solution by using a Flame Photometer as mentioned in[10].

10- Calcium Ca $^{+2}$ and Magnesium Mg $^{+}$2: They were measured using a buffer solution of ammonium hydroxide and ammonium chloride by adding a reagent of E.B.T. reported in[10].

11- Chloride CL: It was measured using potassium chromate guide and silver nitrate solution, as a white precipitate was formed according to to[10].

12- Carbonate CO3 and bicarbonate HCO3: They were measured by adding sulfuric acid, methyl orange index, and phenolphthalein reagent; when the carbonate was present, the color of the solution changed to violet, after which the titration was done with sulfuric acid as mentioned.

13- Sulfate SO_4: The measurement was made using a barium chloride solution at a concentration of 1 N, hydrochloric acid, and ethanol, as reported[10].

14- Cu^{+2}, Zn^{2+}, and Fe^{+2}

These elements were measured using an atomic absorption spectroscopy apparatus. Standard solutions were prepared for all elements by adding an extracting solution, as mentioned in[10].

14-Bulk density: The bulk density was estimated by using a core sample.

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

Trait		Value	Unit
Reaction Degree (pH) (1:1)		7.6	------------------------
Electrical Conductivity (E.C.) (1:1)		2.90	DesiSmens.M^{-1}
Cation exchange capacity (CEC)		19.7	Cml.charge.kg^{-1}.soil
Organic matter O.M.		2.8	g.kg. $Soil^{-1}$
Available elements	N	26.07	Mg. kg.$Soil^{-1}$
	P	13.9	
	K	191.8	
Soluble positive ions	Ca^{2+}	4.8	Cml.charge.L^{-1}
	Mg^{2+}	2.80	
	Na^{1+}	460	
Soluble negative ions	SO_4^{2-}	Nil	Cml.charge.L^{-1}
	HCO_3^{1-}	1.78	
	CO_3^{-2}	10	
	Cl^{-}	7.0	
Soil separators	Sand	180	g.kg. $Soil^{-1}$
	Silt	500	
	clay	320	
Soil texture	silt clay Loamy		
Bulk density	1.40		g.cm^{-3}

Total grain yield (tons. h^{-1}): It was extracted from the average plant yield as it was calculated from the average yield of five plants per experimental unit x plant density after adjusting the weight based on (8)% moisture for all weight-related characteristics and according to the following equation[14]:

$$Factor = (100-\%\ Moist) / (100-8\%\ Moist)$$

Then the product is multiplied by the weight of the model (gm)

3. RESULTS AND DISCUSSION

Effect of bacterial inoculum, vermicompost, and rock phosphate on leaf nitrogen content (mg N kg^{-1}**)**

The application of the bacterial inoculum B1 made an increase in nitrogen availability in the plant, and the highest nitrogen concentration was 2.706 mg.N.kg^{-1} compared with control treatment B0. This reason is attributed to the role of the *Bacillus* that indirectly affects the stimulation of the biologically nitrogen-fixing microorganisms that are initially settled in the soil, which leads to an increase in the availability and absorption of nitrogen by the plant[14].

Vermicompost V1 application increased the concentration of the available nitrogen in the Plant 2.647 mg.N.kg^{-1} compared to V0 by 2.444 mg.N.kg^{-1}. This reason is attributed to the role of vermicompost in increasing the microbial activity in the soil, growth regulators, and humic acids and increasing the nutrients necessary for the plant, especially nitrogen. In a research conducted by [39], he indicated that adding 30% of vermicompost to the soil led to a significant increase in the availability of N, P, K, Ca, and Mg elements. The addition of phosphate rock produced an increase in the concentration of ready nitrogen in the plant, and the highest nitrogen concentration was 2.790 mg.N.kg^{-1} compared to the control treatment 2.191 mg.N.kg^{-1}. This reason is attributed to the role of phosphorous added in the form of phosphate rock, which led to an increase in the size of the root system of the plant and the depth of the root group, and then increased plant growth[9].

The dual interaction of bacterial and vermicompost produced the highest concentration of available nitrogen in the plant, 2.769 mg.N.kg$^{-1,}$ compared with the control treatment. This reason is attributed to the plant's nitrogen content because vermicompost is one of the essential factors that influence the availability of the plant's nutrient content because of the many properties of this substance that affect the mineral content of the soil and then make it ready for absorption by the plant. This reflects positively on the growth of roots and the absorption of essential nutrients from the soil, such as nitrogen, and this is consistent with what he indicated[26]. In addition, vermicompost has a significant role in enriching the soil with many beneficial microorganisms that have a significant role in fixing atmospheric nitrogen and increasing the solubility and readiness of phosphorous. It also analyzes the organic matter and releases nutrients available for absorption by the plant[35,32].

The binary interaction B and P resulted in significant differences in nitrogen availability in the plant, and the highest concentration of available nitrogen was 2.896 mg.N.kg^{-1} compared with the control treatment 1.932 mg.N.kg^{-1}. This is due to the role of *Bacillus megaterium,* which secretes organic acids or increases the dissolution of phosphates and the secretion of organic acids that dissolve phosphorous-bearing compounds, which increases its facilitation to the plant that leads to increased absorption of nutrients, including nitrogen[28]. On the other hand, the binary interaction V and P resulted in a significant increase in nitrogen availability in the plant, and the highest concentration of ready nitrogen was 2.969 mg.N.kg^{-1} compared to the control. This reason is attributed to the role of vermicompost, which increases the permeability of cell membranes and facilitates the transfer of nutrients, especially the elements nitrogen, phosphorous, and potassium, into the plant, and that the presence of phosphate fertilizer increased the amount of nitrogen ready for absorption by the root system in the plant[44].

The triple interaction B1V1P1 resulted in a significant increase in the concentration of available nitrogen in the plant at the level (100) kg.ha^{-1} at the flowering stage, and the highest concentration of available nitrogen in the plant was 3.112 $mg.N.kg^{-1}$, compared with the comparison treatment 1,514 $mg.N.kg^{-1}$ under B1V1P1.

Table 2. Effect of *Bacillus megatherium*, Vermicompost, and phosphate rock on nitrogen concentration ($mg.N.kg^{-1}$) in the vegetative part of the plant.

Rock phosphate (P)	**Vermicompost (V)**	**Bacterial Bio-fertilizer**		**Mean of binary overlap P * V**
		B_0	**B_1**	
P_0	**V0**	1.514	2.256	1.885
	V1	2.350	2.646	2.498
P_1	**V0**	2.540	2.680	2.610
	V1	2.826	3.112	2.969
P_2	**V0**	2.685	2.992	2.838
	V1	2.400	2.550	2.475
LSD .05		**0.173**		**0.122**
Binary overlap B * P				
Rock phosphate (P)		**Bacterial Bio-fertilizer**		Mean of (P)
		B_0	**B_1**	
P_0		1.932	2.451	2.191
P_1		2.683	2.896	2.790
P_2		2.543	2.771	2.657
LSD .05		**0.122**		**0.086**
Binary overlap B * V				
Vermicompost (V)		**Bacterial Bio-fertilizer**		Mean of (V)
		B_0	**B_1**	
V0		2.246	2.642	2.444
V1		2.525	2.769	2.647
LSD .05		**0.010**		**0.070**
Mean of (B)		2.386	2.706	
L.S.D. .05		**0.070**		

Effect of bacterial inoculum, vermicompost, and phosphate rock on the phosphorous content of the leaf ($mg.P.kg^{-1}$)

The application of the bacterial fertilizer B1 increases the concentration of available phosphorous in the plant by 0.390 $mg.P.kg^{-1}$ compared with control B0, Table 3. This reason is attributed to phosphate-dissolving bacteria, which dissolve and increase phosphorus availability through the processes of mineralizing organic phosphorous in the soil and working to dissolve insoluble phosphate compounds in the soil, thus increasing the amount of phosphorus absorbed by the plant. In addition, the effect of microorganisms applied to the soil is to secrete organic acids and produce the enzyme phosphatase, which increases the availability of phosphorus in the soil and its uptake by the plant[21].

The application of vermicompost V1 led to an increase in the concentration of available phosphorous in the Plant 0.381 $mg.P.kg^{-1}$ compared toV0. This reason is attributed to the role of vermicompost in increasing the concentration of nutrients in the leaves of the plant. This may be because vermicompost improves soil fertility and increases the availability of nutrients to the plant, which raises the concentration of these elements in the plant. In addition, vermicompost is a source of nutrients necessary for plant growth, and by absorbing these nutrients, it builds a robust root system that is efficient in absorbing nutrients from the soil solution, in addition to providing the soil with humus, which improves its physical properties by increasing its ability to absorb and retain water[39, 22].

The application of phosphate rock produced an increase in the concentration of phosphorous in the plant, and the highest concentration of phosphorous was 0.403 $mg.P.kg^{-1}$ compared to the control 0.308 $mg.P.kg^{-1}$.This is attributed to the importance of phosphate rock, as its dissolution led to an increase in the concentration of phosphorous in the plant and the liberation of phosphorous, which led to an increase in plant growth. Furthermore, it indicates the possibility of using it as a source of phosphorous because it is available and its cost is low as an alternative to traditional fertilizers with high costs. This agrees with [7, 10, 48,] who found an increase in phosphorous concentration in the plant when phosphate rock was applied.

The dual interaction of bacterial inoculum and vermicompost (B + V) led to significant differences in the concentration of available phosphorous in the plant 0.401 compared to the control. This reason is attributed to the role of vermicompost, which is an organic material that stimulates and encourages the reproduction and growth of microorganisms that secrete organic acids and stimulating hormones such as auxins and gibberellins that stimulate plant growth and increase the readiness of nutrients in the soil, which is reflected in its absorption by the plant and then on the proportion of mineral elements, the most important of which is phosphorus and nitrogen in plants[20, 19].

Bacillus mechatrim can also form complex compounds with calcium and produce H^+ ions simultaneously, which increases the solubility of phosphorus in the soil. In addition, microorganisms can reduce soil P.H. by forming CO2 gas when decomposing organic matter in the soil and then forming carbonic acid, which increases the solubility of insoluble phosphate compounds. This leads to an increase in the plant's ability to absorb phosphorous and increases the plant[30]. The dual interaction of bacterial inoculum and phosphate rock (B+P) led to significant differences in the concentration of available phosphorous in the plant, which amounted to 0.422 $mg.P.kg^{-1}$ compared with the control. This is attributed to the positive role of the bacteria used, which has a wide range of favorable properties that stimulate plant growth and its ability to increase the solubility of phosphorus in the soil as a result of its secretion of inorganic acids, namely sulfuric, phosphoric, nitric and organic, such as gluconic, lysine, acetic, fumaric, succinic, humic, citric, and oxalic more available form, which leads to an increase in the percentage of phosphorous in the plant[43].

The dual interaction of vermicompost and phosphate rock (V + P) at the level (P1) resulted in the highest concentration of available phosphorous in the plant, 0.433 $mg.P.kg^{-1,}$ compared with the control. This reason is attributed to vermicompost, which directly affects the concentration of nutrients, including phosphorous, in the leaves at the maturity stage. Therefore, vermicompost application has an essential role in increasing the availability of nutrients. This helped the roots grow better and form an effective, strong and efficient root system that absorbs nutrients and then reflected positively on the plant's growth. Furthermore, the presence of a quantity of phosphate fertilizer and the available conditions that helped in its readiness, such as the presence of an appropriate degree of reaction as a result of the organic acids resulting from vermicompost, which increased the concentration of phosphorous in the soil and its absorption by the plant and this is consistent with the studies of [51, 41, 49].

The table results confirmed that the triple interaction B1V1P1 led to a significant increase in the concentration of ready phosphorous in the plant at the level of 100 $kg.ha^{-1}$, as the highest average concentration of phosphorous was 0.459 mg.P.kg^{-1} compared to the control 0,198 mg.P.kg^{-1}.

Table 3. Effect of *Bacillus megatherium*, Vermicompost, and phosphate rock on phosphorous concentration (mg.P.kg^{-1}) in the vegetative part of the plant

Rock phosphate (P)	Vermicompost (V)	Bacterial Bio-fertilizer		Mean of binary overlap P * V
		B_0	B_1	
P_0	V0	0.198	0.320	0.259
	V1	0.335	0.379	0.357
P_1	V0	0.363	0.384	0.374
	V1	0.406	0.459	0.433
P_2	V0	0.385	0.431	0.408
	V1	0.342	0.365	0.353
LSD .05		**0.028**		**0.020**
Binary overlap B * P				
Rock phosphate (P)		**Bacterial Bio-fertilizer**		Mean of (P)
		B_0	B_1	
P_0		0.267	0.350	0.308
P_1		0.385	0.422	0.403
P_2		0.364	0.398	0.381
LSD .05		**0.020**		**0.014**
Binary overlap B * V				
Vermicompost (V)		**Bacterial Bio-fertilizer**		Mean of (V)
		B_0	B_1	
V0		0.315	0.379	0.347
V1		0.361	0.401	0.381
LSD .05		**0.016**		**0.012**
Mean of (B)		0.338	0.390	
L.S.D. .05		**????????????**		

Effect of bacterial inoculum, vermicompost, and phosphate rock on potassium content of leaf (mg.K.kg^{-1}) **for the two growing periods**

Table 4 presents that the bacterial inoculum B1 application increased the concentration of available potassium in the Plant 2.927 mg.K.kg^{-1}compared to the control B0. This is attributed to the possibility of the added bacterial inoculum in the production of some essential enzymes that contribute to the hydrolysis process of the intermediate compound (amino-cyclo propane-1-carboxylate) A.C.C. deminase, which has an essential role in making ethylene, which positively affects the size and mass of the roots of the plant Leads to increased absorption of nutrients, including potassium[52,42].

The application of vermicompost V1 increased the concentration of ready potassium in the Plant 2.875 mg.K.kg^{-1} compared with the control. It is attributed to the role of vermicompost, which increases the concentration of potassium in the plant, being an organic substance rich in nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, iron, and other minerals, which are readily soluble in water and easily absorbed by the plant[25]. The application of phosphate rock resulted in an increase in potassium concentration in the Plant

3.159 mg.K.kg^{-1} compared to the control 2.378 mg.K.kg^{-1}. This is attributed to the role of phosphorous liberated from phosphate rock in the formation of a deep and robust root group that absorbs nutrients, including potassium[34]. The interactions between bacterial inoculum and vermicompost (V + B) resulted in 2.943 mg.K.kg^{-1} available potassium compared to the control. This reason is attributed to *Bacillus mucilaginosus* for its significant role in the processing of potassium through its secretion of organic acids and polysaccharides[6, 35, 53, 24, 50].

Worm fertilizer contains many enzymes that increase the activity of living organisms and their activity in the soil, which will increase the availability of significant nutrients, including potassium, in the plant. The dual interaction of bacterial inoculum and phosphate rock (P + B) in the plant produced significant differences in the concentration of available potassium in the Plant 3.292 mg.K.kg^{-1} compared to the control. This may be attributed to the fact that inoculation of phosphate rocks with phosphate-dissolving bacteria caused an increase in the availability of phosphorus and potassium in the soil and the absorption of nitrogen, phosphorous, and potassium from roots and leaves. On the other hand, the dual interaction of vermicompost and phosphate rock (P + V) achieved significant differences in the concentration of available potassium in the Plant 3.359 mg.K.kg^{-1}compared to the control. This reason is that vermicompost plays an essential role in the plant's life, such as fixing nitrogen, dissolving phosphates, releasing potassium, producing amino acids, secreting growth stimulants, and protecting against pathogens[2].

The nutrients released by organic matter when decomposing in the soil are reflected in the growth and activity of the plant and its ability to absorb nutrients, including potassium[15]. The table results confirmed that the triple interaction B1V1P1 led to a significant increase in the concentration of ready potassium in the plant at the level of 100 kg.ha^{-1}, 3.528 mg.K.kg^{-1} compared with the control 1.978 mg.K.kg^{-1}.

Table 4: Effect of *Bacillus megatherium*, Vermicompost and phosphate rock on potassium concentration (mg.K.kg^{-1}) in the vegetative part of the plant

Rock phosphate (P)	**Vermicompost (V)**	**Bacterial Bio-fertilizer**		**Mean of binary overlap P * V**
		B_0	**B_1**	
P_0	**V0**	1.978	2.288	2.133
	V1	2.448	2.798	2.623
P_1	**V0**	2.861	3.055	2.958
	V1	3.189	3.528	3.359
P_2	**V0**	3.013	3.387	3.200
	V1	2.784	2.502	2.643
LSD .05		**0.175**		**0.124**
Binary overlap B * P				
Rock phosphate (P)		**Bacterial Bio-fertilizer**		Mean of (P)
		B_0	**B_1**	
P_0		2.213	2.543	2.378
P_1		3.025	3.292	3.159
P_2		2.898	2.945	2.922
LSD .05		**0.124**		**0.088**
Binary overlap B * V				

Vermicompost (V)	Bacterial Bio-fertilizer		Mean of (V)
	B_0	B_1	
V0	2.617	2.910	2.764
V1	2.807	2.943	2.875
LSD .05	**0.101**		**0.071**
Mean of (B)	2.712	2.927	
L.S.D. .05	**0.071**		

The effect of biological fertilizer (bacterial), vermicompost, and phosphate rock on seeds yield ($kg.ha^{-1}$)

Table (5) presents that the bacterial inoculation B1 application resulted in a significant increase in the total grain yield. The highest average grain yield was (2293 $kg.ha^{-1}$) compared to the comparison treatment B_0. It is attributed to the role of *Bacillus megaterium*, which works to release phosphorous from its non-available sources, thus increasing the number of dissolved orthophosphates and increasing the plant's ability to absorb it, as well as the ability of this bacteria to secrete the enzyme phosphatase[48].

The results showed that V1 worm fertilizer's application resulted in a significant increase in the total grain yield. The highest average grain yield was (2289) $kg.ha^{-1}$ compared with the control treatment V_0. It is attributed to the role of vermicompost in increasing the readiness of nutrients and then increasing the absorption of N.P.K., which will positively affect the growth of the plant and then increase the activity and growth of the root system and increase the yield and the early growth and ripening and increase the weight of the seeds. The application of different levels of phosphate rock resulted in significant differences in the total grain yield compared with the comparison treatment, achieving averages of (2407 and 2313) $kg.ha^{-1}$for the levels of treatments of (P1 and P2), respectively, compared to the comparison treatment (P_0), which had the minor average of (1926) $kg.ha^{-1}$. It is attributed to the increased availability of phosphorus, which is very important for storing and transporting energy. It is essential in photosynthesis and carbohydrates metabolic activities and essential for growth and production[49]. The results are consistent with [50].

The two-way interaction with the bacterial biological inoculation and worm fertilizer (V + B) resulted in significant differences in increasing the total grain yield, as it reached the highest average (2339) $kg.ha^{-1}$. It may be due to the importance of biological inoculation and worm fertilizer in improving plant growth and increasing its productivity. Bio-fertilizer encourages the absorption of water and nutrients through the secretion of hormones, enzymes, gibberellins, and some organic acids that play an essential role in changing the pH of micro-environments and contribute to dissolving some nutrients and then increasing their availability (40, 43, and 15), and this is reflected in the fullness of the grains and their weight gain. The two-way interaction produced the bacterial bio-inoculation and phosphate rock (P + B) significant differences at the level (P_1) in increasing the total grain yield, and the highest average was (2524) $kg.ha^{-1}$. Micro-soil regeneration works to weather the types of rocks when present on surfaces or in minute cracks slowly with time[51]. The results are consistent with[52].

The double overlap of vermicompost and phosphate rock (V + P) resulted in the highest mean increase in the total grain yield at the level (P_1), (2656) $kg.ha^{-1}$. It is due to the role of vermicompost and phosphate fertilizer in increasing the efficiency of the photosynthesis process and transporting the metabolites from the sites of their manufacture in the leaves to the storage sites in the grains, as well as increasing energy production, the formation of ATP, building sugars, starches, and proteins, building sebum and forming nucleic acids that are stored in seeds. It leads to an increase in her weight, and this was obtained by both [53 and 54].

The triple interference $B_1V_1P_1$ (*Bacillus* + vermicompost + phosphate rock) resulted in a significant increase in the total grain yield at the level (100) kg.ha^{-1}, as it reached the highest average (2808) kg.ha^{-1}, compared to the comparison treatment, which had the lowest average of (1692) kg.ha^{-1}.

Table (5): Effect of *Bacillus* bacteria, vermicompost, and phosphate rock on seed yield (kg.ha^{-1}).

Rock phosphate (P)	**Vermicompost (V)**	**Bacterial Bio-fertilizer**		**Mean of binary overlap P * V**
		B_0	**B_1**	
P_0	**V0**	1692	1852	1772
	V1	1993	2167	2080
P_1	**V0**	2076	2240	2158
	V1	2504	2808	2656
P_2	**V0**	2384	2646	2497
	V1	2217	2043	2130
LSD .05		130		92
Binary overlap B * P				
Rock phosphate (P)		**Bacterial Bio-fertilizer**		Mean of (P)
		B_0	**B_1**	
P_0		1843	2009	1926
P_1		2290	2524	2407
P_2		2283	2344	2313
LSD .05		92		
Binary overlap B * V				
Vermicompost (V)		**Bacterial Bio-fertilizer**		Mean of (V)
		B_0	**B_1**	
V0		2038	2246	2142
V1		2238	2339	2289
LSD .05		75		53
Mean of (B)		2138	2293	
LSD .05		53		

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