EVALUATION OF THE COMBINATION OF BACTERIAL BIOFERTILIZER AND VERMICOMPOST IN THE AVAILABILITY OF N, P, K AND SOME OF PLANT PARAMETERS OF BEANS (*PHASEOLUS VULGARIS* L.)

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ABSTRACT

A field experiment was carried out at the Agricultural Research and Experiments (station A), which belong to the college of Agricultural Engineering Sciences/University of Baghdad with a silty loam soil by using Randomized Block Design with three replicates to evaluate the effect of using a combination of bacterial biofertilizer consist of *Bacillus megaterium* , *Bacillus mucilagenosus* and *Rhizobium phaseoli* with two levels of vermicompost (0 and 10 mcgh^{-1}) on plant growth parameters of Green Beans and its yield and availability of N,P and K in soil under two levels of mineral fertilization (0% and 50%) of fertilizer recommendation in addition to using the full fertilizer recommendation treatment(100%) as a second control treatment. The results showed the significant superiority of the bacterial combination biofertilizer with (10 mcgh^{-1}) vermicompost and 50% of mineral fertilizer compared with the treatment of full fertilizer recommendation in most of the growth and yield parameters of green beans, as the number of pods, nodules number and total yield were 150.00 plant pod^{-1} ,8.33 plant node^{-1}and 71.48 mcg h^{-1}respectively,whereas the soil content of a available NPK was 85.00,14.00 and 198.00 mcgh^{-1} in the same treatment above respectively in compare with the control(without any addition) treatment which its availability of NPK was (29.00,4.07 ,89.00)mgkg^{-1}respectively.

Keywords: earthworms, bacillus, rhizobium, legume.
[*]Part of M.S.C thesis of the 1st author.

تقييم توليفة سماد حيوي بكتيري والفيرمكمبوست في جاهزية K,P,N وبعض معايير نمو نبات الفاصولياء *Phaseolus* (*vulgaris* L .)

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المستخلص

نفذت تجربة حقلية في تربة مزيجة غرينية وفق تصميم القطاعات العشوائية الكاملة وبثلاث مكررات في أحد حقول كلية علوم الهندسة الزراعية/جامعة بغداد لتقييم تاثير استخدام توليفة من بكتريا *Bacillus megaterium* و *Bacillus mucilagenosus* و *Rhizobium phaseoli* مع مستويين من سماد الفيرمكمبوست (0% و10 ميكاغرام ه$^{-1}$) في معايير نمو الفاصوليا الخضراء وحاصله وجاهزية N وP و K في التربة تحت مستويين من السماد المعدني (0% و50%)من التوصية السمادية فضلاً عن استعمال معاملة التوصية السمادية الكاملة 100% كمقارنة ثانية.اظهرت النتائج تفوق معاملة اضافة خليط توليفة السماد الحيوي البكتيري مع الفيرمكمبوست مع 50% من السماد المعدني معنوياً مقارنة بمعاملة التوصية السمادية الكاملة في اغلب صفات النمو والحاصل لنبات الفاصوليا الخضراء اذ بلغ عدد القرنات، عدد العقد الجذرية والحاصل الكلي (150.00 قرنة نبات$^{-1}$ ، 8.33 عقدة نبات$^{-1}$ و71.48 ميكاغرام ه$^{-1}$)على التتابع وبلغ محتوى التربة من النتروجين والفسفور والبوتاسيوم الجاهز في نفس المعاملة اعلاه (85.00 و14.50 و198.00)ملغم كغم $^{-1}$ على التتابع مقارنة بمعاملة المقارنة الاولى(بدون أي اضافة) والتي بلغ الجاهز من KPN فيها 29.00 و4.07 و89.00 ملغم كغم $^{-1}$ على التتابع.

الكلمات المفتاحية: ديدان الأرض ، بكتيريا الباسلس ، بكتريا الرايزوبيا ، البقوليات .
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INTRODUTON

To achieve sustainable agriculture, all countries attempt to increase crop yield through improving soil fertility and addition huge amount of mineral fertilizers which cause later different problems for environment and human health, where for researchers develop a new eco-friendly technology referred to as biofertilization. Biofertilization is a modern method used to reduce the risk of excessive addition of mineral fertilizers, decreasing yield costs and improve soil properties (11), biofertilizer was classified according to nutrients suppling to nitrogen biofertilizer like symbiotic nitrogen fixer rhizobia, phosphorous biofertilizer like *bacillus megaterium* and potassium biofertilizer like *bacillus mucilaginosus* which increase the availability of potassium (13,20), add to that soil containing earthworms which play an important role as decomposers as well as it produce a substance rich in its nitrogen, phosphorous, potassium, iron and other content referred to as cast (8). The term vermicompost considered as a very good organic fertilizer because of its nutrients content and enzymes activity (14). This study aimed to evaluate the effect of combination of bacterial biofertilizer consist from nitrogen fixing bacteria, phosphate dissolving bacteria and potassium releasing bacteria on the growth and yield of green bean and on the availability of some soil nutrients under different mineral fertilizer levels.

MATERIALS AND METHODS

Vermicompost preparation

Imported earth worms were grown in plastic containers (56 length * 23 width * 26 height) cm to produce vermicompost, after brushing these containers with sawdust, different daily kitchen foods were added with maintaining temperature around 25-30ºC, starvation method were used to exclude earthworms and obtain vermicompost (7).

Isolation and Diagnosis of *Bacillus megaterium*

Bacillus megaterium was isolated from rhizosphere soil of Alfalfa, eggplant, okra and cowpea, serial dilutions were cultured on solid Pikovskaya medium and then cultural, microscopical and biochemical test were used to diagnose these bacterial colonies that showed clean zone around due to the solubility of phosphate (26).

Rhizobium phaseoli

Abacterial isolate of *Rhizobium phaseoli* was obtained from Ministry of Sciences and Technology/Biotechnology laboratory, this isolate recaptured on Yeast Extract Mannitol Agar and smear of its growth were examine under oil lens of light microscope to make sure from its cell shape and its response to gram staining.

Bacillus mucilaginosus

This isolated was obtained from postgraduate research laboratory /soil sciences and water resources department which isolated from previous study and recaptured on nutrient agar medium.

Field experiment

A field experiment was carried out at college of Agricultural Engineering Sciences / University of Baghdad in silty loam soil in September 2019, before planting, soil samples of depth 0-30 cm were taken to measure chemical, physical and biological properties Table1. The field experiment was carried out with Completely Randomized Block Design (RCBD) and included the following factors.

The first factor: biofertilizer types

*without biofertilizer which is symbolized by (N)

*combination of *Bacillus megaterium, Rhizobium phaseoli* and *Bacillus mucilagenosus* symbolized by (T)

**Rhizobium Phaseoli* fertilizer only symbolized by (R)

**Bacillus megaterium* fertilizer only, symbol (M)

**Bacillus mucilaginosus* fertilizer only, symbol (S)

The second factor: vermicompost

*without vermicompost (V_0).

*with 10 Mg ha $^{-1}$ vermicompost (V_1).

The third factor: mineral fertilization

*without mineral fertilizer (C_0).

*50% of the full recommendation of mineral fertilizer for NPK (C_1).

A drip irrigation system was used to irrigate

The plants after depletion 35% of available water, mineral fertilizers of NPK and vermicompost of the experimental treatments were added before planting, two green beans seeds (Masslawi variety) were planted in each hole on the top of furrows, after germination one plant remain for each hole, the distance between each plant was 25 cm.

Table 1. Some chemical, physical and biological characteristics of the study soil before planting

Character		The value	Unit
$(pH)_{1:1}$		7.60	
$(EC)_{1:1}$ Electrical conductivity		1.70	dSm^{-1}
Organic Matter		9.1	$g\ kg^{-1}$ soil
Available nitrogen		41.20	$mg\ kg^{-1}$ soil
Available phosphorus		4.80	
Available potassium		130.0	
Soil separates	Clay	231.00	$g\ kg^{-1}$ soil
	Silt	569.00	
	Sand	200.00	
Texture		Silty Loam	
Total fungi number		2.4×10^{-4}	C.F.U g^{-1} dry soil
Total bacteria number		4.6×10^{-6}	

Preparation of Bacterial inoculum of *Rhizobium phaseoli, Bacillus megaterium* and *Bacillus mucilagenosus*

Ten ml of each inoculum which prepared previously was added to log of sterilized peat moss and mixed well then incubated at 28ºC for 48 h (16, 30) Green bean seeds were washed by sterile water many times then it divides into five section, each one was then put in sterile plastic container, seeds were moistened with 20% solution of arabic gum. The inoculum of each three bacteria and the combination of each of these three bacterial isolates was added separately to each section of beans seeds while the seeds of section five left without inoculation, seeds were left for one hour before planting in the field to ensure inoculums adhere well to it. The field experiment lasted for five months, plant height, dry weight of shoot part, the number of pods, the number of root nodules and total yield were calculated at the end of field experiment while available nitrogen, phosphorus and potassium was measured.

RESULTS AND DISCUSSION

Plant height (cm)

The results of table 2 showed that addition of bacterial biofertilizer led to a significant increase in the plant height. The treatment of the addition of combination biofertilizer *Rhizobium phaseoli*, *Bacillus megaterium* and *Bacillus mucilagenosus* (T) gave the highest plant height 70.25 cm and it was superior compared to the treatment without adding (N) which was 57.89 cm and the other single biofertilizer treatment. The addition of vermicompost affect significantly and gave 68.95 cm compared with no addition 61.76 cm. The combination between bacterial biofertilizer with vermicompost and 50% of mineral fertilizer gave the superior plant height value 76.56 cm compared to adding full fertilizer recommendation that gave 68.78 cm.

Table 2. Effect of bacterial biological fertilization, vermicompost and mineral fertilizer on green beans plant height (cm)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	60.00	62.22	60.22	64.22	44.67	58.27
	Added 10 Mg ha^{-1}	66.44	68.67	63.44	70.33	62.89	66.35
Add 50% recommendation	Not added	65.44	67.44	65.67	69.89	57.89	65.27
	Added 10 Mg ha^{-1}	70.11	74.78	70.22	76.56	66.11	71.56
LSD 5%				2.01			0.90
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer means
0 %		63.22	65.44	61.83	67.27	53.78	62.31
Add 50% recommendation		67.77	71.11	67.94	73.22	62.00	68.41
LSD 5%				1.42			0.63
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		62.72	64.83	62.95	67.06	51.28	61.76
Added 10 Mg ha^{-1}		68.28	71.73	66.83	73.45	64.50	68.95
LSD 5%				1.42			0.63
Biofertilizer mean		65.50	68.28	64.89	70.25	57.89	
LSD 5%				1.00			
Mean full fertilizer treatment				68.78			
LSD 5%				1.96			

Shoot dry weight (g plant^{-1})

The results of table 3 this study showed an increase in shoot dry weight of green beans plant due to the addition of biofertilizer. The treatment of the addition of combination biofertilizer (T) gave the highest value of shoot dry weight 92.98 g plant^{-1} compared to control treatment (without addition of biofertilizer) that gave 52.65 g plant^{-1}, on the other hand addition of vermicompost gave 86.96 g plant^{-1} shoot dry weight compared with 70.10 g plant^{-1} for the treatment of without vermicompost. Addition of 50% of mineral fertilizer recommendation cause increase in shoot dry weight to 82.39 g plant^{-1} compared with 74.67 g plant^{-1} for the treatment without mineral fertilizer. The statistical analysis of the triple interaction between bacterial biofertilizer, vermicompost and 50% mineral fertilizer showed its superiority and gave 106.71 g plant^{-1} compared with the other triple interaction treatments and full mineral fertilizer recommendation treatment that gave 79.75 g plant^{-1} while the lowest value was 30.12 g plant^{-1} for the control treatment.

Table 3. Effect of bacterial biological fertilization, vermicompost and Mineral fertilizer on the dry weight of the green bean plant (g plant $^{-1}$)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	63.96	82.49	65.75	82.49	30.12	64.96
	Added 10 Mg ha^{-1}	89.88	83.24	86.91	93.69	68.21	84.39
Add 50% recommendation	Not added	87.34	90.20	74.58	89.04	35.04	75.24
	Added 10 Mg ha^{-1}	92.32	84.11	87.37	106.71	77.22	89.55
LSD 5%				7.36			3.29
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		76.92	82.86	76.33	88.09	49.16	74.67
Add 50% recommendation		89.83	87.15	80.97	97.87	56.13	82.39
LSD 5%				N. S			2.33
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		75.65	86.35	70.17	85.77	32.58	70.10
Added 10 Mg ha^{-1}		91.10	83.68	87.14	100.20	72.72	86.96
LSD 5%				5.21			2.32
Biofertilizer mean		83.38	85.01	78.65	92.98	52.65	
LSD 5%				3.68			
Mean full fertilizer treatment				79.75			
LSD 5%				7.24			

Non-significant: N.S*

Nodules number

The results of table (4) showed that there was a significant increase in nodules number with the addition of biofertilizer, *Rhizobium phaseoli* treatment gave the highest number of nodules 19.25 nodule plant^{-1} which the control treatment gave the lowest value 2.59 nodule plant^{-1}. Addition of vermicompost caused significant increase in nodules number 7.93 nodule plant^{-1} compared with the treatment of free of vermicompost 6.40 nodule plant^{-1}, while the addition of 50% of mineral fertilizer gave 6.33 nodule plant^{-1} compared with 7.99 nodule plant^{-1} for the treatment of free of mineral fertilizer. The statistical analysis showed the superiority of the combination between Rhizobial biofertilizer and vermicompost and the treatment of *Rhizobium phaseoli* alone which gave the same number 22.33 nodule plant^{-1}, followed by the treatment of *Rh. phaseoli* with vermicompost and 50% mineral fertilizer that gave 19.33 nodule plant^{-1} while the nodule number was 1.67 nodule plant^{-1} in case of addition of vermicompost with 50% mineral fertilizer but without addition of *Rh. phaseoli* inoculum.

Table 4. Effect of bacterial biological fertilization, vermicompost and Mineral fertilizer on the nodules number of green beans (nodule plant $^{-1}$)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	3.00	22.33	3.00	6.00	2.67	7.40
	Added 10 Mg ha^{-1}	6.00	22.33	2.00	9.33	3.33	8.60
Add 50%	Not added	2.33	13.00	3.00	7.00	1.67	5.40
Recommendation	Added 10 Mg ha^{-1}	3.00	19.33	3.00	8.33	2.67	7.27
LSD 5%				1.69			N. S
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		4.50	22.33	2.50	7.66	3.00	7.99
Add 50% recommendation		2.66	16.16	3.00	7.66	2.17	6.33
LSD 5%				1.20			0.53
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		2.67	17.67	3.00	6.50	2.17	6.40
Added 10 Mg ha^{-1}		4.50	20.83	2.50	8.83	3.00	7.93
LSD 5%				1.20			0.53
Biofertilizer mean		3.58	19.25	2.75	7.67	2.59	
LSD 5%				0.85			
Mean full fertilizer treatment				2.67			
LSD 5%				1.65			

Pods number

The results in table 5 showed the superiority of the treatment of the combination of bacterial biofertilizer (*Rh. phaseoli + B.megaterium +B.mucilagenosus*) in the number of pods that gave 129.67 pod plant^{-1} while the control treatment (without biofertilizer) gave the lowest value 94.17 pod plant^{-1}. The number of pods increase significantly due to the addition of vermicompost compared with no addition and gave the value 126.53 and 102.33 pod plant^{-1} respectively. Addition of 50% mineral fertilizer led to increase significantly the number of pods compared with the control treatment (without mineral fertilizer) and gave 122.50 and 106.36 pod plant^{-1}. The results shows that the number of pods increase significantly to 150.00 pod plant^{-1} due to the addition of bacterial biofertilizer with vermicompost and 50% mineral fertilizer compared with control treatment (without any type of fertilizer) that was 71.00 pod plant^{-1}.

Table 5. Effect of bacterial biological fertilization, vermicompost and Mineral fertilizer on the characteristic of the number of pods of green beans (pod plant $^{-1}$)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	88.00	106.67	95.00	112.33	71.00	94.60
	Added 10 Mg ha^{-1}	119.33	128.67	111.00	131.33	100.33	118.13
Add 50%	Not added	107.00	113.67	105.67	125.00	99.00	110.07
Recommendation	Added 10 Mg ha^{-1}	138.00	144.00	136.33	150.00	106.33	134.93
LSD 5%				6.26			N. S
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		103.66	117.67	103.00	121.83	85.66	106.36
Add 50% recommendation		122.50	128.83	121.00	137.50	102.66	122.50
LSD 5%				N. S			1.98
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		97.50	110.17	100.34	118.67	85.00	102.33
Added 10 Mg ha^{-1}		128.67	136.34	123.67	140.67	103.33	126.53
LSD 5%				4.43			1.98
Biofertilizer Mean		113.08	123.25	112.00	129.67	94.17	
LSD 5%				3.13			
Mean full fertilizer treatment				119.00			
LSD 5%				6.20			

Non-significant: N.S*

Total yield (Mg ha^{-1})

Results in table (6) shows that addition of bacterial biofertilizer combination increase total yield of green beans significantly and gave 57.39 Mg ha^{-1} compared with the total yield of single biofertilizer and control treatment which gave the lowest value 35.72 Mg ha^{-1}. The addition of vermicompost led to significant increase in total yield compared with no addition and gave 56.31 and 41.30 Mg ha^{-1} respectively, while addition of 50% mineral fertilizer increase the total yield to 54.81 Mg ha^{-1} compared with the control treatment 42.80 Mg ha^{-1}. The results showed the superiority of the addition combination of bacterial biofertilizer with vermicompost and gave total yield 65.43 Mg ha^{-1} while the lowest value of total yield was 27.98 Mg ha^{-1} with the treatment of without biofertilizer and vermicompost. On the other hand, the results of the triple interaction between biofertilizer + vermicompost +50% mineral fertilizer shows its superiority ang gave 71.48 Mg ha^{-1} compared with other triple interactions while addition of full fertilizer recommendation gave 48.46 Mg ha^{-1} compared with 22.36 Mg ha^{-1} for the control treatment.

Table 6. Effect of bacterial biological fertilization, vermicompost and Mineral fertilizer on the total yield of green beans (Mg ha^{-1})

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	34.16	42.68	37.18	44.57	22.36	36.19
	Added 10 Mg ha^{-1}	48.52	55.25	45.62	59.38	38.32	49.42
Add 50%	Not added	45.88	52.86	45.64	54.14	33.60	46.42
Recommendation	Added 10 Mg ha^{-1}	65.34	68.62	62.02	71.48	48.58	63.21
LSD 5%				1.57			0.70
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		41.34	48.96	41.40	51.97	30.34	42.80
Add 50% recommendation		55.61	60.74	53.83	62.81	41.09	54.81
LSD 5%				1.11			0.49
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		40.02	47.77	41.41	49.36	27.98	41.30
Added 10 Mg ha^{-1}		56.93	61.94	53.82	65.43	43.45	56.31
LSD 5%				1.11			0.49
Biofertilizer mean		48.48	54.85	47.62	57.39	35.72	
LSD 5%				0.78			
Mean full fertilizer treatment				48.46			
LSD 5%				1.53			

Available Nitrogen, phosphorus and Potassium in the soil

Available nitrogen : The results in table 7 shows the significant effect of the treatment biofertilizer combination on the availability of nitrogen that gave 72.25 mg N kg^{-1} soil, followed by *Rhizobium phaseoli* treatment 67.50 mg N kg^{-1} soil , while the available nitrogen was 52.25 mg N kg^{-1} soil in case of no addition of biofertilizer. The addition of vermicompost increase significantly the available nitrogen to 77.10 mg N kg^{-1} soil compared with 48.20 mg N kg^{-1} soil for treatment without vermicompost while addition of 50% mineral fertilizer increase available nitrogen to 67.00 mgNkg^{-1} soil compared with 58.30 mg N kg^{-1} soil if mineral fertilizers were not added. On the other hand results showed the superiority of the triple interaction between the combination of bacterial biofertilizer, vermicompost and 50% mineral fertilizer that gave the value 85.00 m N kg^{-1} soil followed by *Rhizobium phaseoli* treatment with vermicompost and 50% mineral fertilizer that gave 84.00 mg N kg^{-1} soil while the control treatment (without addition of any type of fertilizer) that gave the lowest value 29.00 mg N kg^{-1} soil but the available nitrogen was 61.00 mg N kg^{-1} soil in the treatment of full addition of mineral fertilizer.

Table 7. Effect of bacterial biological fertilization, vermicompost and Mineral fertilizer on the available nitrogen (mg N kg^{-1} soil)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	42.00	50.00	41.00	60.00	29.00	44.40
	Added 10 Mg ha^{-1}	71.00	78.00	69.00	80.00	63.00	72.20
Add 50%	Not added	51.00	58.00	49.00	64.00	38.00	52.00
Recommendation	Added 10 Mg ha^{-1}	80.00	84.00	82.00	85.00	79.00	82.00
LSD 5%				1.09			0.49
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		56.50	64.00	55.00	70.00	46.00	58.30
Add 50% recommendation		65.50	71.00	65.50	74.50	58.50	67.00
LSD 5%				0.77			0.34
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		46.50	54.00	45.00	62.00	33.50	48.20
Added 10 Mg ha^{-1}		75.50	81.00	75.50	82.50	71.00	77.10
LSD 5%				0.77			0.34
Biofertilizer mean		61.00	67.50	60.25	72.25	52.25	
LSD 5%				0.54			
Mean full fertilizer treatment				61.00			
LSD 5%				1.07			

Available phosphorus

The result of table 8 shows, the significant effect of biofertilizer on the availability of phosphorus in soil with the superiority of the bacterial biofertilizer combination that gave 10.55 mgPkg^{-1} soil followed by *Bacillus megaterium* treatment that gave 9.91 mg P kg^{-1} soil while the control treatment (without biofertilizer) gave 7.43 mg P kg^{-1} soil only. Addition of vermicompost increase available phosphorus in soil significantly to 11.56 mg P kg^{-1} soil compared to 6.65 mg P kg^{-1} soil in case of without vermicompost. The results of the triple interaction between the combination of biofertilizer, vermicompost and 50% of mineral fertilizer show superiority in the available phosphorus and gave 14.50 mg P kg^{-1} soil followed by the treatment *Bacillus megaterium* with vermicompost and 50% mineral fertilizer that gave 14.20 mg P kg^{-1} soil compared with the control treatment (without addition of any type of fertilizer) that gave 4.07 mg P kg^{-1} soil while the mineral fertilizer recommendation of NPK(second control) gave 8.00 mg P kg^{-1} soil.

Table 8. Effect of biological fertilization, vermicompost and Mineral fertilizers on the available phosphorus (mg kg^{-1}soil)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	7.40	6.43	6.00	7.60	4.07	6.30
	Added 10 Mg ha^{-1}	10.80	9.60	9.10	11.40	7.90	9.76
Add 50% recommendation	Not added	7.23	7.00	6.80	8.70	5.27	7.00
	Added 10 Mg ha^{-1}	14.20	13.00	12.70	14.50	12.47	13.37
				0.45			0.20
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		9.10	8.01	7.55	9.50	5.98	8.03
Add 50% recommendation		10.71	10.00	9.75	11.60	8.86	10.18
				0.32			0.14
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		7.32	6.72	6.40	8.15	4.67	6.65
Added 10 Mg ha^{-1}		12.50	11.30	10.90	12.95	10.18	11.56
LSD 5%				0.32			0.14
Biofertilizer mean		9.91	9.01	8.65	10.55	7.43	
LSD 5%				0.23			
Mean full fertilizer treatment				8.00			
LSD 5%				0.44			

Available potassium

The results of table (9) shows the significant effect of the bacterial biofertilizer combination which superiority compared to other treatments and gave 167.75 mg K kg^{-1} soil followed by *Bacillus mucilagenosus* treatment 165.00 mg K kg^{-1} soil while the control treatment gave 129.50 mg K kg^{-1} soil. Addition of vermicompost led to increase the available potassium compared with no addition and gave 176.06, 130.86 mg K kg^{-1} soil respectively, while addition of 50% mineral fertilizer increase K availability to 161.03 mg K kg^{-1} soil compared with 145.90 mg K kg^{-1} soil for control treatment. On the other hand results showed a significant effect of the triple interaction between bacterial biofertilizer, vermicompost and 50% mineral fertilizer that gave the highest value 198.00 mg K kg^{-1} soil followed by *Bacillus mucilagenosus* with vermicompost with 50 % mineral fertilizer that gave 196.00 mg K kg^{-1} soil compared with 89.00 mg K kg^{-1} soil for the control treatment (without addition of any type of fertilizer), while the full addition of mineral fertilizer of NPK gave 146.00 mg K kg^{-1} soil.

Table 9. Effect of bacterial biological fertilization, vermicompost and mineral fertilizer on the amount of available potassium in the soil (mg K kg^{-1}soil)

Mineral fertilization	Vermicompost	Bio-bacterial fertilizer					Vermicompost x Mineral fertilization
		M	R	S	T	N	
Not added	0 Mg ha^{-1}	128.00	136.00	140.00	143.00	89.00	127.20
	Added 10 Mg ha^{-1}	158.00	163.67	179.00	181.00	141.33	164.60
Add 50% Recommendation	Not added	136.00	141.00	145.00	149.00	101.67	134.53
	Added 10 Mg ha^{-1}	176.00	181.67	196.00	198.00	186.00	187.53
LSD 5%				2.79			1.25
Mineral fertilization		Biofertilizer x Mineral fertilization					Mineral fertilizer mean
0 %		143.00	149.83	159.50	162.00	115.16	145.90
Add 50% recommendation		156.00	161.33	170.50	173.50	143.83	161.03
LSD 5%				1.97			0.882
Vermicompost		Biofertilizer x Vermicompost					Vermicompost mean
0 Mg ha^{-1}		132.00	138.50	142.50	146.00	95.34	130.86
Added 10 Mg ha^{-1}		167.00	172.67	187.50	189.50	163.67	176.06
LSD 5%				1.97			0.88
Biofertilizer mean		149.50	155.59	165.00	167.75	129.50	
LSD 5%				1.40			
Mean full fertilizer treatment				146.00			
LSD 5%				2.76*			

From the results in tables (2,3,4,5 and 6), the data indicating that the addition of biofertilizer caused increased in the growth parameters of green beans, the combination of bacterial biofertilizer play a positive role because all these three growth promoting Rhizobacteria have an active role to produce various growth regulators like Auxin, gibberellins and cytokinin in addition to its role in increase the availability of macro and micro nutrients which lead to the development of plant shoot due to cell division and elongation and these results came in agreement with (12) , (24) and (27). On the other hand, the addition of *Rhizobium phaseoli* biofertilizer caused penetration of bean root hair and formation of active root nodules that fix nitrogen and increase its concentration in shoot part and pod of beans plant and the separation of old nodules from root system to the soil and after decomposition of these nodules the available nitrogen increase in the soil (9 and 22). Results of this study shows that bacterial biofertilizer increase number of pods and total yield and these may due to the increasing in the amount of available nitrogen, phosphorus and potassium that uptake by plant (5 and 16). From the results of this study, data indicate that addition of vermicompost lead to increase in all plant growth parameters. On other hands the increase in plant growth parameters due to addition of vermicompost may due to its high solubility in water which making the growth medium of plant suitable for up taking nutrients, In addition vermicompost contains essential nutrients such us nitrogen, phosphorus, potassium and calcium add to that vermicompost play a good role in improving root development through its positive effect on the physical properties of soil. In addition to the role of vermicompost in providing adequate moisture and nutrients around root system which increase its absorption by the roots and improve growth of vegetative part that reflect on plant growth by transferring metabolites to the shoot and then to the pods and in the end increase total yield (4, 21 and 28). As for chemical fertilizers, which have a significant effect on plant growth and yield may be due to the role of the fertilizers in increasing that availability of NPK in soil solution which increase their absorption by the plant that reflect positively on the biosynthesis of food used by plant to build its necessary tissues because of the role of nitrogen in the activity of meristematic cells (2 , 9). The positive effect of the addition of combination of bacterial and mineral fertilizer in increasing the number of root nodules may attributed to the effect of biofertilizer in improving the properties of bean rhizosphere which is reflected positively on plant growth (3,6). The results shows the significant effect of the interaction between biofertilizer, vermicompost and mineral fertilizer and this may due to the role of vermicompost as organic materials rich in nutrients as well as maintains a high level of moisture that consider as good environment for growth of soil microorganisms that use these compost as carbon and energy (17, 23). It is evident from the results of table (7,8 and9) that addition of bacterial biofertilizer had clear significant effects in increasing the available nitrogen, phosphorus and potassium in the soil after planting and these results may due to the role of these bacteria that stimulate plant growth through nitrogen fixation by *Rhizobium phaseoli* or dissolving phosphate by *Bacillus megaterium* or release potassium by *Bacillus mucilagenosus* add to that production of different growth regulators and hormones from these bacteria and all these reflect on the availability of NPK in soil, these results came in agreement with (1), (10), (15) and (20). As for as the increase in the available phosphorus may due to the dissolution process that occurs by *Bacillus megaterium* because of its ability to secrete various organic acids like acetic, lactic, succinic, is butyric, oxalic, citric and ketoaldonic acid which cause increase the solubility of insoluble phosphate compounds and these results agree with the finding of (19), as well as the production of phosphatase enzyme that help to liberation of phosphorus in the soil (18). On other hand, the increasing in potassium availability after the addition of *Bacillus mucilagenosus* biofertilizer may due to the role of this bacteria to produce different enzymes like nuclease, endoglucanase, cellobiose, protease, ribonuclease, dioxo nuclease and phosphomonoester's which play an essential role in the mechanism of potassium liberation (25, 29).

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