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EFFECT OF *Bacillus Circulans* AND *Azotobacter Chroococcum* INOCULATION ON POTATO RODUCTION IN PRESENCE OF DIFFERENT MINERAL POTASSIUM SOURCES

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ABSTRACT

A field experiment was conducted at EL- Ismaielia Agric. Res. Station (ARC), EL- Ismaielia Governorate, in the winter season of 2007 / 2008, to study the effect of inoculation with either *Azotobacter chroococcum* (nitrogen fixers and plant growth promoters) or *Bacillus circulans* (Silicate potassium) dissolving bacteria on the availability of potassium from both potassium sulfate (48 % K_2O) and feldspar (10.5% K_2O) as a natural source of potassium to potato plants, as well as, to investigate their effect on potato yield and its characters and soil available N, P and K contents after potato harvesting and soil biological activities. Results indicated that inoculation with *B. circulans and Azotobacter chroococcum* in the presence of different potassium sources increased all examined potato tuber yield, tuber content of carbohydrate and soluble sugar, soil biological activity and soil available N, P and K compared to the sole use of K- sources. The dual inoculation with *B. circulans and Azotobacter chroococcum* in combination with both K-sources at both tested levels surpassed all the tested treatments and gave the highest potato tuber yield with priority of K- sulfate source than K- feldspar source. However, the use of potassium (K-rock) minerals in combination with biofertilizers can be agronomically more useful and ecofriendly more feasible than that of the soluble sulphate- K.

INTRODUCTION

Potato is the most important food crop I the world after wheat, rice and maize. Potato is a heavy feeder of K, and commonly it suffers from soil-K deficiency leading to disease, pest problems, frost damage, poor yield and reduced quality (Umar and Moinddin, 2001). On the other hand, K deficiencies become problem because K decreases easily in soils due to crop uptake, runoff, leaching and soil erosion (Sheng and Huang 2002). Rock potassium materials may be agronomically more useful and environmentally more feasible than soluble K (Rajan *et al.*, 1996). Rock K materials are cheaper sources of K; however, most of them are not readily available to a plant because the minerals are released slowly and their use as fertilizer often causes insignificant yield increases of current crop (Zapata and Roy, 2004). Potassium dissolving bacteria have been used to improve rock-K value because they convert insoluble K into forms available to plant growth (Lin , 2002). In This concern *Bacillus* circulans is known for its ability to solubilize rock K materials powder such as micas, illite and feldspar through production and excretion of organic acids (Ullman *et al.*, 1996). The use of

plant growth promoting rhizobacteria (PGPR), including potassium solubilizing and nitrogen fixing bacteria as biofertilizers, was suggested as a sustainable solution to improve plant nutrient and production (Vessey, 2003).

The aim of this work is to study the role of silicate bacteria (*Bacillus circulans*) and/or *Azotobacter chroococcum* inoculation both as a biofertilizer in releasing potassium from the natural source of potassium. As well as their effect on potato production and its chracters, soil available NPK soil and soil biological activity.

MATERIALS AND METHODS

A field experiment was carried out at the experimental farm of Agricultural Research Station, Ismailia Governorate, Agric Res. Center (ARC) Egypt, during the winter season of 2007-2008 under sprinkler irrigation system, to study the effect of inoculation with either *Bacillus circulans* (potassium dissolving bacteria) or *Azotobacter chroococcum* (nitrogen fixers and plant growth promoters) on the availability of potassium from both potassium sulfate (48 % K_2O) and feldspar (10.5% K_2O) as a natural source of potassium to potato plants, as well as, to investigate their effect on potato yield and its characters, soil available N, P and K contents after potato harvesting and soil biological activities.

Plant materials:

Certified seed potato tuber Nicola cultivar (locally produced and cold stored), obtained from the General Authority for Producers and Exporters of Horticulture crops, Cairo, Egypt, was used in this experiment. Nicola cultivar is medium early to medium late. The whole seed tubers were cut to small pieces each containing 2-3 buds and planted, on 15th November, 2007.

Soil properties:

Some physical and chemical analyses (Chapman and Pratt, 1961 and page *et al.*, 1982) of the experimental soil are presented in Table (1).

Table (1): Chemical and physical characteristics of the experimental soil

Sample	EC dS/m	pH	Soluble ions (meq L^{-1})								*SAR
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	
Soil	0.37	7.54	1.07	1.82	0.78	0.18	--	1.53	0.96	1.36	0.64

Particle size distribution (%)					Organic matter (%)	$CaCO_3$ (%)
Coarse sand	Fine sand	Silt	Clay	Texture class		
31.82	61.61	1.22	5.35	Sandy	0.52	1.42

***SAR = Sodium Adsorption Ratio.**

Bacteria used:

Two bacterial strains were used in this experiment. The first is *Azotobacter chroococcum* (nitrogen fixers and growth promoters) and the second is *Bacillus circulans* (potassium dissolver), both are kindly supplied with the Dept. Agric. Microbiol. Res., Soils, Water & Environ. Res. Inst., ARC, Giza, Egypt.

Inoculants preparation:

Azotobacter chroococcum inoculum:

A mixture of fine calcium carbonate neutralized peat as a carrier was packed into polyethylene bags (200 g carrier per bag), then sealed and sterilized with gamma irradiation (5.0× 10^6 rads). *Azotobacter chroococcum* was grown on the medium of Hegazy and Neimela (1976), incubated for 48 hr at 28°C to ensure population density of 10^9 cfu/ml culture and then injected into the bags containing the sterilized carrier to have 10^8 cell g^{-1} carrier.

***Bacillus circulans* inoculum:**

Vermiculite supplemented with 10 % Irish peat was packed into polyethylene bags (200 g carrier per bag), then sealed and sterilized with gamma irradiation (5.0× 10^6 rads). *Bacillus circulans* was grown on nutrient broth medium (Difico Manual, 1984) incubated for 48 hr at 28°C to ensure population density of 5×10^9 cfu/ml culture and injected into sterilized carrier as mentioned before.

The efficiency of used strain of *B. circulans* for dissolving silicate minerals was assayed using powdered mica in the Aleksandrov's liquid medium (Zahara, 1969).

The experiment was in split plot design in which the sources of potassium fertilizers represent the main plots and the bacterial inoculation represents the sub plots as in the following:

Potassium treatments (main plots):

1-Full dose of K from potassium sulphate (48 %K_2O)= 100kg $fed^{-1.}$
2-1/2 Full dose of K from potassium sulphate = 50 kg $fed^{-1.}$
3-Full dose of K from feldspar (10.5 k_2O).= 1000kg fed^{-1}
4-1/2 Full dose of K from feldspar.= 500 kg fed^{-1}

Biofertilizer treatments (sub plots):

1- *Bacillus circulans*
2- *Azotobacter chroococcum* (Azoto.)
3- *Azotobacter chroococcum* (Azoto.) + *Bacillus circulans*.
4- Without inoculation.

Consequently, the experiment comprises 16 treatments in three replicates.

In plots that received any of *Azotobacter chroococcum* or *Bacillus circulans* inoculation, potato seeds was coated with the inoculum just before planting using a solution of 10% Arabic gum as adhesive agents. Each experimental plot contained 8 rows (2 m length and 0.7 m width). Each plot received equivalent amount of 250 kg P_2O_5 fed^{-1} as superphosphate 15.5% P_2O_5 before planting. Nitrogen was added in the form of ammonium nitrate (33% N) at the rate of 120 kg fed^{-1} in four equal doses after 25, 35, 45 and 55 days from planting. Feldspar (10.5% K_2O) was added to the plots once at planting in two rates of 500 and 1000 kg fed^{-1} equivalent to 100 and 200kg potassium sulfate (48% K_2O) fed^{-1}, which was added in two split dosed at planting and after 35 days from planting.

At harvest (120 days from planting), potato tubers were collected from the two middle ridges in each plot to determine total tuber yield (ton fed^{-1}), total carbohydrate % (A. O. A. C., 1990) and total soluble sugar (Dubbois, *et al.*, 1956).

Potato rhizosphere soil was also sampled at 75 and 100 days from planting to determine the soil biological activity in terms of dehydrogenase activity (Casida *et al.*, 1964), CO_2 evolution (Pramer and Schmidt, 1964), total bacteria (Allen, 1959), actinomycetes (Williams and Davis, 1965) *Azotobacter* and *Azospirillum* (Cochran, 1950) counts were enumerated. At harvest, soil samples were collected from each plot, air dried, pulverized, passed through 2mm sieve and then subjected to determine the soil available N, p and K contents as described by Page *et al.* (1982).

All obtained results were statistically analyzed and compared to L. S. D. difference at probability level of 0.05 as described by Gomez and Gomez (1984).

RESULTS

Potato yield attributes:

Data in Table (2) indicate the effect of inoculation with *B. circulans* and/or *Azotobacter chroococcum* (biofertilizers) in the presence of different potassium sources, i.e., potassium sulfate and feldspar on potato yield attributes. Results indicated that the use of biofertilizers in combination with K sources had positively enhanced all potato attributes compared to the use of both K sources each alone. This behavior was more obvious with potassium sulfate rather than feldspar.

The use of feldspar alone at half and full dose gave relatively the lowest number of tubers $plant^{-1}$, weight of tubers $plant^{-1}$ (g) and tubers yield (tons fed^{-1}). The corresponding values were 5.17 tubers $plant^{-1}$, 309.17 g $plant^{-1}$ and 5.33 tons fed^{-1}(1/2 K dose from feldspar) and 6.83 tubers $plant^{-1}$, 341.07 g $plant^{-1}$and 7.20 tons fed^{-1} (full K dose from feldspar). The use of full K dose either from feldspar or potassium sulfate had recorded higher potato yield attributes than the use of 1/2 K dose from feldspar and/or potassium sulfate. The inoculation with *B. circulans* recorded better potato attributes than those recorded due to the inoculation with *Azotobacter chroococcum*. However, inoculation with silicate bacteria (*B. circulans*) combined with full K from feldspar gave relatively similar potato tubers yield to that obtained due to the use of full K from potassium sulphate. The corresponding potato yields were 12.24 and 12.82 tons fed^{-1}. On the other respect, the dual inoculation with *B* sulfate*. circulans* and *Azotobacter chroococcum* gave significantly the highest potato yield attributes compared to the inoculation with each alone. The highest potato yield of 15.76 tons fed^{-1} was due to full K dose from K_2SO_4 + *B. circulans* + Azoto. *chroococcum* treatment followed 14.20 tons fed^{-1} (1/2 full K dose from K_2SO_4 + *B. circulans* + Azoto. *chroococcum*) and 13.85 tons (full K dose from feldspar + *B. circulans* + Azoto. *chroococcum*)**.**

Table (2): Potato yield attributes as affected with different potassium sources and levels and inoculation with silicate bacteria (*B. circulans*) and/or *Azotobacter chroococcum*

K Source	K level	Inoculation	Number of tuber plant^{-1}	Weight of tuber plant^{-1} (g)	Tuber yield ton fed^{-1}
K_2SO_4	1/ 2 Full K dose	*B. circulans*	9.33	320.87	10.90
		Azotobacter chroococcum	7.50	300.20	08.33
	Full K dose	*B. circulans*	12.16	410.35	11.95
		Azotobacter chroococcum	8.17	365.83	12.61
Feldspar	1/ 2 Full K dose	*B. circulans*	8.12	375.12	11.65
		Azotobacter chroococcum	7.17	316.60	10.13
	Full K dose	*B. circulans*	9.00	372.00	12.24
		Azotobacter chroococcum	8.17	385.93	11.70
K_2SO_4	1/ 2 Full K dose	*B. circulans* + *Azotobacter chroococcum*	12.52	530.92	14.20
	Full K dose		14.00	640.16	15.76
Feldspar	1/ 2 Full K dose		11.10	415.20	13.31
	Full K dose		11.75	430.20	13.85
K_2SO_4	1/ 2 Full K dose	Without inoculation	9.00	348.23	09.69
	Full K dose		12.67	490.10	12.82
Feldspar	1/ 2 Full K dose		5.17	309.17	05.33
	Full K dose		6.83	341.07	07.20
L. S. D. 0.05			Ns.	Ns.	1.32

Total carbohydrate and total soluble sugar content of potato tubers:

Data in Table (3) show total carbohydrate and total soluble sugars content of potato tubers in response to inoculation with *B. circulans* and/or *Azotobacter chroococcum* (biofertilizers) in the presence of different potassium sources. The dual inoculation with *B. circulans* and/or *Azotobacter chroococcum* in combination with both K sources at both tested levels led to increase both potato carbohydrate and soluble sugars contents in comparison with those achieved with other tested treatments. The highest total carbohydrate (75.23 %) and total soluble sugars (4.36 %) contents were due to full K dose from K_2SO_4 + *B. circulans* + Azoto. *Chroococcum* treatment.

The inoculation with *Azotobacter chroococcum* enhanced the carbohydrate and soluble sugar contents of potato tubers better than the inoculation with *B. circulans*.

Table (3): Total carbohydrate content (%) and total soluble sugar content (%) in potato tubers as affected with different potassium sources and levels and inoculation with silicate bacteria (*B. circulans)* and/or *Azotobacter chroococcum*

Treatment	K - level	Inoculation	Total carbohydrate (%) *	Total soluble sugar (%)*
K_2SO_4	1/ 2 Full K dose	*B. circulans*	51.21	2.80
		Azotobacter chroococcum	58.39	3.40
	Full K dose	*B. circulans*	60.89	3.70
		Azotobacter chroococcum	61.67	3.90
Feldspar	1/ 2 Full K dose	*B. circulans*	46.22	2.70
		Azotobacter chroococcum	53.06	2.94
	Full K dose	*B. circulans*	56.83	3.20
		Azotobacter chroococcum	62.33	3.65
K_2SO_4	1/ 2 Full K dose	*B. circulans* + *Azotobacter chroococcum*	70.20	4.30
	Full K dose		75.23	4.36
Feldspar	1/ 2 Full K dose		63.31	4.21
	Full K dose		66.65	4.26
K_2SO_4	1/ 2 Full K dose	Without inoculation	49.72	2.35
	Full K dose		57.67	2.31
Feldspar	1/ 2 Full K dose		45.72	1.95
	Full K dose		51.73	2.11

Soil biological activity:

Table (4) shows the effect of the tested treatments on potato plant rhizosphere soil biological activity, measured after 75 & 95 days from potato planting in terms of dehydrogenase activity (DHA), CO_2 evolution, actinomycetes, bacteria, *Azotobacter* and *Azospirillum* counts. Results indicate that all these parameters increased in both studied periods in response to inoculation with either *B. circulans* or *Azotobacter chroococcum* and/or both together, compared to the treatment without inoculation.

Nevertheless, increasing soil rhizosphere sampling period from 75 to 95 days decreased all the measured soil biological activity parameters mentioned in Table (4). The inoculation with either *B. circulans* or *Azotobacter chroococcum* and/or both together in combination with both K sources at both levels led to increase (DHA), CO_2 evolution, actinomycetes , total bacterial count, *Azotobacter* and *Azospirillum* counts at 75 days over the treatments without inoculation.

In this period, the highest DHA of 52.86 mg TPF g^{-1} dry soil is due to dual inoculation with *B. circulans* and *Azotobacter* + Full K dose from K_2SO_4. This treatment, also had achieved the highest value of CO_2 evolution and the highest count of actinomycetes, bacteria, *Azotobacter* and *Azospirillum*. The relative values were 174.84 mg CO_2 100 g^{-1} dry soil, 22 x 10^4 cfu, 25 x 10^7 cfu, 19 x 10^4 cfu and 14 x 10^4 cfu.

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However, at 95 days, despite these parameters tended to decrease due to all the tested treatments, the dual inoculation with *B. circulans* and *Azotobacter chroococcum* + full K dose from K_2SO_4 still keeping the highest values for these biological tested parameters (Table 4).

Owing to the potassium source and levels, the use of potassium sulfate was slightly better than feldspar and the level of full K surpassed the level of half K in both K sources. Also, it is of worth to note that, both DHA and CO_2 evolution increased in both tested period along with increasing the numbers of the counted microorganisms. As well as, generally, the use of biofertilizers *B. circulans* and/or *Azotobacter chroococcum* and/or had improved the biological activity of potato rhizosphere area when compared to un-inoculated treatments.

Soil N, P and K availability:

Table (5) shows the effect of the tested treatments on soil N, P & K availability after potato harvesting. Results indicated that the application of biofertilizers combined with both K sources at both tested levels led to increase the soil N, P & K availability after potato harvesting compared to either the initial soil before potato cultivation or the other treatments received no inoculation. However, inculcation with *B. circulans* was superior in saving potassium in soil when applied with both K sources rather than *Azotobacter chroococum*.

Table (5): Soil available N, P & K after potato harvesting as affected with different potassium sources and levels and inoculation with silicate bacteria (*B. circulans*) and/or *Azotobacter chroococcum*

K Source	K level	Inoculation	Soil available nutrients (mg kg soil^{-1})		
			N	P	K
K_2SO_4	1/ 2 Full K dose	*B. circulans*	33.12	117.8	390.70
		Azotobacter chroococcum	43.97	157.20	380.00
	Full K dose	*B. circulans*	54.23	162.00	563.35
		Azotobacter chroococcum	68.20	237.60	590.00
Feldspar	1/ 2 Full K dose	*B. circulans*	44.23	139.20	466.35
		Azotobacter chroococcum	49.00	156.0	430.25
	Full K dose	*B. circulans*	50.15	140.00	625.10
		Azotobacter chroococcum	52.59	216.40	457.70
K_2SO_4	1/ 2 Full K dose	*B. circulans* + *Azotobacter chroococcum*	66.20	260.75	490.65
	Full K dose		85.12	300.86	670.25
Feldspar	1/ 2 Full K dose		60.25	190.00	430.10
	Full K dose		68.40	219.75	490.00
K_2SO_4	1/ 2 Full K dose	Without inoculation	30.20	103.80	302.00
	Full K dose		35.80	116.80	282.10
Feldspar	1/ 2 Full K dose		26.85	090.80	161.40

	Full K dose		38.94	102.75	219.10

The opposite trend for N and p was observed, since, *Azotobacter chroococum* inoculation had successfully ensured more soil available N and P rather than *B. circulans* inoculation. On the other hand, the dual inoculation with *B. circulans* and *Azotobacter chroococum* in combination with both tested K sources gave the highest soil available N, P and K compared with the other tested treatment. However, the priority was also for K-sulfate source rather than K- feldspar source when both accompanied with dual inoculation with both *B. circulans* and *Azotobacter chroococum*.

DISCUSSION

Potassium has an established reputation as a major controlling effect on tuber production in potatoes (Perrenoud , 1993). The present results indicate that co-inoculation of potato with *B. circulans and Azotobacter chroococum* in presence of 1/2 full K from feldspar gave similar potato tuber yield to that produced with full K from potassium sulphate. In this concern, Bisak and Biswas (2010) reported that co-inoculation with *B. circulans* and *Azotobacter chroococum* to forage crop received K from mica resulted in significantly higher biomass accumulation compared to uninoculated control plants. Thus, co-inoculation with K-dissolving and nitrogen fixing bacteria combined with mineral-K source could be promising and alternative option for utilizing this potent source as K fertilizer to crops and maintaining greater nutrients and availability to plants in soil and in turn improves and increases the crop yield. On the other hand, the main source of K for plants comes from K minerals and organic K-source, K-feldspar is one of the most important K minerals (Straaten, 2002). Several laboratory studies have shown that microbes can increase the dissolution rate of silicate and aluminum silicate minerals in laboratory patches experiments, primarily by generating organic and inorganic acids (Barker *et al.*, 1997).

Microbes can enhance mineral dissolution rate by producing and excreting metabolic by-products that interact with the mineral surface. Complete microbial respiration and degradation of particulate and dissolved organic carbon can elevate carbonic acid concentration at mineral surfaces, in soils and in ground water (Paris *et al.*, 1996), which can lead to an increase in the rates of mineral weathering by a proton-promoted dissolution mechanism. In addition to carbonic acid, microbes can produce and excrete organic ligands by a variety of processes such as fermentation and degradation of organic macromolecules, or as a response to nutrient stress (Berthelin, 1983 and Paris *et al.*, 1996). It is well known that many organic compounds produced by microorganisms, such as acetate, citrate and oxalate can increase mineral dissolution rate (Welch and Ullman, 1993). Carboxylic acid groups which shown to promote dissolution of silicates are also common in extra cellular organic materials. Moreover, some microorganisms in soil environment contain enzymes that function in ways

analogous to chitinase and celluloses, i.e., they specifically break down mineral structure and extract elements required for metabolism or structure purposes (e.g., mineralizes) (Barker *et al.*, 1987). In addition, *A*. *chroococcum* as soil inoculant is not only effective in nitrogen fixation but also has other properties such as production of growth hormones, production of fungicidal substances, siderophore production and the property to dissolve insoluble phosphate and releasing K from silicate in soil and add to soil fertility (Kumar and Narula, 1999).

Co-inoculation with *B. circulans* and *Azotobacter chroococum* to potato combined with 1/2 full K from feldspar, full K from feldspar and full K from potassium sulphate increased the soil biological activity in terms of dehydrogenase activity (DHA), CO_2 evolution, actinomycetes, bacteria, *Azotobacter* and *Azospirillum* counts. I this respect, Abou-Hussein *et al*. (2002) found that biofertilization of potato increased the soil microorganisms, which contribute in increasing the soil biological activity, i.e., soil enzyme activity such as dehydrogenase, CO_2 evolution through the increase of the soil microorganisms respiration. They also added that these microorganisms are characterized with their ability to mobilize the unavailable forms of nutrient elements to available form, thus increased the soil available such as N, P & K. These benefits of bacterial inoculation add to the soil fertility and in turn to better crop production and good quality.

As mentioned in the present study, co-inoculation of potato with *B. circulans* and *Azotobacter chroococcum* combined with 1/2 full K from feldspar, full K from feldspar and full K from potassium sulphate increased the carbohydrate content of potato. This results are in accordance with Lin (2010) who explained that K is an activation agent for many plant enzymes and so, it improves many metabolic processes in plants Such as enzymes activated by K that mainly include synthesized enzyme; improving efficiency of photosynthesis and transport of assimilated products. It may also improve photosynthesis activities, promote acidification of oxidative phosphorylation and produce ATP. Additionally, K can promote the transport of photosynthetic products and the formation of carbohydrates. As K is important to plants, the types of K in soils and its absorption by plants are closely related

Finally, it could be concluded that feldspar can be applied as source of potassium for plant growth and crop production when it accompanied with silicate dissolving bacteria.

However, more studies and field trials should be run in the near future to reach the levels of recommendation.

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دور الأسمدة الحيوية في تيسير البوتاسيوم لمحصول البطاطس

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أجريت تجربة حقلية بمحطة بحوث الاسماعيلية – محافظة الاسماعيلية - مركز البحوث الزراعية وذلك لدراسة أثر التلقيح بالأزوتوباكتر وبكتريا الباسيلس سيركيولانس على تحسين انتاجية محصول البطاطس وكذا محتوى البطاطس من الكربوهيدرات والسكريات الذائبة و النشاط البيولوجى فى التربة ومحتوى التربة من كل من النيتروجين و الفوسفور والبوتاسيوم المتاح فى وجود مصدرين من البوتاسيوم هما صخر البوتاسيوم الطبيعى (الفلدسبار) وكبريتات البوتاسيوم . وقد تم استخدام البوتاسيوم نصف المعدل الموصى به والمعدل الموصى به من البوتاسيوم من كل من المصدرين فى وجود التلقيح بكل من الأزوتوباكتر وبكتريا الباسيلس سيركيولانس منفردين أو مجتمعين فى تلقيح مزدوج فى وجود نفس مصدرى البوتاسيوم وبنفس المعدلات.

هذا وقد كانت أهم النتائج مايلى:

1- أدى التلقيح عموما بأى من الأزوتوباكتر أو بكتريا الباسيلس سيركيولانس فى وجود مصدرى البوتاسيوم بالمعدلين تحت الدراسة الى زيادة محصول البطاطس وكذا محتوى البطاطس من الكربوهيدرات والسكريات الذائبة و النشاط البيولوجى فى التربة ومحتوى التربة من كل من النيتروجين و الفوسفور والبوتاسيوم المتاح وذلك بالمقارنة مع استخدام مصدرى البوتاسيوم منفردين.

2- أدى التلقيح المزدوج بالأزوتوباكتر وبكتريا الباسيلس سيركيولانس مجتمعين فى وجود مصدرى البوتاسيوم بالمعدلين تحت الدراسة تسجيل أعلى قيم لمحصول البطاطس ومكوناته وكذلك كانت نفس الملحوظة بالنسبة لباقى القياسات سواء الخاصة بالبطاطس أو بالنشاط البيولوجى للتربة وكذا الكميات المتاحة بالتربة من كل من النيتروجين والفوسفور والبوتاسيوم وذلك بالمقارنة مع باقى المعاملات تحت الدراسة.

3- وعلى أى حال فإن الحصول على البوتاسيوم من مصادره الطبيعية مثل الفلدسبار يكون ذو أكثر فائدة للنبات وأكثر أمانا للبيئة. وكذلك فإنه للوصول لدرجة التوصية فإنه من الواجب تكرار مثل هذه التجارب بإستخدام محاصيل أخرى وانواع اخرى من الأراضى.

قام بتحكيم البحث

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Table (4): Soil biological activity and microbial counts at different period as affected with different potassium sources and levels and inoculation with silicate bacteria *B. circulans* and/or *Azotobacter chroococcum*

K-Source	K-Levels	Inoculation type	Dehydrogenase (µg TPF g^{-1} dry soil		CO_2 evolution mg CO_2 1oo g $soil^{-1}$ day^{-1}		Actinomycetes count x 10^3 cfu* g $soil^{-1}$		Total bacteria count x 10^7 cfu g $soil^{-1}$		*Azotobacter* count x 10^4 cfu g $soil^{-1}$		*Azospirillum* count x 10^4 cfu g $soil^{-1}$	
			75 days	100 days	75 days	100 days	75 days	100 days	75 days	100m days	75 days	100 days	75 days	100 days
K_2SO_4	1/2 full K dose	*B. circulans*	35.74	22.41	107.92	93.34	11	8	12	9	12	4	9	2.
		**Azoto.*	32.35	20.28	94.66	77.03	15	10	15	11	14	2	6	1
	Full K dose	*B. circulans*	45.37	25.78	154.15	89.99	10	7	16	13	15	5	10	2
		Azoto.	35.80	22.68	110.45	94.21	16	12	19	15	17	4	9	2
Feldspar	1/2 full K dose	*B. circulans*	30.50	20.26	106.16	76.14	7	5	12	9	10	2	3	----
		Azoto.	27.59	1.33	83.56	69.73	11	7	14	11	11	2	1	----
	Full K dose	*B. circulans*	36.36	22.69	128.20	97.12	13	8	14	12	12	3	1	------
		Azoto.	33.75	20.66	107.73	77.30	12	11	16	12	10	2	2	------
K_2SO_4	1/2 full K dose	*B. circulans* + *Azoto.*	45.25	23.95	130.17	98.30	17	12	20	14	16	4	10	2
	Full K dose		52.86	31.22	174.84	101.12	22	15	25	16	19	7	14	3
Feldspar	1/2 full K dose		41.12	21.12	103.95	80.02	15	11	15	11	11	3	10	2
	Full K dose		44.25	24.00	143.45	98.32	17	12	18	13	12	3	11	3
K_2SO_4	1/2 full K dose	Without inoculation	24.82	19.23	55.13	38.02	6	5	6	4	15	1	1	-----
	Full K dose		25.35	22.66	75.87	52.69	8	10	11	3	16	1	3	-----
Feldspar	1/2 full K dose		20.12	16.12	43.65	33.51	4	5	5	3	8	1	2	-----
	Full K dose		23. 29	17.61	48.75	37.72	4	6	7	4	10	1	3	-----

cfu = Colony formed uit^{-1}. ***Azoto. = Azotobacter chroococcum