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EVALUATION OF SOME POTASSIUM FERTILIZERS AND POTASSIUM BIOFERTILIZATION WITH *BACILLUS CIRCULANS* ON POTATOES PRODUCTIVITY UNDER SALINE SOIL CONDITION

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ABSTRACT: *Potato crop (Solanum tuberosum L), grown on a saline soil fertilized with three sources of K fertilizer at different rates as soil and foliar applications with or without bio-fertilizer of K-dissolving Bacillus circulans was studied in field experiments during two successive winter seasons of 2011/2012 and 2012/2013 at El- Quntra Shark, East of Suiz Canal, Ismailia Governorate, Egypt. Potassium sulphate at 190 kg K ha^{-1} was applied through the soil application compared foliar spray on soil and plant with K-silicate or K-humate using solutions of 125, 165 and 250 mg K L^{-1}; sprayed at a rate of 952 L ha^{-1} in three time. Plant growth, tuber yield and uptake of N, P, K, Fe, Mn, Zn in tubers, as well as contents of protein and starch increased by K application and more increases were found in combination with biofertilizer. Foliar spray of K-humate at highest concentration in spray solution gave highest increase effect on most of studied parameters. Potassium utilization (KU) was high with K-humate combined with biofertilizer, while decreased with K soil or foliar application alone. Significant correlations were obtained between K tuber uptake and contents of available K in soil after harvest. As well as, significant negative correlations where found between soil salinity and nutrients uptake by tubers. The present results warrant further studies to explore different concentrations of both K-sources foliar application on soil and plant combined with bio-fertilizer to arrive at the appropriate mixing percentages gave greater yield and quality of Potato.*

***Key words**: Potato; Potassium silicate; Potassium humate; Saline soil; Yield productivity and growth parameters.*

INTRODUCTION

Potato crop (*Solanum tuberosum* L.) plays an important agronomic and economic role in Egypt. In Egypt the area cultivated with potatoes is about 90.000 hectares, with an average tuber yield about 25 Mg ha^{-1}, (FAO 2011). It is an important export crop to European markets; potato plants require much more potassium than other vegetable crops (Al-Moshileh and Errebi, 2004). Omran *et al.* (1991) reported that tuber yield increased and tuber increased quality improves with K application. Maas and Hoffman (1977) reported that potato is a moderately salt sensitive compared with other crops. From 1980 to 2011 there was about 25% increase in K fertilizer use and the demand for K is expected to increase further (FAO, 2011). Potassium is essential for plant and has a very important role in plant growth and development. It is essential in photosynthesis, enzyme activity, synthesis of protein, carbohydrates and fats, translocation of photosynthetic and increasing plant ability to resist pests and disease. It is important osmotic active cation in plant cells (Mehdi *et al.* 2007). Smil (1999) reported that, in contrast to N, P and K is generally applied at lower rates, and less than 50 % of the K removed by crops is replenished.

Potassium humate is an active compound of natural origin which increases uptakes N, P, K and micronutrients (Gadimov *et al.* 2007). Davoud *et al.,* (2008) stated that application of potassium humate to potato increased root system, tuber yield, tuber number per plant. Jalil *et al.* (2013) applied K- humate and obtained increased potato tuber yield, tuber, size and weight, and tuber number per plant, even under water-stress conditions. Kumar *et al.,* (2013) stated that the K- humates derived from lignite brown coal are alkaline, rich in carboxylic and phenolic groups, aromatic and provide favorable conditions for soil biological activity and chemical reactions and improves soil physical conditions. They added that accumulation that a humic acid in soil reduces the need for commercial fertilizers.

Potassium solubilizing bacteria (KSB) such as *Bacillus mucilagenosus* and *Bacillus edaphicus* are examples of microorganisms used as bio-fertilizers. KSB are able to solubilize K in rock minerals through production and secretion of organic acids (Han and Lee, 2005). Ahmad (2009) found that KSB increased K availability in soils besides increasing K-contents and uptake in plants. Zakaria and El-Zemrany (2012) reported that soil EC and pH decreased with the increase of addition of mineral K fertilizer combined with K solubilized bacteria. Also, available N, P K, Fe, Mn and Zn in soil increased by such treatments.

Silicon nutrition is reported by Hashemi *et al.* (2010) to increase plant growth and prevents lignin and the Na^+ accumulation in shoots, reduced levels of lipid peroxidation in roots and increase levels of chlorophyll. Application of K to potato grown under salinity conditions needs more studies under field conditions. Wiese *et al.,* (2007) indicated that the foliar silicate solution was affected significantly on nutrients concentration and uptake in plants. Matichenkov *et al.,* (2001) indicated that the silicon substance optimizes soil fertility through improved water, physical and chemical soil properties and maintenance of nutrients in plant-available forms.

The objectives of the current study are assess the effect of K fertilizer sources and rates as soil application of potassium sulphate, foliar spray application of potassium silicate and potassium humate) with or without biofertilizer on (1)some soil properties and its content of macro and micronutrients (2) potato crop production, (3) tubers content of N, P, K, Fe, Mn and Zn plant availability and other compounds plant and (4) estimate K- fertilizers utilization under saline soil conditions.

MATERIALS AND METHODS

Experiment site

A field experiments were conducted at El-Quntra Shark, East Suiz Canal, Ismailia Governorate, Egypt, during the growing two successive winter seasons of 2011/2012 and 2012/ 2013 on saline non alkaline sandy loam soil. Surface soil sample (0-30 cm) were collected from the soil experiment , air-dried, ground, sieved through a 2 mm size and analyzed for some physical and chemical properties according to the standard methods described by Piper (1950), Cottenie *et al* (1982) and Page *et al* (1982). The obtained data are listed in Table (1).

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

Sand (%)	Silt (%)	Clay (%)	Texture	O.M ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)
79.47	8.38	12.15	Sandy loam	5.6	39.2

pH (1:2.5) (Soil :water suspension)	EC (dS/m)	Soluble Cations ($mmolc\ L^{-1}$)				Soluble Anions ($mmolc\ L^{-1}$)		
		Ca^{+2}	Mg^{+2}	Na^+	K^+	HCO^-_3	Cl^-	SO^{-2}_4
8.40	10.4	17.10	27.03	58.82	0.75	1.20	60	42.80

Available macronutrients ($mg\ kg^{-1}$)			Available micronutrients ($mg\ kg^{-1}$)		
N	P	K	Fe	Mn	Zn
35	6.00	189	2.7	3.5	0. 6

Irrigated by El-Salam Canal water (1:1 of Nile water mixed with agriculture drainage water). In the two growing seasons and also at different periods, sample of irrigation water were taken and analyzed for pH, EC and the content of some macro-micronutrients using the methods described by Page *et al* (1982). The obtained data are listed in Table (2).

The experiment design

The field experiment on potato (*Solanum tuberosum)* cv. Spunta was done to study the effect of K-fertilization additions in different sources individually or in combination with K soluble bacteria. The studied treatments were arranged in a randomized complete block design with three replicates. The experiment involved two factors. The first main factor was sources and its application rates including K-fertilization with 8 treatments as follows: (1) non-treated (no-K), (2) 190 kg K ha^{-1} as potassium-sulphate (KS), (3) K-foliar spray using silicate of potassium, solution of 125 mg K L^{-1} (SK1), (4) SK- spray solution of 165 mg K L^{-1} (SK2), (5) SK- spray solution of 250 mg K L^{-1} (SK3), (6) K-foliar spray using humate of potassium(HK) solution of 125 mg K L^{-1} (HK1), (7) HK- spray solution of 165 mg K L^{-1} (HK2), (8) HK- spray solution of 250 mg K L^{-1} (HK3). The second factor is biofertilization with 2 treatments as follows: (1) no biofertilization and (2) biofertilization using K solubilizing bacteria "*Bacillus circulans*". The K-sulphate fertilizer (commercial brand containing 400 g K kg^{-1}) was applied in 2 equal splits 25 and 40 days after planting. Foliar K-spray was done twice 25 days and 40 days after planting at rate of 950 L ha^{-1} each time. All plots were supplied with N (as urea; 460 g N $kg^{-1)}$ at 180 kg N ha^{-1} in two equal splits, 20 and 40 days after planting, and P (as ordinary calcium super phosphate 68 g P kg^{-1}) at 35 kg P ha^{-1} during soil preparation. Biofertilization was done by soaking the tubers immediately before planting into a suspension of *Bacillus circulans* inocula, also biofertilization was done through the soil by spraying the soil with diluted suspension 30 L liquid bacteria mixed within the 600 L water ha^{-1} three times after 20 , 40 and 60 days after planting as recommended by Shaban and Omar , (2006).

Seedling of potato was done on rows 75-cm apart, with 30 cm of cultivation distances within the row. The plot area was 50 m^2 (10×5m). Seedling was at 12/10/2011 for first season and 15/10/2012 for second season. Harvested was at 25 January 2012 and 2013 in each season. Immediately following seedling, the soil of plots was irrigated with water and excess water was surface-flowed to the drain ditches. This was done in order to get rid of a large part of the soluble salts which are usually present in the surface few centimeters of soil. This is a common practice done by farmers, in the area in order to alleviate salinity hazards of the soil.

Table (2): Mean values of pH, EC, macro- micronutrient content in irrigation water.

Period taken of irrigation water	pH	EC (dSm^{-1})	Macronutrients ($mg L^{-1}$)				Micronutrients ($mg L^{-1}$)		
			NO_3-N	NH_4-N	P	K	Fe	Mn	Zn
At sowing	8.02	1.24	14.93	8.93	2.79	6.55	3.58	1.15	0.83
After 30 days	8.00	1.39	19.70	10.73	2.93	8.39	3.69	1.20	0.99
After 60 days	8.03	1.13	20.69	7.13	1.52	10.32	3.94	1.17	0.85
After 90 days	7.98	1.53	17.22	8.02	1.47	9.17	3.22	1.10	0.79

Soil analysis

After harvesting the soil sample was collected from surface (0-30cm) air dried, passed through a 2 mm sieve and mixed thoroughly before analysis, carried out as performed according to the methods described by Cottenie *et al* (1982) and Page *et al* (1982). Available K, Fe, Mn and Zn were extracted by ammonium bicarbonate-DTPA (Soltanpour and Schwab, 1977) and measured using ICP spectrometery.

Plant analysis

Plant tissues (tubers) were analyzed for the content of total N, P, K, Fe, Mn and Zn. Samples were dried at 70° till constant weight, digested using a mixture of concentrated sulfuric (H_2SO_4) and perchloric (HClO) acids (3:1) as described by Chapman and Pratt (1961). Nitrogen was determined by the micro Kheldahl method; P was determined in the H_2SO_4/HClO mixture by the molybdate stannous chloride method and K nwas measured by the flame photometer. Also Fe, Mn and Zn were measured by the atomic absorption apparatus. These determinations were carried according fore methods of Cottenie et al (1982) .Total soluble solids (TSS) in fresh tubers were measured using a refractmeter (Burton, 1948) and starch in tubers was calculated according to the formula of Holm *et al.* (1986).

The parameters in various treatments were subjected to the analysis of variance (ANOVA) according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Soil pH

Soil pH was generally higher in unfertilized soils. Date in Table (3) show that the soils of all treatments are characterized by slightly moderate alkalinity with a ranged between 8.00 to 8.36 in addition, the active organic acids released from the contaminated potassium humate and bio-fertilizer encourages the reduction in soil pH. These results are in agreement with those reported by Wahdan *et al.* (1999). The soil pH tends to decrease with increasing the rates of K application with the foliar spray treatments. Zakaria and El-Zemrany (2012) reported that application of K with bio-fertilizers resulted in slight decrease in soil pH. Wu *et al.* (2006) reported that application of *Azotobacter chroococcum*, *Bacillus megatherium* and *Bacillus mucilaginosus*, biofertilizers was associated with a decrease in soil pH.

Soluble salts

Effect of the studied treatments on soil salinity (EC dSm^{-1}) is given in Table 3. Application of K and biofertilizer singly or combined were decreased soil EC. The decrease in soil salinity was greater with combination of K and biofertilizer with both soil and foliar K applications, but spray application decreased salinity more than application through the soil. Applications of K in combination with biofertilization have a grater effect on salinity decreases compared with the individual treatments. The treatments of potassium humate gave the highest decrease in soil salinity compared with that associated the treatments of potassium sulphate average EC followed the order of potassium sulphate > potassium silicate > potassium humate. These results are in agreement with those reported by Zakaria and El-Zamrany (2012) and Albert *et al.,* (2005) who observed that potassium humate applied as soil conditioner decreased soil salinity. Michael *et al* (2010) reported that soil salinity decreased with application potassium silicate. Shaban and Abd El-Hakam (2009) reported decreased soil salinity with K application in combination with bio-fertilizer more than decrease caused by K alone.

K application combined with biofertilizer decreased soil EC. Soil EC was comparatively greater with soil-applied potassium sulphate combined with low rate of potassium humate compared with soil applied-K combined with other K-sprays. The increase of sprayed K rates was associated with a decreased in soil EC. Biofertilization decreased soil EC by an average of about 12% in both seasons. Foliar application of potassium humate and potassium silicate decreased EC compared to the soil application of potassium sulphate. Matichenkov *et al.,* (2001) indicated that the silicon substance optimizes soil fertility through improved water, physical and chemical soil properties.

Table 3

Soil content of available macronutrient

Data Table 3 show that application of K sources, with or without biofertilizer was associated increased of soil contents of available N and P. Application of K without biofertilizer gave low content of available N and P than when combined with biofertilizer. Application of silicate potassium or humate potassium gave higher soil available N and P compared with potassium sulphate. In first season, the increase of K-soil applied as potassium sulphate for N by 14% increased it by 24% by silicate potassium and to 14-25% by potassium humate increased it by 22 to 30%. In second season comparable increases were 14% by potassium sulphate and 13% to 24% by potassium silicate and 17% to 27% by potassium humate. Available N increased with the rate of increase of K concentration in spray solution. Available K content in soil was increased by K application as well as by biofertilizer application. Application of potassium silicate or potassium humate (foliar application) gave greater available K than potassium sulphate (soil application). Source of potassium humate showed more available K than potassium silicate. Application of biofertilizer combined with different K sources increased soil K content compared application without biofertilizer. Seddik (2006) reported that the application of K biofertilizer may produce bacterial acids, alkalies or chelates which enhance solubility and release of elements from potassium containing minerals in soil.

Soil content of available micro nutrients.

The presented data in Table (4) show that the soil content of available Fe, Mn and Zn were increase with increasing rate of K-sources foliar application. The effect of K-sources foliar application on micronutrients content of available in soil Fe, Mn and Zn were significant, while the soil treated with K- sources combined with K- Solubilizing Bacteria was no significant in first season. As well as, the effect of K- sources and K-Solubilizing Bacteria bacterial on Fe, Mn and Zn content in soil were significant in second season. The highest values Fe and Mn content in soil were 3.02 and 3.86 mg kg^{-1} in first season, while 3.06 and 3.89 mg kg^{-1} in second season as affected by foliar application of potassium humate at rate 250 mg K L^{-1} . These results are in agreement by Shaban *et al* (2012) found that the availability of Fe, Mn and Zn in soil increased with increasing K application rate under the soil salinity. Concerning that the relative increase of mean values Fe, Mn and Zn as affected by K- sources combined with K- Solubilizing Bacteria were 2.13 % for Fe, 1.39 % for Mn and 6.25 % for Zn respectively compared without bio-fertilizer in first season. The relative increase of mean values K- sources combined with K-Solubilizing Bacteria were 2.11 % for Fe; 1.65 % for Mn and 7.57% for Zn respectively compared with K- sources without bio-fertilizer. With increased K concentration in the foliar application solutions there were increases in available micronutrients in soil.

These results are in agreement by Zakaria and El-Zemrany (2012) reported there is increase contents of Fe, Mn and Zn available in soil obtained by K fertilizer application combined with bio-fertilizer.

Tuber parameters of potatoes as affected by the applied treatments

Data are present in Table (5) shows that lower rate of potassium silicate caused a decrease in tuber number per plant. Application of potassium through the soil was comparable to medium and high rates of potassium silicate. Potassium humate application increased tuber number per plant more than to potassium silicate application. Tuber number per $plant^{-1}$ increased significantly by increasing K rates of all sources, while the combination of K sources and biofertilizer, gave a higher number per tubers of plant increased with increasing K rates of potassium silicate and potassium humate application.

Table 4

Table 5

In both seasons, the effects of K sources and rates on fresh yield were detected only with application of K sources singly. Omran *et al.* (1991) reported that potassium fertilizer application led to increased yield and improved tuber quality. The same data also, show that potato fresh yield increased with K application especially at high rates. At different application rates of potassium silicate and potassium humate there was an increase in yields. The found fresh yield was higher than that associated the treatments of potassium sulphate. These results are in agreement by Habib *et al* (2011) who applied foliar spray of K using a solution of 250 mg K L^{-1} and obtained high potato tuber yields. Selim *et al.,* (2009) they found that addition of potassium and humic substances increased the number of potato tubers per plant as well as tuber yield.

Jalil *et al* (2013) indicated that Potassium Humate application at rate 250 m ha^{-1} led to increased potato tuber yield and number and weight of tubers per plant under water stress condition.

Data in Table (5) show that application of K sources with or without biofertilizer increased potato starch, especially with potassium foliar application. Starch content increased with increasing rate of potassium silicate and potassium humate compared with that associated the treatments of potassium sulphate. Also, the same data show that K application with or without biofertilizer increased total soluble solids (TSS) content by applying K and/or biofertilizer. The high content of TSS was potassium humate individually or in combination with biofertilizer. So, clear increase of TSS content was resulted from biofertilization. These results are in agreement by Abd El-Latif *et al.* (2011) indicate that the all treatments of K levels gave a highest significant value of total soluble solids. Selim *et al.,* (2009) found that application of humic substances enhanced tubers yield quantity, starch content and total soluble solids.

Macronutrient uptake by potato tubers:

Data presented in Table (6) reveal that the N, P and K uptake by tubers were increased K soil application and also increase with concentration K increased in spray solutions. Both potassium silicate and potassium humate gave more uptakes of these macronutrients than potassium sulphate. Applying K in combination with biofertilizer was results similar to application without biofertilizer. In the first season under biofertilizer application there was no significance difference between low and medium rates of potassium silicate.

High rate of potassium humate and potassium silicate recorded the increased of N uptake. Potassium application as foliar spray gave higher uptake of N, P and K compared with soil application as potassium sulphate. Medium and high rates of potassium humate increased tuber N uptake significantly compared with low and medium rates of potassium silicate and potassium sulphate. In the second season, there were little differences between the effects of K-sources added on N, P and K uptake than that found in the first season with application of K alone (without biofertilizer), Application of medium and high rates of potassium humate increased N, P and K uptake than potassium sulphate. The high rate of potassium silicate has significantly and higher increase in K uptake compared with potassium sulphate or the medium rate of potassium silicate. Gadimov *et al.* (2007) mentioned that potassium humate is active and increased N, P and K uptake in peas crop. Our results are in agreement with those reported by Abd El-Latif *et al* (2011) who found that K application increased N, P and K of tubers uptake in potato.

Micronutrients uptake:

Effects of applied K sources at the different rates as soil or foliar application on uptake of Fe, Mn and Zn in tuber plants are presented in Table (7). Application of biofertilizer increased Fe, Mn and Zn uptake compared with K fertilizers application alone.

Table 6

Table 7

Uptakes of Fe in first season, followed the following of potassium humate>potassium silicate>potassium sulphate without biofertilizer application. In second season, there were no significant differences in Fe uptake with potassium sulphate and all rates of potassium silicate but, potassium humate gave greater Fe uptake compared with potassium sulphate. Application of K in a mineral fertilizer from in first season led to slight increase in Mn and Zn uptake. Application of K fertilizer combined with biofertilizer increased Mn uptake, whereas, there were little differences between the used K fertilizers sources and its different rates. It can conclude that the higher uptake of micronutrients occurred with K fertilizers combined with biofertilizer. The highest values of Mn and Zn uptake occurred with potassium humate spray. Gadimov et al. (2007) found that application of potassium humate increased micronutrients contents in peas. Zakaria and El-Zemrany (2012) who found that application of K combined or without bio-fertilizer increased Fe, Mn and Zn uptake in wheat.

Relationship between available soil K and its potato K uptakes by tubers

As shown in Figure (1) significant correlations were obtained between soil available K in the end of the experiment with K uptake in potato tubers. Correlations were more significant with combination of K fertilizers with biofertilizer compared with K fertilizers application alone. This indicates a positive effect of soluble potassium bacteria on K availability in soil.

Relationships between soil EC after harvest and potato tuber nutrient uptake (macro and micro nutrients)

At the end of the experiment after harvest, soil EC was correlated negatively with macro and micronutrients. It can conclude that the increased in soil EC leads to decreased availability of nutrients by plant. These results are in agreement by Grattan and Griev (1999) consequently, the relationship between salinity and trace element nutrition is complex and salinity may increase, decrease, or have no effect on the micronutrient concentration in plant. Hu and Schmidhalter (2001) reported that the macro- micronutrients N, P and K, Mn, Zn and Fe in growing plants was largely unaffected by salinity. Finally, it is concluded that the uptake of macro and micronutrients in plants, generally, reflect their available contents in soil and reduce EC soil under different potassium resources used. Hassein and Abou-Baker (2014) indicated that mineral contents N, P, K, and Ca content decreased with increasing salinity level. Potassium silicate is considered a source of Si and K in addition to, SA may ameliorate the negative effect of salinity by increasing K accumulation.

Conclusion

Application of K as potassium sulphate through the soil or as spray solution of potassium silicate or potassium humate increased tuber yield of potato as well as uptake of N, P, K, Fe, Mn and Zn. Similar increases were found with biofertilization treatments. Significant and positive correlations were obtained between K-fertilization treatments and soil K contents after harvest. It can be recommended that spraying with potassium silicate or potassium humate combined with spray biofertilizer of K-dissolving bacteria (*Bacillus circulans)* can alleviate the negative effect of salinity on potato plants.

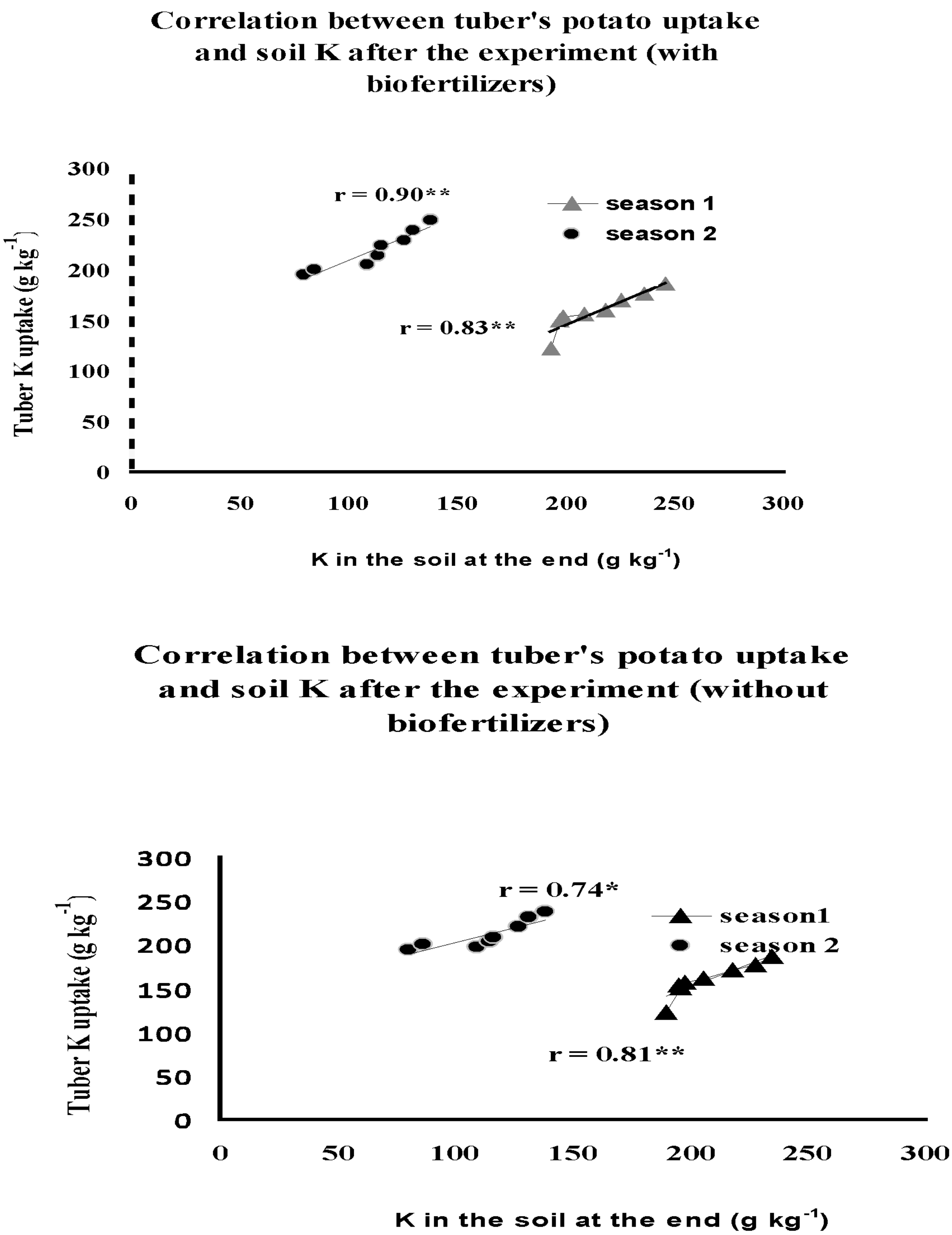

Figure (1): Relationships soil K contents at the end of the experiment and K uptake by tuber potato.

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تقييم بعض مصادر البوتاسيوم والتسميد الحيوى ببكتيريا (*Bacillus circulans*) على انتاجية البطاطس تحت ظروف الاراضى الملحية

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الملخص العربى

محصول البطاطس (*Solanum tuberosum* L), النامى فى ظل ظروف الاراضى الملحيه. تم استخدام ثلاث مصادر من التسميد البوتاسى بمعدلات مختلفه بطريقتين للاضافه و هما اضافه ارضيه و اضافه بالرش على النبات و الارض فى وجود او عدم وجود التسميد الحيوى(*Bacillus circulans*). *اجريت التجربه على موسميين شتويين* ٢٠١١-٢٠١٢ / ٢٠١٢-٢٠١٣ فى منطقه شرق القنطره شرق قناه السويس فى محافظه الاسماعيليه مصر. وكان الهدف من هذه الدراسه هى تقييم أثر كلا من كبريتات البوتاسيوم (تسميد بالتربه) بمعدل (١٩٠ كجم بوتاسيوم هكتار$^{-١}$) و سليكات و هيومات البوتاسيوم (تسميد ورقى بالرش على التربة والنبات) بالمعدلات التاليه (١٢٥ ،١٦٥، ٢٥٠ ملجرام بوتاسيوم لتر$^{-١}$) و قد أجريت الاضافات مع أو بدون التسميد الحيوى بالبكتيريا المذيبه للبوتاسيوم (*Bacillus circulans*) بواسطه الرش على التربه. و قد لوحظت النتائج كالتالى زياده فى نمو النبات و محصول الدرنات و أمتصاص العناصر الكبرى (النيتروجين و الفسفور والبوتاسيوم) و العناصر الصغرى (الحديد و المنجنيز و الزنك) ومحتوى البروتين و النشا بزياده اضافه التسميد البوتاسى مع التسميد الحيوى بالبكتيريا المذيبه للبوتاسيوم .

ادى اضافه المعدل المرتفع من هيومات البوتاسيوم الى زياده التاثيرعلى معظم الصفات المدروسه. وجد ان كفاءه استخدام البوتاسيوم زادت بزياده معدل الاضافه من هيومات البوتاسيوم مع التسميد الحيوى بالمقارنه باضافه المصادر البوتاسيوم منفردا. وجدت علاقه معنويه بين البوتاسيوم الممتص بواسطه درنات البطاطس و البوتاسيوم الميسر فى التربه بعد الحصاد. و كذلك وجدت علاقه عكسيه بين ملوحه التربه و امتصاص العناصر بواسطه درنات البطاطس.

التوصية : لابد من الاستمرار فى المزيد من الدراسات على طريقة الرش على الارض والنبات بالتسميد البوتاسوم متداخل مع التسميد الحيوى للوصول الى افضل مستوى من البوتاسيوم يعطى اعلى انتاجية وافضل نوعية لمحصول البطاطس.

Table (3): Soil pH, EC and its contents of available macronutrients after the harvesting as affected by the study treatments.

Season	Treatment	pH (1:2.5)			EC(dSm^{-1})			N ($mg\ kg^{-1}$)			P ($mg\ kg^{-1}$)			K ($mg\ kg^{-1}$)		
		Bio	None	Mean	Bio	None	Mean	Bio	None	Mean	Bio	None	Mean	Bio	None	Mean
First season	Control	8.23	8.36	8.30	6.89	7.55	7.22	38.88	36.25	37.57	5.96	5.92	5.94	193.00	190.00	191.50
	Potassium sulphate (190 kg K ha^{-1})	8.17	8.28	8.23	6.49	7.14	6.82	44.53	41.29	42.91	6.05	5.98	6.02	197.00	196.00	196.50
	Potassium silicate (125 mg K L^{-1})	8.17	8.29	8.23	6.40	6.85	6.63	44.96	40.59	42.78	6.12	6.01	6.07	199.00	195.00	197.00
	Potassium silicate (165 mg K L^{-1})	8.12	8.22	8.17	5.27	6.42	5.85	45.88	43.94	44.91	6.15	6.07	6.11	208.00	198.00	203.00
	Potassium silicate (250 mg K L^{-1})	8.08	8.17	8.13	5.20	6.30	5.75	48.52	45.38	46.95	6.24	6.14	6.19	218.00	206.00	212.00
	Potassium humate (125 mg K L^{-1})	8.14	8.22	8.18	5.83	6.51	6.17	47.53	43.87	45.70	6.34	6.23	6.29	225.00	218.00	221.50
	Potassium humate (165 mg K L^{-1})	8.08	8.15	8.12	5.40	5.96	5.68	47.86	45.29	46.58	6.73	6.36	6.55	236.00	228.00	232.00
	Potassium humate (250 mg K L^{-1})	8.04	8.11	8.08	4.96	5.88	5.42	51.28	46.52	48.90	6.76	6.64	6.70	246.00	235.00	240.50
Mean		8.13	8.23		5.81	6.58		46.18	42.89		6.29	6.17		215.25	208.25	
LSD 5%	K fertilizer source				0.323			NS			3.53			27.86		
	Rates				1.74			NS			NS			9.08		
	Biofertilizer				1.18			NS			NS			11.75		
	K fertilizer source * rates				5.59			NS			NS			NS		
	Biofertilizer * rates				1.46			NS			NS			NS		
	K fertilizer source * Biofertilizer				1.025			NS			NS			NS		
	K fertilizer source * Biofertilizer* rates				0.709			NS			NS			NS		
Second season	Control	8.20	8.33	8.27	6.53	7.29	6.91	40.21	38.74	39.48	5.98	5.95	5.97	195.00	194.00	194.50
	Potassium sulphate (190 kg K ha^{-1})	8.15	8.25	8.20	6.23	6.89	6.56	46.83	43.41	45.12	6.09	5.99	6.04	199.00	201.00	200.00
	Potassium silicate (125 mg K L^{-1})	8.16	8.25	8.21	6.32	6.72	6.52	45.10	43.85	44.48	6.17	6.03	6.10	205.00	197.00	201.00
	Potassium silicate (165 mg K L^{-1})	8.10	8.21	8.16	5.23	6.35	5.79	45.96	44.29	45.13	6.19	6.11	6.15	213.00	203.00	208.00
	Potassium silicate (250 mg K L^{-1})	8.06	8.16	8.11	5.15	6.22	5.69	51.29	46.54	48.92	6.29	6.17	6.23	223.00	208.00	215.50
	Potassium humate (125 mg K L^{-1})	8.10	8.18	8.14	5.73	6.43	6.08	48.10	44.10	46.10	6.36	6.28	6.32	229.00	221.00	225.00
	Potassium humate (165 mg K L^{-1})	8.06	8.13	8.10	5.32	5.92	5.62	48.39	45.51	46.95	6.77	6.42	6.60	238.00	231.00	234.50
	Potassium humate (250 mg K L^{-1})	8.00	8.09	8.05	4.92	5.72	5.32	52.55	46.82	49.69	6.79	6.66	6.73	249.00	238.00	243.50
Mean		8.10	8.20		5.68	6.44		47.30	44.16		6.33	6.20		218.88	211.63	
LSD 5%	K fertilizer source				1.83			NS			NS			21.62		
	Rates				1.57			13.93			NS			13.30		
	Biofertilizer				NS			21.54			NS			48.17		
	K fertilizer source * rates				NS			NS			NS			NS		
	Biofertilizer * rates				2.69			NS			NS			NS		
	K fertilizer source * Biofertilizer				NS			NS			NS			NS		
	K fertilizer source * Biofertilizer* rates				NS			NS			NS			NS		

Table (4): The soil content of available micronutrients after harvesting affected by the studied treatments

Season	Treatment	Fe (mg kg^{-1})			Mn (mg kg^{-1})			Zn (mg kg^{-1})		
		Bio	None	Mean	Bio	None	Mean	Bio	None	Mean
First season	Control	2.71	2.70	2.71	3.52	3.49	3.51	0.59	0.57	0.58
	Potassium sulphate (190 kg K ha^{-1})	2.75	2.73	2.74	3.58	3.53	3.56	0.63	0.60	0.62
	Potassium silicate (125 mg K L^{-1})	2.79	2.75	2.77	3.58	3.56	3.57	0.67	0.62	0.65
	Potassium silicate (165 mg K L^{-1})	2.85	2.80	2.83	3.59	3.57	3.58	0.68	0.63	0.66
	Potassium silicate (250 mg K L^{-1})	2.93	2.83	2.88	3.62	3.59	3.61	0.74	0.68	0.71
	Potassium humate (125 mg K L^{-1})	2.91	2.85	2.88	3.74	3.65	3.70	0.68	0.64	0.66
	Potassium humate (165 mg K L^{-1})	2.96	2.88	2.92	3.78	3.70	3.74	0.69	0.65	0.67
	Potassium humate (250 mg K L^{-1})	3.02	2.94	2.98	3.86	3.77	3.82	0.72	0.70	0.71
Mean		2.87	2.81		3.66	3.61		0.68	0.64	
LSD 5%	K fertilizer source	NS			0.506			NS		
	Rates	NS			0.499			0.316		
	Biofertilizer	NS			1.056			0.564		
	K fertilizer source * rates	NS			NS			NS		
	Biofertilizer * rates	NS			NS			NS		
	K fertilizer source * Biofertilizer	NS			NS			NS		
	K fertilizer source * Biofertilizer* rates	NS			NS			NS		
Second season	Control	2.73	2.71	2.72	3.54	3.51	3.53	0.62	0.59	0.61
	Potassium sulphate (190 kg K ha^{-1})	2.78	2.75	2.77	3.59	3.55	3.57	0.66	0.63	0.65
	Potassium silicate (125 mg K L^{-1})	2.83	2.78	2.81	3.62	3.59	3.61	0.69	0.64	0.67
	Potassium silicate (165 mg K L^{-1})	2.89	2.82	2.86	3.65	3.61	3.63	0.72	0.65	0.69
	Potassium silicate (250 mg K L^{-1})	2.97	2.88	2.93	3.67	3.63	3.65	0.78	0.71	0.75
	Potassium humate (125 mg K L^{-1})	2.94	2.87	2.91	3.79	3.68	3.74	0.71	0.67	0.69
	Potassium humate (165 mg K L^{-1})	2.99	2.92	2.96	3.82	3.74	3.78	0.73	0.69	0.71
	Potassium humate (250 mg K L^{-1})	3.06	2.97	3.02	3.89	3.79	3.84	0.77	0.72	0.75
Mean		2.90	2.84		3.70	3.64		0.71	0.66	
LSD 5%	K fertilizer source	0.332			0.496			NS		
	Rates	NS			NS			0.142		
	Biofertilizer	NS			0.394			0.326		
	K fertilizer source * rates	NS			NS			NS		
	Biofertilizer * rates	NS			NS			NS		
	K fertilizer source * Biofertilizer	NS			NS			NS		
	K fertilizer source * Biofertilizer* rates	NS			NS			NS		

Table (5): Some growth parameters of potato tubers as affected by studied treatments

Season	Treatment	Tuber number plant^{-1}			Fresh yield(Mg ha^{-1})			Starch(g kg^{-1})			TSS(g kg^{-1})		
		Bio	None	Mean	Bio	None	Mean	Bio	None	Mean	Bio	None	Mean
First season	Control	3.88	3.22	3.55	45.81	30.55	38.18	17.89	15.42	16.66	4.68	4.31	4.50
	Potassium sulphate (190 kg K ha^{-1})	6.30	4.01	5.15	54.41	32.07	43.24	18.22	16.49	17.36	5.02	4.68	4.85
	Potassium silicate (125 mg K L^{-1})	5.14	3.88	4.51	53.88	39.83	46.86	18.46	16.44	17.45	5.08	4.82	4.95
	Potassium silicate (165 mg K L^{-1})	6.02	4.10	5.06	54.50	41.02	47.76	18.49	16.73	17.61	5.17	4.89	5.03
	Potassium silicate (250 mg K L^{-1})	6.07	4.22	5.14	54.52	40.93	47.73	18.69	17.93	18.31	5.23	4.9	5.07
	Potassium humate (125 mg K L^{-1})	6.28	4.93	5.61	56.67	43.38	50.02	18.86	17.85	18.36	5.12	4.89	5.01
	Potassium humate (165 mg K L^{-1})	6.45	5.02	5.74	57.43	44.41	50.92	19.52	17.95	18.74	5.33	4.96	5.15
	Potassium humate (250 mg K L^{-1})	6.83	5.14	5.98	59.76	46.48	53.12	20.49	19.15	19.82	5.4	5.04	5.22
Mean		5.87	4.32		54.62	39.83		18.83	17.25		5.13	4.81	
LSD 5%	K fertilizer source		4.39			NS			3.61			0.401	
	Rates		5.89			NS			2.52			0.579	
	Biofertilizer		7.86			13.72			11.62			2.30	
	K fertilizer source * rates		0.68			NS			1.26			NS	
	Biofertilizer * rates		1.13			NS			1.59			NS	
	K fertilizer source * Biofertilizer		19.96			29.02			0.635			NS	
	K fertilizer source * Biofertilizer* rates		10.31			14.98			0.91			NS	
Second season	Control	3.92	3.25	3.59	46.00	30.62	38.31	17.93	15.48	16.71	4.72	4.35	4.54
	Potassium sulphate (190 kg K ha^{-1})	6.33	4.06	5.20	54.50	32.19	43.35	18.28	16.51	17.40	5.07	4.77	4.92
	Potassium silicate (125 mg K L^{-1})	5.19	3.93	4.56	54.07	40.05	47.06	18.52	16.5	17.51	5.12	4.88	5.00
	Potassium silicate (165 mg K L^{-1})	6.08	4.16	5.12	54.60	41.26	47.93	18.55	16.78	17.67	5.21	4.92	5.07
	Potassium silicate (250 mg K L^{-1})	6.12	4.28	5.20	54.72	41.19	47.95	18.71	17.98	18.35	5.27	4.95	5.11
	Potassium humate (125 mg K L^{-1})	6.33	4.98	5.65	56.86	43.57	50.22	18.93	17.89	18.41	5.19	4.92	5.06
	Potassium humate (165 mg K L^{-1})	6.49	5.09	5.79	57.67	44.57	51.12	19.6	18.98	19.29	5.36	4.98	5.17
	Potassium humate (250 mg K L^{-1})	6.90	5.19	6.05	59.95	46.62	53.29	20.53	19.2	19.87	5.45	5.08	5.27
Mean		5.92	4.37		54.80	40.01		18.88	17.42		5.17	4.86	
LSD 5%	K fertilizer source		2.64			28.36			4.09			2.29	
	Rates		2.41			NS			2.39			0.607	
	Biofertilizer		11.32			NS			10.79			2.301	
	K fertilizer source * rates		NS			NS			1.62			NS	
	Biofertilizer * rates		1.70			30.17			1.35			NS	
	K fertilizer source * Biofertilizer		1.52			NS			0.951			NS	
	K fertilizer source * Biofertilizer* rates		NS			NS			1.99			NS	

Table (6): Effect of different studied treatments on tuber uptake N, P and K (g ha^{-1}) in the two growth seasons.

season	Treatment	N uptake(g ha^{-1})			P uptake(g ha^{-1})			K uptake(g ha^{-1})		
		bio	none	Mean	bio	none	mean	bio	none	mean
First season	Control	79.25	51.32	65.29	9.62	5.50	7.56	121.40	79.12	100.26
	Potassium sulphate (190 kg K ha^{-1})	97.93	55.81	76.87	13.60	6.74	10.17	149.07	84.67	116.87
	Potassium silicate (125 mg K L^{-1})	99.68	70.90	85.29	15.09	9.56	12.32	153.02	108.35	130.69
	Potassium silicate (165 mg K L^{-1})	102.46	74.26	88.36	16.90	11.49	14.19	155.33	113.64	134.48
	Potassium silicate (250 mg K L^{-1})	111.24	78.59	94.91	17.99	11.87	14.93	159.76	115.01	137.39
	Potassium humate (125 mg K L^{-1})	112.21	80.26	96.23	16.43	10.85	13.64	168.87	125.38	147.12
	Potassium humate (165 mg K L^{-1})	117.16	85.26	101.21	18.95	12.88	15.91	175.16	130.11	152.64
	Potassium humate (250 mg K L^{-1})	127.90	92.02	109.96	22.11	14.87	18.49	185.25	138.04	161.65
Mean		112.38	73.55		16.34	10.47		158.48	111.79	
LSD	K fertilizer source	14.45			6.95			19.84		
	Rates	42.96			5.33			10.49		
	Biofertilizer	52.13			39.18			16.94		
	K fertilizer source * rates	NS			NS			NS		
	Biofertilizer * rates	NS			NS			35.76		
	K fertilizer source * Biofertilizer	11.28			NS			91.15		
	K fertilizer source * Biofertilizer* rates	NS			NS			17.6		
Second season	Control	80.04	52.07	66.05	10.12	5.81	7.97	122.36	79.92	101.14
	Potassium sulphate (190 kg K ha^{-1})	99.74	56.98	78.36	14.17	7.40	10.79	150.42	86.27	118.34
	Potassium silicate (125 mg K L^{-1})	102.20	72.89	87.54	16.22	10.41	13.32	154.65	109.33	131.99
	Potassium silicate (165 mg K L^{-1})	104.82	77.16	90.99	17.47	11.97	14.72	157.24	115.12	136.18
	Potassium silicate (250 mg K L^{-1})	113.26	79.91	96.59	19.15	12.77	15.96	161.41	116.57	138.99
	Potassium humate (125 mg K L^{-1})	115.23	81.92	98.58	17.62	11.76	14.69	171.71	126.80	149.25
	Potassium humate (165 mg K L^{-1})	120.51	87.36	103.94	21.14	13.82	17.48	177.67	131.49	154.58
	Potassium humate (250 mg K L^{-1})	130.70	95.11	112.90	22.78	15.85	19.32	187.05	138.93	162.99
Mean		75.42	75.42		17.34	11.22		160.31	113.05	
LSD	K fertilizer source	18.96			13.98			NS		
	Rates	8.98			NS			NS		
	Biofertilizer	55.4			43.38			NS		
	K fertilizer source * rates	NS			NS			NS		
	Biofertilizer * rates	NS			NS			62.31		
	K fertilizer source * Biofertilizer	NS			NS			NS		
	K fertilizer source * Biofertilizer* rates	NS			NS			NS		

Table (7): Effect of different studied treatments on potato's tuber uptakes of micronutrients

Season	Treatment	Fe uptake(g ha^{-1})			Mn uptake(g ha^{-1})			Zn uptake(g ha^{-1})		
		Bio	None	Mean	Bio	None	Mean	Bio	None	Mean
First season	Control	3.46	2.19	2.83	1.53	0.87	1.20	0.69	0.37	0.53
	Potassium sulphate (190 kg K ha^{-1})	4.81	2.35	3.58	1.93	0.96	1.44	0.83	0.40	0.61
	Potassium silicate (125 mg K L^{-1})	4.67	2.92	3.79	1.93	1.23	1.58	0.89	0.53	0.71
	Potassium silicate (165 mg K L^{-1})	4.83	3.06	3.95	1.98	1.30	1.64	0.97	0.56	0.77
	Potassium silicate (250 mg K L^{-1})	4.80	3.08	3.94	2.01	1.30	1.66	0.98	0.57	0.77
	Potassium humate (125 mg K L^{-1})	5.07	3.41	4.24	2.14	1.41	1.78	1.03	0.64	0.84
	Potassium humate (165 mg K L^{-1})	5.48	3.50	4.49	2.19	1.46	1.82	1.07	0.66	0.87
	Potassium humate (250 mg K L^{-1})	5.75	3.72	4.74	2.31	1.55	1.93	1.14	0.70	0.92
Mean		4.86	3.03		2.00	1.26		0.95	0.55	
LSD 5%	K fertilizer source	4.98			0.422			0.479		
	Rates	NS			0.396			0.192		
	Biofertilizer	7.63			5.053			1.036		
	K fertilizer source * rates	NS			0.564			0.107		
	Biofertilizer * rates	NS			0.329			0.122		
	K fertilizer source * Biofertilizer	2.84			0.240			0.055		
	K fertilizer source * Biofertilizer* rates	5.49			0.433			0.107		
Second season	Control	3.48	2.19	2.84	1.54	0.87	1.21	0.69	0.37	0.53
	Potassium sulphate (190 kg K ha^{-1})	4.82	2.36	3.59	1.94	0.96	1.45	0.83	0.41	0.62
	Potassium silicate (125 mg K L^{-1})	4.69	2.94	3.81	1.94	1.24	1.59	0.89	0.53	0.71
	Potassium silicate (165 mg K L^{-1})	4.90	3.08	3.99	1.99	1.30	1.65	0.98	0.57	0.77
	Potassium silicate (250 mg K L^{-1})	4.83	3.10	3.96	2.02	1.32	1.67	0.99	0.57	0.78
	Potassium humate (125 mg K L^{-1})	5.31	3.42	4.37	2.15	1.42	1.78	1.04	0.64	0.84
	Potassium humate (165 mg K L^{-1})	5.51	3.52	4.51	2.20	1.47	1.84	1.08	0.66	0.87
	Potassium humate (250 mg K L^{-1})	5.78	3.74	4.76	2.32	1.56	1.94	1.15	0.71	0.93
Mean		4.91	3.04		2.01	1.27		0.96	0.56	
LSD 5%	K fertilizer source	1.08			0.983			0.481		
	Rates	1.12			NS			NS		
	Biofertilizer	8.06			5.219			2.78		
	K fertilizer source * rates	0.517			NS			NS		
	Biofertilizer * rates	5.25			NS			NS		
	K fertilizer source * Biofertilizer	1.134			NS			NS		
	K fertilizer source * Biofertilizer* rates	0.075			NS			NS		