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GROWTH, PRODUCTIVITY AND TUBER QUALITY OF POTATO CV. SPUNTA AS AFFECTED BY LEVEL AND SOURCE OF POTASSIUM FERTILIZATION

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Abstract

Two field experiment were carried out during two successive summer seasons of 2018 and 2019 at Private Farm, Belbies District, Sharkia Governorate, Egypt, to study the effect of level and source of potassium (K-sulphate, potassium silicate and K-feldspar with silicate dissolving bacteria) on growth, productivity and tuber quality of potato (*Solanum tuberosum* L.) *cv.* Spunta grown in sandy clay soil. Fertilizing potato plants grown in sandy clay soil with 48 kg K_2O as potassium sulphate (KS) with potassium silicate (Ksil) gave the tallest plants, whereas 36 kg K_2O as KS + 36 kg K_2O as feldspar (KF) with silicate dissolving bacteria (SDB) + Ksil gave the highest values of number of main stems, number of lateral branches, leaf area, fresh and dry weight of shoots and number of leaves / plant. Moreover, fertilizing with 72 kg K_2O (36 kg K_2O as KS + 36 kg K_2O as KF) with inoculation with SDB + foliar spray with Ksil increased tuber yield / plant, yield of grade 1, marketable yield and total yield / fad. Potato plants which fertilized with 48 kg K_2O as KS + 48 kg K_2O as KF with SDB + Ksil gave the highest values of tuber dry matter (%) and starch content.

Key words: potato (*Solanum tuberosum.*), K-sulphate and K-feldspar, potassium silicate, silicate dissolving bacteria, growth, productivity and tuber quality.

Introduction

Potato (*Solanum tuberosum,* L.) is one of the most important vegetables in Egypt for both local consumption and exportation. It has a considerable importance as an export crop to the European and Arab markets and one of the national income resources. The total potato cultivated area in 2018 in Egypt, was 424,008 Faddan (fad.), which produced 4,896,476 tons with average 11.54 ton/fad. (FAO, 2018).

The farmers in Egypt used large amounts of K-chemical fertilizers (such as potassium sulphate or chloride) to maximize crop yield per unit area and to compensate K-decreases in soils due to crop uptake. Also, the high price of these fertilizers is responsible for increasing production cost and environmental pollution. The use of natural potassium fertilizer and/or bio-fertilizer is low cost resources for providing plants with K which could alternate the expensive applied K-chemical fertilizers (Labib *et al.,* 2012) . K-feldspar may be valuable as a slow releasing fertilizer and cheaper source of K (Labib *et al.,* 2012). The use of potassium solubilizing bacteria as biofertilizer; *i.e.* silicate dissolving bacteria was suggested as a sustainable solution to improve plant growth, nutrition, root growth, plant competitiveness and responses to external stress factors (Dawwam *et al.,* 2013). Moreover, potassium solbilizing bacteria play an important role in the formation of humus in soil, the cycling of other minerals tied up in organic matter (Zakaria, 2009). Also, it can be able to solubilize rock – K mineral powder, such as mica, lllite and orthoclases (feldspar) through production and excretion of organic acids or chelate silicon ions to bring K into solution (Bennett *et al.,* 1998).

Potassium had significant effect on growth and yield parameters. Aerial stem number, leaf number per plant and plant height were increased with increasing K levels from 0 to 150 kg, while number of days to maturity was increased in the range of 0 - 300 kg K_2O/ha (Zelelew *et al.,* 2016). Addition of feldspar enhanced all of the studied growth parameter (shoots fresh and dry weights/plant), yield components (number of tubers/plant and mean tuber weight), yields (shoots and tuber fresh and dry yields ton/fad) and N, P and K uptake in tuber and shoots (EL

Shabrawy *et al.* , 2014). revealed that foliar spray with potassium silicate increased plant growth, chlorophyll content, N, P and K contents in leaves and yield and its components (Salim *et al.* ,2014).

Therefore, the aim of this work was to study the effect of different potassium fertilization sources and rates on yield and quality of potato plants under sandy clay soil condition.

Materials and Methods

Two field experiment were carried out during the two successive summer seasons of 2018 and 2019 at Private Farm, Belbies District, Sharkia Governorate, Egypt, to study the effect of level and source of potassium (K-sulphate and K-feldspar with potassium silicate and silicate dissolving bacteria on growth productivity and tuber quality of potato (*Solanum tuberosum* L.) *cv.* Spunta grown in sandy clay soil.

The physical and chemical analysis of the experimental soil are presented in table 1.

This experiment included 15 treatment which were the combination among level and source of potassium, with potassium silicate and silicate dissolving bacteria as shown in Schedule 1.

The treatments were arranged in randomized complete block design with three replications.

K– feldspar is a low-grade rock potassium samples from a sedimentary rock materials deposit as raw mining of regrinding to affine powder by Al-Ahram mining and natural fertilizers company in Egypt. Rock potassium as a feldspar and its powder contains 10.6 % K_2O.

The constituents of used feldspar are shown in Schedule 2.

Potassium sulphate and feldspar at different rates were added to the soil (in the mid of the ridges) before planting at soil preparation. Silicate dissolving bacteria (*Bacillus circulans*) was added to the soil at 20 ml/kg feldspar.

Potassium silicate (K_2O_3Si) contains 15% K_2O and 25% Si. The source of potassium silicate was Scientific Center for Soil Analysis and Plant Quality, El-Salhia El-Gedida, Sharkia Governorate, Egypt. The source of silicate dissolving bacteria (*Bacillus circulans*) was unit of Bioformatics, Fac. Agric., Ain Shams University, Cairo, Egypt. Potato plants sprayed with potassium silicate solution (4ml/l) at 45, 60, 75 days after planting. The source of K_2O was potassium sulphate (48 - 52% K_2O) and felspar (10.6% K_2O).

Table 1: The physical and chemical properties of the experimental soil.

pH	ECμS cm^{-1}	$CaCO_3$ (%)	Cation (meg /L)			Anion (meg/L)		
			Ca^{++}	Mg^{++}	Na^{+}	HCO_3^-	CL^-	SO_4^{-2}
8.59	0.82	1.44	7.13	2.63	1.52	2.22	2.65	1.86
N	P	K	Sand		Silt	Clay	Soil	
(ppm)			(%)		(%)	(%)	texture	
89	62	153	47.18		14.57	38.25	Sandy clay	

Schedule 1: Show level and source of potassium with potassium silicate and silicate dissolving bacteria.

Treat. No.	K_2O levels (kg/ fad)	K_2O source (kg/fad)		Potass -ium silicate (KSil)	Silicate dissolving bacteria (SDB)
		K-sulp-hate (KS)	K- felds-par (KF)		
1	96	96 (100%)	-	KSil	-
2	72	72 (75%)	-	KSil	-
3	48	48 (50%)	-	KSil	-
4	96	-	96 (100%)	-	SDB
5	72	-	72 (75%)	-	SDB
6	48	-	48 (50%)	-	SDB
7	96	72 (75%)	24 (25%)	KSil	SDB
8	96	48 (50%)	48 (50%)	KSil	SDB
9	96	24 (25%)	72 (75%)	KSil	SDB
10	72	54 (75%)	18 (25%)	KSil	SDB
11	72	36 (50%)	36 (50%)	KSil	SDB
12	72	18 (25%)	54 (75%)	KSil	SDB
13	48	36 (75%)	12 (25%)	KSil	SDB
14	48	24 (50%)	24 (50%)	KSil	SDB
15	48	12 (25%)	36 (75%)	KSil	SDB

100,75 and 50 of the recommended rates of K_2O were about 96, 72 and 48 kg / fad, respectively, KS: potassium sulphate, KF: Feldspar, DSB: silicate dissolving bacteria, KSil: potassium silicate.

100 % of recommended rate of K_2O/fad were about 96 kg K_2O, 196 kg K_2SO_4 and 905.66 kg feldspar.

Schedule 2: Show the components of used feldspar.

Feldspar rock	Components (%)	Feldspar rock	Components (%)
SiO_2	67.94	Na_2O	1.94
Al_2O_3	13.92	TiO_2	0.01
Fe_2O_3	0.09	MnO_2	0.01
CaO	0.32	P_2O_5	0.04
MgO	8.08	Cl	0.03
K_2O	10.6		

Plot area was 9 m^2, which included 3 ridges of 5 m long and 0.7 m wide each. Spunta tuber seeds were planted on 27th and 11th of January in the 1st and 2nd seasons, respectively, and spaced at 20 cm apart. The weight of potato tuber seed was about 60 gm. Other agriculture practices were carried out as commonly recommended for potato in the district.

Nitrogen, phosphorus and potassium sources were ammonium sulphate (20.5 % N) at 120 kg/fad, calcium super phosphate (15.5% P_2O_5) at 75 kg/fad and potassium sulphate (48 – 52 % K_2O) at 96 kg/fad, respectively. FYM rate (30 m^3/fad) and all amount of P_2O_5 were added before planting with one third of the amounts of N, K in the mid of the ridge then covered by sand. The rest amounts of N, K (two third) were divided into equal portions and added as soil application at 15 days intervals beginning after completely emergence.

Data recorded:

Plant growth:

Two plants were randomly taken from every experimental unit at 80 days after planting to determine the following parameters: Plant height, number of main stem / plants, number of lateral branches / plants, number of leaves / plants, leaf area / plant (cm^2) and fresh weight of shoots / plant.

Leaf area / plant (cm^2) =

$$\frac{leaves\ dry\ weight\ (gm) \times disk\ area}{disk\ dry\ weight\ (gm)}$$

Fresh weight of leaves and branches (shoots) were oven dried at 70 c^o to tell constant weight, then their dry weight were recorded per plant.

Yield and its components:

At 110 days of planting, tubers from every experimental unit were harvested, weighed, counted, and graded into three sizes according to their diameters (above 6.5 cm, 3.5 – 6.4 cm and less than 3.5 cm for grades 1, 2 and 3 respectively) then each grade was weight separately. Also, number of tubers per plant, average tuber weight and tuber yield per plant as well as per fad. (4200 m^2 = 0.42 ha) were calculated.

Tuber quality:

Starch content: It was calculated according to the formula of Burton (1948): Starch (%) = 17.546+0.891 (Tuber dry matter% - 24.18).

Total protein percentage: It was calculating by multiplying total nitrogen × 6.25.

Dry Matter percentage: One hundred grams of the grated mixture were dried at 105 till constant weight and DM (%) was recorded.

Statistical analysis

All the obtained data were statistically analysis using the Statistix 9 program and means separation were done by least significant value (L.S.D.) at 0.05 level of probability according to Snedecor and Cochran (1980).

Results and Discussion

Plant Growth

The obtained result in table 2 and 3 show that fertilizing of potato plants grown in sandy soil with two sources of potassium at different rates had significant effect on plant height, number of main stems, number of lateral branches, leaf area/plant, fresh weight of shoots/ plant, dry weight of shoots/plant and leaf number/plant, except, number of main stem and number of lateral branches/plant and number of leaves/plant in the 1st season.

Fertilizing with 48 kg K_2O as K-sulphate with potassium silicate (Ksil) and 18 kg K_2O as K-sulphate (KS) + 54 kg K_2O as KF with silicate dissolving bacteria (SDB) + Ksil gave the tallest plant in the 1st and 2nd seasons, respectively. Whereas 24 kg K_2O as KS + 24 kg K_2O as KF with SDB + Ksil gave the shortest plants in both seasons. This means that 48 kg K_2O as KS gave the tallest plant, whereas 48 kg K_2O from two sources (50 % KS + 50% KF) gave the shortest plants.

Fertilizing with 36 kg K_2O as KS + 36 kg K_2O as KF with SDB + Ksil gave the higher values of number of lateral branches / plants, leaf area / plant and number of leaves / plants in the 2nd season. Whereas 24 kg K_2O as KS + 24 kg K_2O as KF with SDB + Ksil gave the lowest values.

As for fresh and dry weight of shoots/ plant, 72 kg K_2O as KS with Ksil and 36 kg K_2O as KS + 36 kg K_2O as KF with SDB + Ksil gave the highest values of fresh and dry weight of shoots / plant in the 2nd season with no significant effect differences with 96 kg K_2O as KS with Ksil.

In general, from the foregoing results, it could be concluded that 48 kg K_2O as KS with Ksil gave the tallest plants, whereas 36 kg K_2O as KS + 36 kg K_2O as KF with SDB + Ksil gave the highest values of number of main stems / plant, number of lateral branches / plant, leaf area / plant, fresh and dry weight of shoots / plant and number of leaves / plant.

Potassium is particularly important to obtain large productions. It has an important role in the synthesis of sugars and starch, which can be considered as the reason for the high requirement of this element. Because of its high mobility, potassium assists in the glucose transfer to the tubers. Potassium also diminishes frost damage, while it acts as a solute in the cell cytoplasm, thus low runn the freezing point of the cells. The element exercises a great influence on the plant's water balance as it effectively defends the assimilation tissues against drought damages and assures the uninterrupted sugars and starch development. Potassium also has a strong influence on the potato's texture, coloring and flavor as well as on its conservation as it provides more skin firmness.

Labib *et al.,* (2012) reported that the advantages of applying K- bearing rock on poor fertility sandy soil can be related to their improvement of physical and chemical conditions particularly when combined with organic amendment. Also, the excessive application of relatively soluble chemical fertilizers has hazardous impact on environmental conditions since considerable proportions are usually lost through drainage and cause pollution of water channels. The addition of K-feldspar only, in the fourth treatment, showed high morphological quality of potato tubers, with respect to high diameter and solid material in spite of the lower yield obtained. This can be explained by the slow and long release of K from feldspar rock through stages of growth.

These results agree with reported by labib *et al*., (2012), Abdl-Salam and Shams (2012), El-Shabrawy *et al.,* (2014), Abou El-Khair and Mohsen (2016) and El-Afifi *et al.,* (2016). They reported that combination between K – sulphate and K – feldspar at different rates increased plant growth.

Tuber Weight, Number and Yield / Plant

The obtain result in table 4 indicate that fertilizing potato plants with two sources of K_2O at different rates had no significant effect on average tuber weight and average tuber number / plant in both seasons.

Fertilizing potato plant with 72 kg K_2O (36 kg K_2O as KS + 36 kg K_2O as KF) with SDB + Ksil gave the highest values of tuber yield / plant followed by 96 kg K_2O (24 kg K_2O as KS + 72 kg K_2O as KF) with SDB + Ksil and 72 kg K_2O (54kg K_2O as KS + 18 kg K_2O as KF) with SDB + Ksil in both seasons. 96 kg K_2O as KF with SDB followed by 96 kg K_2O as KS with Ksil and 48 kg K_2O as KF with SDB gave the lowest values of tuber yield / plant.

Average tuber weight ranged from 148.96 to 215.83 gm as average two seasons for all treatments. This means that average of tuber weight of Spunta cultivar was 182.89 gm. Average tuber number / plant ranged from 3.24 to 5 as average two seasons for all treatments. This means that average tuber number / plant of Spunta cultivar was 4.12. Tuber yield / plant ranged from 494.75 to 1024.43 gm as average two seasons for all treatments. This means that tuber yield / plant for Spunta cultivar was 755.59 gm.

In general, fertilizing with different combinations between K – sulphate and K – feldspar at different rate

Table 2: Effect of level and source of potassium, with potassium silicate and silicate dissolving bacteria on plant height, number of main stem, number of lateral branches and leaf area / plant of potato plants grown in sandy clay soil at 80 days after planting during 2018 and 2019 seasons.

Treatments K_2O source (kg / fad)	Plant height (cm)		Number of main stem		Number of lateral branches		Leaf area/ plant(cm^2)	
	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season
96 kg K_2O as KS + Ksil	61.00	59.00	2.66	1.33	7.33	3.33	2278.7	5467.9
72 kg K_2O as KS + Ksil	63.33	63.33	2.33	2.66	6.33	6.33	4635.3	4414.3
48 kg K_2O as KS + Ksil	66.66	65.66	2.33	1.66	6.00	4.33	4048.0	3059.5
96 kg K_2O as KF + SDB	61.33	61.33	2.00	2.00	5.33	5.66	3037.0	3594.9
72 kg K_2O as KF + SDB	59.66	59.00	2.00	2.00	6.00	5.33	3458.7	2493.6
48 kg K_2O as KF + SDB	64.00	57.66	1.66	1.00	5.00	3.33	2776.3	2567.0
72 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	63.33	60.00	1.66	2.66	5.66	5.66	3274.0	5059.2
48 kg K_2O as KS + 48 kg K_2O as KF + Ksil + SDB	59.00	63.33	1.66	1.33	6.00	3.00	3080.3	3131.1
24 kg K_2O as KS + 72 kg K_2O as KF + Ksil + SDB	57.66	59.33	2.00	1.33	6.00	3.00	39.77.3	2678.3
54 kg K_2O as KS + 18 kg K_2O as KF + Ksil + SDB	61.00	59.33	2.33	1.66	5.00	4.00	3021.3	2788.3
36 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	60.00	63.33	2.33	3.33	5.66	9.33	3847.7	5758.0
18 kg K_2O as KS + 54 kg K_2O as KF + Ksil + SDB	64.33	68.33	2.00	2.00	4.33	4.33	3013.7	2674.1
36 kg K_2O as KS + 12 kg K_2O as KF + Ksil + SDB	62.33	61.00	3.00	2.66	6.33	6.00	2927.0	3358.8
24 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	53.66	53.66	2.66	1.00	5.00	3.33	2564.3	2058.3
12 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	60.66a	62.66	2.00	1.33	5.33	4.00	3710.7	3111.3
LSD at 5 %	8.50	7.50	NS	1.57	NS	3.53	1885.9	2580.6

100, 75 and 50 % of recommended rate of K_2O were about 96, 72 and 48 kg / fad, respectively, Ksil: potassium silicate, SDB: silicate dissolving bacteria, KF: feldspar, KS: potassium sulphate.

(96, 72 and 48 kg K_2O/fad) with inoculation with silicate dissolving bacteria and spraying with potassium silicate were the best treatment for increasing tuber yield / plant compared to K – sulphate at 96 kg K_2O with Ksil and K

Table 3: Effect of level and source of potassium with potassium silicate and silicate dissolving bacteria on leaf number / plant, fresh and dry weight of shoots of potato plants grown in sandy clay soil at 80 days after planting during 2018 and 2019 seasons.

Treatments K_2O source (kg / fad)	**Leaves No./plant**		**Fresh weight of shoots/plant(g)**		**Dry weight of shoots/plant(g)**	
	2018 season	**2019 season**	**2018 season**	**2019 season**	**2018 season**	**2019 season**
96 kg K_2O as KS + Ksil	39.33	24.66	156.00	252.67	22.65	51.23
72 kg K_2O as KS + Ksil	54.66	45.33	333.67	291.00	45.38	40.43
48 kg K_2O as KS + Ksil	52.00	39.00	331.67	231.67	41.56	24.89
96 kg K_2O as KF + SDB	40.00	38.00	202.33	222.00	28.50	33.08
72 kg K_2O as KF + SDB	37.00	31.66	233.33	174.00	33.72	21.86
48 kg K_2O as KF + SDB	30.66	19.66	182.00	158.00	26.29	22.97
72 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	39.66	50.33	233.33	272.67	32.15	44.31
48 kg K_2O as KS + 48 kg K_2O as KF + Ksil + SDB	36.66	34.66	206.33	189.00	29.94	28.23
24 kg K_2O as KS + 72 kg K_2O as KF + Ksil + SDB	45.00	33.66	270.33	197.00	40.13	27.88
54 kg K_2O as KS + 18 kg K_2O as KF + Ksil + SDB	39.00	31.33	225.33	190.67	30.45	27.03
36 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	50.33	65.33	303.33	370.67	37.78	50.31
18 kg K_2O as KS + 54 kg K_2O as KF + Ksil + SDB	36.00	46.66	261.33	210.67	36.75	26.89
36 kg K_2O as KS + 12 kg K_2O as KF + Ksil + SDB	38.00	34.33	285.33	244.67	30.69	30.23
24 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	27.33	21.00	217.33	162.33	25.53	16.82
12 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	43.00	31.33	293.33	198.67	37.40	22.57
LSD at 5 %	NS	22.96	147.02	121.92	18.19	24.91

100, 75 and 50 % of recommended rate of K_2O were about 96, 72 and 48 kg / fad, respectively, Ksil: potassium silicate, SDB: silicate dissolving bacteria, KF: feldspar, KS: potassium sulphate.

Table 4: Effect of level and source of potassium, with potassium silicate and silicate dissolving bacteria on average tuber wight, average tuber number and tuber yield / plant of potato plants grown in sandy clay soil during 2018 and 2019 season.

Treatments K_2O source (kg / fad)	**Average tuber weight (gm)**		**Tuber number/plant**		**Tuber yield/plant (gm)**	
	2018 season	**2019 season**	**2018 season**	**2019 season**	**2018 season**	**2019 season**
96 kg K_2O as KS + Ksil	155.42	169.02	3.75	3.83	577.58	646.50
72 kg K_2O as KS + Ksil	168.85	185.55	4.66	4.66	796.33	877.00
48 kg K_2O as KS + Ksil	164.97	170.73	4.58	4.66	752.58	796.17
96 kg K_2O as KF + SDB	156.21	166.55	3.16	3.33	467.83	521.67
72 kg K_2O as KF + SDB	145.55	152.37	4.33	4.50	621.17	678.50
48 kg K_2O as KF + SDB	150.89	157.23	4.08	4.16	596.00	635.50
72 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	186.22	184.66	4.08	4.33	755.17	794.17
48 kg K_2O as KS + 48 kg K_2O as KF + Ksil + SDB	153.27	164.13	3.66	3.83	657.83	729.33
24 kg K_2O as KS + 72 kg K_2O as KF + Ksil + SDB	184.01	199.72	4.75	4.83	872.83	963.67
54 kg K_2O as KS + 18 kg K_2O as KF + Ksil + SDB	177.13	180.07	5.00	5.00	885.67	900.33
36 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	210.97	221.65	4.66	4.83	982.17	1066.7
18 kg K_2O as KS + 54 kg K_2O as KF + Ksil + SDB	173.85	183.96	4.41	4.50	768.17	823.67
36 kg K_2O as KS + 12 kg K_2O as KF + Ksil + SDB	177.45	189.64	4.16	4.33	749.75	833.83
24 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	183.46	183.35	3.91	4.16	709.33	757.33
12 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	182.68	191.46	4.25	4.50	763.00	834.00
LSD at 5 %	NS	NS	NS	NS	314.14	356.11

100, 75 and 50 % of recommended rate of K_2O were about 96, 72 and 48 kg / fad, respectively, Ksil: potassium silicate, SDB: silicate dissolving bacteria, KF: feldspar, KS: potassium sulphate.

Table 5: Effect of level and source of potassium, with potassium silicate and silicate dissolving bacteria on yield and its components of potato plants grown in sandy clay soil during 2018 and 2019 seasons.

Treatments K_2O source (kg / fad)	Yield of grade 1 (ton / fad)		Yield of grade 2 (ton / fad)		Yield of grade 3 (ton / fad)		Marketable yield (ton / fad)		Total yield (ton / fad)	
	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season
96 kg K_2O as KS + Ksil	14.61	16.88	3.90	3.64	0.74	1.03	18.51	20.51	19.25	21.55
72 kg K_2O as KS + Ksil	21.11	24.55	4.63	4.00	0.80	0.68	25.75	28.55	26.54	29.23
48 kg K_2O as KS + Ksil	18.47	19.24	6.19	6.98	0.42	0.32	24.66	26.21	25.08	26.53
96 kg K_2O as KF + SDB	9.52	10.96	5.22	5.66	0.85	0.76	14.74	16.62	15.59	17.38
72 kg K_2O as KF + SDB	11.34	13.03	8.92	9.15	0.43	0.43	20.27	22.18	20.71	22.61
48 kg K_2O as KF + SDB	13.42	15.37	5.99	5.47	0.45	0.33	19.41	20.85	19.87	21.18
72 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	20.10	20.72	3.93	4.44	1.12	1.30	24.04	25.16	25.17	26.47
48 kg K_2O as KS + 48 kg K_2O as KF + Ksil + SDB	15.46	17.26	6.06	6.81	0.40	0.23	21.52	24.07	21.92	24.31
24 kg K_2O as KS + 72 kg K_2O as KF + Ksil + SDB	21.48	25.19	7.37	6.62	0.24	0.31	28.85	31.81	29.09	32.12
54 kg K_2O as KS + 18 kg K_2O as KF + Ksil + SDB	21.61	22.67	7.68	7.20	0.22	0.13	29.30	29.87	29.52	30.01
36 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	25.54	28.94	6.89	6.42	0.30	0.19	32.44	35.36	32.74	35.55
18 kg K_2O as KS + 54 kg K_2O as KF + Ksil + SDB	18.04	20.36	7.02	6.45	0.54	0.64	25.06	26.81	25.60	27.45
36 kg K_2O as KS + 12 kg K_2O as KF + Ksil + SDB	18.01	22.07	6.32	4.87	0.65	0.84	24.33	26.95	24.99	27.79
24 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	18.78	20.76	4.53	4.02	0.33	0.45	23.31	24.78	23.64	25.24
12 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	17.96	19.58	6.89	7.53	0.57	0.69	24.86	27.11	25.43	27.80
LSD at 5 %	10.18	11.46	4.14	4.81	0.79	0.81	10.65	11.91	10.47	11.87

100, 75 and 50 % of recommended rate of K_2O were about 96, 72 and 48 kg / fad, respectively, Ksil: potassium silicate, SDB: silicate dissolving bacteria, KF: feldspar, KS: potassium sulphate, marketable yield = yield of grades 1 + 2 and total yield = yield of grades 1 + 2 + 3.

– feldspar at 96 kg K_2O with SDB.

From the forgoing results, it could be concluded that, potato plants fertilized with 72 kg K_2O (36 kg K_2O as KS + 36 kg K_2O as KF) with SDB + Ksil increased tuber yield / plant in both seasons.

The combination between K – sulphate and K – felspar at different rates increased tuber yield / plant (Abdel – Salam and Shams, 2012 and El – Afifi *et. al.*, 2016).

Marketable Yield and Total Yield

Data in Table 5 show that sources and level of K_2O had significant effect on yield of grades 1, 2, 3, marketable yield and total yield / fad in both seasons.

Fertilizing of potato plant with 36kg K_2O as potassium sulphate (KS) + 36 kg K_2O as feldspar (KF) with inoculation with silicate dissolving bacteria (SDB) + foliar spray with potassium silicate (Ksil) gave the highest values of yield of grade 1, marketable yield and total yield / fad. followed by fertilizing with 54 kg K_2O as KS + 18 kg K_2O as KF with SDB + Ksil and 24 kg K_2O as KS + 72 kg K_2O as KF with SDB + Ksil compared to the other treatments in both seasons. Treatments with 96 kg K_2O as KF + SDB gave the lowest values of yield of grade 1, marketable yield and total yield / fad followed by 72 kg K_2O as KF + SDB and 48 kg K_2O as KF + SDB with respect to yield of grade 1 and 96 kg K_2O as KS + Ksil with respect to marketable yield and total yield / fad compared to the other treatments in both seasons. The yield of grade 1 (large tubers) is linearly related to total yield and number of tubers.

The increase in total yield were about 70.07 and 64.96 % for 36 kg K_2O as KS + 36 kg as KF with SDB + Ksil, 51.11 and 49.04 % for 24 kg K_2O as KS + 72 kg K_2O as KF with SDB + Ksil and 53.35 % and 39.25 % for 54 kg K_2O as KS + 18 kg K_2O as KF with SDB + Ksil over than 96 kg K_2O as KS with Ksil in the 1st and 2nd seasons, respectively.

As for yield of grade 2, fertilizing with 72 kg K_2O as KF with SDB gave the highest yield of grade 2, whereas 96kg K_2O

Table 5: Effect of level and source of potassium, with potassium silicate and silicate dissolving bacteria on dry matter, protein and starch contents in tubers of potato plants grown in sandy clay soil during 2018 and 2019 seasons.

Treatments K_2O source (kg / fad)	Tuber Quality					
	DM (%)		Protein (%)		Starch (%)	
	2018 season	2019 season	2018 season	2019 season	2018 season	2019 season
96 kg K_2O as KS + Ksil	18.770	19.707	7.583	9.416	12.727	13.563
72 kg K_2O as KS + Ksil	19.843	20.820	7.960	9.847	13.683	14.557
48 kg K_2O as KS + Ksil	21.083	22.053	6.918	8.721	14.790	15.653
96 kg K_2O as KF + SDB	20.280	20.997	8.948	10.841	14.073	14.713
72 kg K_2O as KF + SDB	21.697	22.623	11.159	12.926	15.337	16.163
48 kg K_2O as KF + SDB	17.890	18.917	9.901	11.680	11.940	12.860
72 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	21.113	22.033	7.475	9.356	14.817	15.633
48 kg K_2O as KS + 48 kg K_2O as KF + Ksil + SDB	23.077	24.067	7.044	8.913	16.567	17.447
24 kg K_2O as KS + 72 kg K_2O as KF + Ksil + SDB	21.780	22.820	10.566	12.399	15.410	16.337
54 kg K_2O as KS + 18 kg K_2O as KF + Ksil + SDB	21.917	22.863	10.098	11.919	15.533	16.377
36 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	22.843	23.567	8.733	10.662	16.357	17.003
18 kg K_2O as KS + 54 kg K_2O as KF + Ksil + SDB	21.010	21.970	10.116	11.862	14.723	15.580
36 kg K_2O as KS + 12 kg K_2O as KF + Ksil + SDB	22.247	23.173	9.272	11.201	15.827	16.650
24 kg K_2O as KS + 24 kg K_2O as KF + Ksil + SDB	22.987	23.900	6.954	8.757	16.483	17.300
12 kg K_2O as KS + 36 kg K_2O as KF + Ksil + SDB	18.740	20.357	7.888	9.787d	12.700	14.143
LSD at 5 %	NS	3.773	1.603	1.612	3.421	3.360

100, 75 and 50 % of recommended rate of K_2O were about 96, 72 and 48 kg / fad, respectively, Ksil: potassium silicate, SDB: silicate dissolving bacteria, KF: feldspar, KS: potassium sulphate.

as KS with Ksil gave the lowest values compared to the other treatments in both seasons.

Regarding yield of grade 3, data show that 72 kg K_2O as Ks + 24 kg as KF with SDB + Ksil gave the higher values of yield of grade 3, whereas 54 kg K_2O as KS + 18 kg as KF with SDB and Ksil gave the lowest values compared to the other treatments in both seasons.

In general, the best treatment for increasing the total yield were fertilizing potato plants with two sources of K_2O (potassium sulphate and feldspar) at different rates (96,72 and 48 kg / fad) with silicate dissolving bacteria + potassium silicate compared to fertilizing with K_2O as feldspar (natural – K) at 96, 72, 48 kg K2O / fad with SDB and fertilizing with K_2O as potassium sulphate (mineral – K) at 96 kg K_2O/fad with Ksil.

From the foregoing result, it could be concluded that, fertilizing potato plants grown in sandy soil with 36 kg K_2O as potassium sulphate + 36 kg K_2O as feldspar with inoculation with silicate potassium bacteria + foliar spray with potassium silicate increased yield of grade 1, marketable yield and total yield / fad. Therefore, the most effective combination of K – sulphate and K – feldspar as a K sources at (72 kg K_2O / fad) for potato plants grown in sandy soil was 50 % as K – sulphate (36 kg K_2O) + 50 % as K – felspar (36 kg K_2O) with silicate dissolving bacteria + potassium silicate. This treatment reduces potassium quantity about 24 kg K_2O / fad and increase total yield about 67.51 % (average two seasons) over the 96 kg K_2O as KS with Ksil. Also, this treatment could reduce the costs of potato production and environment pollution.

From economic point of view, it may be away to reducing the cost production by replacing partly the expensive potassium chemical fertilizer by the chipper locally available feldspar mineral in combination with silicate dissolving bacteria and potassium silicate.

The simulative effect of 36 kg K_2O as KS + 36 kg K_2O as KF with SDB + Ksil on total yield may be due to that this treatment increases, number of main stems / plant, number of lateral branches / plant and leaf area / plant table 2, fresh and dry weight of shoot and number of leaves / plant table 3, average tuber weight and yield / plant table 4 and yield of grade 1 table 5.

These results agree with those reported by labib *et al.,* (2012), Abdl-Salam and Shams (2012), El-Shabrawy *et al.,* (2014), Abou El-Khair and Mohsen (2016) and El-Afifi *et al.,* (2016). They reported that combination between K – sulphate and K – feldspar at different rates increased total yield/fad.

Tuber Quality

Data in table 6 show that fertilizing potato plants with 48 kg K_2O as KS + 48 kg K_2O as KF with SDB + Ksil gave the highest values of DM % in the 2[nd] season and starch % in tubers in both seasons. Whereas, fertilizing with 48 kg K_2O as KF with SDB and 36 kg K_2O as KS + 36 kg K_2O as KF with SDB + Ksil gave the lowest values. This means that there is positive correlation between DM % and starch % in tubers. DM % in tubers in both seasons ranged from 17.89 % to 24.06 % (20.97 % as average) and starch % ranged from 11.94 to 17.44 % (14.69 % as average).

Starch content associate with dry matter content. For this reason, the highest positive correlation was found between dry matter content and starch content (Arslan, 2007 and Bãrãscu *et al.,* 2016). Starch, comprising 65.80 % of dry matter content, is considered to be the main constituent of potato (Kadam *et al.,* 1991). Starch content ranged from 11.81 % to 18.10 % (Kaur and Aggarwal, 2016). This differences in starch content might be due to differences in dry matter in tubers as starch and dry matter content of potato are directly related to each other. Respecting protein content, fertilizing with 72 kg K_2O as KF with SDB gave the highest values of protein content in tubers followed by 24 kg K_2O as KS + 72 kg K_2O as KF with SDB + Ksil, whereas 24 kg K_2O as KS + 24 kg K_2O as KF with SDB + Ksil gave the lowest values of protein content.

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