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Wheat Response to Potassium Fertilization in Sandy Soil As Affected by Organic Amendments and Silicate Dissolving Bacteria

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SOIL potassium content is a limiting factor of wheat growth and productivity, as it is one of the most important major elements for plant growth. The Need for optimizing use of potassium fertilization using natural amendments is growing up parallel with the accelerating increase in fertilizer prices. A field experiment was carried out during 2014-2015 growing season in Salehia, Egypt. The aim of the study is to investigate the effect of different sources of potassium fertilizers (potassium sulphate and potassium feldspar) at the recommended rate (95 kg K ha^{-1}) and either single or in combination with organic amendments ,*i.e.* chicken manure (Ch.M) and farmyard manure (FYM) with silicate dissolving bacteria (SDB) on yield and nutrients uptake by wheat. The results indicated that the highest values of dry matter yield of wheat, biological yield, protein content, NPK –uptake and available potassium in soil were observed at the treatment of (K sulphate or K-feldspar + Ch.M) in the presence of SDB. Dry matter yield of straw and grain ranged from 8.53 to 11.79 and 5.94 to 8.11 Mg ha^{-1}, respectively. Based on thesa results, the available potassium was remarkably increased after 60 and 90 days and then decreased at 150 days at all treatments for application of potassium sources and organic amendments with SDB.

Key words: K- sulphate, K-feldspar, Nutrients uptake, Wheat.

Introduction

Wheat is considered a very important cereal crop for many countries all over the world. In Egypt, there is a great gap between consumption and production of wheat (FAO, 2011). Potassium (K) is required by crop plants in a large quantity as its concentration in plant biomass is at the second place just after nitrogen (Syers 1998 and Römheld & Kirkby, 2010). Potassium content in clayey soils ranges from 0.4 to 30 g/kg K, distributed between K available to plants (Kavail, *i.e.* solution K and exchangeable K); fixed K and structural K in K-bearing feldspars and layer silicates (Huang, 2005, Rees *et al*., 2013 and Edmeades *et al.,* 2014). Analysis of K availability is standard for judgment of nutritional status of soils; however, a release of fixed K to the available forms takes place when available K is reduced by plant removal (Moritsuka *et al.*, 2004), microbial activity and leaching (Martin and Sparks, 1985). Feldspar is the name of an important group of rock-forming minerals, which make up perhaps as much as 60% of Earth's crust. Feldspars crystallize from magma in both intrusive rocks; they may occur as compact minerals as, veins and present in many types of metamorphic rocks. Feldspars may also be found in many types of sedimentary rocks. In addition, the main source of potassium in soil is primary alumino–silicates, which include K-feldspar. (Wahba & Darwish, 2008 and Hemasheenee et al., 2017).

Organic amendments are soil improving agents. The application of such amendments could improve the retentive capacity of sandy soil for water and fertilization nutrients and also may help in improving the unfavorable structure and in increasing nutrients availability in soil (Setiawati & Mutmainnah, 2016 and Voelkner, 2017). As the majority of Egyptian soils are new reclaimed desert soils, they are poor or marginal in nutrient status and need adequate fertilization supply to sustain high productivity (Badr et al., 2006). Potassium is a major essential macronutrient for plant growth and development and soluble K -fertilizers commonly applied to replace removed minerals for optimizing yield. Rock potassium 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 a fertilizer often causes insignificant yield increases of current crop (Sheng & Huang, 2002 and Zapata & Roy, 2004). Han et al. (2006) reported that the combined application of rock P and K materials with co-inoculation of both bacteria (P + K) DB

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that solubilize them might provide a faster and continuous supply of P and K which maximizes plant growth. Priyono and Gilkes (2008) evaluated the effectiveness of intensively milled gneiss and potassium feldspars as K-fertilizers through a glasshouse experiment with ryegrass. They found that the application of K-Silicate Rock Fertilizer (K-SRF) will be most advantageous for amending K-deficient soils.

Potassium solubilizing bacteria is an aerobic bacteria which plays a significant role in maintaining soil structure by their contribution in the formation and stabilization of water-stable soil aggregates (Zakaria, 2009, Sheng et al. 2002, Vessey, 2003, Sheng, 2005, Setiawati, Handayanto, 2010, Ekin, 2010 and Setiawati & Mutmainnah, 2016). Moreover, KSB are able to solubilize rock K mineral powder, such as micas, illite and orthoclases (feldspar), and also extract K from soil organic matter. Abd El-Hakeem and Fekry (2014) found that the application of potassium sulphate plus K- feldspar with SDB increased yield, NPK-uptake and quality of tuber roots and total sugar in sweet potato. Badr et al. (2006) found that the dry matter of sorghum plants inoculated with silicate dissolving bacteria (SBS strain) and supplied with minerals (feldspar and rock phosphate) increased by 48%, 65% and 58% for clay, sandy and calcareous soil, respectively, compared to the plants supplied with minerals alone. Hellal et al. (2009) reported that the application of organic amendments with feldspar gave the highest values of yield and NPK-uptake by faba bean plants. Abdel-Salam and Shams (2012) and Labib et al. (2012) reported that the addition of potassium sulphate mixed with K-feldspar in the presence of SDB gave the highest values of quality potato tubers, total yield and NPK uptake in tubers and shoots by potato plants. The present work aims to evaluate the efficiency of potassium fertilizers (potassium sulphate and K-feldspar) as influenced by different organic amendments application with and without silicate dissolving bacteria (SDB), (*Bacillus circullans*) and their effect on potassium availability, yield and nutrients uptake of wheat plants in sandy soil conditions.

Materials and Methods

Experiment set up and design

A field experiment was carried out in 2014-2015 growing season at Salehia, Egypt to study the effect of the efficiency of K fertilization (K- sulphate and K- feldspar) as influenced by different organic amendments , *i.e.* chicken manure (Ch.M) and farmyard manure (FYM) application with or without silicate dissolving bacteria (SDB), (*Bacillus circullans*) and their effect on yield and nutrients uptake of wheat plants (*Triticum aestivum* L, cv. Sakha 93). The physical and chemical properties of the soil determined according to Piper (1951), Black et al. (1965) and Jackson (1973) are shown in Table 1. The experiment included 18 treatments with 3 replicates/plots, with a total of 54 plots. The experimental design was a factorial arranged as a split-split blocks with three potassium sources as main-plot, three organic amendments (untreated, Ch.M and FYM) as subplots, and two silicate dissolving bacteria (0 and 20 ml kg^{-1} K- sulphate or K- feldspar) as sub-subplot plots. The plot area was 21 m^2 (3 × 7), each plot had five rows 60 cm apart and 7m long.

The experimental treatments were as follows:

1. Without potassium fertilization or K- sulphate or K- feldspar application in the absence of organic amendments and silicate dissolving bacteria
2. Without potassium fertilization or K- sulphate or K- feldspar application in the absence of organic amendments with SDB.
3. Without potassium fertilization or K-sulphate or K- feldspar application + FYM in the absence of SDB
4. Without potassium fertilization or K- sulphate or K- feldspar application + FYM in the in presence of SDB
5. Without potassium fertilization or K-sulphate or K- feldspar application + Ch.M in the absence of SDB
6. Without potassium fertilization or K- sulphate or K- feldspar application + Ch.M in the in presence of SDB

Fertilization and soil amendments application

Ordinary super phosphate was applied at a rate of 31 kg P ha^{-1} before planting and ammonium sulphate at a rate of 238 kg N ha^{-1} was added during the growing period (after 15 , 40 and 60 days) in three equal doses. Chicken manure (Ch.M) and farmyard manure (FYM) were added at a rate of 20 Mg ha^{-1}) to the soil at a depth of 20 cm before planting. Some characteristics of organic amendments are shown in Table 2. Potassium sulphate (400 g K kg^{-1}) and K- feldspar (94 g K kg^{-1}) were added to the soil before planting at the recommended rate (95 kg ha^{-1}). The biofertilizer, silicate dissolving bacteria (SDB), (*Bacillus circullans*) was attained from the Microbiology Department, National Research Centre, Cairo, Egypt. The biofertilizer, silicate dissolving bacteria was inoculated in a concentration of (1×10^{10} CFU ml^{-1}) at a rate of 20 ml kg^{-1} potassium sulphate or K-feldspar to mix with soil before planting and irrigation (Badr et al., 2006).

Chemical analyses

Plants were harvested at three times in three stages , *i.e.* 40, 70 and 150 days from sowing; corresponding to tillering, booting and harvest stages , respectively. Plant samples were dried at 70 ˚C for 72 hr, weighed, ground and analyzed for total nitrogen, phosphorus and potassium. At harvest, plants were separated into straw and grains and digested with concentration H_2SO_4/$HCLO_4$ (Chapman and Pratt, 1961). Total N was determined using the Micro-Kjeldahl method according to Chapman and Pratt (1961). P and K were determined in digests of concentration H_2SO_4/$HCLO_4$ according to Chapman and Pratt (1961). Measurements of P were done colorimetrically using ascorbic acid (Watanabe and Olsen, 1965), while K was measured by flame photometer (Chapman and Pratt, 1961). Protein percentage "yield quality" in grains was calculated by multiplying N% × 5.70 (Bishni and Hughes, 1979). Soil samples were taken at intervals of 60, 90 and 150 days after sowing.

Statistical analyses

All the obtained data such as dry weight at tillering and butting stages , straw and grains dry weight, straw and grains N, P, K - uptake were statistically analyzed (LSD at 0.05) according to the method described by Russell (1991).

Results and Discussion

Dry weight

In the present experiment, dry matter yield of wheat plants at tillering, booting stages, harvest (straw and grains) stages, biological yield, weight 1000 grain and protein content were significantly affected by the interaction between potassium fertilizer, organic amendments and silicate dissolving bacteria (Table 3). The highest values were observed at the treatment of (K- sulphate or K-feldspar + Ch.M) in the presence of SDB, while the lowest values were obtained with untreated soil (without organic amendments and SDB). Dry matter yield of straw and grain at harvesting stage ranged from 8.53 to 11.79 and 5.94 to 8.11 Mg ha^{-1}, respectively. These results agre with those obtained by Abdel-Salam and Shams (2012) and Abd El-Hakeem & Fekry (2014).

Regarding the mean effect of organic amendments addition, the data show that using chicken manure combined with SDB gave the highest values of dry matter yield, biological yield and protein content comparing with the application of FYM using K sulphate or K-feldspar (Table 1). These results may be attributed to increase the utilization of growing plants from chicken manure than farmyard manure, which is due to the decomposition rate of chicken manure was faster than that of FYM as reported by Hassan et al. (2002), Hellal et al. (2009), Manning (2010) and Merwad et al. (2013).

Data showed that the application of SDB increased grain dry weight compared to the untreated ones. These increases represent 6, 3, 3 % in the case of K sulphate for the treatments of without, Ch.M and FYM, respectively and 5.6, 3.4 and 3% of K-feldspar for the same treatments, respectively. These results are in agreement with those of Gad (2001) who reported that biofertilization on plants increased growth and yield.

On the other hand, treatments under K sulphate gave higher values of grain dry weight than those under K-feldspar. These increases represent 2.3, 3.6 and 1.1% in the presence of SDB for the treatments of without, Ch.M and FYM, respectively, while the increases represent 1.8, 4, 2.3 and 13 % in the absence of SDB application for the same treatments, respectively.

The application of biofertilizer, silicate dissolving bacteria (SDB) to K-feldspar increased biological yield, weight of 1000 grain, protein content and straw and grains yield. Silicate dissolving 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, illite and orthoclases (feldspar), through production and excretion of organic acids or chelate silicon ions to bring K into solution (Ullman et al., 1996, Badr et al., 2006, Eweda et al., 2007, Abou-el-Seoud & Abdel-Megeed, 2012 and Dawwam et al. , 2013).

Results showed that, the interaction effect of potassium sources, organic amendments and silicate dissolving bacteria did not significantly increase straw and grain dry weight and biological yield of wheat plants compared with the untreated soil (Table 3).A significant increase in dry weight at tillering and booting stages, weight of 1000 grains and protein content was reported under the interaction of potassium sources, organic amendments and silicate dissolving bacteria compared to untreated soil (Table 3). Taking the mean effect of interaction between potassium sources, organic amendments and silicate dissolving bacteria into consideration, the data showed that the application of K- sulphate or K-feldspare combined with chicken manure and silicate dissolving bacteria gave a significant increase ($P<0.05$) at all stages in dry weight, biological yield, protein content and weight of 1000 grain compared to other treatments (Setiawati and Mutmainnah, 2016). Application of potassium sulphate or K-feldspar with organic amendments in the presence of SDB demonstrated good results for plant growth parameters , *i.e.* dry weight, biological yield, weight of 1000 grain and protein content. Abdel Wahab et al. (2003) declared that the greatest values of plant growth of pea were found in case of compost mixed with potassium feldspar.

TABLE 1. Some physical and chemical properties of the investigated soil

Characteristics	Values
Soil particles distribution	
Sand ,%	92.35
Silt,%	5.49
Clay,%	2.16
Textural class	Sand
Field capacity (FC),%	9.68
$CaCO_3$, (g kg^{-1})	6.5
Organic matter,(g kg^{-1})	5.6
pH*	8.17
EC,(dSm^{-1}) **	0.62
Soluble cations and anions, (mmolc L^{-1})**	
Ca^{++}	1.78
Mg^{++}	0.98
Na^{+}	2.11
K^{+}	1.33
$CO_3^{=}$	-
HCO_3^{-}	2.27
Cl^{-}	2.91
$SO_4^{=}$	1.02
Available nutrient , (mg kg^{-1}soil)	
N	68.23
P	7.36
K	59.75

* Soil-water suspension 1: 1 ** Soil water extract 1: 1

TABLE 2. Some characteristics of the used organic amendments

Organic Amendments	Characteristics							
	EC**, dSm^{-1}	pH*	Organic matter, (gkg^{-1})	Total nutrients (gkg^{-1})			C/N ratio	WHC,% ***
				N	P	K		
Chicken manure	2.95	7.08	385	30.53	6.56	14.4	6.38	368
Farmyard manure	2.83	7.23	322	20.21	5.16	11.5	9.24	340

*Soil-water suspension 1: 5 **Soil water extract 1: 5 *** Water holding capacity

TABLE 3. Dry weight, biological yield (Mg ha^{-1}),weight 1000 grain and protein content of wheat plants as influenced by potassium sources, organic amendments and silicate dissolving bacteria

Factors of Study			Dry weight (tillering stage)	Dry weight (booting stage)	Dry weight (harvest stage) Straw	Grains	Biological yield (Mg ha^{-1})	weight 1000 grain(g)	Protein content (g kg^{-1})
Effect of K-source (A)									
Without potassium fertilization			2.33c	3.36c	9.08c	6.42c	15.50c	44.97c	8.00c
K-sulphate			2.70a	4.50a	10.33a	7.72a	18.05a	53.20a	10.99a
K-feldspar			2.60b	4.30b	9.96b	7.53b	17.49b	48.21b	9.29b
Effect of Organic amendments (B)									
Untreated			2.24c	3.57c	9.04c	6.87c	15.91c	44.35c	7.37c
FYM			2.59b	4.13b	9.76b	7.25b	17.01b	48.51b	8.97b
Ch.M			2.78a	4.46a	10.57a	7.54a	18.11a	53.51a	11.94a
Effect of SDB (C)									
Without			2.43b	3.94b	9.64b	7.08b	16.73b	47.64b	8.85b
With			2.66a	4.16a	9.94a	7.36a	17.30a	49.94a	10.00a
Effect of the interaction (A*B*C)									
Without K-fertilization	Untreated	Without	1.73l	2.87m	8.53l	5.94k	14.48j	38.95l	63.8k
		With	2.10k	3.10l	8.87k	6.29j	15.16i	39.52l	66.7jk
	FYM	Without	2.30j	3.23k	9.06ijk	6.35j	15.41i	41.35k	69.9ij
		With	2.46i	3.32j	9.20hjik	6.60i	15.80g	42.57j	76.8gh
	Ch.M	Without	2.56h	3.76h	9.37hi	6.54i	15.91gh	43.24j	96.9e
		With	2.83c	3.89g	9.46h	6.79h	16.25g	44.12i	106.4d
K-sulphate	Untreated	Without	2.33j	3.91g	9.08ijk	7.11g	16.19gh	47.24gh	77.9gh
		With	2.62g	4.04f	9.33hij	7.54ef	16.87f	48.50f	88.9f
	FYM	Without	2.71e	4.56d	9.98fg	7.68de	17.66e	50.59e	100.7e
		With	2.82c	4.79b	10.40de	7.90bc	18.30d	53.22d	114.4c
	Ch.M	Without	2.75d	4.68c	11.43b	7.99abc	19.42b	57.98b	128.3b
		With	2.97a	5.05a	11.79a	8.11a	19.91a	62.12a	149.3a
K-feldspar	Untreated	Without	2.13k	3.60i	9.00jk	6.98g	15.98gh	42.36jk	70.5ij
		With	2.58h	3.91g	9.45h	7.37f	16.83f	45.41i	74.5hi
	FYM	Without	2.63g	4.37e	9.80g	7.37f	17.17f	47.03gh	80.9g
		With	2.67f	4.53d	10.14ef	7.62de	17.76e	48.86f	95.8e
	Ch.M	Without	2.70ef	4.55d	10.55cd	7.81cd	18.36d	50.94e	108.1d
		With	2.90b	4.85b	10.85c	8.02ab	18.87c	54.67c	12.81b
Effect of the interaction (B*C)									
Untreated		Without	2.06e	3.46f	8.87f	6.68d	15.55f	43.43f	70.7f
		With	2.43d	3.68e	9.22e	7.07c	16.29e	45.29e	76.7e
FYM		Without	2.55c	4.05d	9.61d	7.14c	16.75d	47.46d	83.8d
		With	2.65b	4.21c	9.91c	7.38b	17.29c	49.58c	95.7c
Ch.M		Without	2.67b	4.33b	10.45b	7.45b	17.89b	52.06b	111.1b
		With	2.90a	4.60a	10.70a	7.64a	18.34a	54.97a	127.9a
A			***	***	***	***	***	***	***
B			***	***	***	***	***	***	***
AB			***	***	***	ns	***	***	***
C			***	***	***	***	***	***	***
AC			**	***	ns	ns	ns	ns	***
BC			***	***	ns	*	ns	***	***
ABC			***	***	ns	ns	ns	*	***

Mean values in the same column for each trait followed by the same letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$

SDB: Silicate dissolving bacteria, Ch.M: Chicken manure, FYM: Farmyard manure.

Nutrients uptake

The application of potassium sulphate or K-feldspar with either organic amendment in the presence of SDB, significantly increased N, P and K-uptake by wheat plants at tillering and booting stages as compared to untreated control (Table 4). The values of N,P and K- uptake at tillering and booting stages ranged from 21.16 to 82.08, 1.5 to 6.86, 22.89 to 78.3 kg ha^{-1}, respectively at tillering stage and ranged from 35.85 to 138 , 3.16 to 12.28 and 39 to 137 kg ha^{-1}, respectively at booting stage. The greatest values of N, P and K-uptake of wheat plants at tillering and booting stages were obtained under the application of K sulphate or K-feldspar plus Ch.M in the presence of SDB. The application of silicate dissolving bacteria (SDB) either with potassium sulphate or K- feldspar in the presences of Ch.M or FYM showed favorable effect on N,P and K-uptake of wheat plants at tillering and booting stages compared to treatments without SDB (Table 4). In this regard, Han et al. (2006) reported that inoculation with potassium solubilizing bacteria (KSB) increased significantly N and K uptake in pepper and cucumber plants especially when the respective rock K was added. Moreover, Ullman et al. (1996) mentioned that this increase was due to the fact that KSB release organic acids which solubilize the insoluble rock K materials. These results are in agreement with those found by Abou-el-Seoud and Abdel-Megeed (2012) and Labib et al. (2012). The highest values of N, P and K-uptake by straw and grain at harvest stage were observed under the treatment of (K sulphate or K-feldspar + Ch.M) in the presence of SDB, while the lowest values were obtained under the untreated soil (Table 5). Values of NPK- uptake by straw and grain ranged from 110 to 399, 11 to 32 and 118 to 377 kg ha^{-1} by straw, respectively and ranged from 66 to 212 , 8.72 to 32.99 and 76.29 to 239 kg ha^{-1} by grains , respectively.

Data showed that inoculation of SDB increased grain K-uptake compared to the untreated ones. These increases represent 13.5, 6 and 8 % in the case of K sulphate for the treatments of without, Ch.M and FYM, respectively and 27, 5.5 and 9.5% of K-feldspar for the same treatments, respectively. In the same respect, Badr (2006) found that inoculation with SDB (silicate dissolving bacteria) into the composition mass appears to enhance the percentage of available K in the matured compost. Similarly, the response of tomato plants was dramatically enhanced in sandy soil of low K content and its effect was higher than potassium sulfate (Priyanka and Sindhu , 2013).

On the other hand, treatments under K sulphate gave higher values of grain K-uptake than those under K-feldspar. These increases represent 11.5, 14 and 8.9% in the presence of SDB for the treatments of without, Ch.M and FYM, respectively, while the increases represent 26, 14 and 10.6 % in the absence of SDB application for the same treatments, respectively.

Taking the mean effect of potassium sources into consideration, the data show that the application of potassium sulphate gave a significant increase in N, P and K-uptake by wheat plants at tillering, booting and harvest (straw and grains) stages compared to K-feldspar under application of organic amendments (Tables 4 & 5). This result is in agreement with those obtained by Eweda *et al.* (2007), Han & Lee (2005), Abou-el-Seoud and Abdel-Megeed (2012). Potassium plays many important regulatory roles in biochemical and physiological functions of plant growth, although it dose not become a part of the chemical structure of plants (Marschner, 1995). The application of chicken manure gave a significant increase in N, P and K-uptake of wheat plants at different stages compared to farmyard manure under K- sulphate or K- feldspar application (Sookdeo et al., 2017). This increase may be due to the high N, P and K content and the low C/N ratio in chicken manure compared to farmyard manure. This result is in a agreement with those obtained by El- Kholy et al. (2000) and Merwad et al . (2013).

A significant synergetic effect on P and K-uptake of wheat at different stages ($P<0.05$) was also noticed due to the combined application of potassium sources, organic amendments and silicate dissolving bacteria inoculation than P and K- uptake obtained by untreated soil (Tables 4 and 5). Results showed that the application of potassium sources, organic amendments and silicate dissolving bacteria did not significantly increase N-uptake in wheat straw or grains compared with the untreated soil (Table 5). A significant increase in N- uptake at tillering and booting stages occurred under the interaction of potassium sources, organic amendments and silicate dissolving bacteria compared to untreated soil (Table 4). Taking the mean effect of interaction among potassium sources, organic amendments and silicate dissolving bacteria into consideration, the data indicated that the application of K- sulphate or K-feldspare combined with chicken manure

TABLE 4. Wheat N, P and K-uptake (kg ha-1) as influenced by potassium sources, organic amendments and silicate dissolving bacteria at tillering and booting stages

Factors of Study			Tillering stage (kg ha^{-1})			Booting stage (kg ha^{-1})		
			N-uptake	P-uptake	K-uptake	N-uptake	P-uptake	K-uptake
Effect of K-source (A)								
Without potassium fertilization			42.01c	3.12c	36.42c	62.32c	5.04c	54.47c
K-sulphate			68.29a	5.43a	69.42a	118.1a	10.01a	117.0a
K-feldspar			57.57b	4.68b	60.89b	98.36b	8.32b	104.3b
Effect of Organic amendments (B)								
Untreated			36.95c	2.83c	42.19c	60.08c	5.04c	68.93c
FYM			55.64b	4.45b	65.73b	93.27b	7.69b	92.29b
Ch.M			75.29a	5.94a	67.82a	125.5a	10.64a	114.6a
Effect of SDB (C)								
Without			51.31b	3.92b	54.55b	86.83b	7.02b	87.29b
With			60.61a	4.90a	59.61a	99.04a	8.55a	93.63a
Effect of the interaction (A*B*C)								
Without K-fertilization	Untreated	Without	21.16k	1.50l	22.89n	35.85o	3.16m	39.01i
		With	25.96j	2.10k	28.48m	39.43n	3.92l	42.43hi
	FYM	Without	36.75i	2.76ij	33.45l	54.37m	4.41l	48.55hi
		With	54.13f	4.52e	51.06i	87.31i	5.09jk	66.74g
	Ch.M	Without	63.85d	4.47f	47.07j	56.81m	6.39gh	54.04h
		With	73.40c	5.12d	55.82h	100.2g	7.29ef	76.06fg
K-sulphate	Untreated	Without	41.06h	3.03i	50.77i	71.09k	5.60ij	87.23ef
		With	50.86f	4.20fg	59.60g	80.35j	7.01fg	93.03e
	FYM	Without	69.01d	5.05e	68.20e	120.3e	8.97d	115.3cd
		With	76.87c	6.11c	74.14d	133.0c	11.04c	119.9c
	Ch.M	Without	78.60c	6.41c	76.12c	136.1b	11.99b	132.4b
		With	93.38a	7.82a	87.74a	167.8a	15.48a	154.7a
K-feldspar	Untreated	Without	35.66i	2.48j	37.37k	61.34l	4.56kl	66.28g
		With	47.05g	3.70h	54.09h	72.41k	5.99hi	85.63ef
	FYM	Without	51.89f	4.38f	62.05f	92.21h	7.72e	104.8d
		With	58.18e	4.98e	63.95f	102.8f	8.91d	111.2cd
	Ch.M	Without	70.62d	5.67d	69.63e	122.9d	10.46c	120.7c
		With	82.08b	6.86b	78.30b	138.5b	12.28b	137.4b
Effect of the interaction (B*C)								
Untreated		Without	32.63f	2.34f	37.01f	56.09f	4.44f	64.18f
		With	41.29e	3.33e	47.39e	64.07e	5.64e	73.70e
FYM		Without	52.55d	4.07d	54.57d	88.97d	7.03d	91.09d
		With	63.06c	5.20c	63.05c	97.58c	8.35c	93.50c
Ch.M		Without	74.20b	5.74b	67.19b	115.4b	9.61b	106.6b
		With	79.77a	6.39a	71.04a	135.5a	11.68a	122.7a
		A	***	***	***	***	***	***
		B	***	***	***	***	***	***
		AB	***	*	***	***	***	***
		C	***	***	***	***	***	***
		AC	**	**	**	***	**	ns
		BC	***	*	***	***	***	*
		ABC	*	*	***	***	*	*

Mean values in the same column for each trait followed by the same letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

SDB: Silicate dissolving bacteria, Ch.M: Chicken manure, FYM: Farmyard manure

TABLE 5 . Straw and grains N, P and K-uptake (kg ha-1) of wheat as influenced by potassium sources, organic amendments and silicate dissolving bacteria

Factors of Study			Straw			Grains		
			N-uptake	P-uptake	K-uptake	N-uptake	P-uptake	K-uptake
Effect of K-source (A)								
Without potassium fertilization			170.0c	14.87c	149.7c	90.79c	11.65c	97.86c
K-sulphate			276.6a	24.52a	288.2a	150.3a	21.07a	197.7a
K-feldspar			234.2b	20.86b	252.9b	123.9b	17.28b	174.3b
Effect of Organic amendments (B)								
Untreated			155.6c	14.12c	184.4c	89.60c	11.80c	124.8c
FYM			219.8b	19.27b	226.3b	115.6b	16.46b	158.8b
Ch.M			305.4a	26.86a	280.8a	159.7a	21.74a	186.2a
Effect of SDB (C)								
Without			213.4b	18.46b	221.3b	111.9b	15.13	148.6b
With			240.4a	21.71a	239.6a	131.1a	18.20a	194.6a
Effect of the interaction (A*B*C)								
Without K-fertilization	Untreated	Without	110.6m	11.09j	118.3l	66.58l	8.72i	76.29l
		With	119.2m	13.30i	125.4kl	73.55kl	10.27h	83.61k
	FYM	Without	154.1l	13.89hi	139.6jk	77.87k	11.15gh	89.53k
		With	164.0kl	15.04gh	150.2j	88.93j	12.26fg	102.8j
	Ch.M	Without	222.6g	17.33f	169.9i	111.1gh	12.84f	110.2i
		With	249.7e	18.61e	195.1h	126.7f	14.69e	124.67h
K-sulphate	Untreated	Without	169.4jk	14.22hi	219.6g	97.18i	12.09fg	149.3g
		With	196.2i	17.43f	245.2f	117.65g	15.74e	169.4f
	FYM	Without	266.7d	20.96d	267.7e	135.7e	18.43d	197.9d
		With	291.8c	25.37c	289.7d	158.6c	22.14c	208.1c
	Ch.M	Without	336.3b	30.85b	333.6b	179.8b	25.04b	221.9b
		With	399.4a	38.34a	377.4a	212.5a	32.99a	239.5a
K-feldspar	Untreated	Without	158.7kl	13.08i	182.4hi	86.36j	11.08gh	118.9h
		With	179.5j	15.63g	215.5g	96.34i	12.93f	151.6g
	FYM	Without	208.5h	18.66e	244.4f	104.7h	15.97e	172.7f
		With	233.6f	21.71d	266.4e	127.9f	18.84d	182.1e
	Ch.M	Without	294.2c	26.07c	291.0	148.1d	20.88c	200.7d
		With	330.5b	30.02b	317.5c	180.1b	24.02b	219.9b
Effect of the interaction (B*C)								
Untreated		Without	146.2f	12.80f	182.0e	83.37f	10.63f	114.8f
		With	165.0e	15.45e	186.8e	95.84e	12.98e	134.8e
FYM		Without	209.7d	17.84d	217.2d	106.1d	15.18d	153.4d
		With	229.8c	20.71c	235.4c	125.1c	17.75c	164.3c
Ch.M		Without	284.4b	24.75b	264.8b	146.3b	19.59b	177.6b
		With	326.5a	28.99a	296.7a	173.1a	23.90a	194.7a
		A	***	***	***	***	***	***
		B	***	***	***	***	***	***
		AB	***	***	***	***	***	***
		C	***	***	***	***	***	***
		AC	***	**	*	***	**	**
		BC	***	***	***	***	***	**
		ABC	ns	**	***	ns	*	***

Mean values in the same column for each trait followed by the same letter are not significantly different according to Duncan's multiple range test at $P \leq 0.05$.

and silicate dissolving bacteria gave a significant increase ($P<0.05$) in N, P and K-uptake by wheat plants at different stages compared to the other treatments. This increase was due to the fact that SDB releases organic acids which solubilize the insoluble rock K materials (Abou-el-Seoud and Abdel-Megeed, 2012). Similarly, Styriakova et al. (2003) reported that the activity of potassium dissolving bacteria played a pronounced role in the release of K from Feldspar. Also, Badr et al. (2006) found that potassium uptake improved markedly with inoculation of bacteria in the tested soils compared to corresponding controls.

Available potassium in soil

Under investigation, the values of available potassium (mg kg^{-1}) as affected by the application of potassium sources (K- sulphate and K- feldspar) and organic amendments (Ch.M and FYM) inoculated with silicate dissolving bacteria are illustrated in Fig.1. The treatment of K- sulphate or K- feldspar plus Ch.M with inoculation SDB at 60, 90 and 150 days gave the highest values of available potassium (261, 292 and 255 mg ka^{-1}, respectively), while the lowest ones (92.3,93 and 88 mg kg^{-1} , respectively) were found with untreated soil. These results agree with those obtained by Blum and Stillings (1995). The highest values of available potassium occurred with K- sulphate treatments followed by K-feldspar and without application of potassium fertilizers in a descending order. The values of available potassium were higher with chicken manure treatments than with farmyard manure ones under the application of K- sulphate and K- feldspar with SDB. These results may be due to the release of amino acids and other organic acids as a result of the decomposition of chicken manure as well, the total potassium content in chicken manure was greater than in FYM (Spaccini et al., 2000, Sarwar et al., 2008 and Voelkner et al., 2017). This finding is in agreement with that obtained by Hassan et al. (2002) and Merwad (2009) who reported that the available K was higher in the treatments of CM than in the treatments of biogas manure in all incubation periods. Wahba and Darwish (2008) found that the addition of both compost and feldspar individually or together increased available potassium in sandy and calcareous soils compared to control.

As a general result, the available potassium was remarkably increased after 90 days at all treatments of any potassium sources application and organic amendments with silicate dissolving bacteria. These increases may be due to the microbial activity which has the ability to affect soil reaction in the soil microenvironment leading to solubilizing mineral potassium (Probert et al., 2005 and Setiawati & Mutmainnah, 2016). This finding is in agreement with that obtained by Hellal et al. (2009) and Badr et al. (2006), the available potassium was remarkably increased after 60 and 90 days of sowing then decreased after 150 days at harvest stage. The increase in the available potassium level after 60 and 90 days may be due to the mineralization of organic amendments and solubilizing action of certain organic acids produced during manure decomposition as well as the significant effect of microbial activities and role of SDB. Similar results were obtained by Badr (2006) who found that the highest values of release potassium was consistent up the end of composting process (feldspar +compost + SDB) after 90 days of incubation. The decrease in available potassium level after 150 days in soil may be attributed to decomposition and/or immobilization of the organic manure source and depletion of available potassium in soil as well as assimilation by microorganisms. This finding is in agreement with that obtained by Girgis et al. (2008) and Merwad et al. (2013).

Conclusion

As a result of the factors mentioned above, there was a significant effect by the combination of potassium sulphate or K-feldspar and organic amendments (Ch.M and FYM) with SDB on NPK-uptake, wheat plants growth, yield and available potassium in soil. The highest values of dry matter yield of wheat plants at the stage of tillering, booting, harvest (straw and grains yield), biological yield, protein content, NPK –uptake and available potassium in soil were obtained by the treatment of (K sulphate or K-feldspar + Ch.M) in the presence of SDB. The available potassium was remarkably increased after 90 days at all treatments by application of various potassium sources and organic amendments with silicate dissolving bacteria. Finally, From economic point of view, this approach of using the naturally deposited materials (K-feldspar) instead of chemical fertilizers or combination together will be very beneficial for the farmers who subsidize the costs of chemical fertilizers (potassium sulphate).

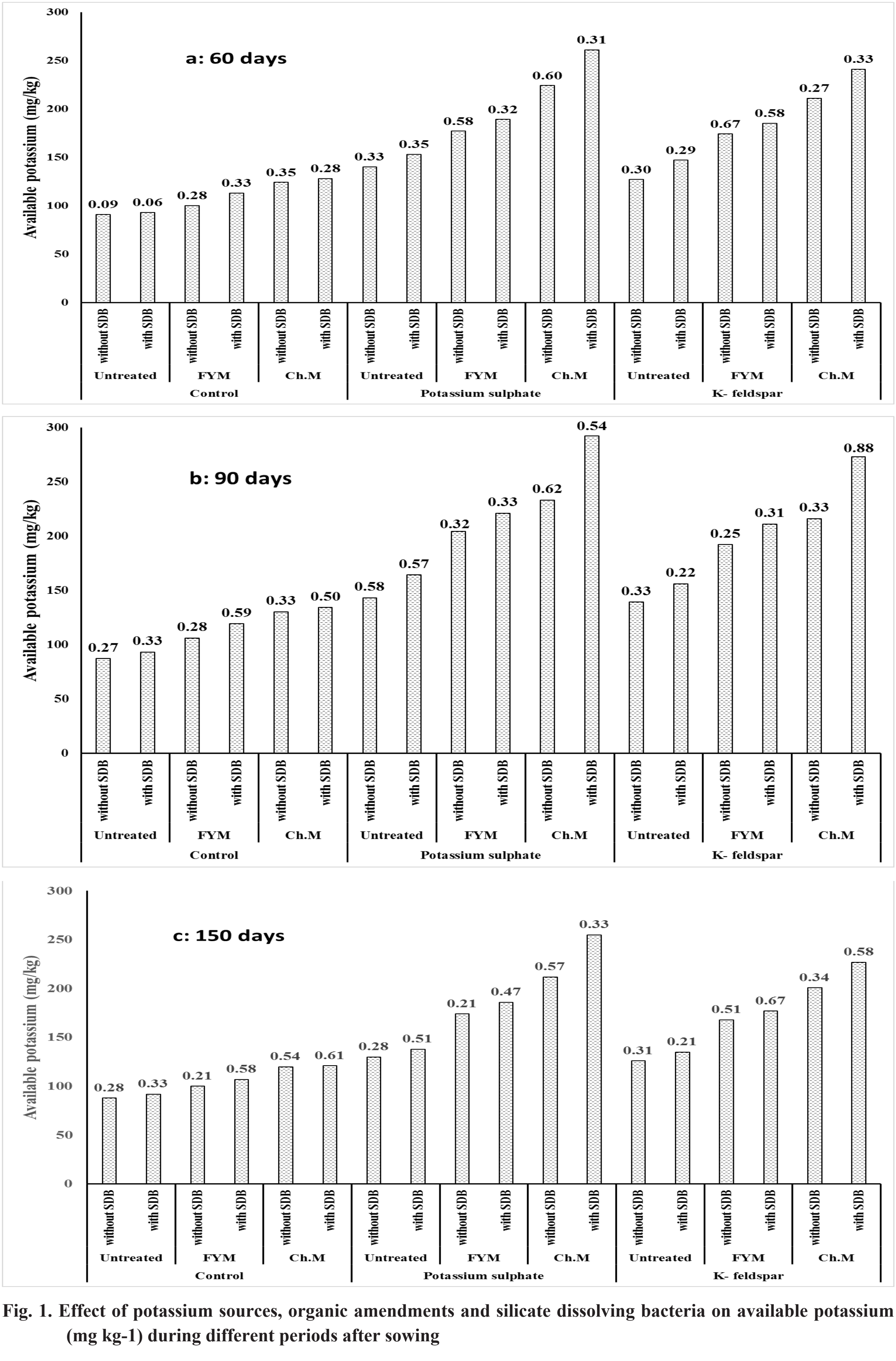

Fig. 1. Effect of potassium sources, organic amendments and silicate dissolving bacteria on available potassium (mg kg-1) during different periods after sowing

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استجابة القمح للتسميد البوتاسى فى الاراضى الرملية متأثرا بالمصلحات العضوية والبكتريا المذيبة للسليكات

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يعتبر محتوى التربة من البوتاسيوم من العوامل المحددة لنمو القمح وانتاجيته, فهو واحد من اكثر العناصر الكبرى اهمية لنمو النبات. الحاجة الى معظمة الاستفادة من التسميد البوتاسى باستخدام المصلحات الطبيعية فى زيادة مضطردة بالتوازى مع الزيادة المتسارعة فى اسعار الاسمدة.

اجريت تجربة حقلية خلال موسم النمو 2014/2015 فى الصالحية بمصر حيث كان الهدف من هذه الدراسة هو دراسة تأثير المصادر المختلفة من الاسمدة البوتاسية (كبريتات البوتاسيوم وفلسبارات البوتاسيوم) بالمعدل الموصى به (95 كجم بوتاسيوم/هكتار) منفردا او مصحوبا بالمصلحات العضوية مثل سماد الدواجن وسماد الاسطبل مع البكتريا المذيبة للسليكات على المحصول وامتصاص العناصر بواسطة نبات القمح.

اوضحت النتائج ان اعلى القيم من محصول المادة الجافة للقمح, المحصول البيولوجى, محتوى البروتين, امتصاص النيتروجين والفوسفور والبوتاسيوم ومحتوى التربة من البوتاسيوم الميسر تم الوصول اليها باستخدام سلفات البوتاسيوم او فلسبارات البوتاسيوم مع سماد الدواجن فى وجود البكتيريا المذيبة للسليكات, حيث تراوح محصول المادة الجافة للقش والحبوب من 53,8 الى 79,11 و 94,5 الى 11,8 ميجاجرام/هكتار على التوالى.مرتكزا على النتائج, فان البوتاسيوم الميسر ازداد بدرجة ملحوظة بعد 60 و 90 يوم ثم انخفض ثانية بعد 150 يوم مع اضافة مصادر البوتاسيوم المختلفة ومصلحات العضوية فى وجود البكتيريا المذيبة للسليكات.