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Growth Promoting Effect of Potassium Solubilizing Actinomycetes and their Ability to Promote Wheat (Triticum Aestivum) Growth

Sreeja Bopin [1]*, Kalavati Prajapati [2]

[1] Research Scholar, Department of Microbiology,
HVHP Institute of Post Graduate Studies and Research, KSV Kadi, North Gujarat, India.
[2] Assistant Professor, Department of Microbiology,
Shri P.H.G. Muni. Arts and Science College, Kalol. India
Email- [1] sreejabopin@gmail.com

ABSTRACT:

Plant nutrition and soil fertility require an adequate management of essential macro- nutrients such as potassium (K) and phosphorus (P) and Nitrogen (N), which are mandatory for plant development. Modern intensive agricultural practices face numerous challenges that pose major threats to global food security. In order to address the nutritional requirements of the ever-increasing world population, instead of chemical fertilizers and pesticides the biofertilizers are increases the crop production. In this study, in vitro and greenhouse experiments were carried out to investigate K solubilization traits of two Actinomycetes (KSA 09 and KSA 16) under fertilization with feldspar. The pot experiments revealed that both strains (*Streptomyces fenghuangensis, Streptomyces atacamensis* compared to the uninoculated control. These findings showed that strains are promising candidates for the implementation of efficient biofertilization strategies to improve soil fertility and plant yield under K fertilization.

Keywords: Actinomycetes, feldspar, potassium solubilization biofertilization, PGPR, wheat germination.

INTRODUCTION:

After nitrogen (N) and phosphorus (P), potassium (K) is the most widely using plant nutrient that has a key role in the growth, metabolism and development of plants. In addition to increasing plant resistance to diseases, pests, and abiotic stresses, K is required to activate over 80 different enzymes responsible for plant and animal processes such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar degradation (Almeida *et al*., 2015; Cecílio Filho *et al*., 2015; Gallegos-Cedilloet *et al*., 2016; Hussain *et al*., 2016; White and Karley, 2010; Yang *et al*., 2015). K is the seventh most abundant element in Earth's crust. Total K content in soils ranges between 0.04 and 3% K. Although K is present as an abundant element in soil, only 1 to 2 % of this element is available to plants (Sparks and Huang, 1985). The rest are bound with other minerals and therefore are

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unavailable to plants. K is present in several forms in the soil, including mineral K, non-exchangeable K, exchangeable K, and solution K. Interrelationships of various forms of soil K are shown in Figure 1. Depending on soil type, from 90 to 98% of soil K is mineral K and most of this K is unavailable for plant uptake (Sparks and Huang, 1985). Minerals containing K are feldspar (orthoclase and microcline) and mica (biotite and muscovite). The non-exchangeable form of K makes up approximately 1 to 10 % of soil K and is trapped between the layers or sheets of certain kinds of clay minerals (Sparks, 1987). Solution K is the form of K that directly taken up by plants and microbes in soil. The concentration of soil solution K varies from 2 to 5 mg l–1 for normal agricultural soils (Sparks and Huang, 1985). Moreover, the major amounts of K in the soil as a fixed form (non-available to plant indirectly), improper fertilizer utilization, large increase of crop yield and the depletion of K in the soil system as a result of not being added crop residue to the soil by farmers, K deficiency has been reported in most of the crop plants (Meena *et al*., 2014; Xiao *et al*., 2017). Since cost of K-fertilizers ($645 per ton current potash price per ton in 2023) is increasing every year (Meena *et al*., 2014) and also use of these fertilizers has harmful effects on the environment, it is necessary to find an alternative indigenous source of K and maintain K level in soils for sustainable crop production. It is proven that microbial soil community is able to influence soil fertility through soil processes viz. decomposition, mineralization, and storage or release of nutrients (Parmar and Sindhu, 2013). It was reported that some beneficial soil microorganisms, a wide range of saprophytic bacteria, fungal strains and actinomycetes, could solubilize the insoluble K to soluble forms of K by various mechanisms including production of inorganic and organic acids, acidolysis, polysaccharides, complexolysis, chelation, polysaccharides, and exchange reactions. One of the most widely grown crops is wheat, which (after rice) is considered in the developing world as the second-most important food source since it provides more calories and proteins (20%) than any other crop (MeCarty *et al*., 2017). Wheat demand is expected to increase by 60%. Therefore, achieving such a goal will require the implementation of efficient and sustainable fertilization approaches to improve bioavailability of essential nutrients such of potassium(K). In fact, K positively affect plant metabolisms and resistance to biotic and abiotic stresses, while leading to a better soil fertility and crop production (Bakhshandeh *et al*.,2017, Maqsood *et al*., 2013 and Nath e al., 2018). The major objective of this current research was to determine the ability of Potassium solubilizing actinomycetes to enhance the growth and K content in wheat plants grown in nutrient-deficient soil.

MATERIALS AND METHODS:

Plant and Soil:

The soil for pot experiments was collected from a nonfertilized field site in Bopal, Ahmedabad Region, Gujarat. The properties of the soil used in the experiments were: pH 7.9; organic carbon 0.72%; total Phosphorous (in ppm) 3.82 kg/hac; available Potash (in ppm) 13

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kg/hac; total K_2O (in ppm) 100 kg/ hac. For Wheat (*Triticum aestivum*) planting seeds (Sagar GW 496) were used in the inoculation experiments.

Microorganisms:

22 Potassium solubilizing actinomycetes strains were selected from ceramic industry soil of Morbi, Meshana, and Kadi region of Gujarat. Secondary screening was carried out from the different isolates by studying their ability of higher potassium solubilization by Khandeparkar's selection ratio. Both actinomycetes strains *Streptomyces fenghuangensis* (KSA 09), *Streptomyces atacamensis* (KSA 16) were selected and identified through standard cultural, morphological and 16S rRNA gene sequence analysis.

Increased K Uptake by Plants:

Experiments for studying the effect of the Potassium solubilizing microorganisms on plant growth and K uptake of Wheat (*Triticum aestivum*) were conducted in pots (12 cm diameter) containing 5 kg soil from Bopal, Ahmedabad (Gujarat, India). The experimental design was as follows-

Treatment 1: Uninoculated soil (control soil)

Treatment 2: Uninoculated soil with addition of soluble K (50 kg/ hec K_2O)

Treatment 3: Uninoculated soil with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O)

Treatment 4: soil inoculated with KSA09 strain with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O)

Treatment 5: soil inoculated with KSA16 strain with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O)

Treatment 6: soil inoculated with KSA09 + KSA16 strains with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O).

Treatment 7: soil inoculated with KSA09 strains with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O) +Foliar KSA09

Treatment 8: soil inoculated with KSA16 strains with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O) +Foliar KSA16.

Treatment 9: soil inoculated with KSA09 + KSA16 strains with addition of soluble K (35 kg/ hec K_2O) + insoluble K (15 kg/ hec K_2O) +Foliar KSA09+KSA16

Treatment 10: soil inoculated with KSA09 strains with addition of insoluble K (30 kg/ hec K_2O)

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Treatment 11: soil inoculated with KSA16 strains with addition of insoluble K (30 kg/ hec K_2O).

Treatment 12: soil inoculated with KSA09 + KSA16 strains with addition of insoluble K (30 kg/ hec K_2O).

The insoluble and soluble potassium were mixed thoroughly with the soil in a plastic bag before use. Three pots were used for each treatment. Five seeds were placed in each pot at a 2 cm depth.

Actinomycetes cells in the exponential phase were collected by centrifugation at 7000 rpm for 10 min at 6^0C, washed with sterile distilled water and recentrifuged. Inoculum was prepared by resuspending pelleted cells in sterile distilled water. Seedlings of Wheat plants were inoculated with 1 ml of actinomycetes suspension which resulted in an inoculum density of 10^8 cfu/ ml.

The three different experiments were planned for microbial application. Experiment A: seed application - seeds were treated with microbial inoculants for 30 minutes before sowing. Experiment B: soil application - microbial inoculants were inoculated in soil Experiment C: seed + soil application - seeds were treated with microbial inoculants for 30 minutes before sowing and microbial inoculants were inoculated in soil.

Plants were grown in pots for 45 days under greenhouse conditions with a temperature of 30–34 ^{0}C. The soil was moistened with water and maintained at 60% of its holding capacity. After 45 days of sowing shoots and roots were separated and dried at 105 ^{0}C before that the root and shoot height, wet weight, number of pods were determined. The criteria for growth promotion were studied as total chlorophyll content (Marker, 1972) and K content of plants (Ullah ,*et al*.,2022).

Statistical Analysis The data were analyzed for significant differences ($P < 0.05$) of main effects using ANOVA test.

RESULTS:

The results of the inoculation assays are shown in Tables 1 to 6. Significant increases of shoot and root dry weights were observed when the soil was inoculated with Potassium solubilizing strains, compared to the soil without inoculum in Wheat plants. The largest increases were obtained for plants grown in soil with strain of KSA 09 and KSA 16 mixed inoculum and uninoculated soil. Plant height after 45 DAS is shown in Table -1. Soil inoculation with KSA 09 and KSA 16 significantly increased plant growth in terms of shoot and root length, Shoot and root weight, Plant height, Total Plant weight and Dry weight especially when the potassium rock was added (Tables 2 and 5). Further significant increases in available K and Chlorophyll content of the plants were generally found in the all-integrated treatments.

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Table 1: Effects of KSA 09 and KSA 16 Strains on Plant Height after 30D AS (cm) and 45 DAS on Wheat Plant.

The Values are the Mean of Three replications (± SD)

S.NO.	Treatment	Plant Height after 30 DAS (Mean±SD) (in cm)			Plant Height after 45 DAS (Mean±SD) (in cm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	**T1 (Absolute control)**	13.25±0.5	13.25±0.5	13.25±0.5	39.67±0.57	35.5±0.5	33.5±0.5
2	**T2 (recommended fertilizer)**	12.9±0.12	12.4±0.53	12.5±0.58	43.3±0.57	42.8±0.7	38.3±0.57
3	**T3 (chemical K+ Rock -K)**	12.5±0.58	12.5±0.58	12.5±0.58	38±0.0	37.6±0.28	37.6±0.28
4	**T4 (chemical K+ Rock – K+KSA 9)**	12±0.23	12±0.23	12±0.23	43.3±0.57	43.54±0.5	36.14±0.7
5	**T5 (chemical K+ Rock – K+KSA 16)**	11.5±0.58	11±0.58	11±0.58	36.6±0.57	36.8±0.28	36.83±0.28
6	**T6 (chemical K+ Rock – K+KSA 9 & 16)**	11.75±0.29	11.25±0.5	11.25±0.5	37.6±0.57	37.83±0.28	37.83±0.28
7	**T7 (chemical K+ Rock – K+KSA 9+ Foliar 09)**	12.75±0.29	12.75±0.29	12.75±0.29	35±0.0	34.83±0.28	34.83±0.28
8	**T8 (chemical K+ Rock – K+KSA 16+Foliar KSA 16)**	13±0.29	13±0.29	13±0.29	35±0.0	34.83±0.28	34.83±0.28
9	**T9 (chemical K+ Rock – K+KSA 9& 16+ Foliar KSA 09 &16)**	13.25±0.5	13.75±0.29	13.75±0.29	45.67±0.57	45.83±0.28	45.5±0.5
10	**T10 (Rock –K+KSA 9)**	14.75±0.29	14.75±0.29	14.75±0.29	52±0.0	52.33±0.28	50.83±0.28
11	**T11 (Rock –K+KSA 16)**	16.3±0.50	16.8±0.23	16.5±0.58	51.3±0.57	52.17±0.28	52.17±0.28
12	**T12 (Rock –K+KSA 9 &16)**	16.4±0.53	16.5±0.58	16.5±0.58	51.67±0.57	52.5±0.5	53.17±0.76

Table 2: Effects of KSA 09 and KSA 16 Strains on Shoot and Root Length (cm) of Wheat Plant

The Values are the Mean of Three Replications (± SD)

S.NO.	Treatment	Shoot Length (Mean+ SD) (in cm)			Root Length (Mean+ SD) (in cm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	**T1 (Absolute control)**	32.87±0.81	33.47±0.42	34.93±0.90	10.33±0.58	10.17±0.29	9.83±0.76
2	**T2 (recommended fertilizer)**	29.6±0.53	29.6±0.53	35.67±0.58	11.33±0.58	11.167±0.29	11.17±0.29
3	**T3 (chemical K+ Rock -K)**	26.6±0.17	26.27±0.46	36.6±0.53	11.67±0.29	11.67±0.29	11.67±0.29
4	**T4 (chemical K+ Rock – K+KSA 9)**	29.03±0.35	29.03±0.35	39.23±0.68	11.5±±0.5	11.5±0.5	11.5±0.5
5	**T5 (chemical K+ Rock – K+KSA 16)**	21.77±0.87	22.6±0.53	32.6±0.53	13.17±0.29	13.33±0.29	13.33±0.29

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S.NO.	Treatment	Shoot Length (Mean+ SD) (in cm)			Root Length (Mean+ SD) (in cm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
6	**T6 (chemical K+ Rock – K+KSA 9 & 16)**	25.3±0.29	25.3±0.29	25.33±0.29	12.67±0.29	12.67±0.29	12.67±0.29
7	**T7 (chemical K+ Rock – K+KSA 9+ Foliar 09)**	21.9±0.1	21.9±0.1	22.67±0.58	10.5±0.5	10.5±0.5	10.5±0.5
8	**T8 (chemical K+ Rock – K+KSA 16+Foliar KSA 16)**	28.57±0.5	28.57±0.5	28.3±0.58	11.67±0.29	11.67±0.29	11.83±0.29
9	**T9 (chemical K+ Rock – K+KSA 9& 16+ Foliar KSA 09 &16)**	34.03±0.15	33.97±0.58	34.5±0.5	13.5±0.5	13.5±0.5	13.5±0.5
10	**T10 (Rock –K+KSA 9)**	40.8±0.8	42.4±0.5	42.4±0.5	13.97±0.25	14.07±0.12	14.07±0.12
11	**T11 (Rock –K+KSA 16)**	43.5±0.5	43.17±0.29	43.3±0.58	14.5±0.5	14.83±0.76	15.5±0.5
12	**T12 (Rock –K+KSA 9 &16)**	41.37±0.8	43.4±0.5	42.67±0.58	14.9±0.36	15.83±0.29	15.67±0.58

Table 3: Effects of KSA 09 and KSA 16 Strains on Shoot and Root Weight (gm/plant) of Wheat Plant

The Values are the Mean of Three Replications (± SD)

S.NO.	Treatment	Shoot Weight (Mean+ SD) (in gm)			Root Weight (Mean+ SD) (in gm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	**T1 (Absolute control)**	0.73±0.13	1.14±0.69	0.58±0.09	0.178±0.01	0.27±0.09	0.27±0.09
2	**T2 (recommended fertilizer)**	0.81±0.12	0.79±0.087	0.43±0.78	0.3±0.07	0.36±0.05	0.36±0.05
3	**T3 (chemical K+ Rock -K)**	0.62±0.06	0.64±0.030	0.59±0.05	0.44±0.09	0.44±0.02	0.44±0.04
4	**T4 (chemical K+ Rock – K+KSA 9)**	0.90±0.17	0.76±0.11	0.60±0.05	0.34±0.04	0.53±0.06	0.53±0.06
5	**T5 (chemical K+ Rock – K+KSA 16)**	1.03±0.14	0.80±0.11	0.65±0.03	0.39±0.05	0.62±0.05	0.62±0.05
6	**T6 (chemical K+ Rock – K+KSA 9 & 16)**	0.96±0.08	0.85±0.03	0.76±0.054	0.48±0.05	0.67±0.004	0.67±0.06
7	**T7 (chemical K+ Rock – K+KSA 9+ Foliar 09)**	0.8±0.13	0.94±0.03	0.75±0.02	0.56±0.009	0.65±0.02	0.66±0.02
8	**T8 (chemical K+ Rock – K+KSA 16+Foliar KSA 16)**	0.78±0.03	0.78±0.03	0.78±0.03	0.58±0.06	0.75±0.002	0.76±0.02
9	**T9 (chemical K+ Rock – K+KSA 9& 16+ Foliar KSA 09 &16)**	0.77±0.005	0.57±0.005	0.87±0.005	0.69±0.08	0.61±0.004	0.63±0.023
10	**T10 (Rock –K+KSA 9)**	1.46±0.02	0.52±0.06	1.07±0.12	0.71±0.07	0.70±0.06	0.70±0.06
11	**T11 (Rock –K+KSA 16)**	1.58±0.1	0.55±0.07	1.07±0.012	0.699	0.8129	0.8129
12	**T12 (Rock –K+KSA 9 &16)**	1.80±0.08	0.98±0.006	1.11±0.15	0.629	0.86105	0.86105

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Table 4: Effects of KSA 09 and KSA 16 Strains on Shoot and Root Dry Weight (gm/plant) of Wheat plant

The Values are the Mean of Three Replications (± SD)

S.NO.	Treatment	Shoot Dry Weight in gm (Mean±SD) (in gm)			Root Dry Weight in gm (Mean±SD) (in gm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	**T1 (Absolute control)**	0.43±0.12	0.35±0.43	0.58±0.09	0.06±0.01	0.07±0.09	0.07±0.09
2	**T2 (recommended fertilizer)**	0.61±0.12	0.69±0.07	0.43±0.78	0.03±0.07	0.16±0.05	0.13±0.05
3	**T3 (chemical K+ Rock -K)**	0.52±0.06	0.64±0.03	0.59±0.05	0.04±0.09	0.04±0.02	0.44±0.04
4	**T4 (chemical K+ Rock – K+KSA 9)**	0.60±0.17	0.76±0.11	0.60±0.05	0.04±0.04	0.013±0.06	0.14±0.06
5	**T5 (chemical K+ Rock – K+KSA 16)**	0.63±0.14	0.80±0.11	0.65±0.03	0.04±0.05	0.06±0.05	0.06±0.05
6	**T6 (chemical K+ Rock – K+KSA 9 & 16)**	0.66±0.08	0.85±0.03	0.76±0.054	0.05±0.04	0.67±0.004	0.07±0.06
7	**T7 (chemical K+ Rock – K+KSA 9+ Foliar 09)**	0.8±0.15	0.74±0.03	0.75±0.02	0.06±0.09	0.06±0.02	0.06±0.02
8	**T8 (chemical K+ Rock – K+KSA 16+Foliar KSA 16)**	0.78±0.03	0.78±0.03	0.78±0.03	0.06±0.04	0.75±0.002	0.07±0.02
9	**T9 (chemical K+ Rock – K+KSA 9& 16+ Foliar KSA 09 &16)**	0.77±0.005	0.67±0.06	0.87±0.005	0.09±0.08	0.08±0.004	0.09±0.02
10	**T10 (Rock –K+KSA 9)**	1.86±0.02	1.82±0.06	1.87±0.12	1.87±0.07	0.87±0.06	0.70±0.06
11	**T11 (Rock –K+KSA 16)**	1.88±0.1	1.85±0.07	1.77±0.012	1.99±0.03	0.89±0.03	0.82±0.03
12	**T12 (Rock –K+KSA 9 &16)**	1.80±0.05	1.98±0.06	1.91±0.15	1.90±0.04	0.89±0.06	0.89±0.05

Table 5: Effects of KSA 09 and KSA 16 Strains on Total Weight of the Plant (gm/plant) and Plant Dry Weight at Harvesting of Wheat Plant.

The Values are the Mean of Three Replications (± SD)

S.NO.	Treatment	Total Weight of the Plant (Mean+ SD) (in gram)			Plant Dry Weight (Mean+ SD) (in gm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	**T1 (Absolute control)**	7.66±0.16	6.15±0.43	6.58±0.06	1.18±0.01	1.27±0.05	1.27±0.07
2	**T2 (recommended fertilizer)**	8.81±0.15	7.59±0.087	8.49±0.56	1.03±0.05	1.36±0.05	1.66±0.05
3	**T3 (chemical K+ Rock -K)**	8.62±0.16	8.64±0.030	7.55±0.05	1.44±0.03	1.48±0.02	1.49±0.03
4	**T4 (chemical K+ Rock – K+KSA 9)**	8.90±0.17	8.76±0.091	8.60±0.05	1.34±0.04	1.53±0.06	1.53±0.07
5	**T5 (chemical K+ Rock – K+KSA 16)**	8.03±0.14	8.80±0.10	7.65±0.03	1.38±0.05	1.62±0.05	1.62±0.08
6	**T6 (chemical K+ Rock – K+KSA 9 & 16)**	8.96±0.08	8.85±0.03	8.76±0.054	1.48±0.15	1.67±0.04	1.69±0.06
7	**T7 (chemical K+ Rock – K+KSA 9+ Foliar 09)**	8.8±0.73	8.94±0.03	8.75±0.02	1.56±0.009	1.65±0.05	1.66±0.02

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S.NO.	Treatment	Total Weight of the Plant (Mean+ SD) (in gram)			Plant Dry Weight (Mean+ SD) (in gm)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
8	T8 (chemical K+ Rock – K+KSA 16+Foliar KSA 16)	8.78±0.03	8.78±0.03	8.78±0.03	1.58±0.06	1.75±0.002	1.76±0.02
9	T9 (chemical K+ Rock – K+KSA 9& 16+ Foliar KSA 09 &16)	8.77±0.005	8.57±0.005	8.87±0.005	1.69±0.08	1.61±0.04	1.63±0.03
10	T10 (Rock –K+KSA 9)	9.46±0.02	9.52±0.06	9.07±0.12	1.71±0.07	1.80±0.06	1.70±0.06
11	T11 (Rock –K+KSA 16)	9.58±0.1	9.55±0.07	9.07±0.012	1.99±0.03	1.89±0.03	1.82±0.03
12	T12 (Rock –K+KSA 9 &16)	9.30±0.08	9.48±0.06	9.11±0.19	1.19±0.06	1.86±0.06	1.88±0.05

Table 6: Effects KSA 09 and KSA 16 Strains on Available K by the Plant (mg%) and Total Chlorophyll Content (mg%) of Wheat Plant.

The Values are the Mean of Three Replications (± SD)

S.NO.	Treatment	Available K at Harvesting (Mean+ SD) (mg%)			Total Chlorophyll Content (Mean+ SD) (mg%)		
		Exp-A	Exp-B	Exp-C	Exp-A	Exp-B	Exp-C
1	T1 (Absolute control)	10.23±0.12	11.15±0.63	10.42±0.05	1.46±0.02	1.52±0.06	1.47±0.12
2	T2 (recommended fertilizer)	11.71±0.12	12.79±0.087	10.53±0.18	1.58±0.1	1.55±0.07	1.07±0.012
3	T3 (chemical K+ Rock -K)	10.62±0.06	10.64±0.030	10.59±0.05	1.80±0.08	0.98±0.006	1.11±0.15
4	T4 (chemical K+ Rock –K+KSA 9)	11.90±0.17	10.76±0.11	10.60±0.05	1.14±0.04	1.53±0.06	1.53±0.07
5	T5 (chemical K+ Rock –K+KSA 16)	11.03±0.14	10.80±0.11	11.65±0.03	1.38±0.05	1.82±0.05	1.62±0.08
6	T6 (chemical K+ Rock –K+KSA 9 & 16)	10.96±0.08	10.85±0.03	10.76±0.054	1.48±0.15	1.67±0.04	1.69±0.06
7	T7 (chemical K+ Rock –K+KSA 9+ Foliar 09)	10.8±0.13	10.94±0.03	10.75±0.02	1.56±0.009	1.65±0.05	1.66±0.02
8	T8 (chemical K+ Rock –K+KSA 16+Foliar KSA 16)	10.78±0.03	10.78±0.03	10.78±0.03	1.34±0.04	1.53±0.06	1.53±0.07
9	T9 (chemical K+ Rock –K+KSA 9& 16+ Foliar KSA 09 &16)	11.77±0.005	11.57±0.005	11.87±0.005	1.38±0.05	1.62±0.05	1.62±0.08
10	T10 (Rock –K+KSA 9)	11.46±0.02	11.52±0.06	12.07±0.12	2.18±0.15	1.97±0.04	2.19±0.06
11	T11 (Rock –K+KSA 16)	11.58±0.1	11.55±0.07	12.07±0.012	2.16±0.009	1.96±0.05	1.99±0.02
12	T12 (Rock –K+KSA 9 &16)	12.80±0.08	11.98±0.006	12.11±0.15	2.10±0.08	2.18±0.006	2.11±0.15

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DISCUSSION:

The poor fertility quality of soil is one of the most important constraint-limiting in crop yields in developing countries (Khosro and Yousef,2012). Fortunately, it can be significantly improved by adopting sustainable approaches such as using beneficial rhizobacteria (e.g., KSMs, nitrogen-fixing bacteria) as biofertilizers. Among KSMs, Actinobacteria are known to be eco-friendly and efficient plant growth promoters (Rani K., *et al*.,2018). Microbial K solubilization has been scarcely investigated, and in our knowledge, only *Arthrobacter sp*., and *Microbacterium sp*. were reported to be K solubilizers (Karlidag, *et al*.,2007). In general, only 5% of potassium-solubilizing bacteria are Actinomycetes (Etesami, *et al*., 2012 and Merchant, and Helmann, 2012). In uninoculated soils, the total K per plant was greatly increased if soluble potassium was added, but this variation scale was higher when the soil was inoculated with the potassium solubilizing strain. Although, in soils inoculated with strain KSB-8 and feldspar the total K per plant is lower than in soil amended with soluble K, the plants have a higher K content showed the higher shoot and root dry weight also demonstrated that bacterial inoculation could resulted significant growth in experimental pot study of *Abelmoscus esculantus* (Prajapati K *et al*.,2013)

Most of the evaluated strains had a positive effect on the germination and growth traits of wheat seedlings (Sharma *et al*.,2007) who demonstrated that the use of PSB inoculants (*P. fluorescens* and *B. megaterium*) improves the radicle and plumule lengths compared to non-inoculated treatments. Under greenhouse conditions, the selected actinomycetes strains significantly enhanced several wheat growth parameters, including plant length, root dry weight, shoot dry weight, Chlorophyll content and K availability over the uninoculated. The maximum results were recorded with the treatments inoculated with KSA 09 and KSA 16 mixture. Those results support our in vitro evaluation of the tested Actinomycetes strains in which a high amount of IAA was positively correlated with the improvement of plant growth parameters. In fact, these phytohormones are known to stimulate wheat germination and accelerate plant growth by enhancing root length and growth, thus enabling the plant to have greater access to soil nutrients and water (Ahemad and Kibret,2014). Our findings are also in concordance with the investigation of increase in chickpea root length (17%) and shoot length (3%) following Streptomyces inoculation. In fact, with their abilities to produce various PGP-related molecules, actinomycetes are well studied.

CONCLUSIONS:

The evidence obtained through this study indicates that the uninoculated soils, the total K per plant was greatly increased if soluble potassium was added, but this increment was higher when the soil was inoculated with the potassium solubilizing strain. Actinomycetes strains were screened for plant growth promoting (PGP) factors, which are considered an effective tool in the investigation of microorganisms that can be used as biofertilizers. Although, in soils inoculated with strain KSA 09 and 16 and feldspar, the total K per plant is higher than in

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soil amended with soluble K, the plants have a higher K content and a higher shoot and root dry weight also demonstrated that actinomycetes strain inoculation could resulted in growth These results demonstrate that actinomycetes influences the growth activity of Wheat plant. From the results it is concluded that effective plant-growth promoting bacterium-plant systems must be tested and established in controlled vegetation experimental designs with consideration of the specific ecological site conditions of practical applications (soil type, plant type). More over the extent of stimulation of plants by the tested microbial strains and the persistence of plant growth promoting activity under actual field conditions needed more clarity. The K-releasing actinomycetes can be used in the K-deficient soils and further research can lead to an alternative mean of K nutrition improvement for use in agriculture.

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