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ORIGINAL ARTICLES

The Response of Bearing Navel Orange Trees to Some Sources and Rates of Potassium Fertilizers and Silicate Bacteria

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ABSTRACT

This study was carried out through two successive seasons (2011 and 2012) in a private orange orchard in Qalubia Governorate, Egypt on 40 years old Navel orange trees budded on sour orange- rootstock grown in a clay loam soil (Typic Torriorthents). Planting distance was 5 × 5 meters apart and flood irrigation was used by river Nile water. Under this orchard conditions no sources of potassium fertilizers were added from many years ago. In the present study ,potassium fertilizers were added at three rates (300, 450 and 600 g K_2O /tree/ year) as potassium sulphate 48% K_2O and K-feldspar, 10% K_2O plus inoculation with *Bacillus circulans* **KSB8** (silicate bacteria).This strain was isolated and identified by 16S rRNA gene sequence. It releases high amount of available K in broth medium supplemented with K- feldspar through the production of organic acids. As well as, it is able to solubilize phosphorus, produce auxins, cytokinin and siderophore which are known to stimulate the growth of plant. The obtained results showed that, inoculation with *Bacillus circulans* **KSB8** only and orchard conditions treatments were not sufficient for giving high yield from Navel orange trees while adding potassium fertilizers irrespective the source and level the yield was increased. The trend was clear in the second season than in the first one due to increases potassium percentage and biological activity, in the soil. The best values of yield, TSS ,TSS / acid ratio and leaf mineral content in most cases were observed by the highest levels from potassium (600 g K_2O) as potassium sulphate+ silicate bacteria or K- feldspar + silicate bacteria treatments followed closely by the second rate (450 g K_2O) from each potassium source. Regarding the effect of potassium source on soil biological activity, it is clear that fertilizing the inoculated plants with potassium sulphate or feldspar at 600 g and 450 g K_2O gave the greatest values of dehydrogenase and CO_2 evolution followed by the treatments amended with 300 g K_2O in second growing season. Thus it could be safely concluded that, using silicate bacteria as effective strain combined with feldspar at the rate of (450 g K_2O / tree / year) may be recommended instead of chemical fertilizers (potassium sulphate) to reduce environmental pollution and alleviate the dependence on imported or costly commercial fertilizer.

Key words: Feldspar, leaf mineral content, Navel orange, potassium sulphate, silicate bacteria, soil biological activity, yield.

Introduction

Citrus Production occupies an important share in the national income of Egypt. According to the census of (M.A.L.R., 2011), citrus acreage is about 483,296 fed. and produced about 3.730,685 ton which meets the demand of local markets and provides suitable quantity for export. Navel orange is considered the major citrus species in Egypt whereas, the total cultivated area in 2011 was about 169,324 fed., and produced about 1,384,129 ton. .

Citrus trees require large quantities of mineral nutrients to attain adequate growth and yield. The requirements for some of the nutrients vary with soil fertility and type. Potassium plays a major role, second only to nitrogen. Potassium does not play a direct role in the plant's cell structure; however, it is fundamental because it catalyzes important reactions such as respiration, photosynthesis, chlorophyll formation, and water regulation. (Lopez and Espinosa, 1998).

Potassium chemical fertilizer became a high expensive due to economic consideration, the cost of applying imported or locally produced water – soluble fertilizers is becoming more expensive. Thus, the use of alternative indigenous resources such as K- feldspar (orthoclase) is gaining importance to alleviate the dependence of imported or costly commercial fertilizers. Bader *et al*., (2006)

About 90 – 98% of total potassium present in soils is found insoluble primary minerals- such as feldspar and micas. These minerals consist of potassium aluminums silicates ($KAlSi_3O_8$) which are resistant to chemical

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breakdown. They release potassium slowly, but in small quantities compared to total needs of growing crops. The main sources of potassium for plants growing under natural conditions come from the weathering of mineral and organic K- sources such as composts and plant residues. Thus, the use of alternative indigenous resources such as K- feldspar (orthoclase) is gaining importance to reduce using chemical fertilizers (McAfee, 2008).Orthoclase (fromul a $KAlSi_3O_8$) is an important tectosilicate mineral which forms igneous rock. It is a common constituent of most granites rocks.

Potassium content in K- feldspar ranges from 10 to 13%. It is a slow release fertilizer, so several laboratory studies have shown that microbes can increase the dissolution rate of silicate and aluminum silicate minerals, primarily by generating organic and inorganic acids (Barker *et al*., 1997 and Aisha and Taalab 2008).

The direct contact between bacteria and minerals may be important in mineral alteration and enhance K mineral dissolution rate by producing and excreting metabolic by products that elevate carbonic acid concentration at mineral surfaces (Chapelle *et al.,* 1987 and Paris *et al*., 1996).

Microbially produced organic ligands include metabolic by products, extracellular enzymes, chelates and both simple and complex organic acids. These substances can influence feldspar dissolution rates either by decreasing pH, by forming framework-destabilizing surface complexes, or by complexing metals in solution (Bennett, *et al* 2001). Bacteria of the genus *Bacillus* are common soil microorganisms that play an important role in silicate biodegradation during the process of rock disintegration (Han *et al.,* 2006 and Liu *et al.,* 2006).The silicate dissolving bacteria (*Bacillus circulans*) are generally used to release potassium from feldspar mineral. Naglaa (1997).

Thus, the main goal of this research is to study the effect of two sources of two sources of potassium [potassium sulphate or K- feldspar] inoculated with silicate bacteria on the yield, fruit quality, leaf mineral content, potassium forms in soil and microbial activity of bearing Navel orange trees to find the best addition rate of an alternative inorganic source of potassium fertilizer locally "feldspar" as natural mineral inoculated with potassium dissolving bacteria.

Materials and Methods

A field experiment was carried out in two successive seasons (2011 and 2012) in a private orange orchard in Qalubia Governorate, Egypt. The citrus trees were "40 years Navel orange- trees (*Citrus sinensis* L) grafted on "Sour orange (*Citrus aurantium* L) rootstock and planted at 5 X 5 meter apart, the soil texture class was clay loam (Typic Torriorthents). Flood irrigation- system was used.

Under this orchard conditions no sources of potassium fertilizers were added from many years ago. The trees had a low level of potassium, and yield was annually decreased and fruits quality was poor.

Potassium fertilizers were added at three rates (300, 450 and 600 g K_2O /tree/ year) as treatments of [potassium sulphate (48% K_2O) or K- feldspar (10% K_2O)] plus silicate bacteria (the- most efficient isolate). Commercial K- feldspar fertilizer was used as fine powder (150 – 250 µm size). Its chemical constituent is shown in Table (1).

The experiment included the following nine treatments:

1- 600 g K_2O /tree/ year as potassium sulphate (as a control according to the citrus program fertilization)
2- 600 g K_2O /tree/ year as potassium sulphate (48% K_2O) + silicate bacteria
3- 450 g K_2O /tree/ year as potassium sulphate(48% K_2O) + silicate bacteria
4- 300 g K_2O /tree/ year as potassium sulphate(48% K_2O) + silicate bacteria
5- 600 g K_2O /tree/ year as K- feldspar (10% K_2O) + silicate bacteria
6- 450 g K_2O /tree/ year as K- feldspar (10% K_2O) + silicate bacteria
7- 300 g K_2O /tree/ year as K- feldspar (10% K_2O) + silicate bacteria
8- Silicate bacteria only.
9- No potassium or bacteria addition (orchard conditions)

Table 1: Chemical constituents of K – feldspar.

Component %	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO
	68.23	0.04	16.25	0.40	0.02	0.03
	CaO	Na_2O	K_2O	P_2O_5	L.O.I.	
	0.47	3.25	10.12	0.02	0.7	

Preparation of biofertilizer inoculants:

The rhizosphere soils of different crops plants were collected in the areas of Qalubia Governorate, Nile Delta. Potassium solubilizing bacteria(KSB) were isolated from collected soil samples using Aleksandrov agar medium (0.2% K- feldspar) (Hu *et al.*,2006).The colonies exhibiting clear zones were selected. The diameter of solubilization zone was measured and expressed by solubilization index {the ratio of the total diameter (colony + halo zone) and the colony diameter} (Edi Premono *et al.,* 1996). The isolates showing the highest solubilziation index on Aleksandrov agar were further examined for their ability to release K in Aleksandrov broth medium (supplemented with 0.2 % feldspar) at pH 7. The amount of available K released in the broth and pH were estimated during 21 days of incubation period, in comparison with uninoculated flasks (control). The available K content in the supernatant was determined by flame photometry. The most efficient isolates (were selected according to their efficiency to solubilize insoluble potassium in liquid medium) were examined for other beneficial traits *viz.,* solubilization of insoluble inorganic phosphate (Subba Rao, 1982), siderophore (Alexander and Zuberer, 1991) and production of plant growth promoting substances like IAA(Glickmann and Dessaux ,1995) and Cytokinin(Fletcher and McCullagh (1971) to select the efficient isolate. The selected bacterial isolate was identified and inoculated in nutrient broth by a standard inoculum and incubation at 30±1°C/ 2days to obtain the biofertilizer inoculant ($3x10^7$cfu/ml).

Different treatments of potassium sulphate, K- feldspar and the first dose of silicate bacterium was added in the first week of March whereas, the second dose of silicate bacteria were applied in the first week of June each at the rate 750 ml ($3x10^7$cfu/ml) / tree / dose in each season. Silicate dissolving bacteria were inoculated and mixed with soil holes around the trunk. The treatments were arranged in a randomized complete block design with five replicates for each treatment and each replicate was represented by one tree.

The effect of the aforementioned treatments on yield, fruit quality, leaf mineral content of the spring growth cycle, different soil potassium forms and soil biological activity in the two studied seasons were investigated as follows:

1- Leaf dry matter:

About forty non- fruiting shoots of the spring growth cycle on each tree were tagged in April in each season. Thereafter, a sample of 40 leaves from these shoots were randomly collected from each tree in late August of each season as recommended by Jones and Embleton (1969). Leaves were washed with tap water, rinsed with distilled water then weighted after air dried. Then leaves were oven dried at 60-70^{o}C till a constant weight and leaf dry matter was recorded.

2- Yield:

At maturity, the average number of fruits / tree was counted on the mid of December of each season. Moreover, 30 fruits from each tree were used to get the average fruit weight of each treatment. Such average was multiplied by the average number of fruits / tree to get the average yield / tree, Kg.

3- Fruit quality:

For each season, one sample of five fruits / tree was randomly taken and used for the determination of the following physical and chemical properties:

a- Peel thickness, mm.
b- Fruit volume, ml.
c- Juice volume, ml.
d- Juice percent.
e- The ascorbic acid content was determined using 2,6 dichlorophenolindophenol dye and 3% oxalic acid as substrate. Ascorbic acid was calculated as milligrams per 100 milliliters of juice according to the method of the A.O.A.C (1970).
f- The titratable acidity was determined by titrating five milliliters of juice against sodium hydroxide, 0.1 N using phenolphthalein indicator. The acidity percentage was calculated as mg anhydrous citric acid per 100 milliliters of juice according to A.O.A.C. (1995).
g- The total soluble solid (TSS) was determined in juice by means of hand refractometer.
h- The TSS / Acid ratio was calculated.

4- Leaf mineral content:

Dry leaves were grounded and digested using sulphoric acid and oxygen peroxide according to Leaf mineral content of N, P, K, Zn , Fe and Mn were determined on dry weight basis according to Jackson, (1973). While, Zn, Fe and Mn were determined by Atomic Absorption Spectrophotometer (Jaril- Ash 850).

5- Soil sample:

The collected soils (0-30) were air dried, crushed and sieved in 2 mm sieve. Some physical and chemical characteristics of the investigated soils are presented in Table 2.

Table 2: Some physical and chemical properties of the orchard soil:

Particale size, %			Texture class	Total $CaCO_3$, %							
Sand	Silt	Clay									
31.33	37.11	31.56	Clay loam	1.42							
Soluble ions in saturated extract, (meq/l)											
ECe	pH	K^+	Na^+	Ca^{2+}	Mg^{+2}		Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}	O.M,%
dS/m	(1:2.5)										
1.70	7.62	1.64	0.70	11.26	3.40		3.50	3.89	0.00	9.61	2.51

Particle size distribution was carried out using the international pipette method as described by Baruah and Barthakur (1997). Electrical conductivity was determined in the extract of saturated soil paste according to the method mentioned by Jackson (1973). pH values were measured in (1:2.5) soil suspension using pH meter according to the method mentioned by Black *et al*. (1965). Soluble cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-}) were determined in the soil paste extract according to Jackson (1973). Available potassium was measured using Flame photometer after extracting by ammonium acetate as described by Page *et al*. (1982).

Potassium forms determination:water soluble (K – H_2O), potassium extracted by NH_4OAC (NH_4OAC-K) and potassium extracted by nitric acid (Acid-K) were determined by the method described by Pratt (1965) in the collected samples at the beginning of the experiment, after 90,180 days in each season. Potassium concentrations were measured by Flame photometer.

6- Soil biological activity:

The humid soil samples, were collected at the beginning of the experiment (before any addition), 90,180 days in each season, were used for the determination of soil biological activity in terms of carbon dioxide evolution (mg CO_2 100g $soil^{-1}$) (Gaur et al., 1971) and dehydrogenase activity (DHA) (µg TPF/g/day) (Casida et al.,1964).

Analysis of organic acids of selected isolate(silicate bacteria):

Culture filtrate of the selected isolate was analyzed for organic acids by high performance liquid chromatography (HPLC) in comparison with standard organic acids (Castellari *et al*., 2000), with Kromasil column(250 mm 4.6 mm) and GBC LC1110 Pump. The operating conditions consisted of methanol: water: phosphoric acid (94:50:1) as the mobile phase, detector GBC (UV 254 nm) and a constant flow rate of 1 ml/ min. The organic acids were quantitively determined by comparing the retention times and peak areas of chromatograms with those of standards.

Identification of the selected isolate:

The selected isolate (applied isolate) was examined for the colony morphology, cell shape, Gram reaction and ability to form spores. Thereafter, it was grown in nutrient broth on a rotary shaker (120 rpm) at 28-30°C for 24 h. Isolation of cellular DNA was performed as described by Ausubell *et al*. (1987) and amplification of 16S rDNA according to Lane (1991) using the universal 16S primers. PCR was run on a Gene Amp PCR System 2400 thermal cycler (Perkin Elmer).The resulting PCR products sizes were ranged from 1450 to 1500 bp. The PCR-product was purified using QIAquik PCR Purification Kit (Qiagen). The sequencing was performed in GATC German Company by use ABI 3730xl DNA sequencer by using forward and reverse primers. Sequencing data was analyzed by two different computer alignment programs, DNAStar (DNASTAR, Inc., USA) and Sequence Navigator (Perkin, Corp., USA).

Statistical analysis:

Data obtained were statistically analyzed by using the analysis of variance as reported by (Snedecor and Cochran, 1980). Means were differentiated by using Duncan's multiple range test at 5 %(Duncan, 1955).

Results and Discussion

The selection of the most efficient inoculant:

From the collected soil samples, fourteen isolates gave clear zone around their colonies on Aleksandrov agar medium. Considerable variation was generally recorded among collected isolates regarding their capabilities for solubilizing insoluble potassium described by solubilization index. The potassium solubilization index of the collected isolates ranged from 1.3 to 2.5 at 30°C /8days.Among the isolates, KSB6 and KSB14 showed the least solublization index (1.3±0.05).However, the isolates KSB3, KSB8 ,KSB9 and KSB10 recorded maximum solublization index being 2.0±0.03, 2.4±0.10, 2.5±0.10 and 2.2±0.10, respectively. So, they were further subjected to solubilize feldspar in liquid medium for 3weeks under laboratory conditions. The results indicated variation between the isolates to solubilize the feldspar. Generally, compared to the control, the pH of inoculated medium supplemented with feldspar was decreased; this was an indication of acid production. The amount of soluble K released from mineral K by the four isolates increased with increasing incubation time and was maximum at 21 days,Fig.1. The differential efficiency of bacteria to solubilize insoluble inorganic potassium could be due to differences in their ability to release organic acids (Liu *et al.*, 2006).Isolate KSB8 released maximum amount of soluble K (29.9 ppm) followed by isolate KSB9 (25.2 ppm) from feldspar after 21 days. Both isolates were significantly superior over all others, Fig.1. In this respect, Badr (2006) reported that potassium release was affected by pH, aerobic conditions and soil mineral properties.

Quantitative assessment of some metabolic activities i.e. IAA (µg/ml), Cytokinin (µg/ml) and siderophore production (µM DFOM) along with phosphate solubilization (ppm) of the most efficient isolates (KSB8& KSB9) were examined. The isolate KSB8 was superior in all parameters along with K solubilization, its recorded figures were 3.21, 1.6, 60.5 and 30.6 whereas being 2.9, 0.3, 20.0 and 12.5 for KSB9,respectively.So the isolate KSB8 was used as bioinoculant for Navel orange trees to improve the plant growth.

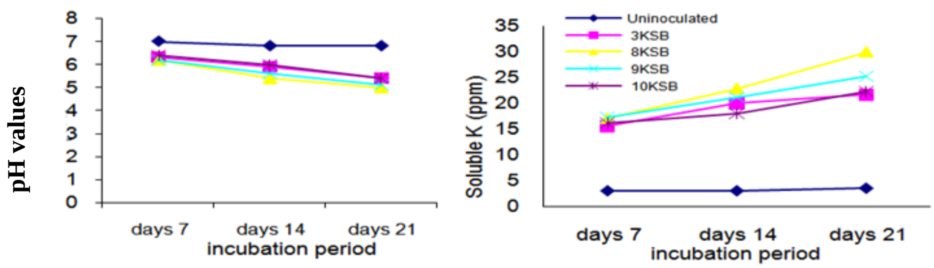

Fig. 1: Soluble potassium ppm and pH values of the selected isolates of potassium solubilizing bacteria grown on Aleksandrov liquid medium amended with feldspar (0.2%) at 30°C during 21 days.

Filed experiment:

Effect on leaf dry matter:

Generally, results in Table 3 revealed that in the two seasons, dry matter % of Navel orange trees was significantly affected by treatments. In the two seasons, T_8 (silicate bacteria only) and T_9 (orchard conditions) gave the lowest values. On the other hand, T_2 and T_5 (600 g K_2O from potassium sulphate or feldspar + silicate bacteria) gave the highest values of leaf dry matter percentage. In this respect El-shenawy and Fayed (2005) found that using feldspar mixed bio-fertilizer increased fresh and dry weight of Crimson seedless grapevines leaves.

Table 3: Effect of different sources and rates, of potassium and silicate bacteria on leaf dry matter of Navel orange trees during 2011 and 2012 seasons.

Treatments	leaf dry matter%	
	Season 2011	Season 2012
T_1- 600 g K_2O^{*}	34.3 c	40.23 c
T_2- 600 g K_2O^{**}	50.9 a	55.6 a
T_3- 450 g K_2O^{**}	46.6 b	46.9 b
T4- 300 g K_2O^{**}	34.14 c	40.11 c
T5- 600 g K_2O^{***}	52.09 a	55.8 a
T_6- 450 g K_2O^{***}	38.67 c	38.0 c
T_7-300 g K_2O^{***}	41.82 b	44.34 b
T_8- silicate bacteria only	28.31 d	26.0 d
T_9- (orchard conditions)	28.8 d	25.11d

*:Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

Effect of different sources and rates of potassium and silicate bacteria on Navel orange fruit weight, fruit number and yield:

Results in Table (4) show the effect of different sources and rates of potassium and silicate bacteria on Navel orange yield in 2011 and 2012 seasons.

A- Fruit weight:

Values of fruit weight in the two seasons were significantly affected by treatments. However, the effect varied slightly from season to season. In the two seasons, T_8 (silicate bacteria only) and T_9 (orchard conditions) gave the least significant values. In the first season, other potassium treatments gave more or less similar values without any significant differences among them. In the second season, all potassium treatments gave higher values than obtained in the first season. Regarding potassium treatment, T_2 and T_5 gave the highest fruit weight values although T_1 tended to reduce fruit weight slightly but not significantly than the above two treatments. Other potassium treatments had no significant differences among them.

B- Fruit number /tree:

In both the two seasons, T_8 and T_9 treatments gave the least values of fruit number/tree**.** The maximum increase was obtained by (T_3) followed closely by (T_5) in the first season. However, in the second season treatments (T_1, T_2, T_3, T_5 and T_6) gave similar values and without significant differences among them. Whereas, other treatments gave significant lower values than the above mentioned treatments but these values were higher than those of both T_8 and T_9 treatments.

C- Yield (Kg) /tree:

In the two seasons (Table 4) in general the yield was increased in the second season than the first one. However, in the two seasons T_8 and T_9 treatments gave the lowest values of yield/tree. Other treatments gave higher values than those of the two mentioned treatments. But, in the first season yield/tree was more or less similar in all other treatments (T_1: T_7). Nevertheless, in the second season treatments (T_1, T_2 and T_5) tended to give significantly higher values than those of the other ones.

In this respect, Quaggio *et.,al* (2011) evaluated K_2SO_4 and KCl fertilizer sources at 0, 100, 200, and 300 kg ha^{-1} per year K_2O on fruit yield and quality of ‘Pêra’ and ‘Valencia’ sweet orange trees in the field. They found that Fruit yield was increased with increased K fertilization. Rasha *et.,al* (2012) reported that fertilizing 20 years old Valencia orange trees budded on sour orange rootstock with feldspar at 1000g K_2O/ tree with two or three doses inoculated with *Bacillus circulans* as soil application had a significant effect on yield kg/ tree and fruit weight. Also, two doses of feldspar at 750g K_2O/ tree gave better results where such treatments considered the promising under orchard conditions.

Effect of different sources and rates of potassium and silicate bacteria on some fruit physical properties of Navel orange:

Results in Table 5 show the effect of different sources and rates of potassium and silicate bacteria on some fruit physical properties of Navel orange in 2011 and 2012 seasons.

A- Fruit peel thickness:

Fruit peel thickness of orchard conditions trees (T_9) was the lowest compared with other treatments in the two seasons. All treatments gave more or less similar values but the highest values were obtained by treatment (T_5) in the two seasons. Thus the potassium sources seem to have no significant effect on fruit peel thickness.

B- Fruit volume:

In the two seasons, all treatments gave higher values than those of the T_8 and T_9 treatments. On the other hand, treatment (T_6) in the first season and treatment (T_2) in the second season gave the highest values of fruit volume, respectively.

C- Juice volume:

In the two seasons, orchard conditions trees (T_9) and silicate bacteria only (T_8) treatments gave the lowest significant values of juice volume. Other treatments gave more or less similar values and it was hard to select the most promising treatment.

D- Juice %:

In the two seasons juice % was not affected significantly by potassium treatments. All treatments gave more or less similar values.

Table 4: Effect of different sources and rates of potassium and silicate bacteria on yield of Navel orange trees during 2011 and 2012 seasons

Treatments	Fruit weight (g)		Fruit No. /tree		Yield (Kg) /tree	
	2011 season	2012 season	2011 season	2012 season	2011 season	2012
T_1- 600 g K_2O^{*}	197.8 a	274.7 ab	144.0 c-e	193.0 ab	28.0 b	53.2 ab
T_2- 600 g K_2O^{**}	204.4 a	294.7 a	152.0 cd	200.0 ab	31.1 ab	58.9 a
T_3- 450 g K_2O^{**}	182.8 a	216.7 cd	218.0 a	213.3 a	40.0 a	46.1 bc
T4- 300 g K_2O^{**}	173.8 a	206.0 de	173.0 bc	161.3 cd	30.3 ab	33.3 de
T5- 600 g K_2O^{***}	189.1 a	290.7 a	200.0 ab	197.3 ab	38.6 ab	57.4 a
T_6- 450 g K_2O^{***}	210.6 a	225.3 cd	170.0 c	186.7 a-c	35.7ab	42.3 cd
T_7-300 g K_2O^{***}	185.0 a	242.7 bc	158.0 c	169.3 bc	29.3 ab	41.0 cd
T_8- silicate bacteria only	133.1 b	180.7 ef	125.0 de	136.0 de	16.8 c	24.6 ef
T_9- (orchard conditions)	134.7 b	164.7 f	115.0 e	110.7 e	15.6 c	18.2 f

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

Table 5: Effect of different sources and rates of potassium and silicate bacteria on some fruit physical properties of Navel orange trees during 2011 and 2012 seasons.

Treatments	Peel thickness (mm)		Fruit volume (ml)		Juice volume (ml)		Juice %	
	2011 season	2012 season	2011 season	2012 Season	2011 season	2012 season	2011	2012 season
T_1- 600 g K_2O^{*}	4.95 a-c	5.07 b-e	184.0 a-c	262.7 ab	98.8 a	136.7 a	53.5 a	53.1 a
T_2- 600 g K_2O^{**}	4.98 a-c	4.87 c-e	195.0 ab	304.0 a	93.1 a	134.2 ab	47.7 a	44.0 a
T_3- 450 g K_2O^{**}	4.54 bc	5.19 b-e	173.8 bc	234.7 a-c	83.8 a	107.3 bc	49.2 a	47.3 a
T4- 300 g K_2O^{**}	4.22 c	4.54de	173.1 bc	218.0 bc	84.4 a	98.2 cd	48.9 a	45.3 a
T5- 600 g K_2O^{***}	6.38 a	6.30 a	193.8 ab	282.0 b	86.9 a	123.0 a-c	44.8 a	44.6 a
T_6- 450 g K_2O^{***}	5.82 ab	5.66 a-c	226.3 a	231.3 a-c	100.6 a	97.2 cd	45.3 a	42.7 a
T_7-300 g K_2O^{***}	5.38 a-c	5.48 a-d	190.0 ab	237.3 a-c	81.9 a	105.5 bc	43.2 a	44.1 a
T_8- silicate bacteria only	5.59 a-c	5.98 ab	136.9 c	173.3 c	59.4 b	72.8 d	45.5 a	43.6 a
T_9- (orchard conditions)	4.24 c	4.12 e	140.0 c	165.3 c	56.9 b	72.3 d	42.4 a	43.9 a

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

Effect of different sources and rates of potassium and silicate bacteria on some fruit chemical properties of Navel orange:

Results in Table 6 show the effect of different sources and rates of potassium and silicate bacteria on fruit chemical properties of Navel orange trees in 2011 and 2012 seasons.

A- Ascorbic acid content:

Generally, results revealed that in the two seasons, ascorbic acid content was affected slightly by potassium treatments. However, orchard conditions trees (T_9) gave the lowest values of ascorbic acid. Other treatments gave more or less similar value. However, it is clear that the potassium source and rate had no effect on ascorbic acid content.

B- Acidity %:

In the first season only acidity % was affected significantly by potassium treatments. All treatments gave more or less similar values .However, (T_2) and (T_1) gave the lowest acidity %values in the first and second season, respectively.

C- TSS%:

Data in (Table 6) indicated that TSS % was affected significantly by different treatments. However, (T_7), (T_8) and (T_9) treatments gave the lowest values of TSS in the two seasons. On the other hand, other potassium treatments irrespective source and rate had a promising effect on TSS %.

D- TSS / acid ratio:

Results in Table 6 revealed that TSS / acid ratio was affected significantly by different treatments in the two seasons. However, (T7), (T8) and (T9) treatments gave the lowest values of TSS / acid ratio especially in the first season. Other treatments gave more or less similar values but these values were higher than those of the above mentioned treatments. On the other hand, (T2) and (T6) gave the highest values of TSS / acid ratio in the first and second season respectively. Thus it seems that potassium irrespective the source had a stimulative effect on TSS / acid ratio.

In this respect, (Obreza, 2003) recommended that fresh market citrus growers should recognize that K affects fresh fruit quality factors such as fruit size and sweetness as well as yield, and negative effect as K fertilizer rate then take all these factors into account when increased formulating a fertilization program.

Table 6: Effect of different sources and rates of potassium and silicate bacteria on some fruit chemical properties of Navel orange trees during 2011 and 2012 seasons

Treatments	Ascorbic acid (mg/ 100ml juice)		Acidity%		TSS%		TSS / acid ratio	
	2011 season	2012 season	2011 season	2012 season	2011 season	2012 season	2011 season	2012 season
T_1- 600 g K_2O^*	57.7 a	44.7ab	0.965 a-c	0.877 a	13.3 ab	13.4 ab	13.84 a-c	15.36 a
T_2- 600 g K_2O^{**}	55.6 ab	42.0 b	0.894 c	0.915 a	13.9 a	13.8 a	15.55 a	15.05 a
T_3- 450 g K_2O^{**}	48.8 b	41.8 b	0.937 bc	0.960 a	13.6 a	13.5 ab	14.58 ab	14.07 ab
T4- 300 g K_2O^{**}	54.7 ab	46.4 ab	1.08 ab	0.909 a	13.9 a	13.7 a	12.89 b-c	15.13 a
T5- 600 g K_2O^{***}	55.3 ab	43.1 b	0.995 a-c	0.977 a	13.8 a	13.9 a	13.93 a-c	13.90 ab
T_6- 450 g K_2O^{***}	52.0 ab	45.0 ab	1.04 ab	0.896 a	13.1 ab	13.6 a	12.40 b-d	15.34 a
T_7-300 g K_2O^{***}	55.0 ab	45.0 ab	1.10a	0.928 a	12.3 b	13.0 bc	10.98 d	13.98 ab
T_8- silicate bacteria only	54.2 ab	49.0 a	1.05 ab	0.934 a	12.4 b	12.4 c	11.72 cd	13.28 b
T_9- (orchard conditions)	48.2 b	41.1 b	0.995 a-c	0.960 a	12.2b	12.4 c	12.02 cd	12.95 b

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

Effect of different sources and rates of potassium and silicate bacteria on leaf mineral content of Navel orange:

Results in Table 7 show the effect of different sources and rates of potassium and silicate bacteria on leaf macronutrient content of Navel orange in 2011 and 2012 seasons.

A-Leaf macronutrient contents:

Leaf nitrogen content:

In the two seasons nitrogen content was affected significantly by different potassium treatments. Generally, treatment T_2 (600 g K_2O) as potassium sulphate+ silicate bacteria gave the highest values of nitrogen content. This could be associated with potassium mainly operations, which consists of the way of protein nitrogen in the plant, and the potassium role in the movement of nitrogen within the plant when absorb nitrates from the soil equalizer consignment solid on this ion with a positively charged ion potassium and thus absorbs nitrogen with a stream to the leaves where they are synthesized protein and at the top of potassium ion combines with organic acids and this image is flowing again to the roots to participate in the next session, and so works as a kind of potassium pump nitrogen. In this way, getting better every use of plant nitrogen and absorb nitrogen from the soil and because of the role of potassium in the representation of nitrogen in plants it happens accumulation of the outputs intermediate for the synthesis of protein when adding large amounts of nitrogen and low supply potassium, which leads to increase supply of potassium to improve the conversion of these vehicles nitrogen with low molecular weight protein substances (Marschner, 1995).

Leaf phosphorus content:

Results in Table 7 revealed that generally, in the two seasons phosphorus content seems to be affected significantly by potassium treatments. The least values in phosphorus were obtained by T_9 (orchard conditions). Other treatments gave more or less similar values however; the highest phosphorus content was obtained by T_2 and T_7 in the first and second seasons, respectively.

Leaf potassium content:

It was affected significantly by different treatments. In the first season, T_8 and T_9 treatments gave the lowest values of potassium content. On the other hand T_2 gave the highest values of potassium content followed closely by (T_4: T_7) with similar statistical stand point. In the second season, T_2 and T_1 gave the highest values of potassium content.

Potassium also plays a major role in the transport of water and nutrients throughout the plant in the xylem. When K supply is reduced, translocation of nitrates, phosphates, calcium, magnesium, and amino acids is depressed. As with phloem transport systems, the role of K in xylem transport is often in conjunction with specific enzymes and plant growth hormones. An ample supply of K is essential to efficient operation of these systems. K is not a constituent of any organic molecule or plant structure, it is involved in numerous biochemical and physiological processes vital to plant growth, yield, quality, and stress (Marschner, 1995 and Cakmak, 2005). In addition to stomatal regulation of transpiration and photosynthesis, K is also involved in photophosphorylation, transportation of photoassimilates from source tissues via the phloem to sink tissues, enzyme activation, turgor maintenance, and stress tolerance (Pettigrew, 2008).

Table 7: Effect of different sources and rates of potassium and silicate bacteria on leaf macronutrient contents of Navel orange trees during 2011 and 2012 seasons.

Treatments	Season 2011 %			Season 2012 %		
	N%	P%	K%	N%	P%	K%
T_1- 600 g K_2O^{*}	2.40 cd	0.19 ab	1.5 bc	2.64 b	0.16 ab	1.30 ab
T_2- 600 g K_2O^{**}	3.04 a	0.20 a	2.30 a	3.16 a	0.14 ab	1.31 ab
T_3- 450 g K_2O^{**}	2.77 abc	0.16 bc	1.08 cd	2.63 b	0.16 ab	1.27 bc
T4- 300 g K_2O^{**}	2.86 ab	0.18 ab	2.20 ab	2.79 b	0.15 ab	1.24 c
T5- 600 g K_2O^{***}	2.64 abcd	0.17 abc	1.94 ab	2.83 b	0.15 ab	1.24 c
T_6- 450 g K_2O^{***}	2.43 cd	0.17 abc	1.87 ab	2.58 b	0.15 ab	1.27 bc
T_7-300 g K_2O^{***}	2.51 bcd	0.19 ab	1.76 abc	2.63 b	0.17 a	1.30 ab
T_8- silicate bacteria only	2.33 d	0.14 c	0.62 d	2.54 b	0.15 ab	0.55 d
T_9- (orchard conditions)	2.32 d	0.15 c	0.52 d	2.83 b	0.12 b	0.45 d

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

B- Leaf micronutrient contents:

Results in Table 8 show the effect of different sources and rates of potassium and silicate bacteria on leaf micronutrient content of Navel orange in 2011 and 2012 seasons.

Generally, results in Table 8 revealed that in the two seasons, Fe, Zn and Mn content was not affected significantly by potassium treatments. All treatments including untreated trees (T_9) were similar from the statistical stand point. From the above mentioned results of the two seasons, it is clear that the potassium source and rate had no effect on micronutrients content.

In this respect, Weatrman *et al*. (1990) mentioned the following optimum levels of leaf macro and micronutrients content in orange tree (N= 2.4-2.8%, P= 0.20 – 0.26%, K=1.3-1.6%, Fe= >500 ppm, Zn= 18-80 ppm and Mn= 50-160ppm).

Table 8: Effect of sources and rates of potassium and silicate bacteria on leaf micronutrient contents of Navel orange trees during 2011 and 2012 seasons.

Treatments	Season 2011			Season 2012		
	Fe (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)	Mn (ppm)
T_1- 600 g K_2O^*	600.0 a	42.0 a	49.6 bc	740.0 c	40.6 ab	47.0 b
T_2- 600 g K_2O^{**}	596.6 a	67.0 a	38.3 c	1766.6 abc	45.0 ab	60.0 ab
T_3- 450 g K_2O^{**}	2340.0 a	65.0 a	57.3 abc	2233.3 a	45.0 ab	61.0 ab
T4- 300 g K_2O^{**}	1666.6 a	57.0 a	64.6 abc	933.3 bc	40.3 ab	56.6 ab
T5- 600 g K_2O^{***}	2033.3 a	58.6 a	89.0 a	1966 ab	51.3 a	78.0 a
T_6- 450 g K_2O^{***}	1766.6 a	53.6 a	74.6 abc	1066.6 bc	48.3 ab	65.0 ab
T_7-300 g K_2O^{***}	1466.6 a	62.0 a	86.0 ab	1273.3abc	52.3 a	68.0 ab
T_8- silicate bacteria only	1633.3 a	60.0 a	61.3 abc	1393.3 abc	46.6 ab	62.6 ab
T_9- (orchard conditions)	1025.0 a	51.5 a	60.0 abc	1885.0 ab	47.5 ab	62.5 ab

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria.
Values having the same letters in the same column in each season are not statistically different by Duncan ´s multiple range test, 5% level

Effect of different potassium sources on potassium forms in the investigated soil:

Potassium exists in soil in different forms

1. Readily available or exchangeable (potassium dissolved in soil water plus that held on the exchange sites, Tisdale *et al.* (1993). This form is well expressed as the NH_4 OAC. Extracted K.
2. Slowly available potassium trapped between layers of clay minerals frequently referred as fixed K, it form, represent 90-98%, in general, of total soil K, Tisdale *et al.* (1993) and could be evaluated throwing (in) $HN0_3$ extract.

Potassium forms in soil during 2011 and 2012 seasons as affected by K-fertilization is shown in Table 9. Obtained data generally show that application of potassium to soil enhanced the readily available K (water soluble + exchangeable). Values of water soluble –K, NH_4 OAC –K and HNO_3-K were recorded at the highest K level. Water soluble and NH_4OAC extractable –K which is easily available to the plant was maintained at higher levels in potassium sulphate or K- feldspar with silicate bacteria. In fact, it could be concluded that the action of bio fertilizer application was very intensive in stimulating K solubility by withdrawing from the total amount; Ali *et al,* 2003 found that the bio fertilizer with functional groups microorganisms, mainly potassium dissolving bacteria are important in soil both through various activities and by the potential to act as nutrient. As time progressed, average of was not obviously affected although the solubility sends to be enhanced generally during the second season particaluer the third soil sample. Montasser (1987) results showed that values of available K generally increased at early time intervals to be then decreased at the end of experment.

Soil biological activity:

Dehydrogenase activity can therefore be used as an indicator of biological redox systems and as measure of microbial activity in soil. Concentration of soil dehydrogenases depends on conditions and intensity of biological conversion of organic compounds. The evolution of CO_2 under field conditions represents respiration by plant roots and soil biota and is a sensitive indicator of abiotic controls, crop residues decomposition, and soil organic carbon turnover and ecosystem disturbance. The data of soil biological activity (dehydrogenase, CO_2 evolution) at 0, 90, 180 days is presented in Fig.(2). Results revealed that all tested soil biological activity parameters under different treatments of silicate bacteria (KSB8) were higher than those without silicate bacteria (T_1, T_9) at different times in two seasons. At 180 days, the recorded values of dehydrogenase activity and CO_2 evolution were the highest figures. It is clear that all potassium fertilizer rates led to a significant increase in the two parameters in both seasons. Moreover, it was found that fertilizing the inoculated plants with potassium sulphate or feldspar at 600 g and 450 g K_2O gave maximum values followed by the treatments amended with 300 g K_2O in second growing seasons while in first season, all potassium fertilizer rates led to the same effect on the two parameters, in presence the silicate bacteria at 180 days. Chendrayan *et al.* (1980) reported that the increase in dehydrogenase activity was mainly due to higher microbial population. Similar results were obtained by Chu *et al.* (2007) who demonstrated that the fertilization greatly increased soil microbial biomass C and dehydrogenase activity after longterm application. The increased biomass and activity by mineral fertilization may be derived from the increased root biomass and exudates because of greater crop yields by fertilization.

Table 9: Effect of different sources and rates of potassium and silicate bacteria on potassium forms in investgated soil of Navel orange trees during 2011 and 2012 seasons.

Treat.	Water solube –K				NH_4OAC-K Cmol Kg^{-1}				HNO_3- K Cmol Kg^{-1}			
					2011 Season							
	Sample 1	Sample 2	Sample 3	Mean	Sample 1	Sample 2	Sample 3	Mean	Sample 1	Sample 2	Sample 3	Mean
T_1- 600 g K_2O^*	0.048 gh	0.35 cd	0.37 bc	0.26BC\	0.3d	0. 44 d	0.39 d	0.37BC\	2.89 f	5.82 bc	4.01de	4.24C\
T_2- 600 g K_2O^{**}	0.054 g	0.77 a	0.66 a	0.49A\	0.45 d	0.90 a	0.64 b	0.66A\	3.67 e	8.14 a	6.86 a	6.22A\
T_3- 450 g K_2O^{**}	0.046 gh	0.50 b	0.32 cd	0.28BC\	0.25de	0.54 b c	0.61 b	0.46BC\	3.01f	5.64 cd	4.12 de	4.25C\
T4- 300 g K_2O^{**}	0.049 g	0.50 b	0.30 ce	0.28BC\	0.28de	0.55b c	0.60 b	0.47BC\	2.71 f	5.53cd	4.33 de	4.19C\
T5- 600 g K_2O^{***}	0.050 g	0.68 a	0.44 b	0.39AB\	0.29de	0.68 b	0.66 b	0.54 AB\	3.43 e	7.17 ab	5.77 bc	5.45BC\
T_6- 450 g K_2O^{***}	0.042 gh	0.62 a	0.28 ce	0.31BC\	0.3d	0.51 bc	0.40 d	0.40BC\	2.89f	4.64 cde	3.01 f	3.51C\
T_7-300 g K_2O^{***}	0.054 g	0.33 cd	0.24 df	0.20C\	0.21de	0.55 b c	0.5 c	0.42BC\	2.03f	4.26 de	3.33e	3.20C\
T_8- silicate bacteria only	0.033 i	0.20 ef	0.21 ef	0.14C\	0.19 ef	0.29 de	0.3 d	0.26C\	2.4 f	3.68 e	3.44 e	3.17C\
T_9- (orchard conditions)	0.018 j	0.10 f	0.15 f	0.08 D\	0.19ef	0.25 de	0.22 d	0.22C\	2.17 f	3.29 e	2.23 f	2.56D\
Mean	0.043C	0.45A	0.33B		0.27C	0.52 A	0.48B		2.8C	5.35A	4.12B	
					2012 Season							
	Sample 1	Sample 2	Sample 3	Mean	Sample 1	Sample 2	Sample 3	Mean	Sample 1	Sample 2	Sample 3	Mean
T_1- 600 g K_2O^*	0.15 h	0.84 ab	0.52 c-f	0.50 AB\	0.90 c-g	1.34 b	0.80 e-h	0.50 AB\	5.5 b-d	4.9 b-e	4.8 b-e	5.07AB\
T_2- 600 g K_2O^{**}	0.23 h	0.90 a	0.58 b-e	0.57A\	0.93 c-f	1.71 a	0.81 d-h	0.57A\	12 a	5.46 b-d	5.7 b-d	7.72A\
T_3- 450 g K_2O^{**}	0.15 h	0.71 a-d	0.43 d-g	0.43AB\	0.83 d-h	1.03 c-f	0.70 f-h	0.43AB\	6.0 b	5.8 bc	1.45 i-k	4.42BC\
T4- 300 g K_2O^{**}	0.17 h	0.72 a-d	0.58 b-e	0.49AB\	0.81 d-h	1.03 c-f	0.40 hi	0.49AB\	4.66 b-e	3.12e-i	2.74 f-i	3.56C\
T5- 600 g K_2O^{***}	0.15 h	0.61 a-e	0.73 a-d	0.49AB\	0.91c-f	1.21 bc	0.65 gh	0.49AB\	5.53 bc	4.58 b-f	3.34 e-h	4.48BC\
T_6- 450 g K_2O^{***}	0.15 h	0.71 a-d	0.44 d-g	0.43AB\	0.71 f-h	1.08 b-e	0.83 d-h	0.43AB\	5.5 b-d	4.0 c-g	4.06 c-g	4.52BC\
T_7-300 g K_2O^{***}	0.11 h	0.73 a-d	0.78 a-c	0.54 A\	0.65 gh	1.11 b-d	0.83 d-h	0.54 A\	3.7 d-g	4.7 bcde	6.01 b	4.80BC\
T_8- silicate bacteria only	0.10 h	0.70 a-d	0.13 h	0.31BC\	0.27 j	0.29 j	0.38 ij	0.31BC\	1.7 h-k	2.71 f-i	0.7 jk	1.70D\
T_9- (orchard conditions)	0.08 h	0.3 e-h	0.087 h	0.16 C\	0.22 k	0.22 k	0.11 k	0.16 C\	0.6 j k	0.39 k	0.7 jk	0.56E\
Mean	0.14C	0.70A	0.47B		0.69B	1.00A	0.61B		5.02A	3.96B	3.27C	

*: Tree/ year (potassium sulphate). **: Tree/ year (potassium sulphate) + silicate bacteria. ***: Tree/ year (feldspar) + silicate bacteria
Sample 1 at the beginning of experiment. Sample 2 at 3 months of the beginning . Sample 3 at 6 months of the beginning
Means of each of treatments, sampling time or their interactions in each season having the same letters are not statistically different by Duncan multiple range test, 5% level.

Organic acid production:

From the abovementioned results, the enhancing effect of silicate bacteria on the host is due to increased K mobilization leading to increase uptake of K along with N and P from the soil. This effect may be attributed to produce different metabolites such as organic acids and growth promoting substances. This finding may indicate how importance to identify the dominant organic acids under laboratory conditions.

Data presented in Fig. 3 show the HPLC separation of the organic acids from culture filtrate of *Bacillus circulans* KSB8 (silicate bacteria). Acids in the sample were identified by comparison of retention times and the UV absorption spectra with those obtained from the corresponding standards. The bacterial strain produced two organic acids i.e., oxalic and citric acid which can specifically break down mineral structure and extract elements required for metabolism or structure purpose. Amount of oxalic and citric acid were 3.95 and 1.07mg/ml, peaks were observed at 4.7min. and 6.0min., respectively. It was observed from the preliminary results that oxalic acid was the main organic acid produced during the growth. Dacey *et al*., (1981) noted that oxalic and citric acid are the most effective acids in leaching aluminosilicate from different minerals.

Organic acids can directly enhance dissolution by either a proton or ligand-mediated mechanism. They can also indirectly enhance dissolution by the formation of complexes in solution with reaction products and as a consequence increase the chemical affinity for the overall dissolution reaction (Ullman and Welch, 2002).

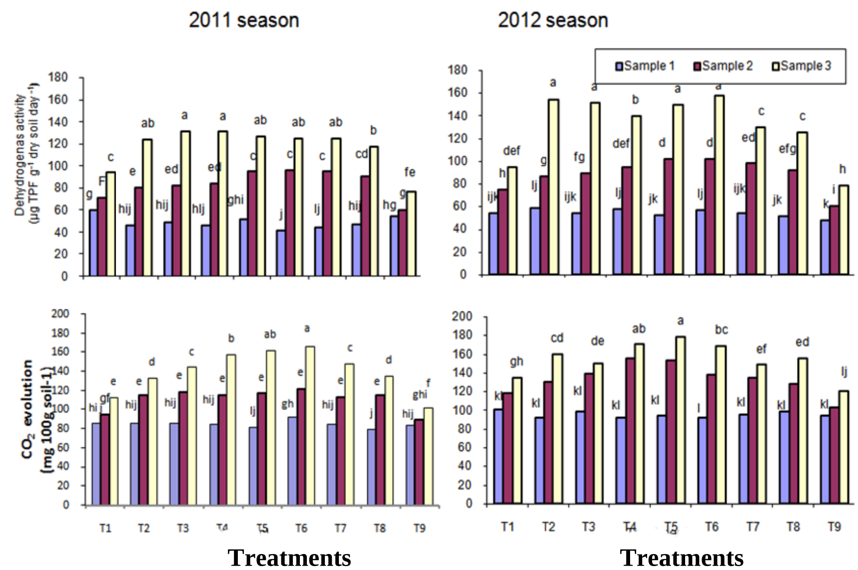

Fig. 2: Effect of efficient potassium solubilizing bacteria and potassium fertilizers treatments on soil biological characters of Navel orange trees at different time during 2011 and 2012 seasons. Sample 1: at zero time(At the beginning of the experiment), Sample 2: at 90 days, Sample 3: at 180 days.
*Columns in the same parameters followed by the same letter don't significantly differ from each other, according to Duncan's at 5% level

Identification of the selected isolate:

The KSB8 isolate was identified up to genus level based on their colony morphological, morphological characters and gram reaction. This isolate was Gram positive, long rod-shaped, spore form and motile belongs to genera *Bacillus*. Comparison of the nucleotide sequences of 16S rRNA genes of the bacterial isolate **KSB8** with sequences available from Gen Bank, performed with the use of the BLASTN 2.2.25 software, , showed that it belonged to genus Bacillus. The identity of these sequences to the closest *Bacillus* strains is about 97-98%. The similarity level was 98% between the isolate KSB8 and *Bacillus circulans*. This value allowed us to assign this isolate to the corresponding species.

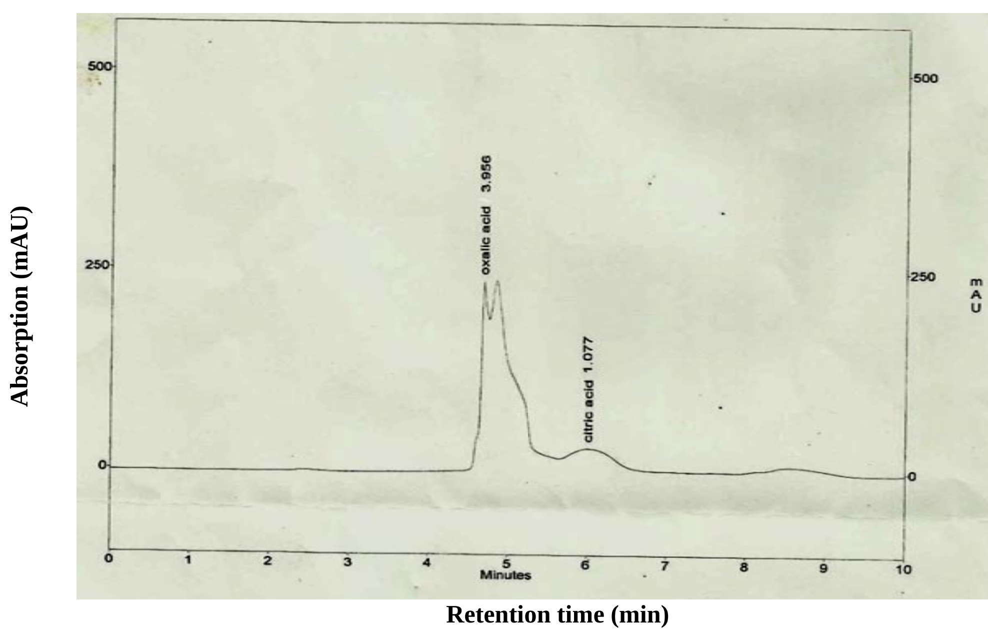

Fig. 3: HPLC chromatograms of culture filtrate of KSB8 isolate grown in the presence of feldspar (0.2%).

Conclusion and Recommendation:

From the foregoing results, *B.circulans* KSB8 is the most efficient strain as potassium solublizing bacteria and was used as bioinoculant in the field experiment. From the data of field experiment, it could be concluded that T_8 and T_9 treatments were not sufficient for giving high yield from Navel orange trees. When potassium fertilizers were added irrespective the source and rate the yield were increased. The trend was clear in the second season than the first one due to increasing potassium and biological activity in the soil. The best values of yield and leaf macronutrients content in most cases were observed by the maximum rates from potassium (600 g K_2O) as potassium sulphate+ *B.circulans* KSB8 or K- feldspar + *B.circulans* KSB8 (T_2 or T_5) followed closely by the second rate (450 g K_2O) from each potassium source (T_3 and T_6). Regarding the effect of potassium source on fruit physical and chemical properties it could be concluded that, T_9 (orchard condition) gave the lowest values of most fruit physical and chemical properties. Generally, potassium had a slight effect on fruit physical properties and leaf micronutrients content. On the other hand, it seems that potassium irrespective the source had a stimulative effect on TSS and TSS / acid ratio however, in most cases T_2 (600 g K_2O) as potassium sulphate+ *B.circulans* KSB8 and the first or second level of feldspar T_5 (600 g K_2O) and T_6 (450 g K_2O) + *B.circulans* KSB8 were the promising treatments. Regarding the effect of potassium source on soil biological activity, it is clear that fertilizing the inoculated plants with potassium sulphate or feldspar **at** 600 g and 450 g K_2O gave maximum values of dehydrogenase and CO_2 evolution followed by the treatments amended with 300 g K_2O in the second season.

Therefore, using *B.circulans* KSB8 as effective strain combined with K- feldspar at the rate of (450 g / tree/ year K_2O) may be recommended instead of chemical fertilizers (potassium sulphate) to reduce environmental pollution and alleviate the dependence on imported or costly commercial fertilizer.

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