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ORIGINAL ARTICLES

Efficiency of Rock-Feldspar Combined with Silicate Dissolving Bacteria On Yield and Fruit quality of Valencia Orange Fruits In Reclaimed Soils.

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ABSTRACT

This investigation was carried out through three successive seasons (2008 & 2009 and 2010) on 20 years old Valencia orange trees budded on sour orange rootstock, cultivated in a private orchard with loamy soil texture, at El Giza Governorate. The purpose of this study was to found an alternative source of potassium fertilizer locally termed "Feldspar", obtained as natural rocks which inoculated with dissolving bio-fertilizer. Their effect on leaf K content, physical properties, yield and juice quality of Valencia orange fruits were checked. Selected trees were fertilized with Fine powder of the rock K-Feldspar at rates (500, 750 and 1000g K_2O/tree) in three dates *i.e* (October, March and July). Each application rate was applied either once at October or in two equal portions at October & March or in three portions at October, March and July. K-Feldspar substrate was inoculated with the bio-fertilizer Silicate dissolving bacteria. Leaf K content for different treatments were determined comparing with the traditional fertilizer potassium sulphate treatment at 600g K_2O /tree in two equal portions during February and August. Obtained results revealed that, using feldspar inoculated with *Bacillus circulans* as soil application had a significant effect for improving leaf K content, fruit weight, yield and fruit quality as kg/tree, especially when added at 1000g K_2O/tree in two or three portions. Also, feldspar treatment at 750g K_2O/tree in two portions gave positive results where such treatments considered the promising under orchard conditions. Meanwhile, 500g K_2O /tree at any dose recorded generally less response. Therefore, It could be recommended to fertilize Valencia orange orchards with feldspar at 1000g K_2O/tree inoculated with the bio-fertilizer *Bacillus Circulans* in two (October& March) or three equal portions (Oct.& Mar. and July) instead of chemical fertilizers *i.e*, (potassium sulphate) to reduce environmental pollution and alleviate the dependence of imported or costly commercial fertilizers.

Key wrods: Valencia Orange, potassium fertilizer, Silicate Dissolving Bacteria.

Introduction

The need for nitrogen and potassium fertilizers in Valencia orange orchards are in a continuous demand to compensate the continuous reduction in soil fertility (Helail et al 2003). More than 40% of citrus production costs are devoted to nutrition practices, particularly potassium fertilization. Its important role in metabolic functions for increasing leaf area serves plant growth and enhances the ability to adverse conditions Hegab (2003). Chemical potassium became a high expensive fertilizer in Egypt, besides the excessive uses of chemical fertilizers have resulted in serious problems, i.e. soil salinity, pollution of the underground water so most farmers ignored using it (Aisha and Taalab, 2008). The main source of K for plants growing under natural conditions comes from the weathering of minerals and organic K-sources such as composts and plant residues. Thus, the use of alternative indigenous resources such as rock Feldspar (Orthoclase) is gaining importance to alleviate the dependence of imported or costly commercial fertilizer.

Potassium content in rock Feldspar ranges from 10 to 13 % and not easily suitable for direct application to Feldspar structure is Aluminum silicate combined with potassium to make Orthoclase ($KAlSi_3O_8$).

It is a slow release fertilizer, so several laboratory studies have shown that micro - organisms can increase the dissolution rate of silicate and aluminum silicate minerals and enduring potassium to available form for the growing plant, primarily by generating organic and inorganic acids Barker (1997) and Aisha & Taalab (2008). Also, the direct contact between bacteria and minerals may be important in mineral alteration and can 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). So, the silicate dissolving bacteria (*Bacillus circulans*) are generally used to release potassium from rock-feldspar. Naglaa (1997) and Sheng (2002).

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Therefore, this work aims to evaluate the effectiveness of K-rock feldspar inoculated by Silicate dissolving bacteria on yield, physical and chemical characteristics of Valencia orange fruits in reclaimed soils comparing with the high cost potassium sulphate.

MAterials And Methods

This study was carried out through three consecutive seasons on 20 years old Valencia orange trees (*C.sinensis*.L) budded on sour orange rootstock at 5x5 meters a part under flood irrigation system. Selected trees were cultivated in a private orchard located at Giza Governorate. All trees were almost uniform in vigor, grown in a clay loamy soil under conventionally accepted practices. The soil texture was characterized by: organic matter= 1.6 %, Sand=10.8%, Silt= 44% and Clay= 45.2%. Where, soil chemical characteristics: pH= 8.4, EC= 0.5 *ds/m*, CaCO3= 1.2%, P= 0.6 %, K= 0.9%, Ca= 4.2%, Mg= 1.1%; Fe=7.8 *ppm*., Mn= 3.2 *ppm* and Zn= 3.4 *ppm*..

Trees received soil fertilizer rates that recommended by (National Program for Improving Citrus Productivity) *i.e,* 600g K_2O/tree/year, in both organic and mineral forms. Commercial rock K-Feldspar fertilizer was used as fine powder (150-250 μm size). Its chemical constituents are shown in Table1. Meanwhile, the bio-fertilizer Silicate dissolving bacteria (*Bacillus circulans*) was inoculated in a concentration of (2.8*107 *cells/ml*) at rate of 50 *ml / kg* feldspar to mix with soil holes around the trunk and irrigated after covering holes with soil.

Table 1: Chemical constituents of rock K- Feldspar % :

Feldspar Component %	L.O.I	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
	0.85	68.10	17.16	0.45	0.80	0.04
	K_2O	Na_2O_3	TiO_2	MnO	P_2O_5	Cl
	10.6	1.40	0.05	0.02	0.11	0.11

Selected trees were bio-fertilized with Feldspar at rates (500, 750 and 1000*g* K_2O/tree) for three dates *i,e* (October, March and July) as follows:

Table 2: Treatments, doses and date of applications.

Doses (Portions)	Treatments		
	T1) Control 600 *g* K_2O *Mineral* (two equal doses)		
One dose October	T2)500g K_2OFeldspar	T3)750g K_2O Feldspar	T4)1000g K_2O Feldspar
Two doses* October March	T5)500 g K_2OFeldspar	T6)750 g K_2O Feldspar	T7)1000g K_2O Feldspar
Three doses** October, March, July	T8)500g K_2O Feldspar	T9)750g K_2O Feldspar	T10)1000g K_2Feldspar

* Two equal portions. ** Three equal portion

The experiment was set up according to complete block design with 6 replicates each of one tree, comparing with control as potassium sulphate treatment at 600g K_2O /tree in two equal portions during February and August.

Measurements:

1- **Leaf Potassium% content**: Dry leaves were grounded, digested and Leaf K content was determined on dry weight basis according to Rebbeca (2004).
2 - **Yield** :Total yield expressed as number and weight of fruits/tree was recorded.
3 - **<u>Fruit quality</u>:**

physical properties:

A- **Fruit weight**(*g*): it was estimated by weight a sample of 10 fruits from each replicate and average fruit weight was calculated.
B- **Fruit volume** (*ml)*: The same sampled fruits were immersed in water and the average fruit volume(*ml*)was calculated.
C- **Fruit dimensions**: fruit length L and diameter D were measured (*cm*) using Vernier Caliper and shape index (length/diameter *ratio*) was calculated.
D- **Peel weight(*g*)**: ten fruits from each replicate were weighted and average weight of fruit peel was calculated.

E- **Peel thickness** (*mm*):it was measured by using Vernier Caliper.
F- **Average juice volume** (*ml*): After juicing the fruit average of juice volume was determined.

Chemical properties:

A- Soluble solid contents (SSC): it was expressed by using hand refractometer. B- Titratable acidity (TA%): it was determined by titration 10 *ml* juice from each sample against (0.1 *N*) NaOH using phenol phethalin as indicator. Acidity was expressed as *gm* tartaric acid/100 *ml* juice according to A.O.A.C (1995).

C- Soluble solids/acid ratio: This ratio was calculated by the percentage of **SSC** on total acidity to be used as a criterion for maturity determination.

D- Ascorbic acid (vitamin C): it was determined by using 2,6- dichlorophenol indophenol dye and 2% oxalic acid as a substrate. Vitamin C content was calculated as mg/100 ml juice using the method described by (A.O.A.C.1995). Obtained data was statistically analyzed according to Snedecor & Cochran (1980).

The means were separated by Duncan's multiple range test Duncan (1955).

Results And Discussions

Effect of K-Feldspar and Silicate Dissolving Bacteria treatments on physical properties And yield of Valencia orange fruits:

Concerning Fruit shape, Table (3) show that mineral potassium treatment revealed the highest fruit length (*L*) values among the three seasons with non significant differences between control and feldspar treatment as added at 1000*g* K_2O/tree with either two or three portions. Contrarily, no stable trend for fruit diameter (*D*) values was observed with different treatments from season to another. For example, as feldspar added at either1000*g* K_2O/tree for three portions increased fruit diameter in the first and the second seasons while no significant differences was recorded in the third season. That led to non significant differences for Fruit shape between different treatments among the three tested seasons.

As for peel thickness, tabulated data shows that feldspar added at 750*g* K_2O/tree for two portions or 1000*g* K_2O/tree with either two or three portions recorded the highest significant values in the first and the second seasons. While, in the third season feldspar added at 1000*g* K_2O/tree for either two or three portions gave the highest significant values compared with all other treatments.

Regarding fruit weight, data shows that mineral potassium treatment revealed the highest significant values among the three seasons. Where, the third season recorded non significant differences between control and feldspar added at 750g K_2O/tree for two portions, 1000g K_2O/tree for either two or three portions. Using feldspar at 500*g* K_2O/tree with any tested dose, reflected the minimum ascending values.

Results also indicated that using feldspar at 1000g K_2O/tree with two or three equal portions gave the highest significant yield Kg/tree as compared with other treatments. This hold true for different tested seasons with values (94 up to 98 Kg/tree).

These results are in agree with those obtained by Dass & Srivastava (1997), El- Safety *et al*., (1998), Hegab (2003), Alva *et al.,* (2006) and Jose *et al*., (2011) who found that increasing addition of potassium sulfate to navel orange trees increased significantly average fruit weight, peel thickness and total yield as kg/ tree. In addition, El-Shenawy& Fayed (2005) reported that feldspar increased berry length and diameter. These results were also in line with those reported by Badr (2006) and Saher (2007) who found that inoculating natural rocks of K-feldspar with *Bacillus sp*. as bio-fertilizer highly increased fruit yield expressed as fruit number or weight/tree.

On the Contrary, Sheo *et al*., (1997) and Saleh *et al*., (2001) found that peel thickness was decreased by increasing potassium dose.

Table 3: Effect of rock Feldspar (Feld.) rates combined with silicate dissolving bacteria on physical properties and yield of Valencia orange. fruits during three successive seasons.

Treatments		Fruit shape L / D*			Peel thickness (*mm*)			Average Fruit weight *(g)*			total Yield / tree *(Kg)*		
		2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Doses	Control (*Mineral)* 600g K_2O	1.07 a	1.07 a	1.06 a	0.44 abc	0.44 b	0.44 ab	181.8 a	183.8 a	182.5 a	108.4 b	110.0 b	115.0 a
One dose	500 g K_2O Feld	1.01 a	1.01 a	1.02 a	0.42 bcde	0.41 c	0.40 de	165.8 e	163.9 d	164.5 ef	94.5 d	96.0 de	98.0 c
	750 g K_2O Feld	1.00 a	1.01 a	1.02 a	0.43 abcd	0.41 c	0.42 bcd	166.4 e	161.6 d	162.2 f	95.5 d	97.0 de	100.0 bc
	1000 g K_2O Feld.	1.11 a	1.11 a	1.04 a	0.40 cde	0.40 cd	0.43 bc	168.2 e	161.4 d	170.0 d	106.0 b	107.5 bc	107.0 b
Two Doses	500 g K_2O Feld	0.98 a	1.00 a	1.01 a	0.40 de	0.39 d	0.41 cde	166.7 e	168.9 c	168.0 de	98.0 d	99.0 d	99.0 bc
	750 g K_2O Feld.	1.06 a	1.01 a	1.03 a	0.45 ab	0.45 ab	0.42 bcd	176.4 b	176.6 b	178.3 ab	102.0 c	105.5 c	107.0 b
	1000 g K_2O Feld	1.06 a	1.04 a	1.06 a	0.45 ab	0.44 b	0.44 ab	169.0 de	168.3 c	179.2 ab	120.0 a	122.4 a	115.0 a
three doses	500 g K_2O Feld.	1.03 a	1.02 a	1.03 a	0.39 e	0.40 cd	0.39 e	171.8 cd	176.6 b	172.1 cd	94.5 d	95.0 g	97.0 c
	750 g K_2O Feld.	1.02 a	1.02 a	1.06 a	0.44 abc	0.44 b	0.40 de	175.6 b	174.2 b	176.2 bc	96.0 d	98.0 f	100.0 bc
	1000 g K_2 Feld.	1.04 a	1.05 a	1.07 a	0.46 a	0.46 a	0.46 a	175.0 bc	176.5 b	180.1 ab	122.0 a	124.0 b	120.0 a

Means with the same letters are not significantly different at 5% level

N.B . L: Fr. length D: Fr. Diameter

2 - Effect of K-Feldspar and Silicate Dissolving Bacteria treatments on leaf K content,

Fruit / juice **%***(V/V) and Peel / Pulp % of Valencia orange fruits:*

Table (**4**) cleared that mineral potassium treatment (control) revealed the highest leaf K% content values among the three seasons. But, both second and third season recorded non significant differences between control and feldspar treatment as added at 1000*g* K_2O/tree for either two or three portions.

As for Fruit / juice % (V/V), tabulated data revealed that highest fruit volume was significantly obtained as feldspar applied at 750*g* K_2O/tree in two portions for the first and second seasons. Where, the third season recorded the highest values with either control or feldspar added at 750, 1000*g* K_2O/tree in two or three portions. Meanwhile, control treatment and feldspar applied at 1000*g* K_2O/tree for any dose proved to be the most efficient treatment in increasing fruit juice volume for the three studied seasons. Where, fruit / Juice volume ratios recorded insignificant differences between control and feldspar treatments except those added at 1000g K_2O/tree for any portion during first or second season.

Table (4) also shows that values of peel/ pulp ratio were dominated with mineral K_2O treatment followed in descending order by feldspar added at 500g K_2O/tree with three portions and750g K_2O/tree with two portions. This hold true in different tested seasons. Also, the third season recorded the highest significant values as feldspar added at1000*g* K_2O/tree with either two or three portions.

These results are in agree with those obtained by El- Safety *et al* (1998), Hegab (2003), Alva *et al* (2006) and Jose *et al* (2011) who noted that increasing the rate of potassium sulphate resulted in a significant increase for average total fruit weight and peel thickness. Similar results were in line with those reported by El-Shenawy& Fayed (2005) that feldspar increased berry length and diameter.

On the contrary, Sheo *et al* (1997) and Saleh *et al* (2001) found that peel thickness was decreased by increasing potassium dose.

3 -Effect of K-Feldspar and Silicate Dissolving Bacteria treatments on chemical properties of Valencia orange fruits:

Data tabulated in table (5) show the effect of mineral potassium and K-Feldspar treatments on chemical properties of Valencia orange trees in 2008 & 2009 and 2010 seasons.

- *Soluble Solid Contents (SSC):*

Data indicates that feldspar added at1000 *g* K_2O/tree for either two or three portions in the Three seasons gave fruits with highest TSS values than other treatments except those of control.

- *Titratable acidity:*

It is clear from tabulated Table (5) that feldspar added at 1000 *g* K_2O/tree for any dose gave the lowest values of acidity in the three tested seasons as compared with other treatments.

- *S.S.C/Acid Ratio:*

It is obvious from data that feldspar added at 1000 *g* K_2O/tree for either two or three portions produced fruits with highest S.S.C/acid ratio in the three seasons of study compared with other used treatments and control while, T4, T6, T7, T9 recorded higher significant values compared with other treatments in the second season. Meanwhile T10 was the highest significant value among all other treatments in the third season.

- *Ascorbic acid:* .

It is quite evident from that control treatment, feldspar added at 750 g K_2O/tree in three doses or 1000 *g* K_2O/tree at any dose significantly increased juice content of ascorbic acid as compared with other treatments.

These results are agreed with the findings of El - Safty *et al* (1998) and Hegab (2003) who reported that K application was very effective in improving fruit quality expressed as total soluble solid and significantly decreased fruit acidity. They revealed that ascorbic acid was increased by increasing K rates up to (400 or 600 *g*/tree). Also, El-Shenawy & Fayed (2005) and Saher (2007) found that adding bio-fertilizers plus natural rocks to trees, significantly increased S.S.C

On the other hand Saleh *et al* (2001) found that total acidity and ascorbic acid values were not significantly affected by different K_2O rates. Contrarily, Sheo *et al* (1997) reported that ascorbic acid content was decreased by increasing K application rate.

Table 4: Effect of rock Feldspar (Feld.)rates combined with silicate dissolving bacteria on leaf K content , fruit / juice and peel / pulp ratios of Valencia orange fruits during three successive seasons

Treatments		K%			Fruit / juice **%** (V/V)			Peel / Pulp %		
		2008	2009	2010	2008	2009	2010	2008	2009	2010
Doses	Control (Mineral) 600g K_2O	0.98 a	0.95 a	0.97 a	47.0 c	48.0bcd	49.0 a	86.0 a	87.0a	82.0 ab
One dose	500 g K_2O Feld.	0.68 g	0.69 g	0.70 g	48.0 bc	47.0 cd	48.0 a	76.0 de	82.0bcd	79.0 bc
	750 g K_2O Feld.	0.70 f	0.75 f	0.79 e	47.0 c	50.0 abc	48.0 a	81.0 bc	84.0abc	84.0 a
	1000 g K_2O Feld.	0.78 e	0.85 e	0.83 d	51.0 ab	53.0 a	50.0 a	76.0 de	84.0abc	81.0 abc
Two Doses	500 g K_2O Feld.	0.69 fg	0.70 g	0.73 f	49.0abc	48.0bcd	48.0 a	82.0 b	85.0 ab	81.0 abc
	750 g K_2O Feld.	0.80 d	0.87 d	0.85 c	47.0 c	46.0 d	46.0 a	79.0 bcd	81.0 cd	78.0 bc
	1000 g K_2O Feld.	0.88 c	0.90 c	0.91 b	51.0 ab	51.0 ab	48.0 a	80.0 bc	79.0 de	81.0 abc
three does	500 g K_2O Feld.	0.70 f	0.74 f	0.74 f	48.0 bc	47.0 cd	46.0 a	75.0 e	64.0 f	77.0 c
	750 g K_2O Feld.	0.88 c	0.90 c	0.92 b	47.0 c	46.0 d	47.0 a	81.0 bc	83.0 bc	82.0 ab
	1000 g K_2O Feld.	0.90 b	0.93 b	0.96 a	52.0 a	52.0 a	49.0 a	78.0 cde	77.0 e	82.0 ab

Means with the same letters are not significantly different at 5% level.

Table 5: Effect of different rock feldspar (Feld.) rates Combined with Silicate Dissolving Bacteria on chemical properties of Valencia Orange fruits during three successive seasons.

Treatments		S.S.C %			Acidity %			S.S.C / Acid ratio			Ascorbic acid *mg/100ml*		
		2008	2009	2010	2008	2009	2010	2008	2009	2010	2008	2009	2010
Doses	Control *(Mineral)* 600g K_2O	9.8c	11.2a	11.1ab	1.2de	1.1ab	1.03c	8.2b	10.2c	10.7b	40.5ab	41abc	42.0ab
One dose	500 g K_2O Feld.	9.5d	10.6cd	10.2f	1.6a	1.2a	1.60a	5.9e	8.8e	6.3c	37.3c	38.7e	38.4d
	750 g K_2O Feld.	9.5d	10.7bc	10.4ef	1.5ab	1.0bc	1.40ab	6.3de	10.7c	7.4e	38.2bc	39.8cde	39.1bcd
	1000 g K_2O Feld.	9.8c	10.4e	10.6ed	1.2de	0.9c	1.10c	8.2b	11.6ab	9.6c	41.7a	41.6ab	41.8abc
Two Doses	500 g K_2O Feld.	9.2e	10.5de	10.8bcd	1.4bc	1.1ab	1.50a	6.6d	9.5d	7.2fe	36.6c	39de	38.5d
	750 g K_2O Feld.	9.1e	10.6cd	10.9bcd	1.3cd	0.9c	1.20bc	7.5c	11.8ab	9.1d	40.0ab	40.5bcd	40.7abcd
	1000 g K_2O Feld.	10.7a	10.5de	11.0abc	1.2de	0.9c	1.01c	8.9a	11.7ab	10.9b	41.8a	42.5a	42.2a
three doses	500 g K_2O Feld.	9.4d	10.4e	10.7cd	1.6a	1.1ab	1.50a	5.9e	9.5d	7.1f	37.1c	38.9de	38.6cd
	750 g K_2O Feld.	10.0b	10.8b	10.8bcd	1.2de	0.9c	1.10c	8.3b	12.0a	9.8c	40.8ab	40.9abc	40.8abcd
	1000 g K_2O Feld.	9.4d	11.3a	11.2a	1.1e	1.0bc	1.00c	8.5ab	11.3b	11.2a	42.4a	42.4a	42.5a

Means with the same letters are not significantly different at 5% level.

Conclusion:

In conclusion, On the basis of the obtained results including improvement of K leaf mineral content that led to increasing yield kg/tree and fruit quality. It could be recommended to fertilize Valencia orange orchards with rock feldspar at 1000*g* K_2O/tree inoculated with the bio-fertilizer *Bacillus Circulans* in two portions (October& March) or three ones (Oct.& Mar. and July) instead of chemical fertilizers *i.e.* (potassium sulphate) to reduce environmental pollution and alleviate the dependence of imported or costly commercial fertilizers.

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