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RESPONSE OF *RUTA GRAVEOLENS* L. TO ROCK PHOSPHATE AND /OR FELDSPAR UNDER BIOLOGICAL FERTILIZERS

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ABSTRACT

Two experiments were consummated at the Experimental Farm, National Research Center (NRC), Dokki, Cairo, Egypt during two successive seasons of 2004/2005 and 2005/2006 to evaluate the effect of natural products as a source of some important elements such as rock phosphate as a source of phosphorous and feldspar mica as a source of potassium with biological potassium phosphorous fertilizer or biological potassium fertilizer (Silicate bacterium) at different levels (0.0, 25, 50 and 100 g/L) on *Ruta graveolens* L. plant instead of the chemical fertilizes. Adding biological fertilizer with feldspar or rock phosphate improved vegetative growth characters such as plant height (cm), branches number/ plant, fresh and dry weights of different plant parts i.e. leaves, stems and roots (g/plant), in addition to some chemical constituents as essential oil, total flavonoides, P, K, Fe, Zn and Cu content. On the other hand, the main constituents of essential oil and N content were decreased compared with adding recommended chemical fertilizers.

INTRODUCTION

Rue, *Ruta graveolens* L. (Rutaceae), a traditional medicinal plant, known to prevent the attacks by fleas and other noxious insects. The plant is also used as a flavoring agent for spirits and foods. Previous research showed the inhibition of in vitro germination and the radical growth of radish seeds by an aqueous extract of rue and some of its constituents, in particular furanocoumarin derivatives **(Aliotta *et al* 1994).** These findings prompted some researchers to investigate the potential effect of rue extracts as an herbicide against the germination of some common weeds in the soil. The total extract of rue and some isolated compounds resulted in an active inhibition of weed germination, in particular *Portulaca oleracea* L., causing an irreversible damage to protruded radicals. Some constituents of this extract (furocoumarins and flavonols) also inhibited in vitro germination of several weeds **(Aliotta *et al* 1995 and 1996).** The essential oil and some of its minor constituents were effective and dose dependent inhibitors of both the germination and radical growth of radish **(Vincenzo *et al* 2002).**

The green tissues of *Ruta graveolens* are a rich source of flavonol glycosides, for example rutin, and gossypetin glycosides and have been identified as the major floral pigments **(Harborne & Boardley 1983).** Moreover rue is thus a valuable natural source of alkaloids such as acridones and furoquinoline alkaloids, which exhibit a wide range of physiological activities **(Waterman and Grundon 1985).**

Phosphorous plays an important role in various metabolism processes. It is a constituent of nucleic acid, phospholipids, the coenzymes, DNA and NADP, and most importantly ATP. It activates coenzymes for amino acid production used in protein synthesis, and it is decomposes carbohydrate production in photosynthesis; as well as involved many other metabolic processes required normal growth, such as photosynthesis, glycolysis, respi-

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ration, fatty acid synthesis. Moreover, phosphorous enhances seed germination and early growth, stimulates blooming, enhances bud set, aids in seed formation and hastens maturity **(Espinnosa *et al* 1993)**. Potassium with phosphorous fertilizer increase the plant growth and essential oil content in some aromatic plants such as anise, coriander and sweet fennel **(Khalid 1996).**

Phosphorous is added to cultivated soil in different forms as mineral phosphate fertilizers or organic manure. The soluble P in these fertilizers is quickly turns into unavailable form for plant nutrition and this problem is well known in Egyptian soils specially those rich in calcium carbonate **(El-Gamal, 1996)**.

Fortunately, soil microorganisms known as phosphate solubilizing microorganisms play a fundamental role in converting P fixed form to be soluble ready available for plant nutrition. The microbial breakdown of soil organic matter is associated with an increase organic, inorganic acids and CO_2 production with possibly increases the solubility of soil phosphate **(Goldstein, 1995).**

Gomaa (1989) demonstrated that, some effects of phosphate solubilizing microorganisms inoculation have been observed in terms of increasing the amounts of available P and plant growth of crop production. Applying phosphate solubilizing microorganisms with calcium superphosphate improved growth, and chemical composition of *Sinapis alba* L. plants than calcium superphosphate fertilizer alone **(Khalid, 2004).**

Potassium is one of the most important elements for plant nutrition, which content occupies 1%-5% of crops dry weight, it plays a very important role in the growth, yield and quality of crops, Potassium is involved in the activities of over 60 kinds of plant enzymes, Potassium affects the metabolism of nitrogen and carbohydrates, and the synthesis of lipid, starch and protein. Potassium also plays a very important role in substance transportation inside plants. **(Espinnosa *et al* 1993)**. Potassium nutrition increases the plant growth and essential oil content on marigold plants **(Somida 2002).**

Silicate bacterium or biological potassium fertilizer can activate the fixed potassium for plant nutrition, as well as prevention and control of plant diseases, also it can effectively prevent crops from early aging and have a strong resistance to drought, cold and lodging **(Subba Rao, 1984). Zahra *et al* (1984)** reported that, silicate-dissolving bacteria played a pronounced role in the biological weathering of soil minerals and it can promote K and Si releasing from feldspar. **Sheng *et al* 2003** showed that, silicate-dissolving bacteria could activate soil P, K, and micronutrients reserves and promote plant growth**. Styriakova *et al* 2003** reported that, the activity of silicate dissolving played a pronounced role in release of Si, Fe and K from feldspar and Fe oxyhydroxides.

However, due to the economic considerations, the cost of applying phosphate and potassium fertilizers is becoming more expensive. Thus, the use of alternative materials such as rock phosphate as a source of phosphorous fertilizer and feldspar as a source of potassium fertilizer are ganging importance the dependency of costly commercial fertilizers. On the other hand, rock phosphate have a very low grade of P a content, also feldspar is not available for direct application as plant nutrient because it low solubility when applied to the soil, so using potassium and phosphate solubilizing microorganisms with rock phosphate and feldspar very important to increasing the mobilization of P and K form rock phosphate and feldspar **(Biswas and Narayanasamy 2002 & Styriakova *et al* 2003).**

In this study we evaluate the natural products as a source of some important elements on *Ruta graveolens* L. plant such as rock phosphate as a source of phosphorous and feldspar mica as a source of potassium with biological potassium phosphorous fertilizer and biological potassium fertilizer (Silicate bacterium) instead of the chemical fertilizes.

MATERIALS AND METHODS

Two experiments were carried out during two successive seasons of 2004/2005 and 2005/2006. The experiments were conducted at the Experimental Farm, National Research Center (NRC), Dokki, Cairo, Egypt to study the effect of rock phosphate and /or feldspar under biological fertilizers on growth characters and chemical constituents of *Ruta graveolens* L. plants.

Mechanical and chemical properties of the soil used in this study were determined according to **Jackson 1973** and **Cottenie *et al* 1982** and are presented in **Table (1).**

Certified seeds of *Ruta graveolens* L were kindly obtained from the Department of Medicinal and Aromatic plants, Ministry of Agriculture, Egypt.

Table 1. Mechanical and chemical properties of the soil

Sand (%)			Silt (%)				Clay (%)		
25%			35%				37%		
Soluble anions (mg/100 soil)			Soluble cations (mg/100 soil)				EC (dsm)	pH	Organic matter
$SO4^{-2}$	Cl^{-1}	HCO_3^{-1}	Na^+	Mg^{++}	Ca^{++}	K^+	0.57	7.7	1.3 %
1.12	2.1	0.69	2.23	0.88	1.11	1.48			

Seeds were sown in the bed on the 1st October at both seasons, after 45 days from sowing seedlings were transplanted to pots of 30cm in diameter, each pot contained 10 kg clay soil and they were divided into three main groups. The first group contains a clay soil with recommended chemical fertilizers (as control). The second group contains a mixture of clay soil with 0.96g feldspar/ pot (contain 11% K_2O) and 1.94 g rock phosphate/ pot (contain 32% P_2O_5). The third groupcontains a mixture of clay soil with 0.96g feldspar / pot.

Each treatment was divided into three subgroups at randomized experiment, the first, second and third subgroups contained the seedlings of *Ruta graveolens* L. inoculated with biological potassium phosphorous fertilizer or biological potassium fertilizer (Silicate bacterium) with 25, 50 and 100 g /litter respectively and the treatments were as follows:

- Treatments of Biological Phosphorous Potassium Fertilizer

1- Control (recommended chemical fertilizers)
2- 25g/ L of Biological Phosphorous Potassium Fertilizer
3- 50g/ L of Biological Phosphorous Potassium Fertilizer
4- 100g/ L of Biological Phosphorous Potassium Fertilizer

+ Rock phosphate & Feldspar

- Treatments of Biological Potassium Fertilizer

1- Control (recommended chemical fertilizers)
2- 25g/ L of Biological Potassium Fertilizer
3- 50g/ L of Biological Potassium Fertilizer
4- 100g/ L of Biological Potassium Fertilizer

+ Feldspar

Each treatment contained three replicates, each replicate contained five pots and each pot contained three plants. All agriculture practices operations other than experimental treatments were don according to the recommendations of Ministry of Agriculture, Egypt.

Biological potassium phosphorous fertilizer and biological potassium fertilizer (Silicate bacterium) obtained from Hebei institute of microbiology, Hebei province, P.R. China.

Vegetative growth parameters

At flowering stage, plant height (cm), branches number/plant, fresh and dry weights of different parts i.e. leaves, stems and roots (g/plant) were determined.

Chemical analysis

The following chemical analyses were determined

Essential oil

Fresh herb at harvesting time (100g) was subjected to hydro distillation for 3h using a Clevenger type apparatus **(Clevenger, 1928)**. Constituents of essential oil were determined by gas-liquid chromatography in the treatments which gave the highest yield of essential oil by g/plant (50g/L and 100g/L of biological potassium phosphorous fertilizer, 50g/L and 100g/L of biological potassium fertilizer) and control treatment. The chromatograph (Model Perkin Elmer 3920B) was equipped with a thermal conductivity detector and a 2.0m X 0.3 cm column packed with 10 percent Carbwax 20M on 80/100 Chromsorb WAW and using hydrogen at 0.5 cm^3/s as the carrier gas. The column temperature was 130 °C and detector and injector temperature were 200 °C. Constituents were identified by retention times and by connection with known structures.

Total flavonoides

Total flavonoides were determined in dried leaves of *Ruta graveolens* L. according to **Zhishen *et al* (1999)**.

Total nitrogen and phosphorous

Total nitrogen and phosphorous in dry leaves, stems and roots of *Ruta graveolens* L, were determined according to the methods of the **Association of Official Agricultural Chemistry (A.O.A.C.) 1970**.

Potassium

Potassium content in leaves, stems and roots of *Ruta graveolens* L. was determined by photometrically methods according to **Brown and Lilleland (1945).**

Micronutrients

The leaves, stems and roots samples of *Ruta graveolens* L were dried, ground and Cu, Zn, Fe, extracted by acid digestion technique **(Cottenie *et al* 1982)**, concentrations were determined by atomic absorption spectrophotometer Berken-Elmer **(Gonzalez *et al* 1973).**

Statistical analysis

The obtained data were statistically analyzed for the mean of two successive seasons according to the procedure outlined by **Snedecor and Cochran** (**1990**).

RESULTS AND DISCUSSION

Effect of biological potassium phosphorous fertilizer with rock phosphate and /or feldspar

Vegetative growth characters

The application of biological potassium phosphorous fertilizer with feldspar and rock phosphate were more effective in enhancing vegetative growth values such as plant height (cm), branches number/plant, fresh and dry weights of different parts i.e. leaves , stems and roots (g/plant) in comparison with the addition of chemical fertilizers **(Table 2)**. The highest values of vegetative growth parameters were resulted from the treatment of 50g/L of biological potassium phosphorous fertilizer with feldspar & rock phosphate compared with other treatments. The increment in plant height, branches number, fresh and dry weight of plant were recorded to 32.9%, 98.4%, 113.1% and 120.8% respectively as a resulted of 50g/L of biological potassium phosphorous fertilizer compared with control treatment.

The increment of vegetative growth characters may be due to, biological potassium phosphorous fertilizer increase the available phosphorous, potassium and some micronutrients which gave a good vegetative growth characters **(Sheng *et al* 2003 and Khalid 2004).** Also these results confirmed by **Strzelezyk and Pokojska (1984),** who reported that**,** this increment of vegetative growth values might be due to the stimulation effect of biological potassium phosphorous fertilizer on the plant growth metabolism such as plant growth – promoting substances**.**

Essential oil content

The application of biological potassium phosphorous fertilizer with feldspar as a source of potassium & rock phosphate as a source of phosphorous resulted higher values of essential oil percentage or ml / plant in comparison with control one **(Table 3)**.

The highest significant increment of essential oil percentage or ml / plant were obtained from the treatment with 50g/L of biological potassium phosphorous fertilizer with feldspar & rock phosphate compared with other treatments.

Table 2. Effect of biological potassium phosphorous fertilizer with rock phosphate and feldspar on the vegetative growth characters of *Ruta graveolens* L plants (Mean values of two successive seasons).

Treatments: Biological Potassium Phosphorous Fertilizer		Plant height (cm)	Branches number/ plant	Leaf fresh weight (g/plant)	Stem fresh weight (g/plant)	Root fresh weight (g/plant)	Total fresh weight (g/plant	Leaf dry weight (g/plant)	Stem dry weight (g/plant)	Root dry weight (g/plant)	Total dry weight (g/plant)
+ Rock Phos-phate & Feldspar	Control	26.1	6.4	5.8	6.9	2.6	15.3	1.4	2.6	0.8	4.8
	25g/ L	30.5	8.9	7.0	9.1	3.8	19.9	1.8	3.6	1.1	6.5
	50g/ L	34.7	12.7	12.7	12.5	7.4	32.6	3.2	5.2	2.2	10.6
	100g/ L	28.9	9.0	9.0	8.7	6.3	24.0	2.2	3.5	1.9	7.6
L.S.D. at 0.05		1.79	0.91	0.6	0.97	0.41	1.16	0.1	0.08	0.05	0.07

Table 3. Effect of biological potassium phosphorous fertilizer with rock phosphate and feldspar on the essential oil and total flavonoides content of *Ruta graveolens* L plants (Mean values of two successive seasons).

Treatments: Biological Potassium Phosphorous Fertilizer		Essential oil percentage	Essential oil (g/plant)	Total flavonoides (mg/g)
+	Control	0.075	0.011	35.0
Rock	25g/ L	0.093	0.019	41.0
Phosphate	50g/ L	0181	0.059	52.0
& Feldspar	100g/ L	0.082	0.020	46.0
L.S.D. at 0.05		0.0085	0.007	2.02

This treatment increased essential oil percentage and oil yield (ml /plant) by 141.3% and 436.4% respectively compared with control treatment. The increase in the essential oil content may be due to the effect of biological potassium phosphorous fertilizer which increasing the available phosphorous, potassium and some micronutrients **(Sheng *et al* 2003)** which increase the essential oil content as shown in some aromatic plants such as anise, coriander and sweet fennel **(Khalid 1996).**

Total flavonoides

Data in **(Table 3)** indicated that, various levels of biological potassium phosphorous fertilizer with feldspar & rock phosphate treatments overcame the control treatment and improved the accumulation of total flavonoides. The highest values of total flavonoides was recorded with 50g/L of biological potassium phosphorous fertilizer with feldspar & rock phosphate, which significantly increased total flavonoides content (mg/g) and reached to 48.6% over control treatment. These results are confirmed with of **Piccaglia *et al* (1997)**, who demonstrated that, the ecological factors change total flavonoides content of *Calendula officinalis* L. plant.

Chemical constituents of essential oil

The qualitative and quantitative analysis of main constituents of essential oil of *Ruta graveolens* L plants treated with feldspar & rock phosphate under biological potassium phosphorous fertilizer **(Table 4)** revealed that, the main constituent was found for control treatment was Undecan-2-one which formed 54.59 %, the second major compound was Nonan-2-one which recorded 15.25 %. The third and fourth order of compounds found in a fewer amount were Methyl salicylate and Linalol 1.5 giving 6.9% and 3.35% respectively. Moreover the identified compound composed 94.06 of the total compounds of *Ruta graveolens* L plants while the unidentified compounds accounted about 5.94%. The recorded data appeared that, the identified compounds were markedly affected by various biological potassium phosphorous fertilizer levels.

Table 4. Effect of biological potassium phosphorous fertilizer with rock phosphate and feldspar on the main constituents of essential oil extracted from *Ruta graveolens* L plants.

Compound identification	Biological Potassium phosphorous Fertilizer Treatments: Control	50g/ L	100g/ L
α-Pinene	0.19	0.22	0.08
Camphene	0.26	0.08	2.80
β-Pinene	0.06	0.70	0.31
Nonan-2-one	15.25	14.63	12.85
Linalool 1.5	3.35	2.71	1.31
Phenyl ethyl alcohol	0.19	0.37	2.40
Nonan-2-ol	0.15	2.40	4.78
Octanoic acid	2.50	5.57	0.24
Methyl salicylate	6.90	0.23	0.34
Decan-2-one	0.24	1.45	0.85
Undecan-2-one	54.59	51.51	51.55
Undecan-2-ol	0.41	0.31	0.34
Dodec-2-ene	1.88	2.03	3.86
Tridecane	1.63	1.57	0.37
Decyl-2-acetate	0.31	2.54	2.01
Dodecan-2-one	2.08	0.22	0.45
Tridecan-2-one	0.19	0.25	1.63
α -Copaene	1.50	0.32	0.60
β -Caryophyllene	0.39	0.15	0.22
α -Humulene	0.12	0.16	0.13
γ-Cadinene	0.16	0.12	0.15
Hexadecane	0.20	0.17	0.12
α -Eudesmol	0.14	0.25	1.23
Pentadecan-2-one	0.11	0.14	0.21
Heptadecane	0.86	0.22	0.10
Pentadecanol	0.15	0.10	3.66
Hexadecanol	0.11	0.10	0.35
Xanthotoxin	0.14	0.67	0.13
Total identified	94.06	89.19	93.07

Biological potassium phosphorous fertilizer at 50 and 100 g/L with rock phosphate and feldspar decreased the components of Undecan-2-one and Nonan-2-one compared with the control treatment. Similar constituents of essential oil extracted from the aerial parts of *Ruta graveolens* L plants were also found by **Feo *et al* 2002,** on the same plant. The effect of different treatments on essential oil constituents may be due to its effect on enzymes activity and metabolism improvements.

Mineral content

Leaves, stems and roots PK content, significantly increased by increasing biological potassium phosphorous fertilizer levels with feldspar & rock phosphate. **(Table 5)**. The highest percentage of leaves, stems and roots P & K content resulted from the treatment of 50g/L of biological potassium phosphorous fertilizer with feldspar & rock phosphate compared with other treatments. Nitrogen percentage of rue plant **(Table 5)** treated with various levels of biological potassium phosphorous fertilizer with feldspar & rock phosphate appeared a marked decreased in various organs compared with control treatment. The lowest leaves, stems and roots N content obtained from the treatment of 25g/L of biological potassium phosphorous fertilizer with feldspar & rock phosphate compared with other treatments and control treatment.

Data of available elements show that, there are significantly increase in the DTPA-extractable of Zn, Cu and Fe in leaves, stems and roots by addition of biological potassium phosphorous fertilizer with feldspar & rock phosphate compared with the control treatment **(Table 5)**.

The decrease of N content due to application of biological potassium phosphorus fertilizer could be attributed to the depletion of N nutrient in building new tissues **(Nijjar, 1985)**. The increase of P, K, Zn, Cu and Fe due to, biological potassium phosphorous fertilizer increases the available phosphorous potassium and some micronutrients for plants **(Khalid 2004 and Sheng *et al* 2003)**.

Effect of biological potassium fertilizer and feldspar

Vegetative growth characters

The effect of the different treatments of biological potassium fertilizer with feldspar on the vegetative growth characters i.e. plant height (cm), branches number/plant, fresh and dry weights of different organs such as leaves, stems and roots (g/plant) is presented in **Table (6)**. Generally, increasing biological potassium fertilizer levels up to 50g/L progressively increased significant the vegetative growth characters compared with control treatment .Thus, the highest values of vegetative growth characters were recorded with treatments of 50g/L of biological potassium fertilizer with feldspar which increased mean values of plant height (cm), number of branches/plant fresh and dry weights of whole plant (g/plant) recorded to 18.4%, 50%, 65.4% and 62.5%.

These results are agreement with **Sheng *et al* (2003)** who observed that, silicate-dissolving bacteria promote plant growth. In addition, Silicate bacterium or biological potassium fertilizer can prevention and control of plant diseases, so plants gave a good growth characters **(Subba Rao, 1984).**

Essential oil content

Biological potassium fertilizer significantly increased herbal essential oil percentage or ml /plant with feldspar treatments compared with the control treatment **(Table 7)**. The highest values of herbal essential oil percentage or ml /plant were resulted from the treatments of 50g/L of biological potassium fertilizer with feldspar which increased essential oil percentage and oil yield (ml/plant) by 154.6% and 456.3% respectively compared with control. These results may be due to, silicate bacterium or biological potassium fertilizer which can activate the fixed potassium for plant nutrition **(Subba Rao, 1984).** and increase the essential oil content **(Somida 2002)** on marigold plants**.**

Total flavonoides

Application various levels of biological potassium fertilizer with feldspar increased total flavonoides content in compared with the control treatment. The highest value of total flavonoides was resulted from the treatment of 50g/L of biological potassium fertilizer with feldspar that recorded 34.6% over the control treatment **(Table 7)**. These results are confirmed with **Piccaglia *et al* (1997)**, working on *Calendula officinalis* L. plant and demonstrated that, the ecological factors change total flavonoides content.

Table 5. Effect of biological potassium phosphorous fertilizer with rock phosphate and feldspar on the nutrient content (N, P, K, Fe, Zn and Cu) of *Ruta graveolens* L plants (Mean values of two successive seasons)

Treatments		Leaves						Stems						Roots					
		Percentage			ppm			Percentage			ppm			Percentage			ppm		
Biological Potassium phosphorus Fertilizer		N	P	K	Fe	Zn	Cu	N	P	K	Fe	Zn	Cu	N	P	K	Fe	Zn	Cu
	Control	3.6	0.25	2.6	136	137	7.8	2.3	0.42	2.4	122	130	7.8	3.7	0.25	136	240	130	7.8
+	25g/ L	2.2	0.26	2.8	156	140	8.1	2.0	0.43	2.7	132	135	8.8	2.3	0.26	156	255	141	8.1
Feldspar & rock	50g/ L	2.8	0.30	2.9	160	142	9.2	2.2	0.49	2.8	147	137	9.6	2.9	0.29	160	260	143	8.9
phosphate	100g/L	2.7	0.28	2.7	140	141	7.9	2.1	0.48	2.5	125	134	7.9	2.8	0.27	140	242	142	8.2
L.S.D. at 0.05		0.08	0.001	0.002	3.9	1.1	0.08	0.06	0.001	0.001	2.19	1.2	0.06	0.06	0.002	0.002	2.36	1.4	0.04

Table 6. Effect of biological potassium fertilizer and feldspar on the vegetative growth characters of *Ruta graveolens* L plant (Mean values of two successive seasons).

Treatments: Biological Potassium Fertilizer		Plant height (cm)	Branches number/ plant	Leaf fresh weight (g/plant)	Stem fresh weight (g/plant)	Root fresh weight (g/plant)	Total fresh weight (g/plant	Leaf dry weight (g/plant)	Stem dry weight (g/plant)	Root dry weight (g/plant)	Total dry weight (g/plant)
	Control	26.1	6.4	5.8	6.9	2.6	15.3	1.4	2.6	0.8	4.8
+	25g/ L	27.3	7.9	6.7	8.5	3.0	18.2	1.7	3.4	0.9	6.0
Feldspar	50g/ L	30.9	9.6	9.1	9.9	5.3	25.3	2.2	4.0	1.6	7.8
	100g/ L	27.1	7.7	7.1	7.3	4.4	18.8	1.8	3.8	1.3	6.9
L.S.D. at 0.05		1.13	0.21	0.31	0.13	0.04	1.2	0.03	0.07	0.01	0.3

Table 7. Effect of biological potassium fertilizer and feldspar on the essential oil and total flavonoides content of*Ruta graveolens* L plants (Mean values of two successive seasons).

Treatments: Biological Potassium Fertilizer		Essential oil percentage	Essential oil (g/plant)	Total flavonoides (mg/g)
	Control	0.075	0.011	35.0
+ Feldspar	25g/ L	0.091	0.017	39.0
	50g/ L	0.191	0.048	47.0
	100g/ L	0.084	0.019	38.0
L.S.D. at 0.05		0.009	0.004	2.49

Table 8. Effect of biological potassium fertilizer and feldspar on the main constituents of essential oil extracted *Ruta graveolens* L plants.

Compound identification	Biological Potassium Fertilizer Treatments		
	Control	50g/ L	100g/ L
α-Pinene	0.19	0.17	0.09
Camphene	0.26	0.24	0.05
β-Pinene	0.06	0.07	0.30
Nonan-2-one	15.25	13.66	7.63
Linalool 1.5	3.35	0.17	2.84
Phenyl ethyl alcohol	0.19	3.6	0.28
Nonan-2-ol	0.15	0.19	1.89
Octanoic acid	2.50	4.23	4.37
Methyl salicylate	6.90	0.27	0.21
Decan-2-one	0.24	1.39	0.35
Undecan-2-one	54.59	50.38	50.16
Undecan-2-ol	0.41	1.94	0.35
Dodec-2-ene	1.88	0.39	2.30
Tridecane	1.63	1.65	1.96
Decyl-2-acetate	0.31	0.60	0.36
Dodecan-2-one	2.08	0.17	2.08
Tridecan-2-one	0.19	0.13	0.50
α -Copaene	1.50	0.11	2.01
β -Caryophyllene	0.39	1.21	0.85
α -Humulene	0.12	0.16	0.24
γ-Cadinene	0.16	0.09	0.20
Hexadecane	0.20	0.17	0.13
α -Eudesmol	0.14	3.78	1.62
Pentadecan-2-one	0.11	0.07	0.19
Heptadecane	0.86	0.30	0.13
Pentadecanol	0.15	0.15	0.48
Hexadecanol	0.11	1.82	0.15
Xanthotoxin	0.14	0.17	3.88
Total identified	94.06	87.28	85.6

Chemical constituents of essential oil

Results in **Table (8)** showed the effect of biological potassium fertilizer with feldspar on the main chemical constituents of essential oil extracted from *Ruta graveolens* L plants. The main constituents were found to be Undecan-2-one (54.59 %), and Nonan-2-one (15.25 %) for control treatment as reported before. Also the identified compounds of essential oil were affected by biological potassium fertilizer with feldspar. Treatments of 50g/L and 100g/L biological potassium fertilizer with feldspar decreased the two main components compared with the control treatment.

The decreased percentage of these components reached 7.5% and 8% compared with control treatment, while the total identified constituents decreased by 7.3% and 9.9 % in comparison with control treatment for both levels 50g/L and 100g/L respectively.

Feo *et al* (2002) also found the same obtained constituents of essential oil extracted from the aerial parts of *Ruta graveolens* L plants. The effect of different treatments on essential oil constituents may be due to its effect on enzymes activity and metabolism improvements.

Mineral content

Leaves, stems and roots N content, significantly decreased by increasing biological potassium fertilizer levels with feldspar **(Table 9)**. On the other hand, the content of P and K of different organs recorded a marked increment with various levels of biological potassium fertilizer with feldspar compared with control treatment. The highest percentage P and K content resulted from the medium level (50g/L) of biological potassium fertilizer with feldspar for different organs.

Table 9. Effect of biological potassium fertilizer and feldspar on the nutrient content (N, P, K, Fe, Zn and Cu) of *Ruta graveolens* L plants (Mean value of two successive seasons).

Treatments	Leaves						Stems						Roots					
Biological Potassium Fertilizer	Percentage			ppm			Percentage			ppm			Percentage			ppm		
	N	P	K	Fe	Zn	Cu	N	P	K	Fe	Zn	Cu	N	P	K	Fe	Zn	Cu
Control	3.6	0.25	2.6	136	137	7.8	2.3	0.42	2.4	122	130	7.8	3.7	0.25	2.7	240	130	7.8
25g/ L + Feldspar	3.2	0.29	2.7	139	140	8.2	2.0	0.50	2.5	125	135	9.1	3.5	0.35	3.3	252	153	12.5
50g/ L + Feldspar	3.3	0.33	2.8	146	145	9.2	2.2	0.53	2.7	129	139	13.0	3.6	0.36	3.7	278	156	14.1
100g/ L + Feldspar	2.9	0.26	2.7	137	138	8.5	2.1	0.43	2.6	126	132	9.2	3.2	0.26	3.6	266	154	13.0
L.S.D. at 0.05	0.04	0.001	0.003	2.17	0.05	0.3	0.03	0.002	0.004	2.34	0.4	0. 2	0.02	0.006	0.005	3.01	2.14	0.3

Meanwhile, the highest mean values of N content of leaves, stems and roots obtained from the control treatment compared with other treatments.

Data of available microelements of rue plants showed that, there are significantly increase in the DTPA-extractable of Fe, Zn and Cu in leaves, stems and roots by addition various levels of biological potassium fertilizer with feldspar compared with the control treatment **(Table 9)**. The highest accumulation for different micro elements were recorded with applied 50g/L biological potassium fertilizer with feldspar for the various organs.

The decrease of N content due to application of biological potassium fertilizer could be attributed to the depletion of N nutrient in building new tissues **(Nijjar 1985)**. Otherwise, the increase of P, K, Zn, Cu and Fe content may be due to, the adding biological potassium fertilizer caused an increase in the available phosphorous potassium and some micronutrients for plants **(Sheng *et al* 2003)**.

CONCLUSION

From above mentioned results, it could be concluded that, we can use natural products as a source of some important elements for rue plant such as rock phosphate as a source of phosphorous and feldspar mica as a source of potassium with biological potassium phosphorous fertilizer or biological potassium fertilizer (Silicate bacterium) of 50g/L instead of the chemical fertilizes hence it caused a marked promotion for various growth characters and chemical composition of rue plants.

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