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Effect of Egyptian Rock Phosphate and Phosphate Dissolving Bacteria on Coriander Plant Growth and Yield

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THE PRESENT experiment was conducted in two successive seasons 2010/2011 and 2011/2012 to study the effect of Egyptian rock phosphate at the rates of 0, 115, 150 and 190kg/fed and inoculation with phosphate dissolving bacteria (*Bacillus megaterium* var. phosphaticum) on growth, fruit yield and oil yield of coriander (*Coriandrum sativum* L.) as well as the effect of these treatments on the activity of rhizospheric soil microorganisms of coriander plants. The results showed that coriander plants were significantly responded to Egyptian rock phosphate (ERP) and phosphate dissolving bacteria (PDB) solely or together. ERP and/or inoculation with PDB increased the vegetative growth expressed as plant height, number of branches, fresh and dry weights of aerial parts of plant. Also it significantly increased fruit yield. This increase was parallel to the gradual increase in the rate of Egyptian rock phosphate from 0 to 150 kg/fed. The interaction between ERP and PDB gave the highest fruit yield, oil percentage, oil yield, with the highest Linalool content.The inoculation with phosphate dissolving bacteria (PDB) significantly increased dehydrogenase enzyme activity of coriander plants, it has been as a valid biomarker to indicate changes in total microbial activity due to soil management and increased gradually with increasing the rate of ERP up to 150 kg/fed.

Medicinal and aromatic plants (MAPs) play an important role in our daily life. That is, of course, because they contain safe and effective ingredients. The world now is giving natural products more attention, reducing the use of chemicals and pollutants, and its harmful side effects which dangerous diseases.

In the last few years the medicinal and aromatic plants gained a great importance, and the increment in exportation rates of these plant raised the national income US$ (Hikal and Omar,1993).

Coriander, *Coriandrum sativum* L. belongs to the family Apiaceae (Umbelliferae) is one of the important MAPs which annually cultivated in about 10.000 feddans in Egypt.It used for improving taste and for the general benefit of digestive system, and is mainly used for spicing pickles, drinks and meat products. High amounts of the essential oil of coriander are used in cosmetics and perfume industry (Mahran,1967).

Phosphorus (P) plays an important role in various metabolic processes. It is a constituent of nucleic acid phospholipids, DNA and NADP and most importantly A.T.P. It activates coenzymes for amino acids production used in protein synthesis and it is decomposes carbohydrate in photosynthesis, as well as involved in many other required metabolic processes for normal growth, such as photosynthesis, glycolysis, respiration, fatty acids synthesis. Moreover, P enhances seed germination and early growth, stimulates blooming, enhances bud set, aids in seed formation and hastens maturity (Espinnosa *et al*., 1993).

Natural rock phosphate contains, in addition to phosphorous, many of the micronutrients that are necessary for healthy plant growth and high productivity, Sastry *et al.* (1997) on *Chrysanthemum cinerariaefolium*, Haque and Lupmayi (1999) on *Trifolium tembense*, concluded that, phosphates is a natural, efficient and economical source of P fertilization. Grham and Timmer (1985) noticed that loss of P from super phosphate-amended soil was exponential where the release of P from rock phosphate-amended soil was linear. Also rock phosphate is chemically reactive and can be substituted in finely ground forms for manufactured fertilizers such as super phosphate (El-Sayed, 2006). In the same way, El- Sayed *et al*. (2009) on Tarragon (*Artemisia dracunculus*, L.). found that, growth character in terms of plant height, fresh and dry weights were stimulated by Egyptian rock phosphate (ERP) fertilizer.

The naturally occurring soil bacteria that capable of stimulating plant growth named as Plant-Growth-Promoting-Rhizobacteria (PGPR) such as *Baccillus spp.* (Kloepper and Schorth, 1981). PGPR are able to exert a beneficial effect upon plant growth. Phosphate dissolving bacteria (PDB) are important for plant nutrition by increasing plant P uptake, where these bacteria are able to dissolve the precipitated phosphorus depends on its efficiency in producing inorganic, or organic acids and/or CO_2. Therefore, the unavailable forms of phosphorus can be partially dissolved by PDB naturally occurring or inoculating into the soil (Zayed, 1998). Moreover, Chakrabotry *et al*., 2006 found that, *B. megaterium* from tea rhizosphore is able to produce IAA and thus it helps plant growth promotion. Regarding the interaction between phosphorus fertilizer and PDB, Ahmed *et al*. (2002) and Badran (2003) found that P fertilizer and PDB treatment led to higher nutrient concentrations in seed and an increment in seed yield of soybean and Lentil plants. Also, Mekhemar *et al*. (2007) stated that improvement of peanut yield could be achieved by the application of 16 kg P_2O_5/fed as rock phosphate in addition to the inoculation with Brady rhizobium + PDB) under sandy soil conditions.

For this reason, this investigation was conducted to determine the effect of Egyptian rock phosphate (ERP) as a source of phosphorus (natural fertilizer) and phosphate dissolving bacteria (PDB) on the growth, yield and oil production of coriander (*Coriandrum sativum* L.).

Materials and Methods

This study was conducted at the experimental farm of medicinal and aromatic plants in El-Kanater El Khairia, Egypt during two successive seasons (2010/2011&2011/2012).

The fruits of coriander (*Coriandrum sativum* L.) were obtained from the experimental farm of Faculty of Pharmacy, Cairo University. The fruits were sown on 5^{th} November in the field at a distance of 30 cm between hills and 60 cm between rows in both seasons.

The layout of this factorial experiment was a complete randomized blocks design, with three blocks (replicates) and 8 combinations of the two studied factors (2PDB X 4 ERP). Each plot contained 20 plants, the area of each plot was ($3x1.2m^2$).

The treatments were:

- Control (without ERP or PDB).
- ERP 115 kg/fed.
- ERP 150 kg/fed.
- ERP 190 kg/fed.
- PDB
- ERP 115 kg/fed + PDB.
- ERP 150 kg/fed + PDB.
- ERP 190 kg/fed + PDB

The plants were fertilized by NK at the recommended doses, using ammonium sulphate (20.5% N) and potassium sulphate (48% K_2O) in both seasons.

The fertilizers were added at two equal splits, after 45 and 75 days from sowing.

Egyptian rock phosphate (ERP, containing 20.5% P_2O_5) was tested as a source of phosphorus. The ERP was applied at the rates of 0, 115 kg/fed, 150 kg/fed and 190kg/fed once a time, then incorporated into the soil to a depth of 12-20 cm, two weeks before sowing the fruits.

Bacillus megaterium var phosphaticum was provided from the Soil Microbiology Department,Water and Environment Research Institute, Agriculture Research Center, Giza, Egypt. This strain was grown on nutrient (Difico Manual 1984) Incubated for 24 hr at 30°C to obtain population of about 5 x 10^8 cFu/ml culture. The seeds were soaked in cell suspension of *B. megaterium* var. phosphaticum for 30 minutes before sowing. Sucrose solution (30%) was added as an adhesive agent prior to inoculation.

The plants were sprayed with cell suspension of *Bacillus megaterium* 45 days of sowing

The determined growth parameters were plant height(cm), number of branches, fresh and dry weights of aerial parts g/plant, fruit yield(kg/fed).

The oil percentage and oil yield ml/plant were determined as described by British Pharmacopoeia (1963). Oil composition was analyzed for some samples only (control, Egyptian Rock Phosphate (ERP at 150kg/fed and Egyptian Rock phosphate (ERP) at 150 kg/fed plus inoculation with phosphate dissolving bacteria (*Bacillus megaterium* var phosphaticum) (PDB) according to Hoftman (1967) and Bunzen *et al.* (1969).

The means were compared using the least significant difference (L.S.D.) test at 5% level, as described by Little and Hills (1978).

Dehydrogenase (DHA) enzyme activity of rhizosphere area of coriander plants was determined by the method described by Thalmann (1967).

The density of phosphate dissolving bacteria was estimated by Bunt and Rovira (1955) medium, modified by, Abdel-Hafez (1966) using the plate count method.

Results and Discussion

Vegetative growth

Results presented in Table 1 showed the response of plant height, number of branches/plant and fresh and dry weights of *Coriandrum sativum* to Egyptian rock phosphate (ERP) and inoculation with phosphate dissolving bacteria (PDB), *Bacillus megaterium* var. phosphaticum.

It is obvious that growth characters of coriander plants are significantly increased due to the tested treatments in both seasons.

Regarding the effect of rock phosphate on the growth of coriander plants, data showed that all studied parameters in Table 1 gradually increased with increasing the rate of rock phosphate fertilizer up to 150 kg ERP/fed, which recorded 105.17 and 111.97 cm for plant height, 14.80 and 16.10 branches/plant, 313.28 and 355.31 g fresh weight and 113.21 and 126.69 g dry weight/ plant in the first and second season respectively. Such effect may be due to that phosphorus encourages the growth of root system and enhances the photosynthesis, carbohydrates metabolism and protein synthesis which in turn increase the amount of metabolites synthesized by plants and concequently increase dry matter of plant parts i.e. roots, leaves and stems. These results are in accordance with those reported by Venturin *et al*. (1995) on Hevea sp, Sharma *et al*. (1995) and Haque and Lupwayi (1999) on clover. Also these results are confirmed by those reported by Aly and Mowafy (2003) El-Sayed and Youssef (2003) and El- Sayed *et al*. (2009).

TABLE 1. Effect of Egyptian rock phosphate (ERP) and phosphate dissolving bacteria (PDB) on the vegetative growth of coriander plant during 2010/2011&2011/2012 seasons.

Treatments	1st season												2nd season											
	Plant height (cm)			Number of branches			Fresh weight (g)			Dry weight (g)			Plant height (cm)			Number of branches			Fresh weight (g)			Dry weight (g)		
ERP (kg/fed)	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean
0	95.31	100.34	97.83	8.11	12.57	10.34	222.29	327.28	274.78	88.89	109.08	98.99	98.27	105.98	102.13	10.26	13.08	11.67	269.95	357.67	313.81	107.98	119.22	113.60
115	96.71	104.08	100.40	9.14	13.37	11.26	226.33	348.31	287.32	90.53	116.10	103.32	99.70	108.78	104.24	10.43	14.28	12.36	277.00	376.74	326.87	110.80	125.58	118.19
150	103.20	107.13	105.17	12.30	17.30	14.80	263.32	363.24	313.28	105.33	121.08	113.21	109.31	114.63	111.97	14.05	18.15	16.10	297.44	413.18	355.31	118.98	134.39	126.69
190	102.86	105.33	104.10	11.22	14.63	12.93	253.98	352.43	303.21	101.59	117.48	109.54	106.49	108.48	107.49	12.62	17.66	15.14	286.25	385.50	335.88	114.50	128.50	121.50
Mean	99.52	104.22		10.19	14.46		241.48	347.81		96.59	115.94		103.44	109.47		11.84	16.79		282.66	383.27	332.97	113.07	126.92	
L.S.D. at 5%	ERP 2.604			1.341			18.471			3.426			ERP 2.015			1.400			20.810			4.122		
	PDB 3.126			3.016			36.033			4.323			PDB 3.084			2.108			40.152			5.088		
	ERP x PDB 4.324			1.972			40.176			3.014			ERP x PDB 3.722			1.533			45.074			3.050		

Inoculation by *Bacillus megaterium* led to higher values of the studied parameters which recorded 104.22 and 109.47 cm for plant height, 14.46 and 16.79 branches/plant, 247.81 and 383.27 g plant fresh weight and 115.94 and 126. 92 g/plant dry weight of first and second season respectively. These increments were attributed to the vital role of phosphate dissolving bacteria (*Bacillus megaterium*) which increased P uptake by plants and produce IAA and cytokinin thus it helps the plant growth promotion.

These results are in harmony with those obtained by Mekhemar *et al.* (2007) and Abou-Zeid *et al.* (2011). The reached results at uninoculated treatments were acceptable even they were lower than the other inoculated treatments, this behavior may be due to the positive role of native bacteria mainly plant growth promoting rhizobacteria (PGPR) that inhabited soil among several decades ago.

Concerning the effect of interaction between ERP and PDB, data in the same table reveal that, the application of *Bacillus bacteria* (PDB) combined with ERP fertilizer at (150 kg ERP/fed) resulted in the highest values of the studied growth characters which recorded 107.13 and 114.63 cm for plant height, 17.30 and 18.15 branches/plant, 363.24 and 413.18 g for plant fresh weight and 121.08 and 134.39 g for plant dry weight in the first and second seasons, respectively. These date are in accordance with those obtained by Malewar *et al*. (2000) on cotton and Mekhemar *et al*. (2007) on peanut.

Fruit yield

From data in Table 2, it can be noticed that treating the plants with ERP significantly increased fruit yield g/plant and fruit yield kg/fed over the control in both seasons.

Raising the rate of ERP from 0 to 150 kg/fed gradually increased fruit yield/plant and fruit yield/fed in the two seasons. In the first season values were 38.03 g/plant and 839.34 kg/fed, while in the second one, values were 39.34 g/plant and 874.63 kg/fed respectively.

The positive effect of increasing phosphorus addition rates from 0 to 150 kg ERP/fed on coriander fruit yield may be due to the favorable effects of phosphorus in stimulating the growth of the root system, consequently increasing the efficiency of various nutrients absorbing that enhance the studied vegetative growth parameters of coriander plants, which in turn increase number of umbels and fruit yield. These results are in harmony with those obtained by El-Sayed and Youssef (2003) and El-Habbasha *et al*. (2005).

The results recorded in the two seasons Table 2 also showed that the inoculation with (PDB) significantly increased fruit yield/plant and fruit yield/fed. compared to control.

These results may be attributed to the nature of root exudates, which are suitable substrates for the associative bacteria, the release plant promote substances mainly indole acetic acid and cytokinins. These plant growth promoters could stimulate plant growth and the metabolism of photosynthates.

TABLE 2. Effect of Egyptian rock phosphate (ERP) and phosphate dissolving bacteria (PDB) on fruit yield at coriander plant during 2010/2011 & 2011/2012.

Treatments	1st season						2nd season					
	Fruit yield/plant (g)			Fruit yield/fed (kg)			Fruit yield/plant (g)			Fruit yield/fed (kg)		
ERP (kg/fed)	**0**	**PDB**	**Mean**	**0**	**PDB**	**Mean**	**0**	**PDB**	**Mean**	**0**	**PDB**	**Mean**
0	29.66	34.19	32.40	659.18	759.78	709.48	30.81	36.08	33.45	684.67	801.71	743.19
115	31.32	35.13	32.76	695.93	780.59	738.26	31.97	37.68	34.83	710.37	837.26	773.82
150	37.24	38.81	38.03	827.63	851.04	839.34	38.27	40.45	39.34	850.44	898.81	874.63
190	37.69	36.58	37.14	837.48	812.81	825.15	37.12	39.12	38.12	824.96	869.41	847.19
Mean	33.98	36.18		755.06	801.06		34.54	38.33		767.61	851.80	
L.S.D. at 5%	ERP 2.151			6.386			2.007			5.206		
	PDB 1.760			10.727			2.135			11.790		
	ERP x PDB 3.408			9.107			4.011			10.571		

These results are stand in accordance with this reported by Tilak *et al*. (2005).

The interaction between (ERP) and (PDB) significantly increased fruit yield/plant and fruit yield/fed. The plants treated with (ERP) at 150 kg/fed combined with phosphate dissolving bacteria (PDB) gave the highest fruit yield/plant and fruit yield/fed in the two seasons. The values were 38.81 g/plant and 851.04 kg/fed respectively in the first season and 40.45 g/plant and 898.81 kg/fed respectively in the second one.

Oil production

Essential oil percentage in coriander fruits, essential oil yield ml/plant and essential oil yield liter/fed were significantly responded to ERP at different rates, PDB inoculation and their interactions as recorded in Table 3.

Regarding the effect of ERP fertilizer rates, data revealed that the treatment of 150kg ERP/fed achieved the highest essential oil percentage in coriander fruits, yield/plant and yield/fed over untreated plants. These values represented 0.325 and 0.329% for essential oil percentage, while in case of essential oil/yield it was 0.124 and 0.130 ml/plant and 2.945 and 2.853 liter/fed. in the first and second seasons, respectively. The enhancement of essential oil production of coriander fruits by the addition of phosphorus fertilizer may be due to the development of plant nucleoproteins, transfer of metabolite compounds and the efficiency of its root system leading to more absorbing of water and nutrients, which led to increasing the rate of physiological processes and finally gave better yields. These results are in line with those obtained by El-Sayed *et al.* (2009) on tarragon and Abou-Zied (2011) on soybean.

Regarding the inoculation factor, data showed that *Bacillus megaterium* gave the maximum values of the above mentioned parameters, these values represented 0.319 and 0.321% for essential oil percentage of fruits, 0.116 and 0.124 oil yield ml/plant and 2.539 and 2.714 liter oil/fed of first and second season, respectively.

These results are partially similar to those reported by Abou- Zeid (2011) who found that inoculation with Bacillus *Bacillus polymyxa* gave the highest oil yields/fed while *Bacillus megaterium* gave insignificant increase in oil yield of soybean.

The interaction between P fertilizer rates and the bacterial inoculation leds to significant increase in oil production., Results indicated that the treatment received 150 kg ERP/fed combined with PDB (*Bacillus megaterium*) gave the highest values of oil percentage, oil yield/plant and oil yield/fed for both seasons followed by plants fertilized with 190 kg ERP/fed combined with PDB.

TABLE 3.Effect of Egyptian rock phosphate (ERP) and phosphate dissolving bacteria (PDB) on the oil production of coriander fruits during 2010/2011 & 2011/2012 seasons.

Treatments	1st season									2nd season								
	Oil percentage %			Oil yield/plant (ml)			Oil yield/fed (liter)			Oil percentage %			Oil yield/plant (ml)			Oil yield/fed (L)		
ERP (kg/fed)	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean	0	PDB	Mean
0	0.288	0.307	0.298	0.085	0.107	0.096	1.877	2.354	2.116	0.302	0.304	0.303	0.093	0.114	0.104	2.053	2.508	2.281
115	0.307	0.313	0.310	0.095	0.108	0.102	2.097	2.369	2.233	0.312	0.316	0.314	0.100	0.115	0.108	2.193	2.523	2.358
150	0.321	0.329	0.325	0.120	0.128	0.124	3.073	2.816	2.945	0.324	0.333	0.329	0.124	0.135	0.130	2.735	2.970	2.853
190	0.319	0.325	0.322	0.120	0.119	0.120	2.647	2.618	2.633	0.322	0.331	0.327	0.120	0.130	0.125	2.633	2.853	2.743
Mean	0.309	0.319		0.105	0.116		2.424	2.539		0.315	0.321		0.109	0.124		2.404	2.714	
L.S.D. at 5%	ERP 0.018			0.013			0.215			ERP 0.015			0.018			0.302		
	PDB 0.007			0.010			0.106			PDB 0.003			0.012			0.258		
	ERP x PDB 0.108			0.009			0.204			ERP x PDB 0.020			0.015			0.266		

These increments in oil yield can be explained by the important role of phosphorus as an essential constituent of phospholipids (Devlin, 1975) also, their positive effects also may be due to their effects on the enzymes activity and metabolism of essential oil production Burbott and Loomis (1969). The present results are in line with those found by Badran (2003) who reported that, phosphate solubilizing microorganisms and phosphorus fertilizer on soybean and lentil plants, led to higher nutrient concentration in seeds and an increment in seed yield. The obtained increment in oil yield of coriander fruits could be explained on the light of the above mentioned results which indicated that ERP and PDB have positive effects in both coriander growth and oil production so, fruit yield was increased and the oil present was stimulated, consequently the oil yield was increased. These are in accordance with those obtained by Abd-El Kader and Ghaly (2003) on coriander, Badran and Safwat (2004) and Badran *et al*. (2007) on fennel plants.

Chemical composition of oil

Chromatographic analysis of oil samples extracted from coriander plant in the second season (table 4) showed that, Linalool was the main component (with content of 69.23 to 75.43%).

The combination between ERP at 150 kg/fed and PDB gave higher Linalool content over control (without PDB or ERP) and the plants treated with (ERP) alone.

TABLE 4. Effect of Egyptian rock phosphate (ERP) and phosphate dissolving bacteria (PDB) on the components (%) of the essential oil of coriander at 2011/2012

Treatments	α pinene	Mycene	B. pinene	P. cymene	Linalool	Geroniol	Lenalyl acetate	Nerol
Control	4.46	1.06	2.99	6.88	69.23	3.92	4.18	4.19
ERP without 150 kg/fed (PDB)	4.02	1.11	2.96	6.25	70.41	6.25	2.88	3.01
ERP 150kg/fed + PDB	3.43	1.14	2.65	5.41	75.43	5.62	3.16	1.87

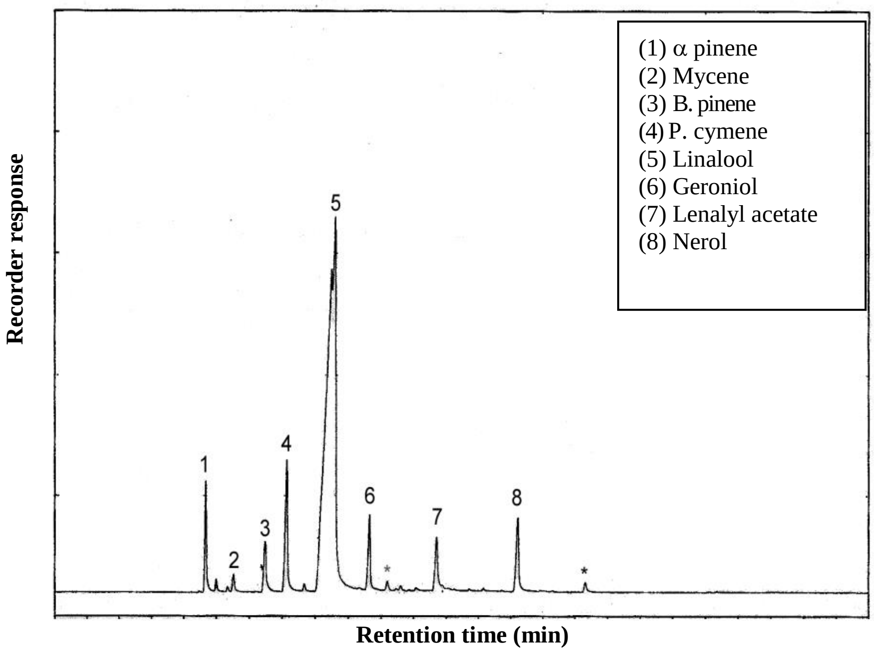

Fig. 1. GLC chromatogram of coriander oil (Control)

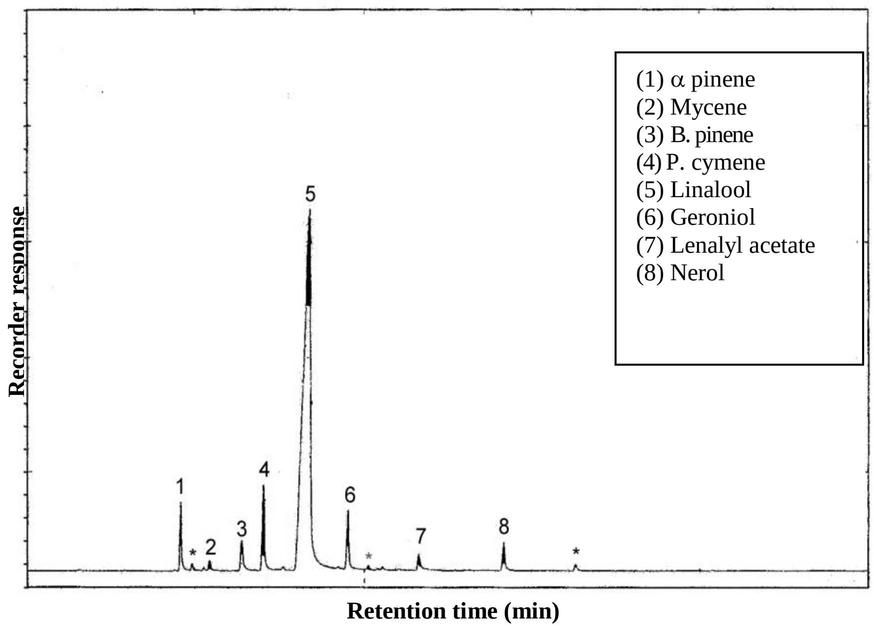

Fig. 2. GLC chromatogram of coriander oil (ERP at 150 kg/fed without PDB)

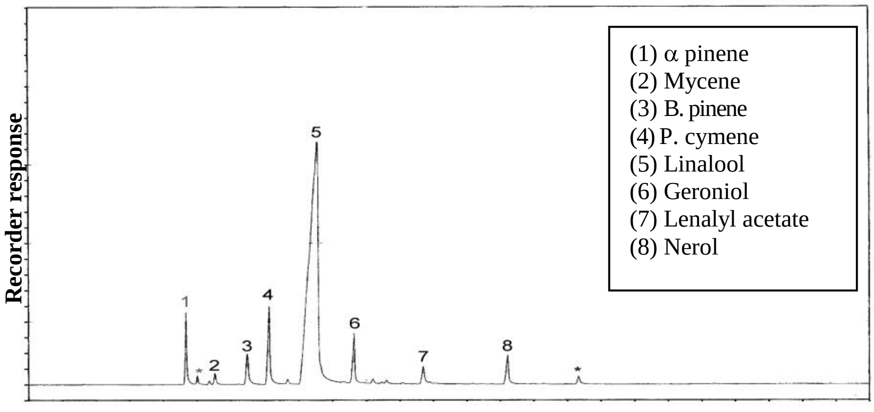

Fig. 3. GLC chromatogram of coriander oil (ERP at 150 kg/fed plus PDB)

Phosphate dissolving bacteria (PDB) count

Data illustrated in Fig. 4 and 5 showed the Changes of dehydrogenase enzyme activity and *Bacillus megaterium* count in the rhizosphere of treated plant.

Regarding dehydrogenase enzyme activity (DHA), data in Fig. 4 revealed that, inoculated treatments gave values of DHA higher than those of untreated treatments in both seasons. Also, these values were increased with increasing rock phosphate up to 150 kg/fed the highest values were 95.74 and 86.88μg tri-phenyl formazan (TPF)/g dry soil/day when the plant inoculated with *Bacillus megaterium* and fertilized with 150 kg rock phosphate/fed. This diversity of DHA activity among the treatments indicate a change in the composition and activity of soil microorganisms.In the respect dehydrogenase enzyme which is only present in viable cells, has been considered as a sensitive indicator of soil quality and it has been proposed as a valid biomarker to indicate changes in total microbial activity due to soil management (Roldan *et al*. 2004). The present data confirmed the previous findings showing an increase in dehydrogenase activity. These results are in harmony with those of Abou- Zeid (2011) who found that, dehydrogenase activity of plant rhizosphere significantly increased as a result of bacillus inoculation and phosphorus fertilizer.

With respect to the count of phosphate dissolving bacteria, Fig. 4 showed that microbial density of abovementioned bacteria group gradually increased with the increasing of Egyptian rock phosphate (ERP) up to 150 kg/fed. These maximum log numbers represented 7.176 and 7.230 for inoculated treatments and 6.752 and 6.778 for uninoculated treatments in the first and second seasons, respectively. These notable increases indicated that the bacterial numbers positively influenced by the plant root exudates and surplus of nutrients. This could be due to the mode of action of the applied bacteria, which not only provide soluble phosphorus, by producing organic acids but also produce a variety of growth promoting substances. These substances stimulate the production of root exudates, which in turn affect their numbers and the number of native bacteria.

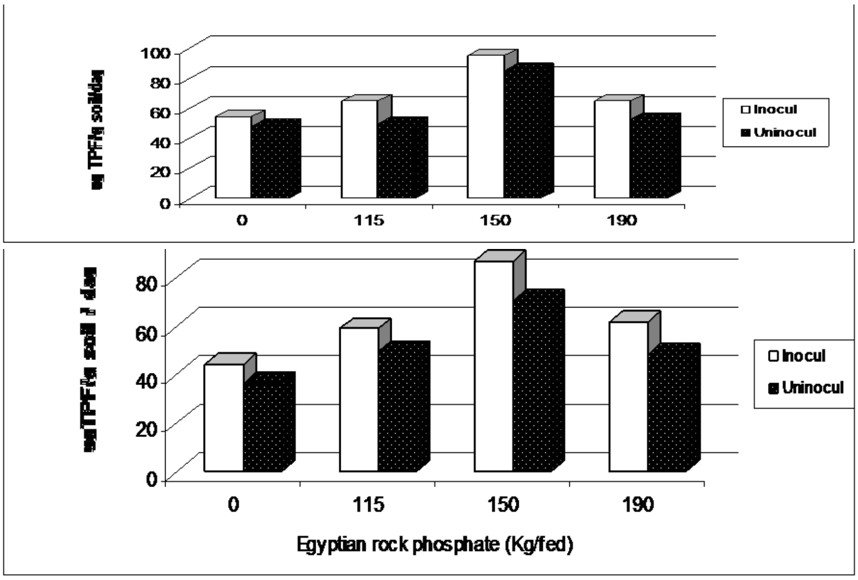

Fig. 4. Effect of ERP and *B. Megaterium* on dehydrogenase enzyme activity in the rhizosphere of *Coriandum sativum* (The first season)

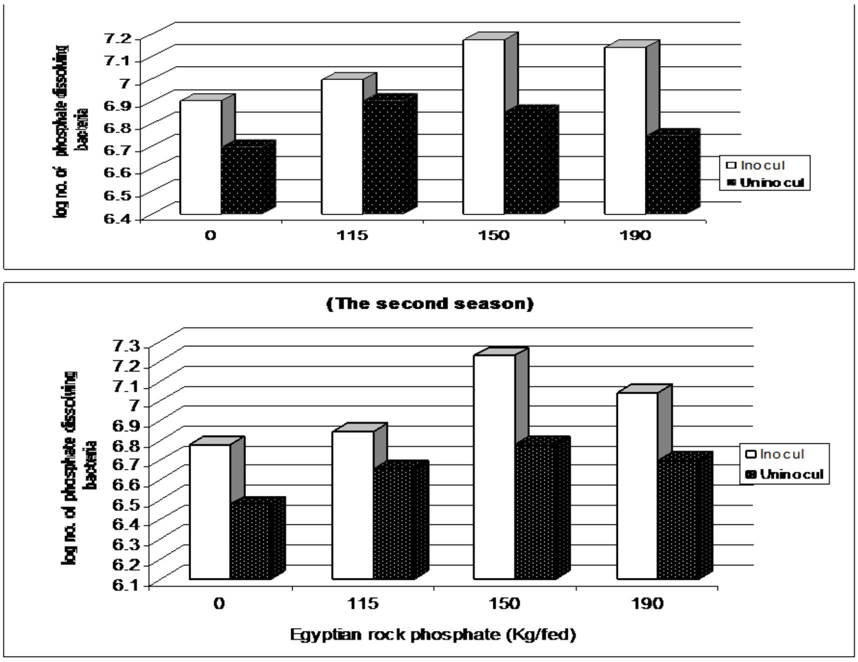

Fig. 5. Effect of Egyptian rock phosphate and *B.* megaterium bacteria on log number of phosphate dissolving bacteria in the rhizosphere of *Coriandum sativum* (The first season)

Similar results were obtained by Abdel-Ati *et al*. (1996) and Saleh *et al*. (1998). The reached results at uninoculated treatments were acceptable even they were lower than the other inoculated ones, this behavior could be due the positive role of native bacteria inhabiting soil among several decades ago.

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تأثير صخر الفوسفات المصرى والبكتريا المذيبة للفوسفات على نمو ومحصول نبات الكزبرة

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أجرى هذا البحث فى موسمى 2011/2010، 2012/2011 فى مزرعة فرع بحوث النباتات الطبية والعطرية بالقناطر الخيرية لدراسة تأثير صخر الفوسفات كمصدر طبيعى للفوسفور بمعدل صفر، 115، 150، 190 كيلو جرام/الفدان وكذلك التلقيح الميكروبى بالبكتريا المذيبة للفوسفات على النمو والمحصول وإنتاج الزيت فى نبات الكزبرة وكذلك تأثير هذه المعاملات على نشاط الكائنات الحية الدقيقة الموجودة فى منطقة الريزوسفير.

وكانت أهم النتائج كالتالى :

- بوجه عام استجابت نباتات الكزبرة معنوياً للتسميد بصخر الفوسفات وكذلك التلقيح الميكروبى بالبكتريا المذيبة للفوسفات سواء مجتمعين أو كلا منهم على حدى

- أدى التسميد بصخر الفوسفات إلى زيادة النمو الخضرى وكانت الزيادة تدريجية مع زيادة معدل صخر الفوسفات حيث كانت أفضل النتائج مع المعدل 150 كيلو جرام/الفدان

- أدى التلقيح الميكروبى بالبكتريا المذيبة للفوسفات إلى زيادة النمو الخضرى زيادة معنوية

- أدى التفاعل بين التلقيح الميكروبى بالبكتريا المذيبة للفوسفات و التسميد بصخر الفوسفات إلى زيادة محصول الثمار وكذلك محصول الزيت ومحتوى الزيت من مركب اللينالول حيث كانت أفضل النتائج من التلقيح الميكروبى بالبكتريا المذيبة للفوسفات مع معدل التسميد 150 كيلو جرام/الفدان

- أدى التفاعل بين التلقيح الميكروبى بالبكتريا المذيبة للفوسفات و التسميد بصخر الفوسفات إلى زيادة محصول الثمار وكذلك محصول الزيت ومحتوى الزيت من مركب اللينالول حيث كانت أفضل النتائج من التلقيح الميكروبى بالبكتريا المذيبة للفوسفات مع معدل التسميد 150 كيلو جرام/الفدان

- ادى التلقيح الميكروبى بالبكتريا المذيبة للفوسفات إلى زيادة أنزيم الدى هيدروجينيز مما يدل على زيادة نشاط الكائنات الحية الدقيقة فى منطقة الريزوسفير حيث كانت الزيادة تدريجية مع زيادة معدل صخر الفوسفات وأفضل النتائج كانت مع المعدل 150 كيلو جرام/الفدان.