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Comparison Between Different Fertilization Sources, Irrigation Frequency And Their Combinations On The Growth And Yield Of Coriander Plant

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Abstract: An experiment was conducted to study the effects of different fertilization sources, irrigation intervals and their combinations on the growth, fruit yield, volatile oil (content & constituents) and chemical composition of *Coriandrum sativum*, L. plant. Fertiliztion sources as a main factor (NPK, compost, bio-fertilizer and Easterna biofert) and irrigation frequency as subsidiary factor (i.e. 2, 3 and 4 weeks) were applied. The results showed that, the highest vegetative growth parameters i.e plant height, herb weight (fresh & dry), branch number and fruit number/plant, fruit yield (plant & fed.) were related to NPK and irrigation every 2 weeks treatment. The highest values of fruit yield, as well as, volatile oil content, N, P, K, carbohydrates and protein percentages in herb were significantly affected by fertilizers and irrigation frequency. The highest values of the previous characters were obtained by NPK and 2 weeks irrigation interval, in most cases. The most principle compounds composing the volatile oil were α-pinene, β-cymene, γ-terpinene, Linalool, Camphor, Geraniol, Geranyle acetate and Stenol. The treatment of bacteria inoculation with irrigation at 2 weeks resulted in the highest linalool percentage (82.13 %) while the lowest value (19.40 %) was obtained by Eastrna biofert with 4 weeks irrigation interval treatment. To decrease the production cost, protect the environment from pollution, obtain high quality coriander fruits and volatile oil and save the chemical fertilizers, the treatment of compost or bio-fertilizers whether as Easterna biofert or bacteria inoculation and applying irrigation every 2 weeks was recommended.

Key words: *Coriandrum sativum*,L., bio-fertilizers, irrigation, yield, volatile oil, protein, carbohydrates.

INTRODUCTION

The cultivation of several medicinal and aromatic plants in Egypt had noticeably increased in recent decades. Because the need of increasing the medicinal plant production all over the world, its production became an ultimate goal to meet the great increase of population to avoid chemical therapy side effects on human health through utilization of the medical herbs. However, the use of the most suitable and recommended agricultural practices in growing such crops could provide the producers with higher income, in comparison with many other traditional crops. They could also be looked at as potential exportable crops and therefore, many become a good source of foreign currency.

Coriander (*Coriandrum sativum*, L.) is an important aromatic annual condiment and spice crop belongs to family *Umbelliferae* (*Apiaceae*). It is native to Mediterranean region and commercially grown in India, Egypt, Morocco, USSR, USA, Hungary, Poland, Rumania, Mexico, etc. Coriander is exported to countries like Malaysia, Singapore, Australia and Central European countries. Coriander is the foremost alliaceous medicinal plant and one of the main medicinal plants in Egypt. In addition to its medical value, it has been used in flavor, soup, sausage and salad. Its leaves and fruits are used in flavoring food, fragrant, condiment, flavor food like sauces, pickles, confectionery and to suppress offensive odors in pharmaceutical preparations as an antispasmodic, carminative, stimulant, and stomachic. Fertilization and irrigation are the major factors affecting the growth, yield and volatile oil content of coriander. However, the chemical fertilizers represent the major cost of plant production. In addition, the excessive use of chemical fertilizers creates pollution of agro-ecosystem as well as deterioration of soil fertility (Lyons *et al.,* 1994).

In order to improve the use of chemical fertilizers and to reduce the environmental pollution in agriculture, a number of integrated its management's strategies have been developed. There is further potential to optimize rate of chemical fertilizers to meet the actual requirements of the plants and thus, reduce chemical fertilizers substantially. Generally, all these strategies will increase the agronomic chemical fertilizers efficiency (Singh, *et al.,* 2007).

Recently, the production of chemical-free medicinal and aromatic plants has been the focus of interest of many researchers and producers in order to ensure the high quality and safety, not only for human, but also for the environment which we live in. Therefore, it has become essential to use untraditional fertilizers. It is well

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known that a considerable number of bacterial species, mostly those associated with the plant rhizospher, are able to exert a beneficial effect upon plant growth. Therefore, their use as bio-fertilizers or control agents for agricultural improvement has been a focus of numerous researchers for a number of years. The utilization of bio-fertilizers is considered today by many scientists as a promising alternative particularly for developing countries. Bio-fertilizers are, generally, based on altering the rhizospher flora, by seed or soil inoculation with certain organisms, capable of inducing beneficial effect on a compatible host. Bio-fertilizers mainly comprise nitrogen fixer, phosphate dissolvers, silicate bacteria and others. These organisms may affect their host plant by one or more mechanisms such as nitrogen fixation, production of growth promoting substance or organic acids, enhancing nutrients uptake or protection against pathogens (Rodriguez and Fraga, 1999).

Inoculation with associative N_2-fixers (*Azotobacter* and *Azospirillum*) is practiced in many countries, where increasing in plant growth and yield were obtained in most cases. During the past two decades, there have been extensive research efforts to increase and exploit biological N_2-fixers by medicinal and aromatic plants. Recently, the world began to come back to nature, in particular, for utilizing medical herbs instead of chemical materials therapy to avoid their side effects on human health. The effective utilization of biological fertilizers for crops not only provides economic benefits to the farmers, but also improves and maintains the soil fertility and sustainability in natural soil ecosystem.

Crop stimulation of different medicinal and aromatic plants by this plant growth promoting rhizobacteria has been demonstrated in different field trials; Gomaa and AboAly, (2001) on anise plant, Kandeel *et al.* (2001) Mahfouz and Sharaf-Eldin (2007) on *Foeniculum vulgare* plant, Nofal *et al.* (2001) on *Ammi visnaga* and Shaalan, (2005) on *Nigella sativa,* L.

Compost is considered to be an environmentally safe, agronomically advantageous and relatively cheap organic amendment, which is able to stimulate soil microbial activity (Garcia *et al*., 1994 and Pascual *et al*., 1997). Moreover, it is known that compost is required to improve the quality of soil organic matter (Rivero *et al*., 2004) by various ways. When composts are applied to soil, not only degradable substrates and nutrients are supplied, but also a wide range of microorganisms (Ryckeboer *et al*., 2003), including harmless heterotrophy but potentially also plant and human pathogens. Furthermore, the application of composts may, in addition to a general stimulation of the indigenous microflora, change the community composition of a soil.

Irrigation is very important factor affecting the growth and yield of medicinal and aromatic plants. Irrigation also may affect the volatile oil composition. From the other point of view, water scarcity is a growing global problem that challenges sustainable development and expansion of cultivated area to meet increasing food requirements. Water is characterized as such no alternative source can substitute it and it is not a commercial resource or commodity. Based on this fact, the great challenge for the coming decades will be the task of increasing the productivity of water unit (Abdin and Salem, 2009). Prolonging the irrigation intervals reduced the growth and yield of various medicinal and aromatic plants; Toima, (1992) on coriander, Eid *et al.* (1995), Hammam (1996) on *Pimpinella anisum,*L plant, Osman (2000) on coriander, Osman and El-Feky (2005) on coriander, Sharma and Prasad (1990) on fennel, Tomar *et al.* (1994) on *Coriandrum sativum* and Kumar *et al*. (2008) on *Coriandrum sativum* and Mohamed (2000) on *Carum carvi,* L. plants.

Bacterial inoculants have been used to increase plant yields in several countries and commercial products are currently available. Easterna biofert is one of commercial biofertilizers and employed with different crops. Easterna biofert has the ability to release macro and micro nutrients gradually and supply the crop throughout the vegetation periods (Adediran *et al.,* 2004). Therefore, it caused a significant increase in growth parameters and yield component compared to NPK fertilizers (El-Gamal and Hammad, 2005). However, little is known on Easterna biofert and not much information is yet available regarding the use of Easterna biofert to increase the productivity of medicinal and aromatic plants.

Improving not only the quantity but also the quality of coriander yield was and still the main goal of several investigators. So, the aim of this study was to investigate the effect of different fertilization sources (NPK, compost, biofertilizer and Easterna Biofert), irrigation frequency and their combinations on the growth, yield and the main components of coriander oil to reveal the suitable treatment which produce the highest coriander yield containing the highest quantity and quality of volatile oil.

MATERIALS AND METHODS

This investigation was carried out at the Experimental farm of Faculty of Agriculture, Tanta University, Tanta, Egypt, during two successive seasons of 2009/2010 and 2010/2011. This study aimed to investigate the effect of different irrigation intervals in combination with various fertilization sources on the growth and yield of *Coriandrum sativum,* L. plant. The seeds were obtained from Medicinal and Aromatic plants Department, Horticulture research Institute, Ministry of Agriculture, Egypt. The soil was prepared and divided into plots, each of them was 1x2 m and contained 2 rows at 50 cm apart and each plot contained 24 plants. The physical and chemical properties of the experimental soil were presented below:

Sand = 16.19 %	EC = 1.20 (ds/m)
Silt = 40.33 %	PH = 8.4
Clay = 43.48 %	N = 0.91 %
Field capacity = 36.14 %	P = 10 mg/kg
$CaCo_3$ = 1.21 %	K = 299 mg/kg

Fertilization sources:

The fertilization sources used in this experiment were as follows:

1-The recommended dose of NPK (RD) used was 400 kg/fed ammonium sulphate (20.5 % N), 200 kg/fed. calcium super phosphate (15.5 % P_2O_5) and 100 kg/fed potassium sulphate (48 % K_2O) according to Ministry of Agriculture, Egypt. Ammonium sulphate was added as a basal dressing, in four doses (100 kg/fed was added 6 weeks after sowing, then three equal doses of 100 kg/fed each, was applied at three weeks intervals), while calcium super phosphate was added during soil preparation prior to sowing and potassium sulphate was added in two equal doses, which were added at the beginning of flowering stage and the second one was added three weeks later.

2- Plant Compost. The compost was used at the rate of 10 m^3/fed. as recommended by the manufacturer's recommendations. Analysis of compost was added as follows:

C/N ratio = 21.50	EC = 2.05 (ds/m)
N (%) = 1.51	PH = 7.6
P (%) = 0.89	K (%) = 2.20 %
Fe (%) = 133	Mn (%) = 193 %
Zn (%) = 29.15	Waxes (%) = 8.65
Lignin (%) =17.29	Hemi-cellulose (%) = 24.94
Ash(%) = 9.85	

3- Mixture of bacterial strains as biofertilizer. The strains of bacteria used for seed inoculation were *Azospirillum lipoferum* (1.8 × 10^9 cell/cm^3), *Bacillus polymyxa* (3.8 × 10^9 cell/cm^3) and *Pseudomonas fluorescens* (1.8 × 10^9 cell/cm^3). The strains were grown separately on different media and obtained from microbiology department, National Research Center, Cairo, Egypt and the treatment was applied as mentioned by Hassan (2009).

4- Easterna biofert is a commercial biofertilizer which contain (microbial strains as sources of NPK, protein, amino acids, carbohydrates, calcium, magnesium and some micro elements). Easterna biofert were used at 50 kg/fed and added, as a basal dressing, to the plant in two equal doses. The first one was after thinning and the second was at flowering according to the manufacturer's recommendations.

Irrigation frequency treatments:

Plants were treated with three different irrigation intervals i.e. 2, 3 or 4 weeks. Plots were isolated by borders of one and half meter width, to avoid the effect of lateral movement of irrigation water. The quantity of irrigation water used at each interval was 5 cm depth as 100 L/2 m (200 m^3/fed).

The experiments were planned as a split plot design with three replicates. The fertilization treatments were put in the main plot and irrigation treatments were in the subplot. Plants were harvested at mature stage at April 15^{th} for both seasons. The following measurements were recorded; Plant height, number of main branches, herb weight (fresh & dry), fruit yield (plant & fed), volatile oil percentage, as well as, oil yield (plant & fed). The wet digestion procedure for dried sample (0.5 g) was performed to determine nutrient content according to Jackson (1978). Samples of coriander herb were taken for determination of N, P, K, total carbohydrates and protein percentages. Nitrogen percentage was determined in the digestion using the micro-Kjeldhl method (Black *et. al.,* 1965). The protein percentage was calculated using the conversion factor of 6.25 based on the assumption that the protein contains 16 % nitrogen according to Ranganna (1978). Phosphorus was spectrophotometrically determined and potassium was determined by flame photometer as described by A.O.A.C. (1995). Total carbohydrate percentages were in the leaves determined by using the anthrone sulphoric acid method as previously described by El-Enany (1986).

The volatile oil percentages in coriander fruits samples obtained from each replicate of every treatment were determined by a water distillation method described in British Pharmacopea (1963), using the following equation:

Volatile oil percentage = oil volume in the graduated tube / fresh weight of sample x 100. Then, the oil yield (plant & fed) were calculated.

The obtained volatile oil from the second season was dehydrated over anhydrous sodium sulphate and stored in refrigerator until GC-MS analysis. The GC-MS analysis was carried out at the Central Laboratory of National Research Center, Giza. Essential oil samples were performed using a Hewlett-Packard 5890 A series

11 instrument equipped with flame ionization detector (FID) and a carbon wax fused silica column (50 m x 0.25 mm. i. d., film thickness 0.32 µm). The oven temperature was programmed from 60 to 200 ^{o}C, respectively. Percentages of peak area were calculated with a Hewlett–Packard 3396 integrator.

The obtained data were subjected to statistical analysis using Michigan Statistical Program Version C (MSTATC). Least significant difference (L.S.D.) value at 0.05 and 0.01 for comparison between means of treatments were used as mentioned by Snedecor and Cochran (1973).

Results:

Plant height and branch number:

Data presented in Table (1) clearly indicate that the plant height and branch number of coriander plant was positively affected by applying different fertilization sources. The tallest plants with the highest branch number were obtained by applying NPK in the two experimental seasons. Increasing the irrigation intervals from 2 to 4 weeks significantly decreased plant height, as well as, branch number of coriander plants since the treatment of 2 weeks resulted in the best results in this respect. Concerning the interaction between fertilization sources and irrigation frequency, the plants treated with NPK with 2 weeks irrigation interval resulted in the highest plants with maximum branch number in both seasons.

Table 1: Plant height and branch number of coriander grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
Plant height (cm)								
RD[1] of NPK	113.00	104.33	96.33	104.56	110.50	101.67	94.50	102.22
Compost	103.00	100.00	86.33	96.44	100.00	96.83	83.50	93.44
Bacteria inoculation[2]	95.67	82.33	77.00	85.00	93.50	81.50	75.50	83.50
Easterna biofert	98.33	91.33	85.00	91.56	96.50	89.83	82.83	89.72
Mean	102.50	94.50	86.17		100.13	92.46	84.08	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	1.69		2.45		2.10		3.06	
Irrigation frequency	1.20		1.62		1.57		2.11	
Fert. x Irri.	2.41		3.24		3.14		4.23	
Branch number/plant								
RD[1] of NPK	10.67	9.67	7.33	9.22	9.17	8.43	8.50	8.70
Compost	10.67	8.67	7.00	8.78	8.97	7.67	5.90	7.51
Bacteria inoculation[2]	9.67	7.67	6.67	8.00	7.50	6.57	5.43	6.50
Easterna biofert	10.67	8.00	6.33	8.33	8.77	8.17	5.23	7.39
Mean	10.42	8.50	6.83		8.60	7.71	6.27	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.47		0.68		1.11		1.61	
Irrigation frequency	0.39		0.53		1.29		1.73	
Fert. x Irri.	0.79		1.06		2.57		3.46	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Fresh and dry weights:

The effect of fertilization sources, irrigation frequency and their combinations on fresh and dry weight of coriander herb was tabulated in Table (2). The fresh and dry weights were promoted as a result of using different fertilization sources. The treatment of NPK resulted in the maximum values in this concern. The fresh weight was (127.22, 117.56, 99.44 and 100.44 g) and (126.33, 116.11, 98.78 and 99.11 g), however the dry weight was (42.43, 39.76, 38.77 and 37.88 g) and (40.00, 37.07, 36.74 and 35.75 g) in the first and second seasons, respectively. Regarding irrigation frequency, increasing irrigation interval led to decrease both fresh and dry weight of coriander herb during both seasons (Table 2). The interaction effect between fertilization sources and irrigation frequency show that compost treatment with 2 weeks irrigation intervals gave the heaviest fresh weight in the first season, however the NPK with 2 weeks resulted in maximum value in the second one. Although, the NPK with 2 weeks treatment recorded the heaviest herb dry weight, there were no significant differences between this treatment and compost with 2 weeks in both seasons.

Table 2: Fresh and dry weights of coriander herb grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
Herb fresh weight (g)								
RD[1] of NPK	130.33	129.67	119.00	127.22	130.33	129.67	119.00	126.33
Compost	130.67	120.00	102.00	117.56	129.33	118.67	100.33	116.11
Bacteria inoculation[2]	110.00	98.33	90.00	99.44	110.67	97.67	88.00	98.78
Easterna biofert	106.67	100.67	94.00	100.44	104.67	99.67	93.00	99.11
Mean	119.92	112.00	101.58		118.75	111.42	100.08	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.93		1.35		1.75		2.54	
Irrigation frequency	1.22		1.65		1.18		1.59	
Fert. x Irri.	2.45		3.29		2.36		3.18	
Herb dry weigh (g)								
RD[1] of NPK	44.49	42.48	40.32	42.43	42.96	39.60	37.42	40.00
Compost	43.49	39.88	35.91	39.76	41.34	37.11	32.78	37.07
Bacteria inoculation[2]	41.70	38.87	35.75	38.77	39.33	37.11	33.77	36.74
Easterna biofert	40.30	37.94	35.41	37.88	38.42	35.44	33.40	35.75
Mean	42.49	39.79	36.85		40.51	37.31	34.34	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.81		1.18		0.84		1.22	
Irrigation frequency	0.56		0.76		0.75		1.00	
Fert. x Irri.	2.36		3.18		1.49		2.01	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Fruit yield:

Data concerning total fruit yield (plant & fed.) as affected by different fertilization and irrigation treatments are shown in Table (3). The maximum fruit yield/plant (28.67 and 25.67 g) and fed. (1274.07 and 1140.74 kg) was obtained by using NPK treatment in both seasons, respectively. Coriander plants which irrigated every 2 weeks recorded the highest fruit yield/plant or fed. in comparison with 3 and 4 weeks treatments. The interaction treatment between NPK and 2 weeks irrigation interval resulted in the maximum values in this respect compared to the other treatments in both seasons (Table 3).

Table 3: Fruit yield (plant & fed.) of coriander grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
Fruit yield (g/plant)								
RD[1] of NPK	32.67	29.00	24.33	28.67	29.67	26.00	21.33	25.67
Compost	27.67	25.00	20.67	24.44	24.67	22.00	17.67	21.44
Bacteria inoculation[2]	24.67	20.67	17.33	20.89	21.67	17.67	14.33	17.89
Easterna biofert	27.00	22.67	19.00	22.89	24.00	19.67	16.00	19.89
Mean	28.00	24.33	20.33		25.00	21.33	17.33	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.67		0.97		0.59		0.85	
Irrigation frequency	0.66		0.89		1.00		1.35	
Fert. x Irri.	1.32		1.78		2.01		2.70	
Fruit yield (kg/fed.)								
RD[1] of NPK	1451.85	1288.89	1081.48	1274.07	1318.52	1155.56	948.15	1140.74
Compost	1229.63	1111.11	918.52	1086.42	1096.30	977.78	785.19	953.09
Bacteria inoculation[2]	1096.30	918.52	770.37	928.40	962.96	785.19	637.04	795.06
Easterna biofert	1200.00	1007.41	844.44	1017.28	1066.67	874.07	711.11	883.95
Mean	1244.45	1081.48	903.71		1111.11	948.15	770.37	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	29.77		43.31		26.03		37.87	
Irrigation frequency	29.29		39.45		44.62		60.09	
Fert. x Irri.	58.58		78.89		89.24		120.18	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Volatile oil percentage:

The volatile oil (%) of coriander fruits was significantly affected by applying different fertilization sources, irrigation frequency and their combinations. The treatment of bacteria inoculation or Easterna biofert significantly increased volatile oil percentage compared to either NPK or compost treatments. However, there were insignificant differences between them in both seasons (Table 4). The volatile oil percentage was gradually increased with decreasing irrigation interval from 4 to 2 weeks. The combination between fertilization sources and irrigation frequency was presented in Table (4). The obtained results revealed that the treatment of Easterna biofert irrigated with 2 weeks resulted in the maximum oil percentage (1.06 %) in the first season, while in the second one, the treatment of bacteria inoculation irrigated at 2 weeks recorded the highest oil percentage (1.02 %). However, there were no significant differences between these two treatments in this concern.

Table 4: Volatile oil (%) of coriander grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
Volatile oil (%)								
RD[1] of NPK	1.05	0.97	0.87	0.96	0.95	0.87	0.97	0.93
Compost	0.99	0.98	0.94	0.97	0.97	0.97	0.94	0.96
Bacteria inoculation[2]	1.02	0.98	0.94	0.98	1.02	0.97	0.92	0.97
Easterna biofert	1.06	0.97	0.93	0.99	0.99	0.96	0.92	0.95
Mean	1.03	0.98	0.92		0.98	0.94	0.94	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.02		0.03		0.02		0.03	
Irrigation frequency	0.02		0.02		0.02		0.02	
Fert. x Irri.	0.03		0.04		0.04		0.05	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Volatile oil yield (plant and fed.):

The response of coriander oil yield to fertilization sources and irrigation frequency were tabulated in Table (5). The oil yield per plant and fed. were significantly increased by using NPK treatment compared to the other fertilization sources in the two experimental seasons. Decreasing irrigation interval from 4 to 2 weeks resulted in significant increase in oil yield per plant and fed. The volatile oil yield/plant was (0.288, 0.237 and 0.187 ml) and (0.245, 0.199 and 0.163 ml) when plants irrigated at 15, 21 and 4 weeks in the first and second seasons, respectively. Regarding the interaction between fertilization sources and irrigation frequency, the treatment of NPK with 2 weeks irrigation interval resulted in the highest oil yield per plant (0.342 and 0.294 ml) and per fed. (15.19 and 12.52 L) in both seasons, respectively (Table 5).

Table 5: Volatile oil yield (plant& fed) of coriander grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
Volatile oil (ml/plant)								
RD[1] of NPK	0.342	0.281	0.213	0.278	0.294	0.246	0.218	0.253
Compost	0.275	0.245	0.194	0.238	0.252	0.239	0.193	0.228
Bacteria inoculation[2]	0.251	0.203	0.164	0.206	0.233	0.209	0.157	0.200
Easterna biofert	0.285	0.220	0.177	0.227	0.266	0.205	0.180	0.217
Mean	0.288	0.237	0.187		0.245	0.199	0.163	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.010		0.014		0.008		0.011	
Irrigation frequency	0.007		0.009		0.010		0.013	
Fert. x Irri.	0.013		0.018		0.020		0.027	
Volatile oil yield (L/fed.)								
RD[1] of NPK	15.19	12.47	9.46	12.37	12.52	10.02	9.19	10.58
Compost	12.19	10.89	8.61	10.57	10.60	9.46	7.36	9.14
Bacteria inoculation[2]	11.13	9.03	7.27	9.14	9.83	7.62	5.88	7.77
Easterna biofert	12.65	9.79	7.88	10.11	10.53	8.36	6.55	8.48
Mean	12.79	10.55	8.31		10.87	8.86	7.24	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.44		0.64		0.33		0.49	
Irrigation frequency	0.29		0.39		0.44		0.59	
Fert. x Irri.	0.58		0.79		0.88		1.19	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Volatile oil constitutes:

The results of GC-MS analysis of coriander volatile oil indicate that the main constituents of the oil were α-pinene, β-cymene, γ-terpinene, Linalool, Camphor, Geraniol, Geranyle acetate and Stenol (Table 6 and Figs 1-12). Linalool recorded the highest percentage compared to the others. The fertilization sources, irrigation frequency and their combinations affected the percentages of coriander volatile oil. Interestingly, the linalool percentage, which the main component, was varied between 19.40 and 82.13 %. The treatment of bacteria inoculation with irrigation at 2 weeks resulted in the highest linalool percentage (82.13 %) while the lowest value (19.40 %) was obtained by Eastrna biofert with 4 weeks irrigation interval treatment. Increasing the irrigation interval from 15 to 4 weeks under any fertilization treatments led to a gradual decrease in linalool percentage. There was no clear trend concerning the other oil constituents as a result of applying fertilization and irrigation treatments.

Table 6: Volatile oil constituents of coriander grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Components Treatments		α-pinene	β-cymene	γ-terpinene	Linalool	camphor	Geraniol	Geranyle acetate	Stenol
RD[1] of NPK	2 weeks	6.8	8.66	5.12	46.41	2.44	3.69	5.77	1.8
	3 weeks	4.69	6.94	10.40	49.47	2.01	2.29	4.06	2.75
	4 weeks	4.43	8.30	14.35	28.27	5.93	2.94	5.39	1.29
Easterna biofert	2 weeks	3.33	8.23	1.92	45.42	3.13	0.98	2.04	1.05
	3 weeks	2.19	11.14	6.70	35.10	1.63	2.29	3.24	1.26
	4 weeks	6.01	5.48	9.10	19.40	1.61	1.70	4.26	1.36
[2]Bacteria inoculation	2 weeks	0.72	4.50	0.78	82.13	2.76	1.29	2.15	-
	3 weeks	7.61	9.81	11.93	41.38	3.57	4.01	6.94	1.69
	4 weeks	5.01	5.18	4.04	38.95	2.41	2.13	4.28	2.19
Compost	2 weeks	4.89	10.07	2.52	51.66	4.37	5.48	6.41	2.99
	3 weeks	6.63	12.24	6.26	26.88	1.73	3.43	4.47	2.35
	4 weeks	0.30	1.75	1.61	39.33	1.49	2.10	4.39	0.65

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

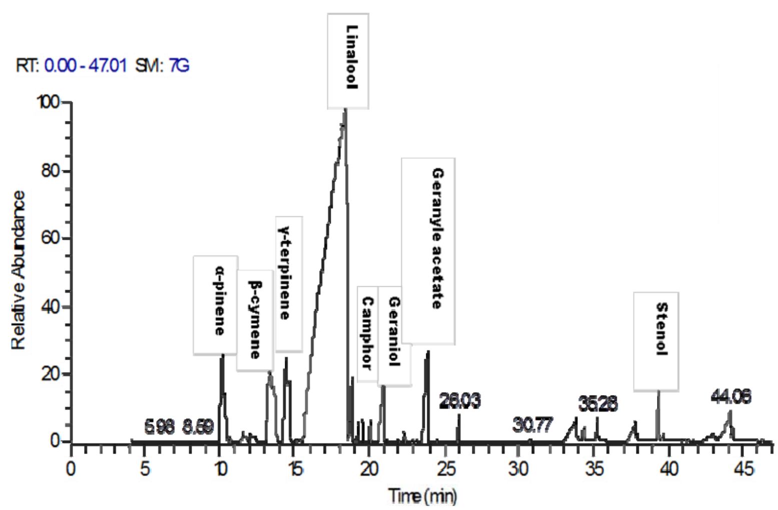

Fig. 1: Volatile oil constituents of coriander fruits grown under RD of NPK with 2 weeks irrigation interval treatment.

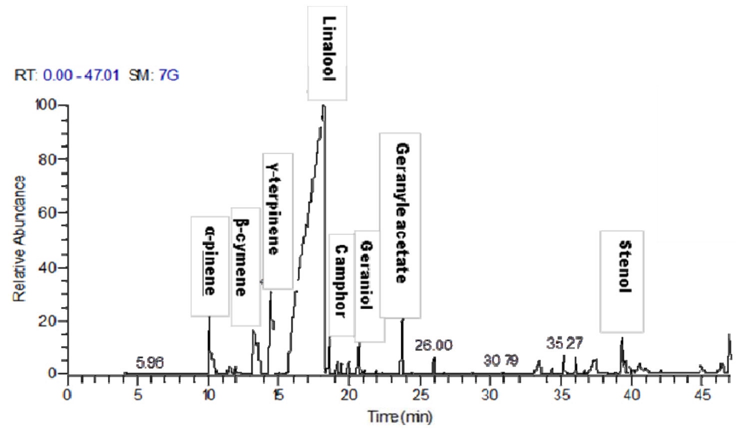

Fig. 2: Volatile oil constituents of coriander fruits grown under RD of NPK with 3 weeks irrigation interval treatment.

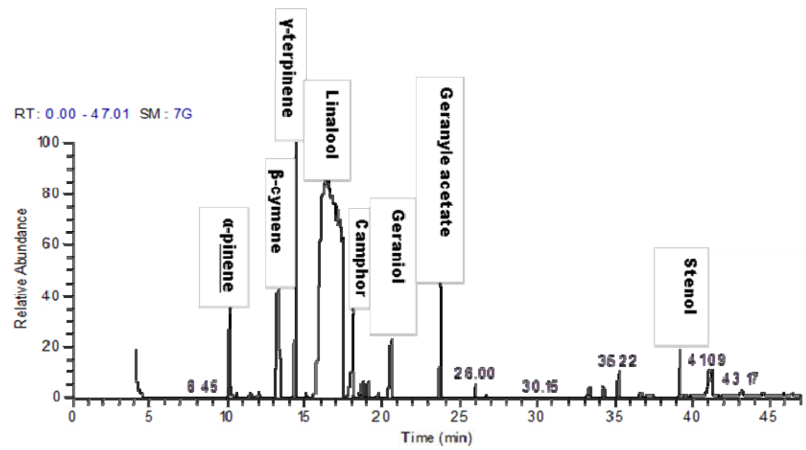

Fig. 3: Volatile oil constituents of coriander fruits grown under RD of NPK with 4 weeks irrigation interval treatment.

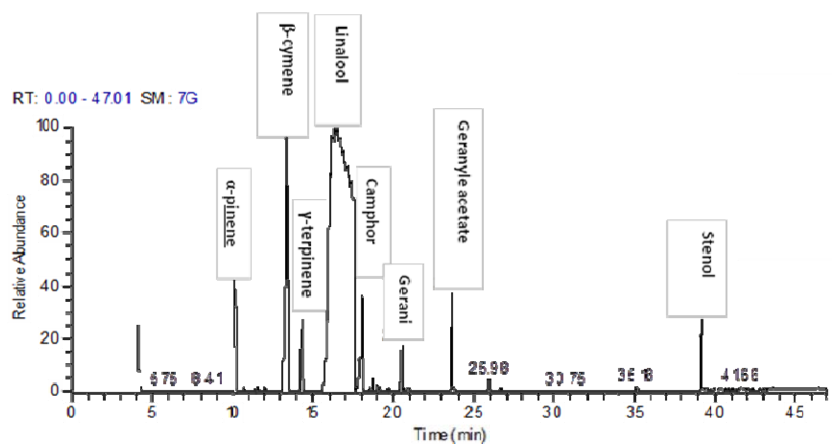

Fig. 4: Volatile oil constituents of coriander fruits grown under Easterna biofert with 2 weeks irrigation interval treatment.

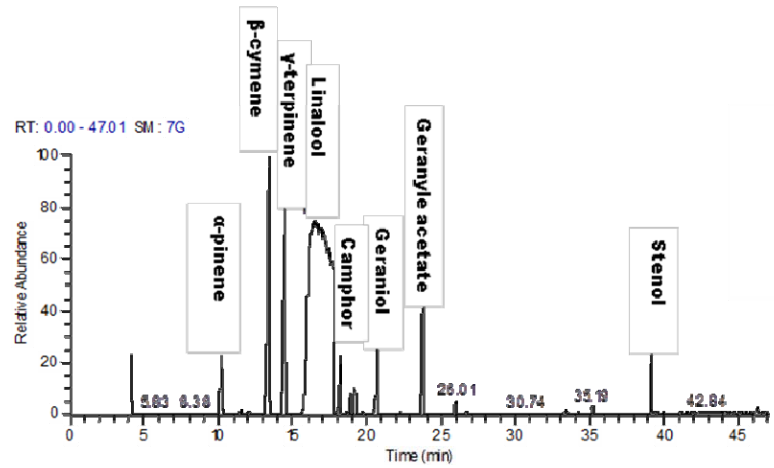

Fig. 5: Volatile oil constituents of coriander fruits grown under Easterna biofert with 3 weeks irrigation interval treatment.

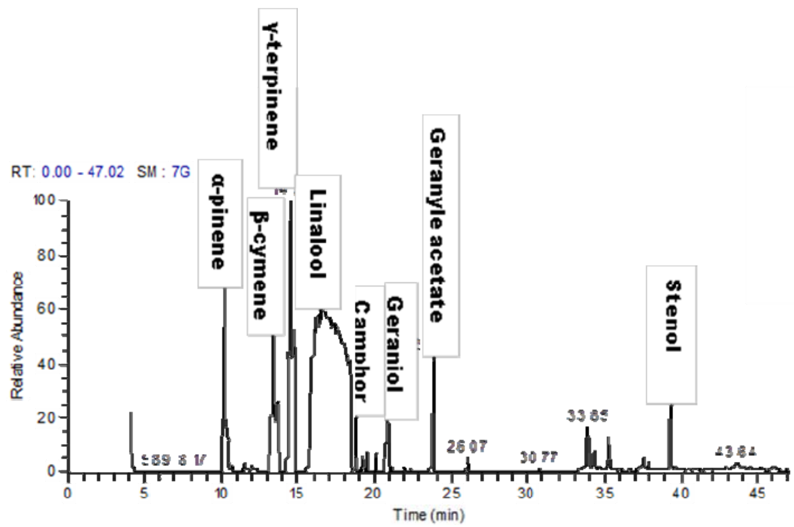

Fig. 6: Volatile oil constituents of coriander fruits grown under Easterna biofert with 4 weeks irrigation interval treatment.

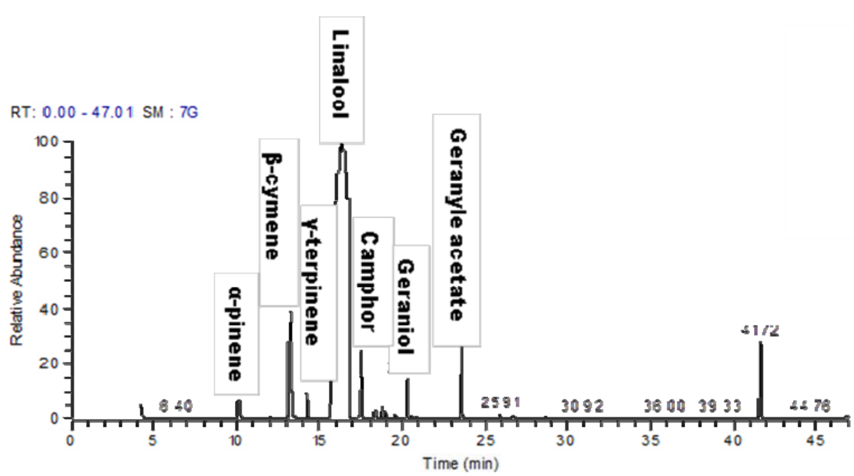

Fig. 7: Volatile oil constituents of coriander fruits grown under bacteria inoculation with 2 weeks irrigation interval treatment.

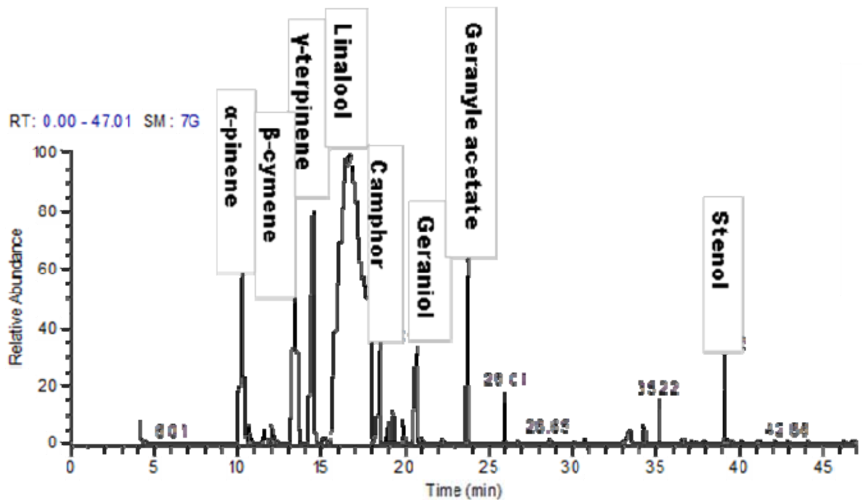

Fig 8: Volatile oil constituents of coriander fruits grown under bacteria inoculation with 3 weeks irrigation interval treatment.

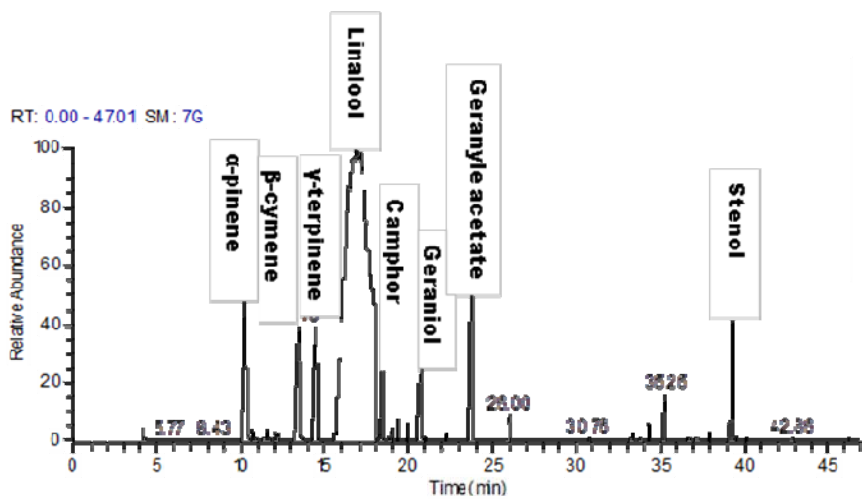

Fig. 9: Volatile oil constituents of coriander fruits grown under bacteria inoculation with 4 weeks irrigation interval treatment.

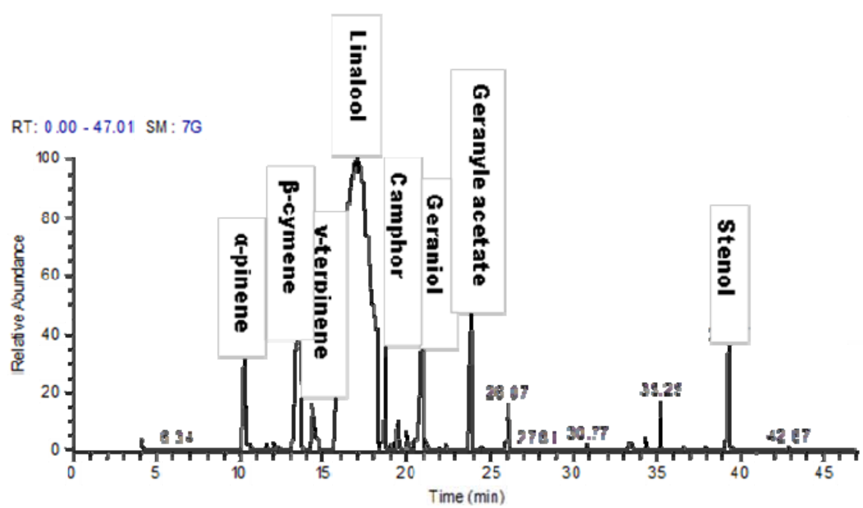

Fig. 10: Volatile oil constituents of coriander fruits grown under compost with 2 weeks irrigation interval treatment.

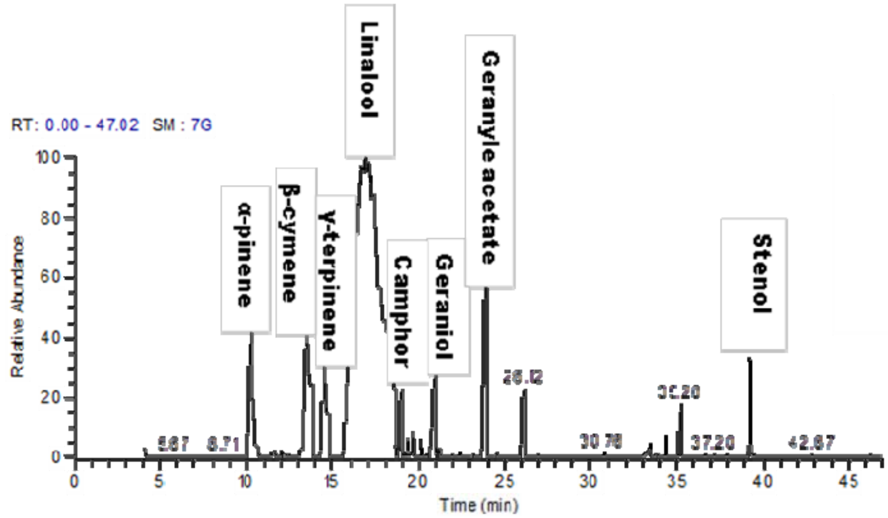

Fig. 11: Volatile oil constituents of coriander fruits grown under compost with 3 weeks irrigation interval treatment.

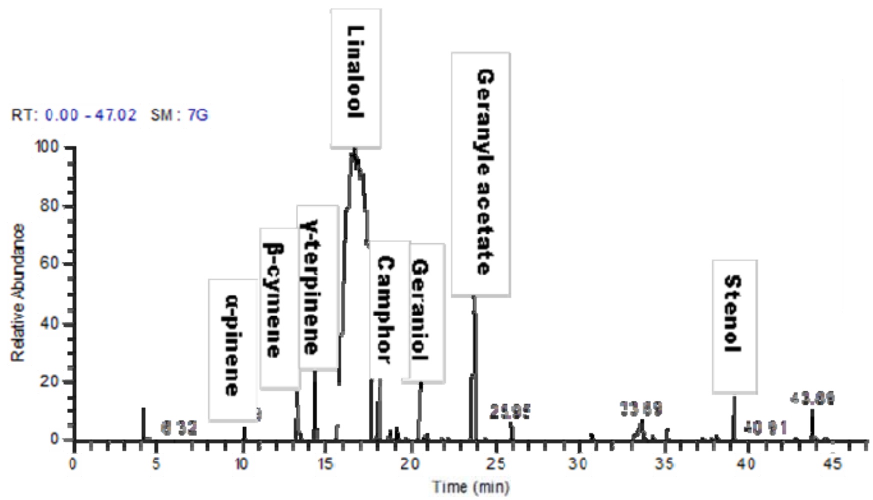

Fig. 12: Volatile oil constituents of coriander fruits grown under compost with 4 weeks irrigation interval treatment.

N and protein percentages:

Data concerning N and protein percentages of coriander leaves as affected by fertilization sources and irrigation frequency were shown in Table (7). In general, the obtained data indicate that, application of NPK followed by compost recorded the highest N and protein percentages compared to either Easterna biofert or bacteria inoculation in the two seasons. Increasing irrigation interval from 2 to 4 weeks gradually increased N and protein percentages (Table 7). The interaction treatment between NPK and irrigation every 4 weeks resulted in the maximum values in this respect in both seasons.

Phosphorus (P) and potassium (K) percentages:

The chemical analysis of coriander herb presented in Table (8) clearly indicates that P and K percentages were influenced by using different fertilization sources, irrigation frequency and their combinations. The highest P and K percentages were obtained by applying Easterna biofert followed by bacteria inoculation in both seasons. In addition, increasing irrigation interval led to a gradual increase in P and K percentages. The interaction between fertilization sources and irrigation frequency show that the treatment of Easterna biofert combined with 4 weeks interval resulted in the maximum values in this respect.

Table 7: Nitrogen and protein contents of coriander leaves grown under different fertilization and irrigation treatments during 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
N (%)								
RD[1] of NPK	2.86	2.88	2.96	2.90	2.77	2.84	2.91	2.84
Compost	2.78	2.78	2.83	2.80	2.75	2.75	2.81	2.77
Bacteria inoculation[2]	2.69	2.79	2.86	2.78	2.68	2.77	2.84	2.76
Easterna biofert	2.69	2.75	2.78	2.74	2.67	2.72	2.76	2.72
Mean	2.76	2.80	2.86		2.72	2.77	2.83	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.06		0.09		0.06		0.09	
Irrigation frequency	0.03		0.04		0.03		0.04	
Fert. x Irri.	0.06		0.09		0.05		0.07	
Protein (%)								
RD[1] of NPK	17.86	18.00	18.48	18.11	17.31	17.77	18.21	17.76
Compost	17.40	17.38	17.71	17.49	17.19	17.21	17.56	17.32
Bacteria inoculation[2]	16.82	17.46	17.88	17.38	16.73	17.33	17.73	17.26
Easterna biofert	16.82	17.19	17.40	17.13	16.69	17.02	17.25	16.99
Mean	17.22	17.51	17.87		16.98	17.33	17.69	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.39		0.57		0.40		0.58	
Irrigation frequency	0.20		0.27		0.16		0.22	
Fert. x Irri.	0.40		0.55		0.33		0.44	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Table 8: Phosphorus and potassium percentages of coriander leaves grown under different fertilization and irrigation treatments 2009/2010 and 2010/2011seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
P (%)								
RD[1] of NPK	0.34	0.36	0.37	0.36	0.32	0.33	0.36	0.34
Compost	0.33	0.35	0.36	0.34	0.31	0.33	0.34	0.33
Bacteria inoculation[2]	0.35	0.36	0.37	0.36	0.34	0.34	0.35	0.35
Easterna biofert	0.35	0.38	0.39	0.37	0.34	0.36	0.37	0.36
Mean	0.34	0.36	0.37		0.33	0.34	0.36	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.008		0.012		0.010		0.014	
Irrigation frequency	0.005		0.006		0.011		0.015	
Fert. x Irri.	0.010		0.013		0.023		0.031	
K (%)								
RD[1] of NPK	2.82	2.91	3.00	2.91	2.78	2.87	2.96	2.87
Compost	2.89	2.97	3.00	2.95	2.86	2.94	2.99	2.93
Bacteria inoculation[2]	2.93	2.98	3.03	2.98	2.92	2.95	2.97	2.95
Easterna biofert	2.95	3.08	3.16	3.06	2.86	2.97	3.15	2.99
Mean	2.90	2.98	3.04		2.86	2.93	3.02	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.034		0.049		0.027		0.040	
Irrigation frequency	0.035		0.047		0.026		0.035	
Fert. x Irri.	0.070		0.094		0.052		0.070	

[1]RD means Recommended dose of NPK fertilization

[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Carbohydrates (%):

Data in Table (9) postulated that Easterna biofert and NPK treatments significantly improved carbohydrate percentage of coriander herb compared to compost or bacteria inoculation during both seasons. Increasing irrigation interval from 2 to 4 weeks resulted in a significant increase in carbohydrate percentage in both seasons. Regarding the interaction between fertilization sources and irrigation frequency, the maximum carbohydrate percentages (19.85 and 19.38 %) were observed by applying the treatment of Easterna biofert with 4 weeks irrigation interval.

Table 9: Carbohydrates (%) of coriander leaves grown under different fertilization and irrigation treatments 2009/2010 and 2010/2011 seasons.

Treatments	First Season				Second Season			
	Irrigation intervals							
	2 weeks	3 weeks	4 weeks	Mean	2 weeks	3 weeks	4 weeks	Mean
	Carbohydrate (%)							
RD[1] of NPK	19.57	19.89	19.59	19.68	19.06	18.39	18.44	18.63
Compost	18.76	18.68	18.91	18.79	18.50	18.36	18.73	18.53
Bacteria inoculation[2]	18.42	18.75	18.91	18.69	18.22	18.38	18.80	18.47
Easterna biofert	18.61	19.43	19.85	19.30	18.24	19.22	19.38	18.95
Mean	18.84	19.19	19.32		18.51	18.59	18.84	
L.S.D.	0.05		0.01		0.05		0.01	
Fertilizer sources	0.224		0.325		0.23		0.34	
Irrigation frequency	0.171		0.230		0.27		0.37	
Fert. x Irri.	0.342		0.460		0.54		0.73	

[1]RD means Recommended dose of NPK fertilization
[2]Bacteria inoculation means that strains of *Azospirillum chroococcum, Bacillus polymyxa* and *Pseudomonas fluorescens* were mixed in equal parts and used for seed inoculation.

Discussion:

From the previous results, it could be concluded that the growth characters and yield component of coriander were improved as a result of applying different fertilization sources, irrigation frequency and their combinations. Generally, the NPK fertilization source resulted in the maximum measurements followed by compost then, Easterna biofert came in the third rank and finally bacteria inoculation. It is well known that the chemical fertilizers promote plant growth through the role of nitrogen in protein synthesis and increasing the meristmatic activity. In this respect, Marschner (1995) stated that a change in the supply nutrients to the roots, nitrogen in particular, can markedly modulate not only the levels but also the balance of phytohormones in plant. The application of nitrogen fertilizers can therefore affect growth and development not only directly (supplying nitrogen as a constituent of protein) but also indirectly by changing the phytohormones balance. In addition, mineral-P is an essential component of the energy compounds (ATP and ADP) and phosphoproteins. These results are in accordance with the findings of Mahfouz and Sharaf-Eldin (2007), Hassan (2009) and Hassan *et al*., (2012).

The promotion effect of compost on the growth and yield of coriander plant could be explained through the role of organic materials including composts in improving soil P availability (Reddy *et al.,* 2005; Gichangi *et al.,* 2009). Since during composting, labile nutrients are converted into stabilised organic material (Zucconi and De Bertoldi, 1987), therefore a large proportion of nutrients are labile. Composts provide microbes not only with P but also C and N and are therefore likely to induce changes in P pools that differ from those of inorganic P addition. In addition, compost led to increase protein content (Kanwar and Paliyal (2002), Sharma *et al.* (2006) and fertilization with organic manure increased not only available nitrogen but also exchangeable potassium in soil (Ohallorans *et. al.,* 1993).

Promoting the growth characters and increased the yield component of coriander plant by using Easterna biofert and bacterial inoculation biofertilizers treatments could be attributed to the effect of non symbiotic N_2-Fixing and phosphate solubilizing bacteria in exerting a positive effect on plant growth through the synthesis of phytohormones, N_2 fixation, reduction of membrane potential of the root, synthesis of some enzymes (such as ACC deaminase) that modulate the level of plant hormones as well as the solubilization of inorganic phosphate and mineralization of organic phosphate, which make phosphorus available to the plants (Rodriguez and Fraga, 1999).

Increasing the microorganisms in the soil had a positive effect in converting the unavailable forms of nutrient elements to available forms. The microorganisms also produce growth promoting substances resulting in more efficient absorption of nutrients, which main components of photosynthetic pigments and consequently the carbohydrate as well as N, P and K percentages were increased (Gomaa and Abou-Aly, 2001). In addition, the non symbiotic N_2-fixing bacteria (*Azospirillum)* produced adequate amounts of IAA and cytokinins with increasing the surface area per unit root length and enhanced the root hair branching with an eventual increase on the uptake of nutrients from the soil (Rodriguez and Fraga, 1999). Phosphate solubilizing bacteria (*Bacillus polymyxa* and *Pseudomonas fluorescens*) release organic and inorganic acids which reduce soil pH leading to change of phosphorus and other nutrients to available forms ready for uptake by plants (Singh and Kapoor, 1999). Therefore, the percentages of N, P and K elements in the herb were increased and this increment led to promote the growth and yield of coriander plants. Similar results have been reported on different medicinal and aromatic plants (Kandeel *et al.,* 2001, Mahfouz and Sharaf-Eldin, 2007 and Hassan, 2009).

The micro-organisms play a central role in the natural phosphorus cycle, this cycle occurs by means of the cyclic oxidation and reduction of phosphorus compounds, where electron transfer reactions between oxidation stages range from phosphine to phosphate (Ohtake *et al.,* 1996). The positive effect of bio-nitrogen on plant growth may be for its containing *Azotobacter* and *Azospirillum*, which produced adequate amounts of IAA and cytokinine, thus increased the surface area per unit of root length and responsible for root hair branching with an eventual increase in uptake of nutrients from the soil (Jagnow *et al.,* 1991).

Water is very important factor affecting the growth and yield of coriander plant. The results of our experiment showed that increasing the irrigation interval from 2 to 4 weeks significantly decreased the growth parameters and yield component of coriander plant. As the water content of the plant decreases, its cells shrink and the cell walls relax which results in lower turgor pressure and the subsequent concentration of solutes in the cells as well as cell expansion. Because leaf expansion depends mostly on cell expansion, the principals that underlie the two processes are similar. The smaller leaf area transpires less water, effectively conserving a limited water supply from the soil over a longer period (Taiz and Zeiger, 2002). Such results might be reasonable, since Doorenbos and Pruitt (1979) mentioned that more frequent irrigation periods gave chance for more luxuriant use of soil moisture, which ultimately resulted in greater foliage and increase of transpiration. Shortening irrigation interval had a positive effect on chemical constituents of *Strelitzia reginae* plant. As a result of vegetative growth promotion, the absorption of nutrient elements could be increased. The metabolic processes can also be promoted. However, water stress reduced photosynthesis rate (Pascale *et al.,* 2001). In addition, water stress lead to more loss in photosynthesis area in the plant (Taiz and Zeiger, 2002). The reduced yield obtained at low frequency resulted from deficiency of nutrients rather than of water, and that high irrigation frequency could compensate for nutrient deficiency (Silber *et al.,* 2003).

Increasing fruit yield of coriander plant by increasing irrigation level could be explained through the effect of frequent irrigation on stimulating the vegetative growth. This stimulation may reflect in increasing plant fruit yield and consequently fruit yield/fed. These results support other results obtained by Singh and Rao (1994) on cumin and Tomar *et al*. (1994), Osman (2000), Osman and El-Faeky (2005), Kumar *et al*. (2008) and Hassan *et al.* (2012) on coriander plants.

Increasing volatile oil yield with decreasing irrigation interval may be due to the water stress in lower rates, which reduces the rate of metabolic process for secondary products which lead to biosynthesis of volatile oil; however, in the presence of frequent irrigation water the accumulation of products may be increased. In addition, the increment in volatile oil yield could be explained through the increment in fruit yield as a result of using higher irrigation levels. These results are in accordance with the results of Hamam (1996) on *Pimpinella anisum*, L., Mohamed (2000) on *Carum carvi*, L., Osman (2000), and Osman and El-Fiky (2005) on coriander. the highest linalool percentage obtained by bacteria inoculation may be due to the effect of microorganisms which produce growth promoting substances resulting in more efficient absorption of nutrients, which main components of photosynthetic pigments and consequently the carbohydrate was increased as our data indicated and this may reflected on increasing the main constituents of coriander oil. This effect of bacteria inoculation was very clear when frequent irrigation was applied. These results were in accordance with the findings of Reynders and Vlassak (1982), Talaat and El-Din (1998), Abdel-Kader (1999), Harridy *et al.* (2001), Khater (2001), Edris *et al.* (2003), and El-Hady (2005).

To decrease the production cost, protect the environment from pollution, obtain high quality coriander fruits and volatile oil and save the chemical fertilizers, the treatment of using compost or bio-fertilizers whether as Easterna biofert or bacteria inoculation and applying irrigation every 2 weeks was recommended.

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