Bull.Fac, Agric.,Cairo Univ.,62:342-354 (2011).

EFFECT OF COMPOST, SULPHUR AND NITROGEN FERTILIZATION ON ESSENTIAL OIL PRODUCTION OF *Achillea millefolium* L. GROWN IN THE NEWLY RECLAIMED LAND

(Received: 2. 6. 2011)

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ABSTRACT

Field experiments were done in the Agricultural Experimental Station of the National Research Centre at Nubaria, Behira Governorate, west of the Nile Delta, Egypt using a drip irrigation system during the two successive seasons of 2007/2008 and 2008/2009, to investigate the effect of compost (10, 20 and 30 ton/fed.), sulphur (100, 200 and 300 kg S/fed.) and nitrogen (100, 150 and 200 kg N/fed.) on the essential oil yield and its composition during the different growing cuts of *Achillea millefolium* L..

The essential oil of *A. millefolium* flowering head is characterized by containing β–pinene (33.4 – 47.9 %), sabinene (7.4 – 14.7 %), chamazulene (5.6 - 21.9%) and β-caryophyllene (0.8 – 8.0 %). The results showed that the highest relative concentration of β–pinene (47.9%) was obtained with the application of compost at the rate of 20 ton/fed. combined with 300 kg S/fed. and 200 kg N/fed.. Further more, the application of 10 ton/fed. compost mixed with 300 kg S/fed. and 200 kg N/fed. gave the highest content of chamazulene (21.9%) and β-caryophyllene (8.0 %) as well as it was accompanied by low amounts of β-pinene (33.4 %) and sabinene (7.4 %).

Thus, ammonium sulphate at 200 kg N/fed. combined with compost at 20 or 30 ton/fed. and sulphur at 100 kg S/fed. was the most recommended treatment for increasing the essential oil productivity and quality of *A. millefolium* grown in the newly reclaimed sandy soil.

Key words: *Achillea millefolium, compost, essential oil, fertilizer, newly reclaimed soil, nitrogen, sulphur.*

1. INTRODUCTION

Achillea millefolium L. (Yarrow plant, Family: Asteraceae) is a widely distributed medicinal plant that has been used for over 3000 years (Mitich, 1990). Its name is said to go back to the Greek hero Achilles who used the herb to heal his soldier's bleeding wounds by stopping the flow of blood (Lawless, 1992). It is commonly known as Yarrow, milfoil, thousand leaf, green arrow and wound wort (Sweetman, 2002). It is native to Europe, North America, Southern Australia and Asia (Balbach, 1995). Now, it is widely distributed and cultivated in the temperate regions of the world (Blumenthal *et al.*, 2000).

The essential oil is found in different levels in all above ground parts of the plant (Hofmann and Frtiz, 1993). The inflorescence of yarrow contains 0.2-0.5% of the essential oil, while the leaves and stem parts contain only 0.02-0.07% (Hornok, 1974). The essential oil is characterized by containing sesquiterpenes with high amounts of chamazulene, β-caryophellene and geramacrene–D, while the major components of monoterpenes were β-pinene, sabinene and 1,8 cineole (Aziz, 2004), α-pinene and camphor (Ragažinskienė *et al.,* 2005), myrcene, limonene and camphene (Rohloff *et al*., 2000) and borneol (Hofmann and Frtiz, 1993).

Yarrow in modern medicine is used in healing ointments applied to wounds (Sampson *et al.,* 1997) and in reducing ulcer size (Nilforoushzadeh *et al.,* 2008). It also has antitumor (Tozyo *et al*., 1994), antioxidant and antimicrobial activities (Candan *et al*., 2003), liver protective (Lin *et al*., 2002), gastric anti-secretory and gastro-protective activities (Baggio *et al*., 2002).

Achillea millefolium is an important medicinal plant, its multi-therapeutic and nutritional values have been established through years of traditional and scientific applications. Thus, plant production is developed due to the use of high yielding cultivars and enhanced consumption of organic and inorganic fertilizers.

In addition, the plant is perennial in nature, the nitrogen fertilizer applied at the time of initial growth may not be fully utilized by the plant and much of the excess nitrogen will be lost by leaching and/or volatilization. Nitrogen fertilizers, leaching losses of nitrogen on sandy soils vary from 30 to 70% depending on the type of applied fertilizers (Seng, 1986). These losses from the soil could be controlled by using elemental sulphur and organic fertilizer.

Sulphur is the fourth major plant nutrient next only to nitrogen, phosphorus and potassium. Sulphur is now; very much, a part of balanced fertilization (Gosh *et al.*, 2000). It has been recognized to enhance plant growth through its oxidization by soil micro- organisms to sulphuric acid; which in turn, lowers soil pH, improves soil structure, and increases the availability of certain plant nutrients, notably phosphorus and several of micronutrients such as iron, manganese and zinc (Aziz and Taalab, 2004).

Application of organic fertilizer has various advantages such as increasing soil physical properties, water holding capacity and improving soil chemical properties (decreases soil pH, increases cation exchange capacity and enhances most nutrients) that are important for plant growth (Snyman *et al*., 1998). The addition of organic sources could increase the yield through improving soil productivity and higher fertilizer use efficiency (Santhi and Selvakumari, 2000).

This work aimed to investigate the effect of compost , sulphur and nitrogen fertilizers on the essential oil production of *Achillea millefolium* L. grown in the newly reclaimed land.

2. MATERIALS AND METHODS

The field experiments were carried out in the Agricultural Experimental Station of the National Research Centre at Nubaria, Behira Governorate west of the Nile Delta, using a drip irrigation system during the two successive seasons of 2007/2008 and 2008/2009 to investigate the effect of sulphur, nitrogen and organic fertilizers on the essential oil yield and its composition of *Achillea millefolium* L. grown under the newly reclaimed sandy soil conditions.

The physical and chemical characteristics of the soil were determined according to Jackson (1973), and presented in Table (1).

Table (1): The physical and chemical properties of the experimental soil.

Physical properties							
Season	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt+Clay	Texture
2007/2008	34.77	35.31	0.48	15.98	12.45	1.01	Sandy
2008/2009	31.52	39.25	0.43	16.57	11.31	0.92	Sandy

Chemical properties										
	pH	E.C. (dSm^{-1})	(meq/l)							
			Cations				Anions			
	(2.5:1)	(1:1)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	So_4
2007/2008	7.71	0.2	0.8	0.4	0.8	0.1	-	0.8	0.1	0.3
2008/2009	7.96	0.4	1.5	1.0	1.3	0.2	-	2.1	1.0	0.9

Maximum, minimum & average air temperature and relative humidity of the Experimental Farm area during the growing period are presented in Table (2).

The layout of the experiment was split-split plot design. The main plots were assigned to compost doses (10, 20 and 30 ton/fed.), the sub plots were assigned to sulphur fertilizer (100, 200 and 300 kg S/fed.), which was added as agricultural sulphur (99.9% S); while the sub-sub plots were assigned to nitrogen fertilizer (100, 150 and 200 kg N/fed.), which was added as ammonium sulphate (20.5% N) in four doses during plant growth. Thus, the experiment included twenty seven treatments; each treatment was replicated three times and each replicate contained ten plants.

Table (2): Monthly average of meteorological data of the Experimental Farm of Nubaria, Behira, Egypt during the years 2007, 2008 and 2009.

2007/2008 season					2008/2009 season				
	Air temperature °C			R.H.%		Air temperature °C			R.H.%
Month	Max.	Min.	Average		Month	Max	Min	Average	
Sept. 07	30.02	22	27.02	61.1	Sept. 08	30.63	20.47	25.6	67.8
Oct. 07	30.64	20.34	25.48	63.39	Oct. 08	25.84	15.71	21.06	71.1
Nov. 07	25.61	15.37	20.5	56.86	Nov. 08	23.9	13.27	18.77	70.23
Dec. 07	20.89	11.54	16.21	59.83	Dec. 08	19.71	9.68	14.87	71.58
Jan. 08	16.06	7.48	11.9	73.61	Jan. 09	18.81	8.03	13.52	70.26
Feb. 08	16.28	6.86	11.72	74.72	Feb. 09	19.07	7.82	13.54	67.54
Mar. 08	23.42	10.16	16.94	66.58	Mar. 09	19.55	8.65	14.19	64.29
Apr. 08	23.52	13.72	18.62	66.07	Apr. 09	23.43	11.67	17.63	68.93
May 08	26.16	14.97	20.71	63.77	May 09	25.45	14.81	20.29	65.55
June 08	30.03	18.47	24.37	67.87	June 09	29.9	19.77	24.93	65.43
July 08	29.94	21.1	25.58	70.29	July 09	30.29	21.9	26.13	71.06
Aug. 08	–	–	–	–	Aug. 09	30.35	20.9	25.68	69.32
Sept. 08	–	–	–	–	Sept. 09	29.63	20.23	25.03	67.23

Source: Central Laboratory for Agricultural Climate, Ministry of Agriculture, Cairo, Egypt.

The chemical characteristics of compost were determined according to Jackson ,1973 and presented in Table (3).

Table (3): The chemical analysis of compost during the seasons of 2007/2008 and 2008/2009.

Character	2007/2008	2008/2009
pH (1:10)	7.74	7.54
E.C. (dSm^{-1}) (1:10)	4.40	3.90
Organic matter %	38.0	43.6
Organic carbon %	22.1	25.3
Total nitrogen %	1.20	1.30
C/N ratio	1:18	1:20
Total phosphorus %	0.44	0.15
Total potassium %	1.00	0.84
Ash (%)	62.0	56.4

Compost and sulphur were added during soil preparation, whereas nitrogen was added in four doses during plant growth. All treatments were fertilized with calcium superphosphate (15.5% P_2O_5) at the rate of 100 kg P_2O_5/fed. and potassium sulphate (48.5% K_2O) at the rate of 100 kg K_2O/fed. during soil preparation.

Rhizomes of *Achillea millefolium* L. were obtained from the Experimental Farm of the Faculty of Pharmacy, Cairo University, Egypt. Divided plants of *Achallea millefolium* were planted, one plant every 50 cm adjacent to dripper lines, which were 75cm apart, on the 3rd October in 2007/2008 season and the 19th October in 2008/2009 season. The replanting was done after two weeks from planting. Irrigation of the plants was done using drip system (10.5 l/day).

The flowering heads of *Achillea millefolium* were collected in the first cut at the 21st Feb. 2008 and the 10th of March 2009, in the first and second seasons, respectively. The second cut was at the 10th of April and the 5th of May, then the third cut was at the 15th of May and the 21st of July and the fourth cut was at the 7th of July and the 30th of Sept. in the first and second seasons, respectively.

Essential oil percentages of the fresh flowering heads at different cuts were determined by hydro-distillation for 3 hours using Clevenger-type apparatus, according to the Egyptian Pharmacopoeia (1984). Then, essential oil yield (ml/plant and l/fed.) was calculated. The obtained essential oil was dehydrated using anhydrous sodium sulphate, and then analyzed by using gas liquid chromatograph (GLC). The chromatograph apparatus was fitted with capillary column BPX-5, 5% phenyl (reqiv.) polysillphenylene- siloxan 30m× 0.25mm ID×0.25 µm film. Temperature program ramp increases with a rate of 8ºc/min from 70 to 200ºC. Flow rates of gases were nitrogen at 1 ml/min., hydrogen at 30 ml/min. and 330 ml/min. for air. Detector and injector temperatures were 300ºC and 250ºC, respectively. The obtained chromatogram and report of GC analysis for each sample were analyzed to calculate the percentage of main components of volatile oil. The area of each peak was first calculated by an automatic integrator. The areas were then summed. The total area of the peaks represented the whole sample. The percentage of each component was the ratio between its peak areas to the total peak area, multiplied by 100. The identification of these compounds was achieved by matching their retention times with those of authentic samples injected at the same conditions.

The data recorded were analyzed using the MSTAT-C program (MSTAT, 1988). Least significant difference test (LSD) was applied at 0.05 probability level to compare mean treatments.

3. RESULTS AND DISCUSSION

The data presented in Tables (4, 5 ,6 and 7) showed the effect of compost, sulphur and nitrogen fertilizers on flowering heads and essential oil production during the first and second seasons.

3.1. Effect of compost

The application of compost at 30 ton/fed. recorded the highest increase in the essential oil percentages (0.069, 0.137, 0.184 and 0.172 % in the 1*st*, 2*nd*, 3*rd* and 4*th* cuts, respectively) in the 1st season and reached the maximum value (0.184% in the 3*rd* cut (15*th* May)) (Table, 4). The same trend was found in the 2*nd* season (Table, 5), while the maximum value (0.170%) was obtained from the 4*th* cut (21*st* July).

Table (6) showed that, adding 20 ton compost/fed. gave the highest fresh yield in both seasons.

Moreover, the addition of compost at 30 ton/fed. gave the greatest mean values of essential oil total yield as shown in Table (7) (0.31 ml/plant and 3.50 L/fed. in the 1*st* season) and (0.23 ml/plant and 2.55 L/fed. in the 2*nd* season). It was observed that, there were no significant differences between compost at 30 and 20 ton/fed. on essential oil total yield (ml/plant and L/fed.) in both seasons.

The increase in flowering head essential oil production with the increase of compost levels might be due to its superior and improved role to supply the growing plants with the required micro and macro nutrient elements. Naturally, these elements play an important role in the metabolic processes like photosynthesis, respiration and carbohydrate synthesis (Abo El-Seoud *et al.*, 1997). It is claimed that the precursor of essential oil could be resulted from the degradation of carbohydrates and proteins (Guenther, 1961). Positive effects of fertilizer on secondary metabolites have been reported by several investigators for a variety of medicinal and aromatic species, Aziz (2004) on *Achillea millefolium,* Ali (2009) on *Foeniculum vulgare,* Ateia *et al.* (2009) on *Thymus vulgaris,* El-Sayed *et al.* (2009) on *Artemisia dracunculus* and Hendawy *et al*. (2010) on *Thymus vulgaris*.

3.2. Effect of sulphur fertilizer

In the 1*st* season (Table, 4), the addition of agricultural sulphur at 300 kg S/fed. gave the greatest increase of essential oil percentages (0.066, 0.135, 0.183 and 0.175 % in the 1*st*, 2*nd*, 3*rd* and 4*th* cut, respectively). The highest dose of sulphur (300 kg S/fed.) resulted in the greatest fresh yield in both seasons (Table 6) and produced the highest mean values of essential oil total yield as shown in Table (7) (0.34 ml/plant and 3.77 L/fed.). The results of the 2*nd* season (Tables, 5 and 7) gave similar trend.

The enhancement in essential oil yield may be attributed to that sulphur is recognized to enhance plant growth in arid and alkaline soils through oxidation by soil microorganisms that convert the sulphur to sulphuric acid which in turn lower soil pH, improves soil structure, and increases the availability of certain plant nutrients, notably phosphorus and of micronutrients (iron, manganese, and zinc) (Stamford *et al.*, 2003). As well as sulphur participates in various coenzymes, which have an important role in essential oil synthesis (Haneklaus *et al*., 1997). The results agreed with other earlier studies on *Allium cepa* (Lancaster *et al*., 2001), *Cynara cardunculus* (Rodrigo *et al.*, 2005), and *Dracocephalum moldavica* (Aziz *et al.*, 2010).

3.3. Effect of nitrogen fertilizer

The highest rate of nitrogen (200 kg N/fed.) resulted in the greatest increment in flowering head essential oil percentages in the 1*st* season (0.138, 0.183 and 0.172 % in the 2*nd*, 3*rd* and 4*th* cut, respectively) as shown in Table (4) and in the 2*nd* season (0.077, 0.136 and 0.169 % in the 1*st*, 3*rd* and 4*th* cut, respectively) as shown in Table (5).

Results in Tables (6) revealed that, Treating plants with 200 kg N/fed. gave the greatest fresh yield in both seasons. At the same time, this level of nitrogen resulted in the highest increase in flowering heads essential oil total yield (0.34 ml/plant and 3.85 l/fed. in the 1*st* season) and (0.26 ml/plant and 2.95 l/fed. in the 2*nd* season) as illustrated in Table (7).

Table (4): Effect of compost, sulphur and nitrogen fertilizers on essential oil (%) of *Achillea millefolium* flowering heads during 2007/2008 season.

A*B*C Interaction	1st cut								
	Sulphur (kg S/fed.)								
	100			200			300		
Compost (ton/fed.)	Nitrogen (kg N/fed.)								
	100	150	200	100	150	200	100	150	200
10	0.052	0.055	0.056	0.053	0.057	0.060	0.056	0.062	0.065
20	0.054	0.057	0.060	0.057	0.059	0.063	0.061	0.063	0.067
30	0.059	0.065	0.065	0.064	0.069	0.076	0.066	0.074	0.081
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.057		**100**	0.058		**100**	0.058	
	20	0.060		**200**	0.062		**150**	0.062	
	30	0.069		**300**	0.066		**200**	0.066	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	N.S	0.001	N.S	N.S	N.S		
	2nd cut								
10	0.098	0.122	0.123	0.103	0.125	0.134	0.113	0.129	0.139
20	0.124	0.127	0.133	0.127	0.130	0.139	0.129	0.137	0.144
30	0.125	0.135	0.139	0.129	0.138	0.143	0.131	0.141	0.150
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.121		**100**	0.125		**100**	0.120	
	20	0.132		**200**	0.130		**150**	0.132	
	30	0.137		**300**	0.135		**200**	0.138	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
	3rd cut								
10	0.157	0.158	0.165	0.163	0.170	0.176	0.166	0.174	0.180
20	0.166	0.170	0.178	0.172	0.177	0.184	0.177	0.181	0.186
30	0.171	0.178	0.184	0.173	0.183	0.187	0.184	0.193	0.207
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.168		**100**	0.170		**100**	0.170	
	20	0.177		**200**	0.176		**150**	0.176	
	30	0.184		**300**	0.183		**200**	0.183	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
	4th cut								
10	0.144	0.151	0.157	0.154	0.156	0.158	0.161	0.170	0.174
20	0.155	0.159	0.163	0.162	0.165	0.174	0.168	0.176	0.183
30	0.160	0.166	0.173	0.162	0.170	0.179	0.172	0.179	0.188
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.158		**100**	0.159		**100**	0.160	
	20	0.167		**200**	0.164		**150**	0.166	
	30	0.172		**300**	0.175		**200**	0.172	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.002		

A = Compost **B = Sulphur** **C = Nitrogen**

Table (5): Effect of compost, sulphur and nitrogen fertilizers on essential oil (%) of *Achillea millefolium* flowering heads during 2008/2009 season.

A*B*C Interaction	1st cut								
	Sulphur (kg S/fed.)								
	100			200			300		
Compost	Nitrogen (kg N/fed.)								
(ton/fed.)	100	150	200	100	150	200	100	150	200
10	0.063	0.064	0.071	0.064	0.071	0.073	0.065	0.073	0.076
20	0.065	0.067	0.072	0.067	0.070	0.077	0.070	0.075	0.082
30	0.068	0.074	0.078	0.069	0.076	0.081	0.073	0.080	0.087
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.069		**100**	0.069		**100**	0.067	
	20	0.072		**200**	0.072		**150**	0.072	
	30	0.076		**300**	0.076		**200**	0.077	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
	2nd cut								
10	0.088	0.094	0.107	0.101	0.102	0.110	0.109	0.113	0.115
20	0.095	0.104	0.116	0.106	0.115	0.121	0.105	0.117	0.127
30	0.111	0.116	0.123	0.113	0.119	0.124	0.119	0.122	0.129
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.104		**100**	0.106		**100**	0.105	
	20	0.112		**200**	0.112		**150**	0.111	
	30	0.120		**300**	0.117		**200**	0.119	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	N.S	0.001	N.S	N.S	N.S		
	3rd cut								
10	0.103	0.106	0.113	0.105	0.109	0.118	0.110	0.122	0.129
20	0.114	0.121	0.128	0.132	0.138	0.144	0.137	0.140	0.148
30	0.127	0.135	0.141	0.132	0.140	0.148	0.139	0.146	0.153
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.113		**100**	0.121		**100**	0.122	
	20	0.134		**200**	0.130		**150**	0.129	
	30	0.140		**300**	0.136		**200**	0.136	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
	4th cut								
10	0.149	0.151	0.155	0.151	0.155	0.162	0.153	0.160	0.171
20	0.153	0.156	0.162	0.156	0.159	0.166	0.162	0.164	0.177
30	0.155	0.161	0.170	0.162	0.169	0.176	0.173	0.177	0.185
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.156		**100**	0.157		**100**	0.157	
	20	0.162		**200**	0.162		**150**	0.161	
	30	0.170		**300**	0.169		**200**	0.169	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.001	0.001	0.001	0.001	0.001	0.001	0.001		

A = Compost **B = Sulphur** **C = Nitrogen**

Table (6): Effect of compost, sulphur and nitrogen fertilizers on total fresh yield (g/plant and ton/fed.) of *Achillea millefolium* flowering heads during 2007/2008 and 2008/2009 seasons.

	2007/2008 season								
A*B*C Interaction	**Total fresh yield (g/plant)**								
	Sulphur (kg S/fed.)								
	100			**200**			**300**		
Compost (ton/fed.)	**Nitrogen (kg N/fed.)**								
	100	**150**	**200**	**100**	**150**	**200**	**100**	**150**	**200**
10	143.53	174.97	202.77	162.87	184.83	211.10	189.30	204.80	233.60
20	170.23	196.43	214.80	184.27	204.73	226.37	199.83	216.53	250.57
30	158.73	186.80	212.90	171.30	196.23	219.77	190.07	209.90	239.60
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	189.75		**100**	184.57		**100**	174.46	
	20	207.09		**200**	195.72		**150**	197.25	
	30	198.37		**300**	214.91		**200**	223.50	
LSD at 5%		**A**		**B**	**C**		**ABC**		
		4.05		3.60	3.39		N.S		
	Total fresh yield (ton/fed.)								
10	1.61	1.96	2.27	1.82	2.07	2.36	2.12	2.29	2.62
20	1.91	2.20	2.41	2.06	2.29	2.53	2.24	2.43	2.81
30	1.78	2.09	2.38	1.92	2.20	2.46	2.13	2.35	2.69
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	2.13		**100**	2.07		**100**	1.95	
	20	2.32		**200**	2.19		**150**	2.21	
	30	2.22		**300**	2.41		**200**	2.50	
LSD at 5%		**A**		**B**	**C**		**ABC**		
		0.05		0.04	0.04		N.S		
	2008/2009 season								
	Total fresh yield (g/plant)								
10	126.43	141.40	185.77	158.60	178.07	203.50	159.13	186.87	216.97
20	141.80	160.33	204.77	179.90	194.10	227.33	189.50	200.77	245.07
30	150.00	161.43	196.73	171.00	180.50	222.17	173.93	187.33	226.20
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	172.97		**100**	163.19		**100**	161.14	
	20	193.73		**200**	190.57		**150**	176.76	
	30	185.48		**300**	198.42		**200**	214.28	
LSD at 5%		**A**		**B**	**C**		**ABC**		
		3.35		3.14	4.08		N.S		
	Total fresh yield (ton/fed.)								
10	1.42	1.58	2.08	1.78	2.00	2.28	1.78	2.09	2.43
20	1.59	1.80	2.29	2.01	2.17	2.54	2.12	2.25	2.74
30	1.68	1.81	2.20	1.92	2.02	2.49	1.95	2.10	2.53
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	1.94		**100**	1.83		**100**	1.80	
	20	2.17		**200**	2.13		**150**	1.98	
	30	2.08		**300**	2.22		**200**	2.40	
LSD at 5%		**A**		**B**	**C**		**ABC**		
		0.03		0.03	0.05		N.S		

A = Compost **B = Sulphur** **C = Nitrogen**

Table (7): Effect of compost, sulphur and nitrogen fertilizers on essential oil total yield (ml/plant and l/fed.) of *Achillea millefolium* flowering heads during 2007/2008 and 2008/2009 seasons.

A*B*C Interaction									
	2007/2008 season								
	Total yield (ml/plant)								
	Sulphur (kg S/fed.)								
	100			**200**			**300**		
Compost (ton/fed.)	**Nitrogen (kg N/fed.)**								
	100	**150**	**200**	**100**	**150**	**200**	**100**	**150**	**200**
10	0.19	0.24	0.29	0.22	0.27	0.31	0.27	0.31	0.36
20	0.24	0.28	0.32	0.27	0.30	0.35	0.30	0.34	0.40
30	0.23	0.29	0.33	0.26	0.31	0.35	0.30	0.35	0.41
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.27		**100**	0.27		**100**	0.25	
	20	0.31		**200**	0.29		**150**	0.30	
	30	0.31		**300**	0.34		**200**	0.34	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.01	0.01	0.01	N.S	N.S	N.S	N.S		
	Total yield (l/fed.)								
10	2.10	2.68	3.19	2.50	2.99	3.43	3.04	3.50	4.00
20	2.67	3.18	3.54	3.02	3.41	3.87	3.39	3.80	4.44
30	2.60	3.20	3.73	2.87	3.42	3.90	3.33	3.87	4.59
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	3.05		**100**	2.99		**100**	2.83	
	20	3.48		**200**	3.27		**150**	3.34	
	30	3.50		**300**	3.77		**200**	3.85	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.06	0.06	0.06	N.S	N.S	N.S	N.S		
	2008/2009 season								
	Total yield (ml/plant)								
10	0.12	0.14	0.20	0.16	0.18	0.23	0.17	0.21	0.26
20	0.14	0.17	0.24	0.20	0.23	0.28	0.21	0.24	0.32
30	0.17	0.19	0.25	0.20	0.22	0.29	0.21	0.23	0.30
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	0.18		**100**	0.18		**100**	0.17	
	20	0.23		**200**	0.22		**150**	0.20	
	30	0.23		**300**	0.24		**200**	0.26	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.01	0.01	0.01	0.01	N.S	N.S	N.S		
	Total yield (l/fed.)								
10	1.29	1.53	2.27	1.75	2.04	2.55	1.86	2.34	2.89
20	1.58	1.92	2.71	2.20	2.52	3.18	2.37	2.69	3.60
30	1.86	2.11	2.77	2.18	2.44	3.20	2.34	2.62	3.41
Mean	**Compost (ton/fed.)**			**Sulphur (kg S/fed.)**			**Nitrogen (kg N/fed.)**		
	10	2.06		**100**	2.00		**100**	1.94	
	20	2.53		**200**	2.45		**150**	2.25	
	30	2.55		**300**	2.68		**200**	2.95	
LSD at 5%	**A**	**B**	**C**	**AB**	**AC**	**BC**	**ABC**		
	0.04	0.05	0.06	0.09	N.S	N.S	N.S		

A = Compost **B = Sulphur** **C = Nitrogen**

The increment in essential oil percentage by application of the nitrogen fertilizer may be due to that nitrogen is a constituent of several precursors to essential oil constituents (Ram *et al*., 2006) and could be expected to increase essential oil production. These results are in accordance with those obtained by Aziz (2004) on *Achillea millefolium*, who showed that 50 kg N/fed. as ammonium sulphate was the most effective treatment for increasing flowering heads essential yield, as well as Ram *et al.* (2006) on *Mentha arvensis*, who found that essential oil yield was significantly influenced by the application of 200 kg N/ha in the form of urea. Sifola and Barbieri (2006) on *Ocimum basilicum* reported that 300 kg N/ha as ammonium nitrate increased leaf essential oil percentage and yield. Zheljazkov *et al.* (2008) on *Ocimum basilicum* demonstrated that essential oil yield was maximized at N fertilization of 60 kg N/ha as ammonium nitrate and Abbaszadeh *et al*. (2009) on *Melissa officinalis* showed that the highest essential oil percentage and yield was obtained under the application of 60 kg N/ha as urea.

3.4. Effect of the interaction between compost, sulphur or nitrogen fertilizers

The data in Tables (4 and 5) showed that, the application of compost at 30 ton/fed. combined with 300 kg S/fed. and 200 kg N/fed. gave the highest percentages of flowering heads essential oil (0.150, 0.207 and 0.188 % in the 2nd, 3rd and 4th cuts of the 1st season, respectively) as well as (0.087, 0.153 and 0.185 % in the 1st, 3rd and 4th cuts of the 2nd season, respectively).

3.5. Essential oil constituents

The results in Table (8) showed that the essential oil of *Achillea millefolium* flowering heads was characterized by containing monoterpene hydrocarbons and the major components were β–pinene (33.4 – 47.9 %) and sabinene (7.4 – 14.7 %). Whereas β-pinene was the prevalent monoterpene of the plant. Chamazulene (5.6 - 21.9 %) and β-caryophyllene (0.8 – 8.0 %) were the principal sesquiterpenes. Oxygen containing terpenes were found only in small amounts and 1,8-cineole (1.7 - 5.4 %) was the most prominent oxygen-containing monoterpenes. These results are in agreement with those reported by Hofmann and Fritz (1993) as well as Grth and Czygan (1999).

The data in Table (8) and in Figures (1 and 2) showed that the highest relative concentration of β-pinene (47.9 %) was obtained with the application of compost at the rate of 20 ton/fed. combined with sulphur at 300 kg S/fed. and ammonium sulphate at 200 kg N/fed.. Further more, the application of 10 ton/fed. compost mixed with 300 kg S/fed. and 200 kg N/fed. gave the highest content of chamazulene (21.9 %) and β-caryophyllene (8.0 %) as well as it was accompanied by lower amounts of β-pinene (33.4 %) and sabinene (7.4 %). Moreover, variable effects either ascending or descending were noticed in the content of some components of *Achillea* oil as affected with different fertilization treatments.

The positive influence of different fertilization treatments on the essential oil constiuents was reported by many investigators, Aziz (2004) on *Achillea millefolium* showed that the application of ammonium sulphate at 50kgN/fed. combined with 15 ton/fed. of poultry manure gave the highest content of chamazulene (39.57 %), β-caryophyllene (20.24 %) and geramacrene -D (14.58 %). Zheljazkov *et al.* (2008) on *Ocimum basilicum* L. demonstrated that 50 to 60 kg N/ha as ammonium nitrate maximized linalool and eugenol yields. El-Sayed *et al.* (2009) on *Artemisia dracunculus* L. stated that 60 m^3/fed. cattle manure was the most effective treatment in limonene content. Hendawy *et al*. (2010) on *Thymus vulgaris* pointed out that the highest value of oxygenated compounds was obtained from plants received 20 L/fed. of compost tea + 150 kg/fed. rock phosphate. More over Aziz *et al.* (2010) reported that ammonium sulphate at 100 kg N/ha increased the relative concentration of neral, geranyl acetate, and geraniol of *Dracocephalum moldavica*.

It could be concluded that ammonium sulphate may become suitable for development of a slow fertilizer when combined with compost , and agricultural sulphur. Thus, ammonium sulphate at 200 kg N/fed. combined with 20 or 30 ton/fed. of compost and sulphur at 100 kg S/fed. was the most suitable treatment for increasing the productivity and quality of *Achillea millefolium* L. grown in the newly reclaimed land.

Acknowledgement

Special appreciation to Prof. Dr. Salah Sayed Ahmed, Researcher Professor of Medicinal and Aromatic plants, at the National Research Centre, for his help during the preparation of this work.

Table (8): Effect of compost, sulphur and nitrogen fertilizers on essential oil composition of *Achillea millefolium* plants during 2007/2008 season.

Treatments			α-pinene	Sabinene	β-pinene	Myrcene	Limonene	1,8 cineole	Camphor	Bornyl acetate	Chamazulene	β-caryophyllene	Total
C1	S1	N1	4.1	9.7	33.8	1.8	11.8	3.8	3.2	4.5	8.1	1.8	82.6
		N2	4.2	10.6	33.6	1.2	11.8	1.7	3.8	3.2	12.9	2.5	85.5
		N3	3.2	9.5	35.0	1.7	11.5	3.1	3.9	5.0	7.3	1.8	82.0
	S2	N1	4.4	11.8	34.4	1.5	10.2	2.1	2.6	3.2	14.5	3.0	87.7
		N2	4.9	10.3	38.0	1.3	12.9	2.2	4.2	2.6	10.6	1.7	88.7
		N3	5.1	11.7	36.6	1.7	12.3	2.1	3.4	2.6	10.4	2.2	88.1
	S3	N1	3.8	9.6	40.3	1.4	10.5	2.2	3.1	2.2	12.3	3.7	89.1
		N2	4.2	10.6	38.0	-	11.8	4.7	3.7	6.3	6.3	0.8	86.4
		N3	2.5	7.4	33.4	1.5	8.8	2.2	2.8	2.3	21.9	8.0	90.8
C2	S1	N1	3.7	10.3	37.9	1.8	10.3	2.7	3.1	4.8	7.6	1.8	84.0
		N2	4.6	9.2	34.9	1.7	11.3	5.1	4.0	5.6	6.9	2.4	85.7
		N3	4.1	8.4	37.1	1.6	11.7	2.6	3.4	2.9	9.8	2.1	83.7
	S2	N1	4.0	10.8	37.5	3.3	11.1	4.2	3.4	4.6	6.4	4.2	89.5
		N2	4.0	12.4	46.2	1.3	11.7	2.1	2.4	3.6	8.8	1.7	94.2
		N3	3.2	10.2	37.5	-	9.5	5.2	3.2	2.8	5.8	6.1	83.5
	S3	N1	3.5	11.8	42.0	2.2	8.9	2.4	2.9	3.2	9.1	2.8	88.8
		N2	5.2	11.1	35.9	1.4	10.8	2.5	4.1	3.0	9.9	2.4	86.3
		N3	3.7	14.7	47.9	2.9	13.2	1.9	1.6	2.4	6.7	1.5	96.5
C3	S1	N1	3.5	9.3	38.3	1.6	11.3	3.5	3.1	4.0	8.9	2.7	86.2
		N2	3.8	9.2	39.8	1.4	12.7	3.4	4.4	4.8	5.6	0.9	86.0
		N3	5.7	12.2	37.5	1.6	7.6	3.7	3.9	3.7	7.4	2.6	85.9
	S2	N1	3.9	9.0	35.0	1.6	11.9	5.4	3.4	4.9	7.9	7.2	90.2
		N2	4.7	12.5	37.0	0.9	13.6	2.8	2.9	2.2	10.6	2.1	89.3
		N3	4.2	9.5	35.1	1.4	11.6	3.1	4.0	3.5	12.4	3.0	87.8
	S3	N1	4.3	11.4	39.0	1.0	12.0	3.0	3.6	3.3	10.4	2.6	90.6
		N2	3.6	8.8	45.1	1.0	13.4	3.2	2.2	4.5	9.3	1.7	92.8
		N3	6.2	8.3	40.4	2.3	12.8	3.9	4.5	2.1	8.6	2.2	91.3

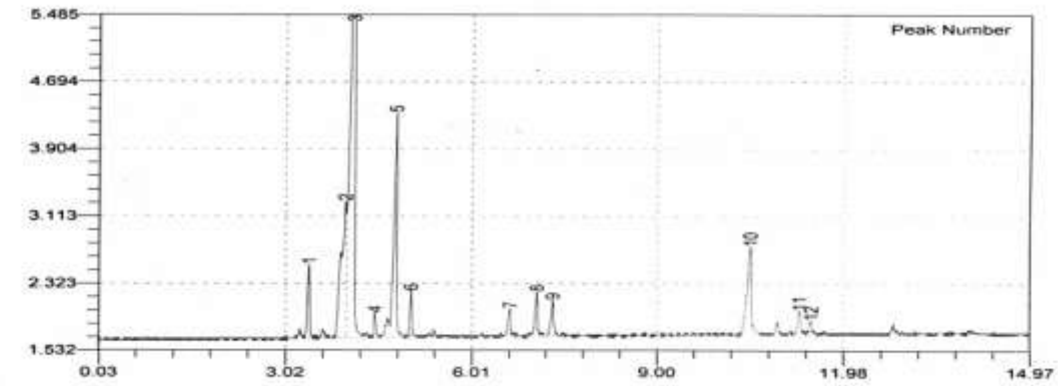

Fig. (1): GLC Chromatogram of the essential oil of flowering heads of *Achillea millefolium* **plants fertilized with 20 ton/fed. compost, 300 kg S/fed. and 200 kg N/fed.**

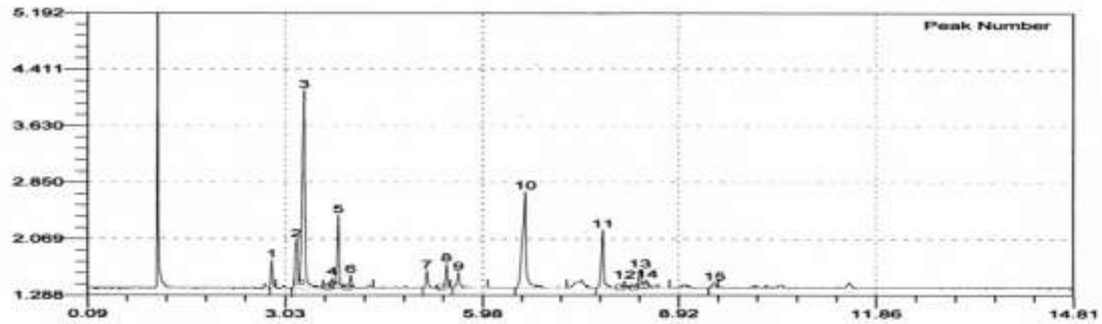

Fig.(2): GLC Chromatogram of the essential oil of flowering heads of *Achillea millefolium* **plants fertilized with 10 ton/fed. compost, 300 kg S/fed. and 200 kg N/fed.**

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تأثير التسميد العضوي, الكبريتي و النيتروجينى علي إنتاج الزيت الطيار لنبات الآشيليا (*Achillea millefolium* **L.**) تحت ظروف الأراضي الرملية المستصلحة

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ملخص

أجريت هذه التجارب الحقلية فى محطة التجارب الزراعية التابعة للمركز القومي للبحوث بالنوبارية – محافظة البحيرة – منطقة غرب الدلتا بإستخدام نظام الري بالتنقيط خلال الموسمين المتتاليين ٢٠٠٨/٢٠٠٧ و ٢٠٠٩/٢٠٠٨ لدراسة تأثير الكمبوست (١٠، ٢٠ و٣٠ طن/الفدان)، الكبريت (١٠٠، ٢٠٠ و ٣٠٠ كجم كبريت/الفدان) و النيتروجين (١٠٠، ١٥٠ و ٢٠٠ كجم نيتروجين/الفدان) على محصول و مكونات الزيت الطيار لنبات الآشيليا (*Achillea millefolium* L.) خلال الحشات المختلفة.

يتميز الزيت الطيار للقمم الزهرية لنبات الآشيليا بإحتوائه على β-pinene (٣٣,٤ – 47.9 ٪)، sabinene (٧,٤ - ١٤,٧ ٪)، chamazulene (٥,٦ - ٢١,٩ ٪) وβ-caryophyllene (٠,٨ - ٨,٠ ٪). أظهرت النتائج أن أعلى تركيز نسبي ل β-pinene (٤٧,٩ ٪) تم الحصول عليه من إضافة ٢٠ طن/الفدان من الكمبوست مع ٣٠٠ كجم كبريت/الفدان و ٢٠٠ كجم نيتروجين/الفدان. بينما أعطت إضافة ١٠ طن/الفدان كمبوست مع ٣٠٠ كجم كبريت/الفدان و ٢٠٠ كجم نيتروجين/الفدان أعطت أعلى محتوى من chamazulene (٢١,٩ ٪) و β-caryophyllene (٨,٠ ٪) و لكن في نفس الوقت أدت إلى أقل محتوى من β-pinene (٣٣,٤ ٪)،sabinene (٧,٤ ٪).

لذلك، فإن إضافة سماد سلفات الأمونيوم بمعدل ٢٠٠ كجم نيتروجين/الفدان مع ٢٠ أو ٣٠ طن/الفدان كمبوست و٣٠٠ كجم كبريت/الفدان كانت أفضل معاملة أدت إلى زيادة إنتاج وجودة الزيت الطيار لنبات الآشيليا النامي تحت ظروف الأراضي المستصلحة.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (62) العدد الثالث (يوليو2011): 342-354.