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Effect of different planting locations in Egypt on volatile oil of geranium (*Pelargonium graveolens* L.) plant

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Abstract: This work was carried out during the two successive seasons (2012/2013 and 2013/2014) to investigate the effect of different planting locations on quantity and quality of *Pelargnium graveolens* L. volatile oil. The experiment was conducted at five different locations in Egypt in newly reclaimed lands as follows: North Sinai Governorate (El-Qantara Sharq), El-Monofia Governorate (El-Sadat City), Matrouh Governorate (Siwa Oasis - Khamisa Village), Beni-Suef Governorate (West of Semsta Center) and Giza Governorate (El-Bahariya Oasis - Mandisha Village). Results indicated that all studied parameters such as essential oil percentage, essential oil yield per feddan, essential oil chemical composition and essential oil quality factors (citronellol content, geraniol content and citronellol : geraniol ratio) were affected and varied according to planting location and harvesting time. The best locations for production of geranium oil were El-Qantara Sharq followed by El-Sadat City and then Beni-Suef Governorate locations.

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INTRODUCTION

Pelargonium graveolens plant (Geraniaceae family) is native to South Africa, introduced and cultivated widely (Algeria, Morocco, Madagascar, Réunion, Russia, China, Egypt and Guinea). *Pelargonium graveolens* produces the main commercial oil of geranium in the world with a rose fragrance which is particularly in demand (Pitman, 2004 and Groom, 2012).

Geranium (*Pelargonium graveolens*) oil is one of the most important essential oils produced in Egypt for the local market and exportation. The current world production of geranium oil is dominated by Egypt and China, with minor quantities available from a range of East and South African origins. Combined annual production for Egypt and China is currently estimated in the range 280 to 350 tons, against a world total in the range 350 to 400 tons. In Egypt it is estimated that the current crop is around 3,500 ha. The oil is obtained by steam distillation of the leaves. It is estimated that around 8,000 families are involved in the production of geranium oil in Egypt; and if all others involved in the whole supply chain are included (middlemen, factory workers etc.), together with dependents, some 30,000 to 35,000 people are dependent on the trade (International Trade Center Report, July 2015).

Geranium oil has many uses in cosmetics, fragrances and flavorings. In aromatherapy it has been attributed beneficial effects in a variety of conditions including menstrual disorders, and as an anti-inflammatory, diuretic, antiseptic, antidepressant, calmative and balancing for the endocrine system. The typical composition of geranium oil would show: citronellol (21-28%), geraniol (14-18%), linalool (10-14%), geranyl acetate (0.3-4.5%), menthone (0.7-2.2%), limonene (0.1-0.6%), geranyl butyrate (0.5-1.3%), myrcene (0.2-0.4%) and pinene (0.18-0.4%) (Clarke, 2009).

The geranium essential oil industry in the world is characterized by a number of difficulties, including lack of stable quality and variability of active ingredients of the oil owing to environmental effects. These results were approved by several authors who reported that quantity and chemical composition of geranium oil is largely affected by planting location and seasonal climatic changes (Rao *et al*., 1990 and 1996; Bhan *et al*., 2006; Juliani *et al*., 2006; Nozipho *et al*., 2006; Dyubeni *et al*., 2012; Kritika *et al*., 2012 and Agriculture, Forestry & Fisheries of Republic of South Africa, 2012).

Egypt climate is arid and semi-arid desert, characterized by hot dry summers, moderate winters, and very little rainfall. In Egypt, production of geranium oil is concentrated in the Beni-Suef location in Upper Egypt and very little information is available about the effect of different planting locations on quantity and chemical composition of geranium oil especially in the newly reclaimed lands.

The Egyptian government‘s policy is concerned to reclaim new lands for increasing the production of medicinal and aromatic plants. Thus, this work was conducted to evaluate the effect of different planting locations on quantity and quality (chemical composition) of volatile oil of

Pelargonium graveolens L. plants to introduce a base line of information for producers and exporters of geranium oil in Egypt.

MATERIALS AND METHODS

This work was carried out during the two successive seasons (2012/2013 and 2013/2014) to investigate the effect of different planting locations on quantity and chemical composition of geranium oil. The field experiment was conducted at five different locations in Egyptian newly reclaimed lands as follows:-

1- North Sinai Governorate (El-Qantara Sharq).
2- El-Monofia Governorate (El-Sadat City).
3- Matrouh Governorate (Siwa Oasis - Khamisa Village).
4- Beni-Suef Governorate (West of Semsta Center).
5-Giza Governorate (El-Bahariya Oasis - Mandisha Village).

The rooted terminal stem cuttings of *Pelargonium graveolens* L. were planted at different locations on November 2012 and 2013 for the first and second seasons, respectively. Planting was done under drip irrigation system in rows 75 cm apart and 50 cm between hills as one plant/hill. In all locations, compost manure was added during soil preparation at a rate of 10 m^3/ feddan. The chemical fertilizers were added as the recommended fertilization dose for geranium plants in sandy soil (Abd El-Wahab, 2002). All agricultural practices were done according to the recommendations of the Egyptian Ministry of Agriculture.

Geranium plants were harvested two times per season, i.e. the first cut (spring cut) was done at flowering period during May to mid-June months while the second one (autumn cut) was carried out on November. Harvesting was done by cutting the vegetative parts of plants 15 cm above the soil surface leaving 2 branches for regrowth.

The experimental layout was a complete randomized block design (5 treatments) with three replicates. L.S.D. test at 0.05 was used to compare the average means of treatments, according to Snedecor and Cochran (1982).

The following data were recorded:-

A- Geographical information about the different locations:

1- GPS data:

The latitude and longitude data for different locations were recorded and are presented in Table (A).

2- Soil analyses:

At the beginning of the experiment, soil samples were collected from the soil surface layer (30 cm) to determine the mechanical and chemical soil properties for different locations. All soil samples were analyzed at the laboratories of Desert Research Center and Soils, Water and Environment Research Institute. The results are shown in Tables (B&C).

3- Irrigation water analyses:

Irrigation water samples were analyzed at the laboratories of Desert Research Center and Soils, Water and Environment Research Institute. The results are illustrated in Table (D).

4- Meteorological Data:

The meteorological data for the different locations during the seasons of 2012/2013 and 2013/2014 are shown in Tables (E, F, G, H and I).

B- Essential oil percentage:

Essential oil percentage was determined in the fresh leaves of geranium plants by hydrodistillation for 3 hours using a Clevenger type apparatus. The essential oil content was calculated as a relative percentage (v/w) (British Pharmacopoeia, 1963).

C - Essential oil yield per feddan (l):

This was calculated as follows: essential oil yield per plant × number of plants/feddan.

D- Essential oil constituents at different locations:

The GC-MS analysis of essential oils was conducted in the second season using Gas Chromatography-Mass Spectrometry instrument at the National Research Center, Egypt. The GC-MS analysis was done with the following specifications. Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TR-5MS column (30 m x 0.32 mm i.d., 0.25 μm film thickness). Analyses were carried out using helium as carrier gas at a flow rate of 1.3 ml/min at a split ratio of 1:10 and the following temperature program: 80ºC for 1 min; rising at 4ºC/min to 300ºC and held for 1min. The injector and detector were held at 220 and 200ºC, respectively. Diluted samples (1:10 hexane, v/v) of 1 μL of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. The separated components of the essential oil were identified by matching with the National Institute of Standards and Technology (NIST) published.

Table (A): The GPS data for different locations.

Locations	Latitude (N)	Longitude (E)
El-Qantara Sharq	30.75	32.50
El-Sadat City	30.44	30.63
Siwa Oasis	29.21	25.40
Beni-Suef Governorate	28.94	30.89
El-Bahariya Oasis	28.36	28.92

Table (B): The mechanical analysis of the soil at the experimental sites.

Locations	Sand (%)	Silt (%)	Clay (%)	Soil texture
El-Qantara Sharq	91.80	5.80	2.40	Sandy
El-Sadat City	86.50	9.00	4.50	Sandy
Siwa Oasis	92.91	5.21	1.88	Sandy
Beni-Suef Governorate	66.00	12	22	Sandy clay
El-Bahariya Oasis	96.75	2.15	1.10	Sandy

Table (C): The chemical analysis of the soil at the experimental sites.

Locations	pH	E.C.	O.M.	Soluble anions (meq/l)				Soluble cations (meq/l)			
		(ds/m)	(%)	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
El-Qantara Sharq	8.2	0.9	0.2	-	0.6	4.9	2.0	2.1	0.9	3.8	0.7
El-Sadat City	8.2	1.5	0.6	-	3.8	5.3	5.6	2.6	2.4	9.2	0.5
Siwa Oasis	7.5	4.1	0.5	-	3.6	31.3	6.1	8.6	7.5	0.2	24.7
Beni-Suef Governorate	8.1	0.7	0.6	-	99.1	0.9	0.5	8.2	4.3	0.9	6.3
El-Bahariya Oasis	7.9	4.0	0.3	-	1.5	3.1	6.6	3.3	5.2	2.2	0.5

Table (D): The chemical analysis of irrigation water at the experimental sites.

Locations	pH	E.C.	Soluble anions (meq/l)				Soluble cations (meq/l)			
		ppm	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
El-Qantara Sharq	7.14	1152.00	-	1.30	13.20	2.50	7.30	2.10	7.37	0.23
El-Sadat City	7.83	403.28	-	2.86	2.35	1.23	1.87	1.38	3.06	0.13
Siwa Oasis	7.41	2155.00	-	3.63	16.87	14.43	7.27	4.50	22.12	1.04
Beni-Suef Governorate	7.36	571.20	-	3.09	4.23	1.71	2.41	1.68	4.54	0.40
El-Bahariya Oasis	7.33	314.00	-	2.15	1.95	0.90	2.89	1.00	0.98	0.13

Table (E): Means of the meteorological data of El-Qantara Sharq location during the seasons of 2012/2013 and 2013/2014.

Month		Air temperature (^oC)			Solar (MJ/m^2)	Precipitation (mm)	Relative Humidity (fraction)	Wind (m/s)
		Max.	Min.	Average				
Winter months	21to31December	20.05	8.64	14.35	11.23	0.56	0.6564	1.34
	January	19.73	8.49	14.11	12.75	0.85	0.6747	1.44
	February	21.72	8.71	15.22	16.25	0.54	0.6379	1.57
	1 to 19-20 March	25.76	10.81	18.29	19.16	0.22	0.5223	1.91
Mean		21.82	9.16	15.49	14.85	0.54	0.6228	1.57
Spring months	20-21to31 March	27.11	9.31	18.21	23.99	0.00	0.5633	1.94
	April	28.70	11.30	20.00	25.61	0.04	0.5461	1.89
	May	33.04	14.82	23.94	27.44	0.37	0.5228	1.82
	1 to 20 June	34.55	16.00	25.28	28.84	0.02	0.5316	1.87
Mean		30.85	12.86	21.86	26.47	0.12	0.5410	1.88
Summer months	21 to 30 June	36.11	16.41	26.26	29.51	0.01	0.5905	1.72
	July	35.62	17.54	26.58	28.93	0.00	0.6114	1.70
	August	36.82	18.50	27.66	27.00	0.00	0.6175	1.62
	1to22 September	34.60	18.54	26.57	23.88	0.00	0.6351	1.68
Mean		35.79	17.75	26.77	27.33	0.00	0.6136	1.68
Autumn months	23to30September	30.69	15.75	23.22	20.19	0.03	0.6630	1.52
	October	29.99	15.71	22.85	18.52	0.01	0.6313	1.72
	November	26.81	14.13	20.47	13.52	0.28	0.6448	1.46
Mean		29.16	15.20	22.18	17.41	0.12	0.6464	1.57

Table (F): Means of the meteorological data of El-Sadat City location during the seasons of 2012/2013 and 2013/2014.

Month		Air temperature (^oC)			Solar (MJ/m^2)	Precipitation (mm)	Relative Humidity (fraction)	Wind (m/s)
		Max.	Min.	Average				
Winter months	21to31December	19.87	8.61	14.24	12.02	0.15	0.6312	2.72
	January	20.37	8.21	14.29	13.14	0.32	0.6166	2.70
	February	22.56	8.53	15.55	16.85	0.09	0.5975	2.94
	1 to 19-20 March	26.00	10.54	18.27	19.36	0.17	0.4965	3.63
Mean		22.20	8.97	15.59	15.34	0.18	0.586	3.00
Spring months	20-21to31 March	28.41	9.86	19.14	24.66	0.01	0.4859	3.38
	April	30.03	12.24	21.14	25.98	0.07	0.4778	3.40
	May	34.74	16.50	25.62	27.42	0.08	0.4426	3.41
	1 to 20 June	36.42	18.13	27.28	29.39	0.01	0.4551	3.62
Mean		32.40	14.18	23.30	26.86	0.04	0.4654	3.45
Summer months	21 to 30 June	37.68	18.59	28.14	29.90	0.01	0.5121	3.56
	July	37.06	18.97	28.02	29.33	0.00	0.5350	3.50
	August	38.25	19.89	29.07	27.44	0.00	0.5408	3.06
	1to22 September	36.18	19.09	27.64	24.41	0.00	0.5498	3.22
Mean		37.29	19.14	28.22	27.77	0.00	0.5344	3.34
Autumn months	23to30September	32.94	16.77	24.86	21.50	0.00	0.5834	2.59
	October	30.73	16.00	23.37	18.96	0.01	0.5751	3.18
	November	26.94	14.09	20.52	13.46	0.08	0.6023	2.69
Mean		30.20	15.62	22.92	17.97	0.03	0.5869	2.82

Table (G): Means of the meteorological data of Siwa Oasis location during the seasons of 2012/2013 and 2013/2014.

Month		Air temperature (°C)			Solar (MJ/m^2)	Precipitation (mm)	Relative Humidity (fraction)	Wind (m/s)
		Max.	Min.	Average				
Winter months	21to31December	19.21	8.13	13.67	12.73	0.01	0.6293	3.28
	January	19.24	7.86	13.55	13.89	0.20	0.5438	3.03
	February	21.74	8.64	15.19	18.77	0.02	0.4591	3.44
	1 to 19-20 March	25.95	11.17	18.56	22.45	0.00	0.3835	4.18
Mean		21.54	8.95	15.24	16.96	0.01	0.5039	3.48
Spring months	20-21to31 March	29.27	12.37	20.82	25.27	0.00	0.3070	4.08
	April	30.69	12.67	21.68	27.37	0.01	0.3323	3.57
	May	35.87	18.25	27.06	28.59	0.06	0.2721	3.84
	1 to 20 June	37.62	18.88	28.25	29.93	0.02	0.2963	3.94
Mean		33.36	15.54	24.45	27.79	0.02	0.3019	3.86
Summer months	21 to 30 June	39.24	18.44	28.84	30.48	0.00	0.3143	3.72
	July	38.68	18.47	28.58	29.82	0.00	0.3670	3.46
	August	38.93	19.35	29.14	28.00	0.00	0.3631	3.25
	1to22 September	37.50	18.51	28.01	25.17	0.00	0.3948	3.48
Mean		38.59	18.69	28.64	28.37	0.00	0.3598	3.48
Autumn months	23to30September	34.54	17.83	26.19	23.01	0.00	0.4302	3.08
	October	30.62	14.86	22.74	19.74	0.00	0.5082	3.32
	November	26.07	12.25	19.16	15.01	0.01	0.5411	2.87
Mean		30.41	14.98	22.70	19.25	0.00	0.4932	3.09

Table (H): Means of the meteorological data of Beni-Suef Governorate location during the seasons of 2012/2013 and 2013/2014.

Month		Air temperature (°C)			Solar (MJ/m^2)	Precipitation (mm)	Relative Humidity (fraction)	Wind (m/s)
		Max.	Min.	Average				
Winter months	21to31December	20.12	5.71	12.92	12.09	0.15	0.6610	1.63
	January	21.54	5.22	13.38	13.95	0.07	0.6129	1.68
	February	24.18	6.41	15.30	18.00	0.05	0.5501	1.90
	1 to 19-20 March	27.98	9.40	18.69	21.14	0.02	0.4296	2.32
Mean		23.46	6.69	15.07	16.30	0.07	0.5634	1.88
Spring months	20-21to31 March	30.82	9.39	20.11	25.28	0.00	0.3790	2.33
	April	31.88	12.15	22.02	27.05	0.02	0.3768	2.50
	May	36.80	17.38	27.09	28.42	0.03	0.3068	2.68
	1 to 20 June	38.25	18.64	28.45	29.94	0.00	0.3246	2.79
Mean		34.44	14.39	24.42	27.67	0.01	0.3468	2.58
Summer months	21 to 30 June	39.24	19.85	29.55	30.31	0.00	0.3580	3.09
	July	38.73	19.13	28.93	29.61	0.00	0.4076	2.77
	August	39.41	20.00	29.71	27.92	0.00	0.3931	2.50
	1to22 September	37.48	19.05	28.27	24.96	0.00	0.4434	2.71
Mean		38.72	19.51	29.12	28.20	0.00	0.4005	2.77
Autumn months	23to30September	34.55	18.10	26.33	22.63	0.00	0.4720	2.57
	October	32.16	15.83	24.00	19.88	0.00	0.4892	2.64
	November	28.27	12.47	20.37	14.83	0.05	0.5493	1.96
Mean		31.66	15.47	23.57	19.11	0.02	0.5035	2.39

Table (I): Means of the meteorological data of El-Bahariya Oasis location during the seasons of 2012/2013 and 2013/2014.

Month		Air temperature (°C)			Solar (MJ/m^2)	Precipitation (mm)	Relative Humidity (fraction)	Wind (m/s)
		Max.	Min.	Average				
Winter months	21to31December	17.79	6.85	12.32	13.99	0.19	0.6293	2.90
	January	18.54	6.90	12.72	15.01	0.06	0.5568	2.65
	February	21.07	7.52	14.30	19.58	0.00	0.4685	2.99
	1 to 19-20 March	25.57	10.68	18.13	23.30	0.00	0.3751	3.60
Mean		20.74	7.99	14.37	17.97	0.06	0.5074	3.04
Spring months	20-21to31 March	28.10	10.96	19.53	26.21	0.00	0.3202	3.15
	April	29.68	12.64	21.16	28.00	0.01	0.3214	3.27
	May	34.85	17.54	26.20	29.27	0.03	0.2776	3.58
	1 to 20 June	36.40	18.97	27.69	30.46	0.00	0.2975	3.69
Mean		32.26	15.03	23.65	28.49	0.01	0.3042	3.42
Summer months	21 to 30 June	37.15	18.11	27.63	30.93	0.00	0.3364	3.95
	July	36.63	18.75	27.69	30.28	0.00	0.3635	3.56
	August	37.40	19.39	28.40	28.63	0.00	0.3532	3.22
	1to22 September	35.47	17.96	26.72	25.92	0.00	0.4118	3.58
Mean		36.66	18.55	27.61	28.94	0.00	0.3662	3.58
Autumn months	23to30September	32.64	16.62	24.63	23.78	0.00	0.4613	3.14
	October	29.48	14.46	21.97	20.81	0.00	0.5006	3.63
	November	25.47	12.29	18.88	15.85	0.01	0.5399	2.83
Mean		29.20	14.46	21.83	20.15	0.00	0.5006	3.20

RESULTS AND DISCUSSIONS

1. Essential oil percentage:

Data presented in Table (1) and illustrated in Fig. (1 and 2) show the effect of different planting locations on volatile oil percentage for *Pelargonium graveolens* L. in both seasons (2012/2013 and 2013/2014).

1.a. First cut (spring season cut):

In the first cut (spring season cut), there was a general increment in essential oil percentage accompanied by increasing in air temperature (warmth of climate) and increasing of solar radiation during spring season especially at southern locations in the country where the air temperature and solar radiation are increased.

The lowest essential oil percentage was recorded at El-Sadat City location in the North of Egypt (0.10%) (maximum air temperature 32.40ºC, minimum air temperature 14.18ºC and solar radiation 26.86 MJ/m^2). On the other side, the highest essential oil percentage was recorded in the southern location in Egypt at Beni-Suef Governorate location (0.30%) (maximum air temperature 34.44ºC, minimum air temperature 14.39ºC and solar radiation 27.67MJ/m^2) followed by El-Bahariya Oasis location (0.25%) (maximum air temperature 32.26ºC, minimum air temperature 15.03ºC and solar radiation 28.49MJ/m^2) and then Siwa Oasis location (0.22%) (maximum air temperature 33.36ºC, minimum air temperature 15.54ºC and solar radiation 27.79MJ/m^2). The differences were significant between the different locations.

These results coincided with those obtained by Weiss (1997) who described geranium as a plant that produces high oil content under warm sunny conditions.

Table (1): The mean values of geranium essential oil percentage at different locations in both seasons (2012/2013 and 2013/2014).

Location	First cut (spring cut)	Second cut (autumn cut)
El-Qantara Sharq	0.26	0.20
El-Sadat City	0.10	0.35
Siwa Oasis	0.22	0.09
Beni-Suef Governorate	0.30	0.30
El-Bahariya Oasis	0.25	0.10
L.S.D. at 0.05	0.02	0.02

1.b. Second cut (autumn season cut):

In the second cut (autumn season cut), there was a sharp decrease in essential oil percentage at Siwa Oasis (0.09%) and El-Bahariya Oasis (0.10%) locations. This may be due to that the summer months in the Egyptian Oases are hot and dry (characterized by the lowest amount of atmospheric humidity) where the average of relative humidity were 0.3598 and 0.3662, maximum air temperature were 38.59ºC and 36.66ºC, precipitation (0.00 and 0.00) and wind speed (3.48 m/s and 3.58 m/s) at Siwa and El-Bahariya Oases, respectively. In such locations, during summer season, the crop was subjected to a thermal atmospheric stress which made a negative effect on oil concentration during the next cut (autumn cut).

These results were in agreement with those obtained by Guenther (1950) who described the importance of atmospheric humidity on growth of geranium plants. He reported that geranium requires a certain amount of atmospheric humidity. He mentioned that at Réunion Island the plant grows well in those parts of which are neither too moist nor too dry.

Excessive moisture causes rust. Prolonged spells of drought weather, causes yield of oil diminishes greatly. The temperate sections of the island, where the atmosphere contains sufficient moisture (slight sea breezes or dew), are those best suited for cultivation of geranium. Also, he mentioned that geranium plants were originated to South Africa and imported to Egypt from Grasse region in southern France.

Rao *et al*., (1996) discussed the summer thermal stress on geranium plants and mentioned that geranium oil is biosynthesized as a secondary plant metabolite from the products of photosynthesis. The low concentrations of essential oil during summer months, therefore, appear to be due to:

(a) the restricted availability of photosynthatyes for essential oil synthesis due to suboptimal levels of photosynthesis during summer.

(b) the low proportion of essential oil rich young and expanding leaves in the harvested biomass and

(c) the probable turnover (catabolism) of essential oil in response to the seasonal stress.

On the other hand, the highest essential oil percentage was obtained at the locations which are characterized by a temperate climate and a suitable atmospheric humidity during summer and autumn seasons. The highest essential oil concentration was recorded at El-Sadat City (0.35%) followed by Beni-Suef Governorate (0.30%) and then El-Qantara Sharq (0.20%) locations, respectively. The differences were significant between the different locations.

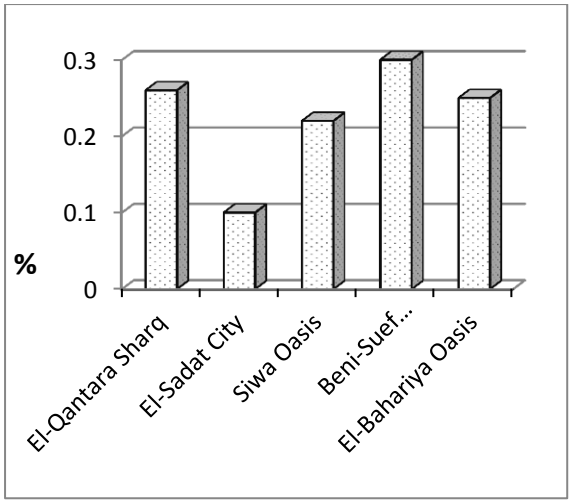


Fig. (1): Effect of different planting locations on geranium essential oil percentage (spring cut).

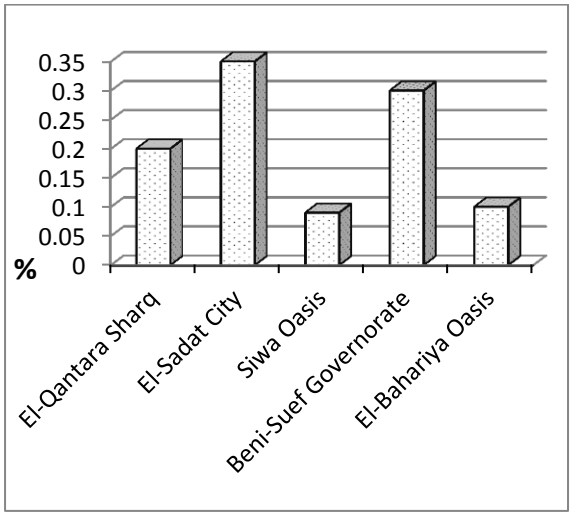


Fig. (2): Effect of different planting locations on geranium essential oil percentage (autumn cut).

2. Essential oil yield per feddan (l):

Data presented in Table (2) revealed that the oil yield per feddan varied clearly according to planting location and harvest time.

Table (2): The mean values of geranium essential oil yield/feddan (l) at different locations in both seasons (2012/2013 and 2013/2014).

Location	First cut (spring cut)	Second cut (autumn cut)	Total oil yield per year (l)
El-Qantara Sharq	20.97	17.40	38.37
El-Sadat City	9.33	23.52	32.85
Siwa Oasis	6.21	3.02	9.23
Beni-Suef Governorate	22.85	13.44	36.29
El-Bahariya Oasis	14.56	2.33	16.89
L.S.D. at 0.05	1.13	1.35	1.90

In most locations, the highest essential oil yield per feddan was obtained in spring cut while the lowest oil yield was obtained in autumn cut. These values were 20.97, 6.21, 22.85 and 14.56 l/fed. in spring cut and 17.40, 3.02, 13.44 and 2.33 l/fed. in autumn cut at El-Qantara Sharq, Siwa Oasis, Beni-Suef Governorate and El-Bahariya Oasis locations, respectively. This was in line with the results of essential oil percentage since the increasing of heat stress during summer months led to a negative effect on plants and a decrease in essential oil percentage as discussed before.

From the aforementioned data the highest total oil yield per year was obtained at El-Qantara Sharq (38.37 l/fed.), Beni-Suef Governorate (36.29 l/fed.) and El-Sadat City (32.85 l/fed.) locations. Thus, such locations can be chosen as economic production areas for production of geranium oil. The differences were significant between the different locations.

Similar results were obtained by Solomon *et al*. (2015) who discussed the problem of climatic changes for agriculture and reported that current climate-change models forecast that agricultural productivity will increase in some areas and decline in others.

3. Constituents of *Pelargonium graveolens* L. volatile oil:

The obtained results indicated that the chemical composition of *Pelargonium graveolens* volatile oil had been affected by the different planting locations and harvesting time (Fig. 3 and Tables 3 and 4). These results can be summarized as follows:

At El-Qantara Sharq location the most abundant components in spring cut oil were citronellol (30.58%), geraniol (21.42 %), citronellyl formate (10.82%), 10-epi-ç-eudesmol (8.55%), L-linalool (7.70%), l-menthone (6.83%) and geranyl formate (3.78%) while in autumn cut oil the abundant constituents were citronellol (29.97%), geraniol (17.31 %), citronellyl formate (10.31%), 10-epi-ç-eudesmol (10.20%), L-linalool (9.47%), l-menthone (8.05%) and geranyl formate (2.09%).

At El-Sadat City location the major components in spring cut oil were citronellol (29.22%), L-linalool (15.18%), 10-epi-ç-eudesmol (12.41%), geraniol (11.83%), citronellyl formate (11.07%), l-menthone (7.12%), geranyl formate (1.51%) and à terpineol (1.33%) while in autumn cut oil the major components were citronellol (29.02%), geraniol (14.80 %), 10-epi-ç-eudesmol (14.29%), citronellyl formate (12.88%), l-menthone (7.06%), geranyl formate (3.63%), L-linalool (3.34%), and germacrene-D (3.01%).

At Siwa Oasis location the dominant components in spring cut oil were citronellol (35.12%), 10-epi-ç-eudesmol (16.83%), citronellyl formate (10.09%), l-menthone (6.35%), geraniol (3.29%), germacrene-D (2.96%), aristolenepoxide (1.89 %),

4-epi-cubedol (1.67%), caryophyllene (1.55 %), eudesm-4(14)-en-11-ol (1.32%), à-pinene (1.13%), geranyl formate (1.11%) and (-)-aristolene (1.07%). On the other hand in autumn cut oil the dominant constituents were citronellol (26.21%), geraniol (18.78%), 10-epi-ç-eudesmol (14.28%), citronellyl formate (11.48%), L-linalool (4.94%), l-menthone (4.37%), geranyl formate (3.13%), germacrene-D (2.05%) and eudesm-4(14)-en-11-ol (1.24%).

At Beni-Suef Governorate location the main constituents in spring cut oil were citronellol (43.17%), citronellyl formate (10.79%),10-epi-ç-eudesmol (9.16%), L-linalool (8.33%), l-menthone (7.71%), geraniol (6.55%) and rose oxide (2.04%) while in autumn cut oil the main constituents were citronellol (36.05%), geraniol (16.32%), 10-epi-ç-eudesmol (13.55 %), citronellyl formate (11.28%), l-menthone (6.11%), geranyl formate (3.31%), L-linalool (2.92%) and eudesm-4(14)-en-11-ol (1.03%).

At El-Bahariya Oasis location the highest components in spring cut oil were citronellol (30.64%), 10-epi-ç-eudesmol (15.36%), citronellyl formate (13.63%), L-linalool (8.01%), geraniol (7.79%), l-menthone (6.11%), geranyl formate (1.72%) and eudesm-4(14)-en-11-ol (1.66%) while in autumn cut oil the highest constituents were citronellol (30.48%), 10-epi-ç-eudesmol (15.23%), citronellyl formate (13.23%), geraniol (8.43%), L-linalool (7.92%), l-menthone (5.96%), geranyl formate (1.74%), eudesm-4(14)-en-11-ol (1.71%) and (-)-aristolene (1.04%).

These results were in agreement with those obtained by Rao *et al*. (1996) who found that seasonal climatic factors changed the terpenoid composition of rose-scented geranium (*Pelargonium* species) oil. Motsa (2006) reported that beside the seasons' influence on rose-scented geranium oil composition, there is also influence of geographic location where the crop is grown. Duybeni *et al*. (2012) revealed that the chemical composition of rose-scented geranium oil differed with harvesting time at different planting sites. Kritika *et al*. (2013) on *Pelargonium graveolens* found that various geographical regions and the different seasons have a considerable impact on the geraniol concentration in the oil.

Also, the main chemical constituents of extracted geranium oils are coincided by those identified by Guenther (1950) who reported that the chief constituents of geranium oil are geraniol and citronellol. Abd El-Wahab (2002) found that the chemical constituents of geranium oil are citronellol, geraniol, linalool, geranyl formate, menthol, geranyl butrate, geranyl tiglate and eugenol. Fayed (2009) reported that the major compounds of geranium oil are citronellol, trans-geraniol, 10-epi-γ-eudesmol, isomenthone and linalool. Verma *et al*. (2010) mentioned that the chemical composition of *Pelargonium graveolens* oil is citronellol, geraniol, linalool, iso-menthone, citronellyl formate, 10-epi-γ-eudesmol and geranyl formate. Sharopove *et al*. (2014) indicated that the main constituents of *Pelargonium graveolens* essential oil are citronellol, geraniol, caryophyllene, menthone, linalool, β-bourbonene, iso-menthone and geranyl formate.

4. Quality of *Pelargonium graveolens* L. volatile oil:

Rose-like odour of geranium oil is a mixture of citronellol, geraniol and other alcohols (rhodinol). The quality of geranium oil is mainly determined by citronellol content, geraniol content and the ratio of citronellol:geraniol (Table 5).

A) Citronellol content:

Citronellol content is a very important feature of the evaluation of geranium oil (Guenther, 1972). Citronellol is used in perfumes and insect repellent (Taylor and Schreck 1985). The results indicated that the citronellol content was affected by planting location and harvest time. In most locations the highest citronellol content was obtained in spring cut while the lowest contents were obtained in autumn cut. These values were 30.58, 29.22, 35.12, 43.17 and 30.64% in spring cut and 29.97, 29.02, 26.21, 36.05 and 30.48 % in autumn cut at El-Qantara Sharq, El-Sadat City, Siwa Oasis, Beni-Suef Governorate and El-Bahariya Oasis locations, respectively. This may be due to that the increase in air temperature favor the accumulation of citronellol content (Doimo *et al*., 1999 and Motsa, 2006).

B) Geraniol content:

Geraniol content was affected by planting location and harvest time. In most locations the highest geraniol content was obtained in autumn cut while the lowest values were obtained in spring cut. These values were 11.83, 3.29, 6.55 and 7.79% in spring cut and 14.80, 18.78, 16.32 and 8.43 % in autumn cut at El-Sadat City, Siwa Oasis, Beni-Suef Governorate and El-Bahariya Oasis locations, respectively. This may be due to that the decrease in air temperature favors the accumulation of geraniol content (Motsa, 2006).

C) Citronellol : geraniol ratio:

Citronellol : geraniol ratio (Table 5) is a key parameter determining the quality of geranium oil for perfume industry. A C:G ratio of 1:1 – 3:1 is acceptable, while the most desirable ratio is 1:1. Oil with a C:G ratio of more than 3:1 is considered to be of poor quality for the perfume industry, but it can still be used by other industries for the

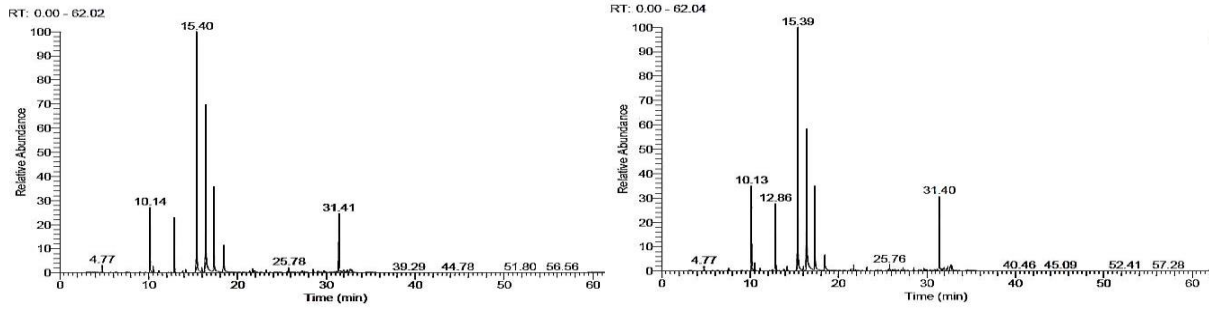
manufacture of creams, soaps, toiletries and aromatherapy products (Nejad and Ismaili, 2014).

The results indicated that the C:G ratio was affected by planting location and harvest time. The citronellol : geraniol ratio was within the desired limit at El-Qantara Sharq location (1.43 and 1.73 in spring and autumn cuts, respectively), El-Sadat City location (2.47 and 1.96 in spring and autumn cuts, respectively), Siwa Oasis location (1.40) and Beni-Suef Governorate location (2.21) in autumn cuts, respectively.

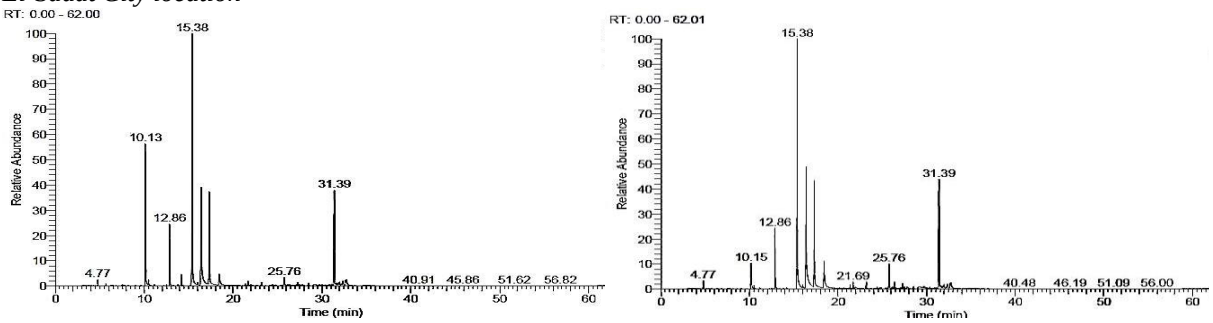
From the aforementioned results the producers can choose the location and manipulate the harvesting time to suit their desired oil composition. These results were in a parallel line with those obtained by Dyubeni *et al*., 2012 and Moustafa and Abdel-Wahab, 2016.

The current exported Egyptian geranium oil is remarkable by its chief chemical constituents of citronellol (25-36%), geraniol (10-18%), 6,9-guaiadiene </=0.5% and 10-epi λ eudesmol (International Trade Center Report, July 2015). Therefore, most of chemical compositions of these oils are in the acceptable range.

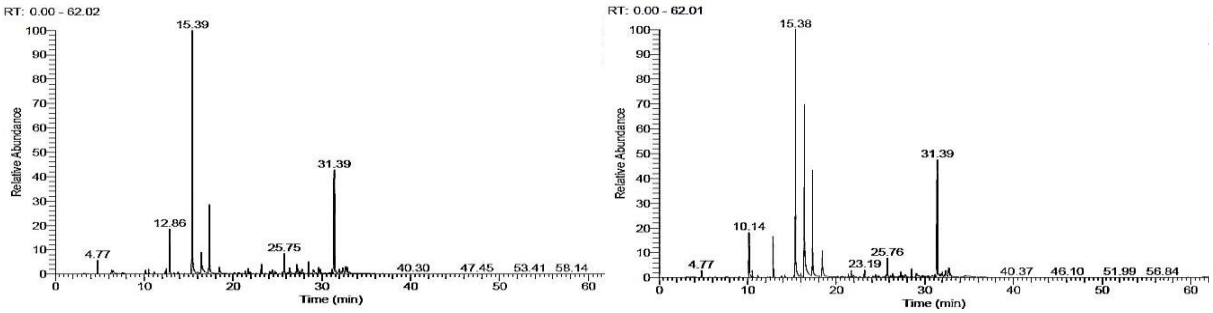
El-Qantara Sharq location



El-Sadat City location



Siwa Oasis location



Beni-Suef location

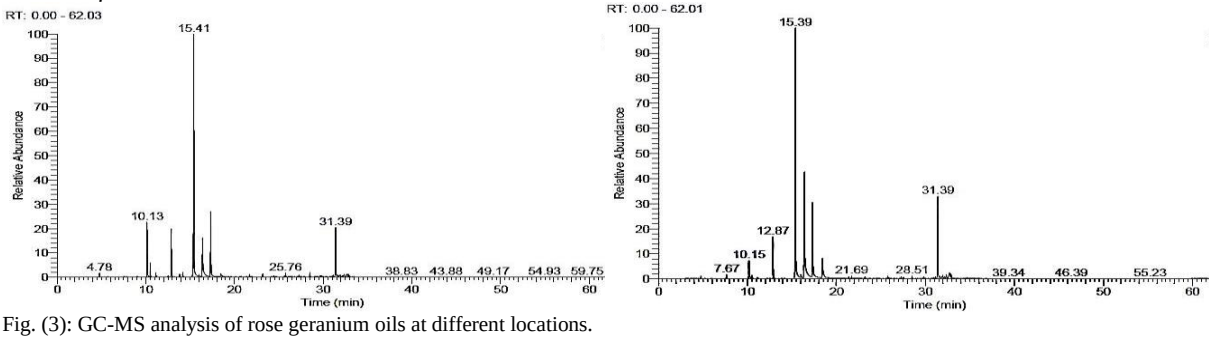
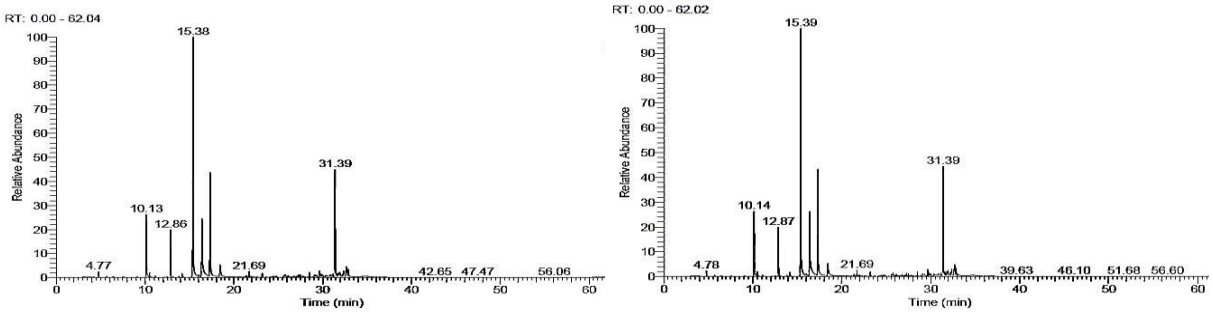


Fig. (3): GC-MS analysis of rose geranium oils at different locations.

El-Bahariya Oasis location



(Spring cut) (Autumn cut)

Fig. (3): *continue*

Table (3): Chemical constituents (%) of essential oil at different locations (spring cut).

No	R.T.	Constituents	El-Qantara Sharq	El-Sadat City	Siwa Oasis	Beni-Suef	El-Bahariya Oasis
1	4.77	à-pinene	0.54	0.41	1.13	0.41	0.43
2	5.69	2,2-dimethyl-6-methyl-6vinyltetrahydropyran	-	0.18	-	-	-
3	6.31	5-hepten-2-one,6methyl-	-	-	0.67	-	-
4	6.49	6-methyl-hept-5-en-2-ol	-	-	0.38	-	-
5	10.13	L-linalool	7.70	15.18	0.59	8.33	8.01
6	10.50	Rose oxide	0.73	0.56	0.63	2.04	0.51
7	11.14	Cis-rose oxide	0.25	0.15	0.30	0.64	-
8	12.34	Citronella	-	-	0.34	-	-
9	12.50	p-menthan-3-one	-	0.17	0.75	0.22	-
10	12.86	l-menthone	6.83	7.12	6.35	7.71	6.11
11	13.81	Menthol,trans-1,3,cis-1,4-	0.25	0.16	0.27	0.47	-
12	14.16	à terpineol	0.39	1.33	-	0.76	0.53
13	15.26	Nerol	0.26	-	-	-	-
14	15.38	Citronellol	30.58	29.22	35.12	43.17	30.64
15	16.00	à-citral	0.58	0.31	-	0.28	0.25
16	16.38	Geraniol	21.42	11.83	3.29	6.55	7.79
17	17.31	Citronellyl formate	10.82	11.07	10.09	10.79	13.63
18	18.42	Geranyl formate	3.78	1.51	1.11	0.63	1.72
19	20.63	Citronellyl acetate	0.11	-	-	0.16	-
20	21.36	à-copaene	0.21	0.25	0.45	0.16	0.29
21	21.69	à bourbonene	0.49	0.59	0.79	0.50	0.85
22	21.92	Geranyl acetate	0.32	0.16	0.35	-	-
23	23.19	Caryophyllene	0.37	0.45	1.55	0.58	0.61
24	24.11	à-Gurjunene	-	-	0.34	-	-
25	24.33	Citronellyl propionate	-	-	0.28	-	-
26	24.44	Aromadendrene	-	0.17	0.63	0.35	0.22
27	24.70	à-humulene	-	-	0.38	0.15	-
28	25.62	Diepicedren-1-oxid	0.26	-	-	0.19	0.27
29	25.76	Germacrene-D	0.83	0.99	2.96	0.93	0.50
30	26.11	Ledene	-	0.16	-	0.13	0.27
31	26.34	Bicyclogermacrene	-	-	0.81	0.16	-
32	26.75	Dihydro-á-agarofuran	-	-	-	-	0.19
33	27.09	ç-muurolene	0.12	0.14	-	-	0.18
34	27.21	4-epi-cubedol	-	-	1.67	-	-
35	27.27	ë-cadinene	0.24	0.44	-	0.42	0.38
36	27.48	Cadina-1,3,5-triene	0.18	0.26	0.49	0.25	0.33
37	27.76	Citronellyl butyrate	0.22	-	0.89	-	0.27
38	27.80	Eudesma-3,11-diene	-	0.29	-	0.29	-
39	28.50	Aristolenepoxide	0.41	0.35	1.89	0.73	0.83
40	29.02	Geranyl butyrate	0.33	0.20	0.97	0.17	0.45
41	29.67	(+)spathulenol	0.25	0.14	0.96	0.25	0.86
42	29.83	(-)-caryophyllene oxide	0.14	-	0.65	0.19	0.38
43	29.99	Globulol	-	-	-	-	0.24
44	30.32	Veridiflorol	-	-	-	-	0.25
45	30.87	Rosifoliol	0.11	0.14	-	-	0.3
46	31.12	Cubenol	0.17	0.18	0.72	0.30	0.43
47	31.39	10-epi-ç-eudesmol	8.55	12.41	16.83	9.16	15.36
48	31.61	Cubenol	0.14	0.18	-	0.22	0.39
49	31.80	ç-eudesmol	0.17	0.26	-	0.21	0.63
50	31.93	Agarospirol	0.36	0.51	0.79	0.39	0.79
51	32.16	Cubenol	0.13	0.20	0.31	0.23	0.34
52	32.33	(-)-aristolene	0.44	0.62	1.07	0.52	0.99
53	32.61	Guaiol	0.36	0.50	0.76	0.36	0.78
54	32.71	Eudesm-4(14)-en-11-ol	0.53	0.85	1.32	0.60	1.66
55	32.88	Widdrol hydroxyether	0.29	0.23	0.85	0.40	0.99
56	33.07	Ledol	-	-	0.27	-	-
57	34.51	Geranyl tiglate	0.14	0.13	-	-	0.35

Table (4): Chemical constituents (%) of essential oil at different locations (autumn cut).

No	R.T.	Constituents	El-Qantara Sharq	El-Sadat City	Siwa Oasis	Beni-Suef	El-Bahariya Oasis
1	4.77	à-pinene	0.35	0.58	0.45	0.23	0.40
2	7.55	dl-limonene	0.37	-	-	0.11	-
3	7.67	1,8-cineole	-	-	-	0.48	-
4	10.13	L-linalool	9.47	3.34	4.94	2.92	7.92
5	10.50	Rose oxide	0.88	0.34	0.63	0.49	0.50
6	11.14	Cis-rose oxide	0.29	0.15	0.23	0.21	-
7	12.20	(+)-2-bornanone	-	-	-	0.13	-
8	12.50	p-menthan-3-one	0.16	-	-	-	-
9	12.86	l-menthone	8.05	7.06	4.37	6.11	5.96
10	13.81	Menthol,trans-1,3,cis-1,4-	0.23	-	-	0.15	-
11	14.16	à terpineol	0.56	0.16	0.28	0.15	0.52
12	15.26	Nerol	0.16	-	-	-	-
13	15.38	Citronellol	29.97	29.02	26.21	36.05	30.48
14	16.00	à-citral	0.47	0.38	0.34	0.47	0.24
15	16.38	Geraniol	17.31	14.80	18.78	16.32	8.43
16	17.31	Citronellyl formate	10.31	12.88	11.48	11.28	13.23
17	18.42	Geranyl formate	2.09	3.63	3.13	3.31	1.74
18	21.36	à-copaene	0.22	0.46	0.33	0.28	0.28
19	21.69	à bourbonene	0.79	0.89	0.83	0.44	0.82
20	21.92	Geranyl acetate	-	0.21	0.25	0.13	-
21	23.19	Caryophyllene	0.51	0.88	0.86	0.35	0.62
22	24.44	Aromadendrene	0.19	0.22	0.37	0.11	0.22
23	24.70	à-humulene	-	0.15	0.19	-	-
24	24.85	Alloaromadendrene	-	0.18	-	0.10	-
25	25.62	Diepicedren-1-oxid	-	-	-	-	0.28
26	25.76	Germacrene-D	0.79	3.01	2.05	0.45	0.57
27	26.11	Ledene	0.19	0.20	0.18	-	0.27
28	26.34	Bicyclogermacrene	0.17	0.80	0.38	-	-
29	26.75	Dihydro-á-agarofuran	-	-	-	-	0.19
30	27.09	ç-muurolene	-	0.16	0.20	-	-
31	27.27	ë-cadinene	0.43	0.67	0.64	0.25	0.42
32	27.48	Cadina-1,3,5-triene	0.26	0.32	0.35	0.23	0.30
33	27.76	Citronellyl butyrate	0.19	0.48	0.57	-	0.31
34	28.50	Aristolenepoxide	0.45	0.28	0.98	0.42	0.79
35	29.02	Geranyl butyrate	0.24	0.34	0.78	-	0.48
36	29.67	(+) spathulenol	0.31	0.25	0.21	0.16	0.90
37	29.83	(-)-caryophyllene oxide	-	-	-	0.27	0.42
38	29.99	Globulol	-	0.16	-	-	0.40
39	30.32	Veridiflorol	-	0.18	0.18	-	0.26
40	30.43	Veridiflorol	-	-	-	-	0.20
41	30.87	Rosifoliol	0.17	0.15	0.20	0.13	0.27
42	31.12	Cubenol	0.24	-	0.30	0.24	0.41
43	31.39	10-epi-ç-eudesmol	10.20	14.29	14.28	13.55	15.23
44	31.61	Cubenol	0.20	0.16	0.20	0.22	0.40
45	31.80	ç-eudesmol	0.29	0.23	0.32	0.20	0.60
46	31.93	Agarospirol	0.47	0.56	0.67	0.61	0.78
47	32.16	Cubenol	0.20	0.18	0.21	0.20	0.32
48	32.33	(-)-aristolene	0.65	0.61	0.88	0.64	1.04
49	32.61	Guaiol	0.47	0.57	0.67	0.60	0.84
50	32.71	Eudesm-4(14)-en-11-ol	0.89	0.85	1.24	1.03	1.71
51	32.88	Widdrol hydroxyether	0.51	0.22	0.35	0.65	0.94
52	34.51	Geranyl tiglate	0.30	-	0.49	0.33	0.31

Table (5): The quality parameters (as the main constituents) of geranium oil at different locations.

Location	First cut (spring cut)			Second cut (autumn cut)		
	Citronellol %	Geraniol %	C:G ratio	Citronellol %	Geraniol %	C:G ratio
El-Qantara Sharq	30.58	21.42	1.43	29.97	17.31	1.73
El-Sadat City	29.22	11.83	2.47	29.02	14.80	1.96
Siwa Oasis	35.12	3.29	10.67	26.21	18.78	1.40
Beni-Suef Governorate	43.17	6.55	6.59	36.05	16.32	2.21
El-Bahariya Oasis	30.64	7.79	3.93	30.48	8.43	3.62

CONCLUSION

The best locations for cultivation and production of geranium oil were El-Qantara Sharq location (North Sinai) followed by El-Sadat City location and then Beni-Suef Governorate location.

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