# EFFECT OF DIFFERENT PLANTING LOCATIONS IN EGYPT ON *SALVIA FRUTICOSA* MILL. PLANTS

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This work was carried out during the two successive seasons of 2012/2013 and 2013/2014 to study the effect of different planting locations on three-lobed sage (*Salvia fruticosa* Mill.) plants. The experiment was conducted at three different locations in newly reclaimed lands as follows: El-Qantara Sharq (North Sinai Governorate), El-Maghara Village (North Sinai Governorate) and Siwa Oasis (Matrouh Governorate). The results indicated that all herb quantity and quality parameters were varied according to location and harvesting time. The best location for cultivation of this plant was El-Maghara location, which recorded the highest herb quantity parameters (number of cuts per season, fresh and dry weights of herb per plant or per feddan) as well as the highest herb quality parameters (essential oil yield per plant or per feddan with a suitable content of 1,8 cineole compound as the main chemical constituent of the oil), followed by El-Qantara Sharq location and then Siwa Oasis location.

**Keywords:** three–lobed sage, growth, essential oil, North Sinai, Siwa Oasis

Evaluation of the productivity and quality of medicinal and aromatic plants at variable ecosystem locations in Egypt is considered a main target today, especially under current global climate changes problem and its negative impacts on agriculture (Abd El-Wahab, 2013; Amedie, 2013 and FAO, 2015).

*Salvia fruticosa* Mill. (syn. *Salvia triloba* L.f.) or three-lobed sage (syn. Greek sage, Turkish sage) is an interesting medicinal and aromatic shrub belongs to family Lamiaceae, clearly differentiated from *Salvia officinalis* because of its trifoliate leaves. The plant is endemic to the Eastern Mediterranean basin and its total native range extends from Cyrenaica, Sicily and Southern Italy, through the southern part of the Balkan Peninsula to West Syria. On the world market, the main suppliers of three-lobed sage are

Greece, Turkey, Albania, Cyprus and Crete, where most of production is collected from wild populations (Putievsky et al., 1986; Rivera et al., 1994; Kintzios, 2003 and International Trade Center Report, September and December 2015).

In the Middle East, the plant is known as mariamia and it is used widely in folk medicine as a medicinal tea to improve digestion and relieve cold symptoms, a cure for liver diseases, to regulate menstruation, to treat mouth sores, to accelerate wound healing and to relive recall pains. The essential oil isolated from its leaves is antifungal, antibacterial and is mainly composed of 1,8-cineole compound. Considering the importance of this wild plant, some countries in the Middle East; such as Lebanon, regulated wild collection and export *Salvia fruticosa* by ministerial decision 179/1, March 2012. Also, in Israel the plant was marked as a protected plant due to excessive gathering from the wild by healers and users (UNDP, GEF and LARI, 2013; Yaniv and Dudai, 2014 and European Medicines Agency, 2015).

In Egypt, three-lobed sage plants are currently cultivated at small scale in El-Sheikh Zowayed and Rafah locations (North Sinai Governorate) and there is no literature on the effect of different planting locations on quantity and quality of the herb and its essential oil. The government‘s policy is concerned to reclaim new lands and medicinal and aromatic plants are very suitable crops for these lands. So, the aim of this work was to evaluate the production of *Salvia fruticosa* under different locations to introduce a database of information for herbs growers and pharmaceutical industry in the country.

## MATERIALS AND METHODS

This experiment was carried out during the two successive seasons of 2012/2013 and 2013/2014 at three different locations in newly reclaimed lands as follows:

1- North Sinai Governorate (El-Qantara Sharq).
2- North Sinai Governorate (El-Maghara Village).
3- Matrouh Governorate (Siwa Oasis - Khamisa Village).

Seedlings of *Salvia fruticosa* were kindly obtained from El-Sheikh Zowayed Experimental Station, Desert Research Center, North Sinai Governorate. The seedlings were transplanted successfully in the open field at the different locations on March 2012 and 2013 for the first and second seasons, respectively. Planting was carried out 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 sage plants in sandy soil (Abd El-Azim, 2003). All

agricultural practices were done according to the recommendations of the Egyptian Ministry of Agriculture.

The plants were harvested three times per season, i.e. on July, November and March at El-Qantara Sharq and El-Maghara locations, while at Siwa Oasis location two cuts were taken per season, i.e. on November and March. Harvesting was done by cutting the vegetative parts of plants 15 cm above the soil surface leaving two branches for regrowth.

The experimental layout was a complete randomized design (3 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:**

**1. Geographical Information about the Different Locations**

**1.1. GPS data**

The latitude and longitude data for the different locations were recorded and are presented in table (1).

**1.2. 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 the 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 (2 and 3).

**1.3. 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 (4).

**1.4. Meteorological data**

The meteorological data for the different locations during the seasons of 2012/2013 and 2013/2014 are shown in tables (5, 6 and 7).

**Table (1).** The GPS data for the different locations.

| Locations | Latitude (N) | Longitude (E) |
|---|---|---|
| **El-Qantara Sharq** | 30.75 | 32.50 |
| **El-Maghara** | 30.71 | 33.33 |
| **Siwa Oasis** | 29.21 | 25.40 |

**Table (2).** 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-Maghara** | 95.00 | 4.00 | 1.00 | Sandy |
| **Siwa Oasis** | 92.91 | 5.21 | 1.88 | Sandy |

**Table (3).** 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-Maghara** | 7.9 | 2.8 | 0.5 | - | 1.0 | 20.0 | 7.0 | 6.0 | 8.0 | 12.6 | 1.4 |
| **Siwa Oasis** | 7.5 | 4.1 | 0.5 | - | 3.6 | 31.3 | 6.1 | 8.6 | 7.5 | 0.2 | 24.7 |

**Table (4).** 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-Maghara** | 7.32 | 2547.15 | - | 4.26 | 23.59 | 11.44 | 11.45 | 9.64 | 17.31 | 0.89 |
| **Siwa Oasis** | 7.41 | 2155.00 | - | 3.63 | 16.87 | 14.43 | 7.27 | 4.50 | 22.12 | 1.04 |

**Table (5).** 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** | 23to30 September | 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 (6).** Means of the meteorological data of El-Maghara location during the seasons of 2012/2013 and 2013/2014.

| Month | | Air temperature ($^{o}$C) | | | Solar (MJ/m$^{2}$) | Precipitation (mm) | Relative humidity (fraction) | Wind (m/s) |
|---|---|---|---|---|---|---|---|---|
| | | Max. | Min. | Average | | | | |
| **Winter months** | 21to31December | 17.52 | 4.88 | 11.20 | 12.77 | 0.01 | 0.62 | 2.17 |
| | January | 18.17 | 5.62 | 11.90 | 13.84 | 0.20 | 0.58 | 2.36 |
| | February | 20.54 | 6.30 | 13.42 | 18.06 | 0.16 | 0.52 | 2.53 |
| | 1 to 19-20 March | 23.31 | 8.01 | 15.66 | 21.83 | 0.32 | 0.46 | 3.28 |
| **Mean** | | 19.89 | 6.20 | 13.05 | 16.63 | 0.17 | 0.55 | 2.59 |
| **Spring months** | 20-21to31 March | 25.20 | 6.99 | 16.10 | 25.45 | 0.00 | 0.47 | 2.79 |
| | April | 28.72 | 9.45 | 19.09 | 27.71 | 0.00 | 0.40 | 3.07 |
| | May | 33.66 | 13.49 | 23.58 | 29.23 | 0.00 | 0.36 | 3.11 |
| | 1 to 20 June | 36.36 | 14.87 | 25.62 | 30.83 | 0.00 | 0.37 | 2.95 |
| **Mean** | | 30.99 | 11.20 | 21.10 | 28.31 | 0.00 | 0.40 | 2.98 |
| **Summer months** | 21 to 30 June | 36.72 | 15.61 | 26.17 | 30.80 | 0.00 | 0.41 | 2.60 |
| | July | 36.90 | 15.57 | 26.24 | 30.26 | 0.00 | 0.45 | 2.64 |
| | August | 36.55 | 15.94 | 26.25 | 28.45 | 0.00 | 0.45 | 2.50 |
| | 1to22 September | 34.59 | 15.02 | 24.81 | 25.13 | 0.00 | 0.56 | 2.71 |
| **Mean** | | 36.19 | 15.54 | 25.87 | 28.66 | 0.00 | 0.47 | 2.61 |
| **Autumn months** | 23to30 September | 32.71 | 14.15 | 23.43 | 22.65 | 0.00 | 0.59 | 2.32 |
| | October | 29.54 | 11.93 | 20.74 | 19.79 | 0.01 | 0.57 | 2.35 |
| | November | 25.04 | 10.79 | 17.92 | 14.82 | 0.04 | 0.57 | 2.16 |
| **Mean** | | 29.10 | 12.29 | 20.70 | 19.09 | 0.02 | 0.58 | 2.28 |

**Table (7).** 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** | 23to30 September | 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 |

**2. Quantity Parameters of Three-lobed Sage Herb**

- Number of cuts per season.
- Fresh weight of herb/plant (g).
- Dry weight of herb/plant (g).
- Dry weight of herb/fed (ton).

**3. Quality Parameters of Essential Oil of Three-lobed Sage Herb**

**3.1. Essential oil percentage**

Essential oil percentage was determined in the air dried herb by hydrodistillation for 3 hours using a Clevenger type apparatus. The essential oil (%) was calculated as a relative percentage (v/w) (British Pharmacopoeia, 1963).

**3.2. Essential oil yield per plant**

Essential oil yield per plant (ml) was calculated as follows:

$$\frac{\text{oil percentage} \times \text{herb dry weight (g/plant)}}{100}$$

### 3.3. Essential oil yield per feddan

Essential oil yield per feddan (l) was calculated as follows :essential oil yield per plant × number of plants/feddan (11200 plants/feddan).

### 3.4. Essential oil chemical constituents

The GC-MS analysis of essential oils was conducted in the second season using Gas Chromatography-Mass Spectrometry instrument stands at the Laboratory of Medicinal and Aromatic Plants, National Research Center, Egypt 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 $\mu$m 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 1 min. The injector and detector were held at 220 and 200ºC, respectively. Diluted samples (1:10 hexane, v/v) of 1 $\mu$L 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.

## RESULTS AND DISCUSSION

### 1. Effect of Different Locations on Quantity Parameters of Three-lobed Sage Herb

Data of the effect of different planting locations on quantity parameters of three-lobed sage herb are shown in tables (8, 9 and 10).

The obtained results indicated that all herb quantity parameters (number of cuts per season, fresh weight of herb/plant, dry weight of herb/plant and dry weight of herb/fed) were affected and varied according to the different planting locations.

These variations in herb productivity may be due the existence of a wide range of climatic conditions among the different studied locations. At North Sinai Governorate, there was an increment in the yield quantity parameters accompanied with increasing air temperature and solar radiation, especially at southern locations in Sinai where the air temperature and solar radiation are increased (Tables 5 and 6). The significantly highest yield parameters were obtained at El-Maghara location at the middle of Sinai Peninsula (30.71º N and 33.33º E), while lower parameters were recorded at El-Qantara Sharq at the North of Sinai (30.75º N and 32.50º E) for the three cuts in both seasons.

On the contrary, at Siwa Oasis location, which is located in the western desert of Egypt (29.21º N and 25.40ºE, 300 km South of the Mediterranean Sea and -19 m below sea level), the extremely high air

temperature during summer months (Table 7) led to a heat or thermal stress on plants and therefore, the lowest yield parameters were detected at this location; i.e. lowest number of cuts per season (two cuts per season) as well as the lowest fresh and dry weights of herb/plant during both seasons.

Similar results were obtained by Roberts and Summerfield (1987), who mentioned that, the rate of plant development is a function of temperature and usually increases linearly from above the species-specific base temperature until the optimum temperature. Kintzios (2003), on wild *Salvia fruticosa* plants, reported that the plants were affected by the mean annual temperature and the total annual sunshine at the different growing locations. Mastro et al. (2006), Zawislak (2006) and Hückstädt et al. (2013) found that, the interactive effects of light with temperature play an important role on plant growth of *Salvia officinalis*. Also, these results are in harmony with the earlier publications on cultivation of wild three-lobed sage plants by Putievsky et al. (1986), who found that the fresh matter yield in the first year of growth increased in each harvest, but from the second year there was a special pattern. In spring, the fresh yield was the highest.

In general, the superiority of North Sinai Governorate locations for cultivation and production of the highest herb yield may be due to that the environmental conditions at North Sinai are to some extent similar to the environmental conditions of some countries like Palestine, Syria, Lebanon and Jordan, where three-lobed sage plants are grown as wild plants (Khan and Ather, 2006).

**Table (8).** Effect of different locations on fresh weight of herb/plant (g) of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| **Location** | **First season (2012/2013)** | | | **Second season (2013/2014)** | | |
|---|---|---|---|---|---|---|
| | **Harvesting date** | | | **Harvesting date** | | |
| | **July 2012 (summer cut)** | **November 2012 (autumn cut)** | **March 2013 (spring cut)** | **July 2013 (summer cut)** | **November 2013 (autumn cut)** | **March 2014 (spring cut)** |
| El-Qantara Sharq | 133.87 | 207.87 | 270.23 | 134.04 | 173.33 | 216.40 |
| El-Maghara | 250.18 | 293.00 | 345.03 | 290.00 | 330.11 | 386.09 |
| Siwa Oasis | - | 151.67 | 250.55 | - | 146.21 | 210.37 |
| LSD 0.05 | 1.430 | 1.674 | 5.446 | 2.338 | 1.635 | 2.921 |

**Table (9).** Effect of different locations on dry weight of herb/plant (g) of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| Location | First season (2012/2013) | | | Second season (2013/2014) | | |
|---|---|---|---|---|---|---|
| | Harvesting date | | | Harvesting date | | |
| | July 2012 (summer cut) | November 2012 (autumn cut) | March 2013 (spring cut) | July 2013 (summer cut) | November 2013 (autumn cut) | March 2014 (spring cut) |
| El-Qantara Sharq | 43.00 | 65.13 | 78.97 | 45.61 | 58.09 | 70.12 |
| El-Maghara | 85.15 | 106.38 | 118.20 | 104.50 | 121.00 | 132.11 |
| Siwa Oasis | - | 39.33 | 73.13 | - | 34.41 | 61.07 |
| LSD 0.05 | 0.530 | 2.506 | 2.160 | 3.605 | 1.208 | 2.021 |

**Table (10).** Effect of different locations on dry weight of herb/fed (ton) of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| Location | First season (2012/2013) | | | | Second season (2013/2014) | | | |
|---|---|---|---|---|---|---|---|---|
| | Harvesting date | | | Total yield per season | Harvesting date | | | Total yield per season |
| | July 2012 (summer cut) | November 2012 (autumn cut) | March 2013 (spring cut) | | July 2013 (summer cut) | November 2013 (autumn cut) | March 2014 (spring cut) | |
| El-Qantara Sharq | 0.48 | 0.73 | 0.88 | 2.09 | 0.51 | 0.65 | 0.79 | 1.95 |
| El-Maghara | 0.95 | 1.19 | 1.32 | 3.46 | 1.17 | 1.36 | 1.48 | 4.01 |
| Siwa Oasis | - | 0.44 | 0.82 | 1.26 | - | 0.39 | 0.68 | 1.07 |
| LSD 0.05 | 0.010 | 0.002 | 0.002 | 0.002 | 0.004 | 0.100 | 0.190 | 0.072 |

**2. Effect of the Different Planting Locations on Quality Parameters of Essential Oil of Three-lobed Sage Herb**

Data presented in tables (11, 12, 13 and 14) show the effect of different planting locations on quality parameters of essential oil of three-lobed sage herb. The obtained data showed that the quality parameters of the herb (essential oil percentage, essential oil yield per plant or per feddan and chemical constituents of essential oil) were affected and varied according to different planting locations and harvesting time.

**2.1. Essential oil percentage**

In both seasons, the significantly highest essential oil percentage was recorded at Siwa Oasis location, while the lowest one was detected at El-Qantara Sharq location for all cuts. Also, the highest essential oil percentage was found in the summer cut followed by autumn cut, while the lowest percentage was observed in the spring cut during both seasons. These results proved the strongly positive correlation between the increment of air temperature, solar radiation and volatile oil synthesis in the plant leaves.

Similar results were obtained by Mastro et al. (2006), Zawislak (2006) and Hückstädt et al. (2013) on common sage (*Salvia officinalis*). On cultivated wild three-lobed sage plants, Putievsky et al. (1986) found that from the second year in spring the essential oil content was quite low. Moreover, these results were approved by several author, who reported that the essential oil content of wild three-lobed sage plants is largely affected by growing location and different environmental conditions (Müller et al., 1997; Karousou et al., 1998; Aziz et al., 2008 and Cvetkovikj et al., 2015).

Also, these obtained values of essential oil percentage (ranging from 1.17 to 3.12%) are in agreement with the Standards of the European Pharmacopoeia (2005), which concluded that the whole drug of three-lobed sage should contain not less than 18 ml/kg of essential oil as calculated with reference to the anhydrous drug.

**Table (11).** Effect of different locations on essential oil percentage of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| Location | First season | | | Second season | | |
|---|---|---|---|---|---|---|
| | Harvesting date | | | Harvesting date | | |
| | July 2012 (summer cut) | November 2012 (autumn cut) | March 2013 (spring cut) | July 2013 (summer cut) | November 2013 (autumn cut) | March 2014 (spring cut) |
| El-Qantara Sharq | 2.05 | 1.95 | 1.24 | 2.10 | 1.90 | 1.20 |
| El-Maghara | 3.04 | 2.26 | 1.19 | 3.12 | 2.21 | 1.17 |
| Siwa Oasis | - | 2.52 | 1.43 | - | 2.31 | 1.49 |
| LSD 0.05 | 0.130 | 0.002 | 0.002 | 0.004 | 0.002 | 0.033 |

**2.2. Essential oil yield**

In both seasons, the significantly highest essential oil yield (ml/ plant) was resulted from El-Maghara location followed by El-Qantara Sharq. This may be attributed to that plants at this location recorded its highest dry weight of herb per plant and/or essential oil percentage. These results coincided with the standards of the European Pharmacopoeia (2005), which concluded that the cut drug of three-lobed sage should contain not less than

12 ml/kg of essential oil. Also, the essential oil yield (l/ feddan) had the same trend as shown with ml/plant.

**Table (12).** Effect of different locations on essential oil yield per plant (ml) of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| Location | First season | | | Second season | | |
|---|---|---|---|---|---|---|
| | Harvesting date | | | Harvesting date | | |
| | July 2012 (summer cut) | November 2012 (autumn cut) | March 2013 (spring cut) | July 2013 (summer cut) | November 2013 (autumn cut) | March 2014 (spring cut) |
| El-Qantara Sharq | 0.88 | 1.27 | 0.98 | 0.96 | 1.10 | 0.84 |
| El-Maghara | 2.59 | 2.40 | 1.41 | 3.26 | 2.67 | 1.55 |
| Siwa Oasis | - | 0.99 | 1.05 | - | 0.80 | 0.91 |
| LSD 0.05 | 0.004 | 0.002 | 0.007 | 0.004 | 0.002 | 0.002 |

**Table (13).** Effect of different locations on essential oil yield (l/ feddan) of *Salvia fruticosa* during the two successive seasons (2012/2013 and 2013/2014).

| Location | First season | | | | Second season | | | |
|---|---|---|---|---|---|---|---|---|
| | Harvesting date | | | Total yield per season | Harvesting date | | | Total yield per season |
| | July 2012 (summer cut) | November 2012 (autumn cut) | March 2013 (spring cut) | | July 2013 (summer cut) | November 2013 (autumn cut) | March 2014 (spring cut) | |
| El-Qantara Sharq | 9.86 | 14.22 | 10.98 | 35.06 | 10.75 | 12.32 | 9.41 | 32.48 |
| El-Maghara | 29.01 | 26.88 | 15.79 | 71.68 | 36.51 | 29.90 | 17.36 | 83.77 |
| Siwa Oasis | - | 11.09 | 11.76 | 22.85 | - | 8.96 | 10.19 | 19.15 |
| LSD 0.05 | 0.004 | 0.140 | 0.072 | 0.002 | 0.004 | 0.002 | 0.002 | 0.072 |

### 2.3. Essential oil constituents

The results revealed that, the constituents of *Salvia fruticosa* volatile oil had been affected by the different planting locations and harvesting time. The compound of 1,8-cineole was the main dominant chemical constituent in the oil (Table 14). These results can be summarized as follows:

At El-Qantara Sharq location the most abundant components in summer cut oil were 1,8-cineole (44.18%), camphor (14.22%), β-pinene (7.91%), camphene (5.47%) and α-pinene (5.06%) while in autumn cut oil

the abundant constituents were 1,8-cineole (42.91%), camphor (10.39 %), β-pinene (8.45%), caryophyllene (6.95%), camphene (4.55%) and α-pinene (4.49%).

At El-Maghara location the major components in summer cut oil were 1,8-cineole (31.87%), camphor (23.68%), camphene (8.72%), β-pinene (6.86%) and α-pinene (5.66%) while in autumn cut oil the major components were 1,8-cineole (44.70%), camphor (16.57%), β-pinene (6.66%), camphene (5.62%) and α-pinene (5.32%).

At Siwa Oasis location the dominant components in autumn cut oil were 1,8-cineole (45.67%), camphor (12.23%), β-pinene (9.20%), α-pinene (4.63%) and camphene (4.21%) while in spring cut oil the major components were 1,8-cineole (39.09%), caryophyllene (11.50%), β-pinene (9.94%), camphor (5.13%) and α-myrcene (4.04%).

These results coincided with those obtained by Müller-Riebau et al. (1997), Karousou et al. (1998), Aziz et al. (2008) and Cvetkovikj et al. (2015), who stated that the essential oil chemical composition of wild three-lobed sage plants was affected by the different geographical growing locations and environmental conditions.

Also, it is clear that the main component of the essential oil was 1,8-cineole (ranging from 31.87-45.67%) which has the pharmaceutical effect, differentiating it from thujone rich *Salvia officinalis* cultivars. The current analysis of *Salvia fruticosa* oil indicated that the amounts of α- and β-thujone, the major components in *Salvia officinalis* were below 2.80%. Nowadays, due to the toxicity issues associated with thujone, low thujone sources of sage leaf and sage oil are finding increasing market interest (International Trade Center, 2015).

Finally, from the aforementioned data, it is obvious that the highest herb quantity parameters (number of cuts per season, fresh weight of herb per plant, dry weight of herb per plant and per feddan) and quality parameters (essential oil yield per plant and per feddan with a suitable content of 1,8-cineole) were detected at El-Maghara location at North Sinai Governorate as compared to other locations in this experiment. Therefore, this kind of research studies is very important for planners of agriculture policy in Egypt for expansion of sowing the suitable plants in suitable places thereby increasing the farmers' income which may reflect on the national income.

**Table (14).** Chemical constituents (%) of essential oil at the different locations.

| No. | R.T. | Constituents | El-Qantara Sharq | | El-Maghara | | Siwa Oasis | |
|---|---|---|---|---|---|---|---|---|
| | | | Harvesting date | | Harvesting date | | Harvesting date | |
| | | | July 2013 (summer cut) | November 2013 (autumn cut) | July 2013 (summer cut) | November 2013 (autumn cut) | November 2013 (autumn cut) | March 2014 (spring cut) |
| 1 | 4.52 | Tricyclene | - | - | 0.63 | 0.43 | - | - |
| 2 | 4.57 | 2-thujene | 0.51 | 0.60 | - | - | 0.47 | 0.55 |
| 3 | 4.76 | α-pinene | 5.06 | 4.49 | 5.66 | 5.32 | 4.63 | 2.90 |
| 4 | 5.21 | Camphene | 5.47 | 4.55 | 8.72 | 5.62 | 4.21 | 1.91 |
| 5 | 5.80 | Sabinene | 0.13 | 0.31 | 0.11 | 0.06 | 0.18 | 0.36 |
| 6 | 5.96 | β-pinene | 7.91 | 8.45 | 6.86 | 6.66 | 9.20 | 9.94 |
| 7 | 6.21 | α-myrcene | 2.51 | 3.78 | 1.61 | 2.15 | 3.16 | 4.04 |
| 8 | 6.81 | L-phellandrene | 0.05 | 0.04 | - | - | - | - |
| 9 | 7.12 | α-terpinene | 0.27 | 0.22 | 0.16 | 0.17 | 0.22 | 0.34 |
| 10 | 7.44 | p-cymene | 0.20 | 0.12 | 0.42 | 0.71 | 0.21 | 0.35 |
| 11 | 7.53 | D-limonene | 1.99 | 1.42 | 2.74 | 1.78 | 1.65 | 0.87 |
| 12 | 7.67 | 1,8-cineole | 44.18 | 42.91 | 31.87 | 44.70 | 45.67 | 39.09 |
| 13 | 8.53 | ç-terpinene | 0.49 | 0.60 | 0.26 | 0.17 | 0.46 | 1.34 |
| 14 | 9.04 | 4-thujanol | 0.22 | 0.70 | 0.18 | 0.11 | 0.31 | 0.81 |
| 15 | 9.50 | α-terpinolene | 0.18 | 0.15 | 0.19 | 0.06 | 0.17 | 0.16 |
| 16 | 10.13 | L-linalool | 0.17 | 0.13 | 0.34 | 0.21 | 0.17 | 0.16 |
| 17 | 10.21 | Terpineol,cis-á- | 0.12 | 0.24 | 0.12 | 0.07 | 0.16 | 0.27 |
| 18 | 10.47 | β-thujone | 1.71 | 1.19 | 1.94 | 1.65 | 1.57 | 0.46 |
| 19 | 10.92 | α-thujone | 0.67 | 0.52 | 0.86 | 0.74 | 0.69 | 0.57 |
| 20 | 11.81 | Pinocarveol | - | - | 0.06 | 0.07 | - | - |
| 21 | 12.18 | Camphor | 14.22 | 10.39 | 23.68 | 16.57 | 12.23 | 5.13 |
| 22 | 12.45 | 2-norbornanol,2,3,3-trimethyl- | - | - | - | 0.04 | - | - |
| 23 | 12.68 | Pinocamphone | 0.48 | 0.80 | 0.45 | 0.55 | 0.61 | 0.93 |
| 24 | 13.14 | Borneol | 2.76 | 1.91 | 3.33 | 2.96 | 2.26 | 2.00 |
| 25 | 13.36 | 3-pinanone,cis | 0.17 | 0.33 | - | - | 0.25 | 0.45 |
| 26 | 13.45 | 4-terpineol | 0.81 | 0.43 | 0.82 | 0.61 | 0.66 | 0.32 |
| 27 | 14.13 | p-menth-1-en-8-ol | 2.68 | 2.36 | 0.97 | 2.10 | 2.91 | 2.93 |
| 28 | 16.19 | Linalyl acetate | 0.23 | 0.17 | 0.77 | 0.29 | 0.22 | - |
| 29 | 17.73 | L-bornyl acetate | 1.15 | 0.83 | 2.13 | 0.88 | 0.72 | 0.44 |
| 30 | 18.96 | Ocimenyl acetate | 0.08 | 0.04 | 0.11 | 0.12 | 0.08 | - |
| 31 | 19.43 | 2-pinen-10-ol,acetate | 0.05 | 0.07 | 0.06 | - | - | - |

**Table (14) Cont.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 32 | 20.07 | Exo-2-hydroxycineole acetate | 0.05 | - | 0.05 | - | 0.07 | - |
| 33 | 20.38 | α-terpinenyl acetae | 2.20 | 1.07 | 2.45 | 2.37 | 1.72 | 0.49 |
| 34 | 22.74 | (-)-Aristolene | 0.05 | - | 0.07 | - | 0.07 | - |
| 35 | 23.18 | Caryophyllene | 1.73 | 6.95 | 0.91 | 1.23 | 2.28 | 11.50 |
| 36 | 23.51 | 1,1,3a-trimethyl-7-methylenedeca Hydro-1H-cyclopropa[a] naphthalene | - | - | - | - | - | 0.22 |
| 37 | 23.76 | Selina-3,7(11)-diene | - | - | - | - | - | 0.22 |
| 38 | 23.95 | Aromadendrene | 0.06 | 0.24 | - | 0.05 | 0.14 | 2.20 |
| 39 | 24.30 | ç-gurjunene | - | - | - | - | - | 0.17 |
| 40 | 24.69 | α-humulene | 0.62 | 1.51 | 0.30 | 0.28 | 1.11 | 3.13 |
| 41 | 24.84 | α-cyclo-homogeraniol | 0.05 | 0.05 | 0.07 | - | 0.08 | - |
| 42 | 25.52 | ç-muurolene | - | - | 0.05 | - | - | - |
| 43 | 26.11 | Ledene | - | 0.09 | - | - | 0.05 | 0.75 |
| 44 | 26.34 | Bicyclogermacrene | - | 0.18 | - | - | 0.04 | 0.75 |
| 45 | 27.26 | ë-cadinene | - | - | 0.07 | 0.04 | - | 0.26 |
| 46 | 29.66 | (-)-spathulenol | 0.06 | 0.14 | 0.06 | 0.06 | 0.11 | 0.56 |
| 47 | 29.82 | (-)-caryophyllene oxide | 0.29 | 0.53 | 0.37 | 0.54 | 0.29 | 0.23 |
| 48 | 30.32 | Veridiflorol | 0.28 | 1.20 | 0.30 | 0.22 | 0.60 | 2.33 |
| 49 | 30.93 | Humulene oxide | 0.10 | 0.12 | 0.13 | 0.15 | 0.16 | 0.17 |
| 50 | 32.00 | Tetracyclo[6.3.2.0 (2,5).0 (1,8)] tridecan-9-ol, 4,4-dimethyl- | - | - | - | 0.07 | - | - |
| 51 | 32.71 | (-)-caryophyllene oxide | - | - | - | 0.08 | - | - |
| 52 | 33.30 | Isoaromadendrene epoxide | | - | - | 0.06 | - | - |
| 53 | 34.10 | 6-epi-shyobunol | - | - | - | - | - | 0.41 |
| 54 | 46.04 | 13-epimanool | 0.04 | 0.17 | 0.12 | 0.05 | 0.21 | 0.29 |

## CONCLUSION

The best locations for cultivation and production of three-lobed sage as a promising land in the desert were El-Maghara location followed by El-Qantara Sharq location and then Siwa Oasis location.

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# تأثير مواقع الزراعة المختلفة فى مصر على نباتات المريمية ثلاثية الورقة

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أجري هذا البحث خلال موسمين متتاليين ٢٠١٣/٢٠١٢ و٢٠١٤/٢٠١٣ لدراسة تأثير مواقع الزراعة المختلفة على نباتات المريمية ثلاثية الورقة. تم تنفيذ التجربة في ثلاث مواقع مختلفة بالأراضي المستصلحة الجديدة على النحو التالي: القنطرة شرق (محافظة شمال سيناء)، قرية المغارة (محافظة شمال سيناء)، واحة سيوة (محافظة مطروح). وقد أوضحت النتائج أن جميع قياسات كمية وجودة العشب قد اختلفت وفقًا لمكان الزراعة وميعاد الحصاد. وكان أفضل موقع لزراعة هذا النبات هو موقع المغارة الذي سجل أعلى قياسات كمية للعشب (عدد حشات في الموسم، أوزان طازجة وجافة للنبات أوللفدان)، وأعلى قياسات جودة للعشب (محصول زيت طيار للنبات أو للفدان مع محتوى مناسب من مركب ١,٨ سنيول المكون الكيميائي الرئيسي في الزيت) يليها موقع القنطرة شرق ثم موقع واحة سيوة.