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EFFECT OF SOIL TYPE AND MYCORRHIZA INOCULATES ON GROWTH, YIELD AND CHEMICAL COMPONENTS OF *SALVIA OFFICINALIS* L.

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ABSTRACT: The present study was conducted on sage (*Salvia officinalis* L.) plants throughout two successive seasons 2020/2021 and 2021/2022 at a private farm in Fayoum Governorate, Egypt. The experiments aimed to find out the individual and the combined effects of mycorrhiza inoculates at three concentrations (2, 4 and 8 g/plant) under two types of soils (clay and sandy) on vegetative growth, chemical composition and essential oil components of *Salvia officinalis*. The results emphasized that using mycorrhiza inoculate under two types of soils significantly affected all vegetative growth parameters in this study. Likewise, increased oil percentage and chemical constituents of sage essential oil were obtained especially using clay soil and high levels of mycorrhiza. Additionally, the interaction between soil type and levels of mycorrhiza improved all the studied parameters, particularly by using the combinations between mycorrhiza at 8 g/plant under clay soil.

Keywords: sage, clay, sandy soils, mycorrhiza

INTRODUCTION

In recent years the importance of medicinal and aromatic plants which form the essential active ingredient of many medicines and cosmetics was increased. Common sage (*Salvia officinalis* L.) is one of the important species of these aromatic plants. In Egypt, expansion of medicinal and aromatic plants production is because of our suitable climate conditions, abundance of employment, abundance of new reclaimed lands and our special site. Nowadays, great attention has been focused on the possibility of using natural, safe fertilizer and growth substances. Reducing chemical fertilizers which maintain high crop yield has become a trend of agricultural practice. In pharaonic Egypt, they used medicinal and aromatic plants for folk medicine instead of chemical medicinal preparations. Medicinal and aromatic plants are considered essential economic products which have been recognized and detected in Egypt to cover the increasing demands of the local industries as well as for export and local purposes (Abbas, 2011). The need of increasing medicinal plants production in many parts of the world becomes an ultimate goal to avoid the dramatic side effects induced by chemical therapy on human health and also to increase the economic return from exporting their products. Due to increasing demands for the active ingredients in medicinal plants for drug industry and exportation, the area of cultivated medicinal plants has been expanded. In Egypt, more than 150 species of medicinal plants are grown in an area reaching about 70 thousand feddans and the total exports of these crop products were more than 200 million Egyptian pounds (Kandeel, 2003).

The Labiatae (Lamiaceae) family includes a large number of economically herbal plants (such as *Mentha sp., Marjoram sp., Salvia sp*., etc.). Salvia genus includes about 700 species, one of which is *Salvia officinalis* (sage). It is a perennial herb indigenous in southern Europe, cultivated in central Europe and found now in temperature climate regions such as Mediterranean region and, North Africa, America and Asia. The shoots are long spindle shaped with an erect woody stalk and straight branches. It grows to approximately 60 cm in height and has pale blue or purplish flowers. The leaves are elongated spear shaped with a soft velvety texture (Greenhalgh, 1992). There are several different species and cultivars which have been developed, such as the Mexican sage (*S. azurea grandiflora*) and the red sage (*S. colorata*) both of which are used medicinally. Essential oils are also produced from other species including the Spanish sage (*S. lavendulaefolia)*, common or garden sage (*Salvia officinalis*) and clary sage (*S. sclarea*). Sage was considered as remedy for coughs and bad cold, it is included in gargles and mouth washes. The fresh leaves are used for whiten the teeth, while the dried ones are used cosmetically to restore the natural color to hair that is turning grey (Daisley, 1982). It has been used for different diseases including respiratory infections, menstrual difficulties and digestive complaints. It was also believed to strengthen the memory. It is used in some pharmaceutical preparation, such as mouthwashes, gargles, toothpastes, employed as a fragrance component in soaps, Shampoo, detergents antiperspirants, colognes and perfumes, especially, men's fragrances. It has been also served as a source of natural anti-oxidants. The principal constituents of the essential oil are thujone about 42%, cineol; alcohol; carophyllene and other terpenes. In general, sage growth and production (i.e., morphological characters, and chemical characters) can be influenced by different environmental factors, including drought and nutrition deficiency.

The soil type directly influences basic agronomic factors, such as water storage capacity and the plant nutrient availability of the soil. Moreover, the soil type affects the infiltration, runoff, and movement of water in the soil. Sandy soil has a low water storage capacity and, therefore, reduced soil fertility. For these reasons, there is a loss of yield on sandy soils for food crops. The tiny particles in clay soils both bind water tightly and hinder root penetration, making it harder for plants to establish rapidly (Reinhardt *et al*., 2021b). Growing soil media as well as mineral fertilization are among the important agricultural treatments that have proved to improve and augment the growth and productivity plants. Gülser *et al*. (2010) clearly indicated that plant growth in different textured soils improved the soil physical properties and that planting sustained better soil physical health.

Mycorrhiza fungi are among the most important microorganisms which can be applied in soil as biofertilizers. Mycorrhiza fungi are among the most important microorganisms which can be applied in soil as biofertilizer. They form symbiotic relations with 83% and 79% of the dicotyledons and monocotyledons (Wilcox, 1991). It is possible to replace mycorrhiza instead of high doses of chemical fertilizers to reduce the need for chemical fertilizers and prevent the associated problems (Ghoushchi *et al*., 2015), also arbuscular mycorrhizal symbiosis is recognized for its multiple positive effects on plant growth and its important contribution towards the maintenance of soil quality. These fungi are known to improve the nutritional status of the host, particularly that of phosphorous, and thereby enhance their growth, development and yield (Bagyaraj and Varma, 1995 and Copetta *et al*., 2006). Mycorrhizae fungi contribute to the secondary metabolism and production of active ingredients in aromatic and medicinal plants. This symbiotic association is particularly affected by the availability of phosphorus (P) in the soil and many species belonging to the Lamiaceae form mycorrhizae associations. In addition to increasing uptake of poorly accessible nutrients or conferring protection against pathogens, mycorrhizae can also induce changes in the accumulation of secondary metabolites in host plant roots (Devi and Reddy, 2002). Relatively little is known about the effects of mycorrhizae colonization on the accumulation of active compounds in shoots of medicinal plants, which are often the harvest products. However, it was recently reported that mycorrhizae directly increases the essential oil content in shoots of different species of Lamiaceae medicinal plants (Copetta *et al*., 2006).

Therefore, this study focuses on the following main research question: how do sage plants perform in terms of biomass yield and volatile oil in different soil types (clay and sandy) and to evaluate the possibility of using mycorrhizae fungi in the sustainable and healthy production system?.

MATERIALS AND METHODS

The experiment for this study was conducted at the private nursery in Fayoum Governorate, Egypt throughout the two successive growing seasons of 2020/2021 and 2021/2022. This is for the purpose of studying the effect of mycorrhizal inoculation at three concentrations: 2, 4 and 8 g/plant on growth, chemical and essential oil constituents under two soil media (clay and sandy) of *Salvia officinalis* L. The interaction effect between them was also studied.

Plant material:

Sage seeds were acquired from the Agricultural Research Centre, Giza, Egypt. Seeds were sowed at the end of November in seedling trays (7×12) in the greenhouse and received the normal agriculture practices until transplanting after 45 days into 25 cm diameter pots (one plant/pot) filled with clay or sandy soil in both seasons.

Experiment treatments:

The experiment focused on two factors, the first factor is soil media type namely clay and sandy soils. The second factor was the mycorrhiza inoculate at three concentrations 2, 4 and 8 g/plant.

1. Soil media:

Two different textured (clay and sandy) soils used in this study were taken from Fayoum Governorate, Egypt. Analyses of some chemical and physical properties of the used medium were carried out according to Klute (1986) and Page *et al*. (1982) and are presented in Table (a).

2. Mycorrhiza treatment:

The bio-fertilizers were obtained from Agricultural Research Center, Egypt, to be used as seedling inoculants at three concentrations of 2, 4 and 8 g/plant. The

Table a. Some mechanicals and chemicals analysis of clay and sandy soil samples used for experiment.

Characters	1	2
Mechanical analysis:		
Clay %	56.80	5.00
Fine sand %	27.90	89.86
Silt %	13.40	6.09
Soil texture	Clay	Sandy
Chemical analysis:		
pH (at 25 °C)	7.80	8.90
EC ds/m (at 25 °C)	2.66	2.60
Organic matter (O.M) %	0.74	0.70
N (mg/kg)	73.22	55.50
P (mg/kg)	2.10	21.14
K (mg/kg)	0.54	0.89
Ca (meq)	7.00	1.50
Mg (meq)	9.30	0.42
Na (meq)	15.70	0.73
Cl (meq)	15.00	0.40
HCO_3 (meq)	3.50	1.30
SO_4 (meq)	15.80	0.98

inoculation was added to the pot and covered with soil. The seedlings were irrigated immediately during both growing seasons of the study.

Harvesting:

Sage plants were harvested two times, by cutting the aerial parts of each plant at 10 cm above the soil surface on 15th May (at the commencement of the flowering), and on 15th August during the first and second growing seasons. Four plants were randomly chosen from each experimental unit at each cut in both seasons.

Experimental design:

The experiment was set in a split-plot design with three replications (eight pots/replicate) where the soil media types were the main plot and the mycorrhiza inoculate was in the subplots.

Data recorded:

1. Vegetative growth characters:

Plant height (cm), number of branches per plant, herb fresh and dry weights/plant (g).

2. Chemical constituents:

a. Determination of carbohydrates in the herb:

The percentage of total carbohydrates was determined in the dry herb using the method described by Herbert *et al*. (1971). Five ml of 67% sulphuric acid were added to a known weight of the dry matter in a test tube. One hour later, the volume was completed to 100 ml with distilled water and the solution was filtered. One ml of the filtrate pipette into a test tube and an aqueous phenol solution 1 ml (5%) was added to the solution, followed by concentrated H_2SO_4 (5 ml) from a fast-delivering pipette. Measurements of the color intensity were taken using a Milton Roy colorimeter (model Spectronic 21 D) at 490 nm and the content was calculated by the standard curve of glucose.

b. Determination of chlorophyll (a and b) and carotinoids in leaves:

The contents of chlorophylls (a and b) and carotenoids were determined according to the method described by Saric *et al.* (1976) where 0.5 g of fresh leaves of sage were macerated in 5 ml acetone for 48 hours in the dark. The filtration has been done using vacuum filtration through a centred glass funnel G_4. The residue was washed several times with acetone until the filtrate become colorless. Chlorophyll a and b was determined using the following equation:

Chlorophyll a = (9.784 × E660) - (0.99 × E640)

Chlorophyll b = (21.426 × E640) - (4.65 × E660)

Total carotenoids = (4.695 × E440) - (0.268 × (chl.+chl.b)

E= optical density at the wavelength indicated

c. Determination of N, P and K in the dry leaves:

The leaves were oven dried at 70 °C until a constant weight was obtained. The obtained dry matter was ground and 0.5 g of ground dry matter was digested using sulphuric acid and H_2O_2 and the wet digestion procedure was performed as follows: **c**oncentrated sulphuric acid (8 ml) was added to the dried sample and heated for 15 minutes and then H_2O_2 was added and heating was continued until a clear solution was obtained (Piper, 1947). Nitrogen determination was carried out using the modified micro-Kjedahl method, as described by Jackson (1967).

The phosphorus % was estimated calorimetrically according to the method of Murphy and Reily (1962). While potassium (K) was determined by using an atomic absorption/Flame spectrophotometer (3300) according to Wilde *et al.* (1985).

3. Determination of essential oil percentage in the dry herb:

The essential oil percentage of each treatment of sage plants was determined in the air-dried herb using hydro-distillation method according to the British Pharmacopoeia (1983). The herb was placed in a flask of 1000 ml capacity and an amount of water (500 ml) was added. A proper essential oil trap and condenser were attached to the flask and enough water was added to fill the trap. The flask was placed on an electrically heated bath. The distillation continued for 2.5 hours after boiling until no further increase in the oil was observed, after finishing the distillation process the apparatus was left to be cooled and the essential oil percentage was estimated as follows:

Essential oil percentage=

$$\frac{\begin{array}{c}\text{Essential oil vol.}\\ \text{(reading measured pipette)}\end{array}}{\text{Weight of sample}} \times 100$$

4. Essential oil constituents (G.L.C analysis of the oil):

Essential oil constituents were analyzed using gas liquid chromatography (GLC) to determine the main constituents according to Heftmann (1967). The chromatograph apparatus was fitted with capillary column BPX-5,5% phenyl (reqiv) polysillphenylene-siloxan 30 m × 0.25 mm ID × 0.25µm film. Temperature program ramp increase with a rate of 80 °C/min from 70 to 200 °C. Flow rates of gases were nitrogen at 1 ml/min, hydrogen at 30 m/min and 330 ml/min for air. The detector and injector temperatures were 300 °C and 250 °C, respectively. The obtained chromatogram and report of GC analysis for each sample were analyzed to calculate the percentage of main components of essential oil. The area each peak was first calculated by an automatic integrator. The areas were then summed. The total area of 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.

Statistical analysis.

Obtained data were subjected to the statistical analysis as a usual technique of analysis of variance (ANOVA) of the combined analysis in split-split plot design as mentioned by Gomez and Gomez (1984), using the least significant difference (L.S.D.) at 5% for comparison between means of the different treatments.

RESULTS AND DISCUSSION

Effects of soil type and mycorrhiza inoculation on vegetative growth of *Salvia officinalis* L.

1. Plant height (cm):

Data dealing with the effect of soil type and mycorrhiza inoculation individually on the plant height during both growing seasons are presented in Table (1). The plants cultivated in clay and sandy soil were affected by soil type where the plant height was increased in clay soil (64.43 and 62.93 cm) in the 1st and 2nd seasons, respectively, compared with sand soil (45.99 and 44.92 cm) in the 1st and 2nd seasons, respectively. These results are in agreement with Badawy (1998) on tuberos, Barbara (2002) on *Solidago virgaaurea* L., Abdel-Sattar *et al.* (2010) on tuberose, El-Nashar (2016) on calendula and Youssef *et al*. (2019) on *Swietenia mahagoni*. However, treating sage plant with mycorrhiza inoculation with 8 g led to an increase in plant height which was 61.06 and 60.17 cm compared to 2 g (50.45 and 47.00 cm) or 4 g (54.44 and 53.47cm). These results are in agreement with Kandeel and Sharaf (2003) on *Majorana hortensis* L. plants, Mohamed and Saad (2004) on yarrow (*Achillea milefolium*), Badway (2015) on *Pimpinlla anisum* L., Tarraf *et al.* (2017), Amer *et al.* (2019), Samani *et al*. (2019), Giannoulis *et al.*, (2020) Khaledigan *et al.* (2021), and Karagiannidis *et al*. (2021) on *Salvia officinalis*, Rad and Radbact (2021) on *Ducrosia anethifolia*, Moghith *et al*. (2021) on chia and Gaafar *et al.* (2021) on *Hibiscus sabdariffa* L.

Data in Table (2) showed that the interaction between soil type and mycorrhiza inoculation affected the plant height of *Salvia officinalis* L. It can be noticed that the tallest plants were obtained in both soils with mycorrhiza inoculation (8 g). The best result was clay soil (74.82 cm and 73.31 cm) in two

Table 1. Effects of soil type and mycorrhiza inoculation on plant height (cm) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	**Cut No.**	**Plant height (cm)**	**Mean**	**Plant height (cm)**	**Mean**
Clay	**Cut 1**	59.50	64.43	60.43	62.93
	Cut 2	69.36		65.43	
Sandy	**Cut 1**	41.50	45.99	41.38	44.92
	Cut 2	50.48		48.46	
L.S.D at 5%			6.38		6.68
Mycorrhiza (g/plant)					
2	**Cut 1**	54.10	50.45	42.0	47.00
	Cut 2	46.80		52. 0	
4	**Cut 1**	58.46	54.44	56.91	53.47
	Cut 2	50.42		50.02	
8	**Cut 1**	58.05	61.06	54.12	60.17
	Cut 2	64.06		66.22	
L.S.D at 5%			3.40		6.77

Table 2. Effects of the interactions between soil type and mycorrhiza inoculation on plant height (cm) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	**Mycorrhiza (g/plant)**	**Cut No.**	**Plant height (cm)**	**Mean**	**Plant height (cm)**	**Mean**
Clay	**2**	**Cut 1**	58.33	56.44	56.80	53.78
		Cut 2	54.55		50.76	
	4	**Cut 1**	64.56	61.74	63.70	61.69
		Cut 2	58.91		59.68	
	8	**Cut 1**	76.73	74.82	76.34	73.31
		Cut 2	72.91		70.28	
Sandy	**2**	**Cut 1**	47.60	43.54	44.20	40.22
		Cut 2	39.48		36.24	
	4	**Cut 1**	49.05	45.08	49.30	46.25
		Cut 2	41.11		43.20	
	8	**Cut 1**	50.38	47.34	45.28	48.31
		Cut 2	44.30		51.34	
L.S.D at 5%				7.64		3.92

seasons compared to sandy soil (47.34 cm and 48.31 cm), respectively. These results are in accordance with those reported by Youssef *et al*. (2019) on *Swietenia mahagoni*, Badawy (2015) on *Pimpinlla anisum* L., Ghoushchi *et al.* (2015) and Bagdat *et al.* (2017) on *Salvia officinalis*, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis*, Badawy (1998) on tuberose, Abdel-Sattar *et al.* (2010) on tuberose, Sardoei and Rahbarian (2014) on medicinal plant and El-Nashar (2016) on calendula plant.

2. Number of branches per plant:

Data dealing with the effect of soil type and mycorrhiza inoculation individually on the number of branches per plant during both growing seasons on sage plants were presented in Table (3). Considering the effect of clay and sandy soil treatments on number of branches per plant, planting in the clay soil increased the number of branches per plant (7.50 and 5.35) in the 1st and 2nd seasons, respectively compared with sandy soil (5.57 and 4.80) in the 1st and 2nd seasons, respectively. However, treating sage plants with mycorrhiza inoculation led to an increase in branch numbers per plant as mycorrhiza levels increased (7.59 and 5.50) with 8 g compared to 2 and 4 g. These results are in agreement with those obtained by Badawy (1998) on tuberose, Abdel-Sattar *et al*. (2010) on tuberose, Sardoei and Rahbarian (2014) on some medicinal plants, Badawy (2015) on *Pimpinlla anisum* L., Ghoushchi *et al.* (2015) on *Salvia officinalis*, El-Nashar (2016) on

Table 3. Effects of soil type and mycorrhiza inoculation on number of branches/plant of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	**Cut No.**	**Number of branches/plant**	**Mean**	**Number of branches/plant**	**Mean**
Clay	**Cut 1**	5.47	7.50	2.32	5.35
	Cut 2	9.53		8.38	
Sandy	**Cut 1**	3.53	5.57	2.76	4.80
	Cut 2	7.61		6.83	
L.S.D at 5%			0.62		0.60
Mycorrhiza (g/plant)					
2	**Cut 1**	3.90	5.92	6.74	4.65
	Cut 2	7.94		2.56	
4	**Cut 1**	3.34	6.37	4.01	5.01
	Cut 2	9.40		6.00	
8	**Cut 1**	2.55	7.59	2.46	5.50
	Cut 2	12.63		8.54	
L.S.D at 5%			0.47		0.51

calendula plant, Tarraf *et al.* (2017) on *Salvia officinalis* and Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis*.

Data in Table (4) showed the interaction between soil type and mycorrhiza inoculation on the number of branches/plant of *Salvia officinalis* L. It can be noticed that the highest value was on both soil types with mycorrhiza inoculation at 8 g. The best results were clay soil (8.32 and 5.82) in two seasons compared to sandy soil (6.85 and 5.04), respectively. The interaction of soil type with 2 g mycorrhiza inoculation showed the lowest branches number per plant in the two seasons of study being 6.90 and 4.93 in clay and sandy soil during the 1st season while were 5.16 and 4.37 during the 2nd season. These results are in agreement with Badawy (2015) on *Pimpinlla anisum* L., Ghoushchi *et al.* (2015) and BagdEl-Nashar (2016) on calendula plant, Tarraf *et al.* (2017) on *Salvia officinalis* and Khaledigan *et al*. (2021) on *Ocimum basilicum* and sage *Satureja hortensis*.

3. Herb fresh weight/plant:

Data dealing with the effect of soil type and mycorrhiza inoculation individually on the herb fresh weight during both growing seasons were presented in Table (5). Planting sage plants on clay soil increased the herb fresh weight per plant (50.85 and 31.28 g) in the 1st and 2nd seasons, respectively compared with sandy soil (26.82 and 30.70 g) in the 1st and 2nd seasons, respectively. These results are in agreement with those obtained by Magalhaes *et al*. (1995) on *Artemisia annual* plants, Gurumurthy and Sreenivasa (1996) on chilli, Badawy (1998) on tuberose, Barbara (2002) on *SalidagoVirgaaurea* L., Abdel-Sattar *et al.* (2010) on tuberose, El-Nashar (2016) on calendula, Youssef *et al.* (2019) on *Swietenia mahagoni* and Moghith *et al*. (2021) on *Salvia hispanica*.

However, treating sage plants with mycorrhiza inoculation led to increasing herb fresh weight per plant which was (47.86 and 44.70) with 8 g compared to 2 and 4 g which were less effect than 8 g treatment. These results are in agreement with those obtained by Kandeel and Sharaf (2003) on *Majorana hortensis* L. plants, Mohamed and Saad (2004) on yarrow (*Achillea milefolium*), Karagiannidis *et al*. (2012) on selected medicinal plants, Badway (2015) on *Pimpinlla anisum* L., Tarraf *et al*. (2017), Amer (2019), Samani *et al*. (2019), Giannoulis *et al*. (2020), Khaledigan *et al.* (2021) on *Salvia officinalis*, Rad and Radbact, (2021) on *Ducrosia anethifolia*, Moghith *et al*. (2021) on chia (*Salvia hispanica*) and Gaafar *et al.* (2021) on *Hibiscus sabdariffa* L.

Data in Table (6) show the interaction between soil type and mycorrhiza inoculation on the herb fresh weight per plant (g) of *Salvia officinalis* L. It can be noticed that the highest

Table 4. Effects of the interactions between soil type and mycorrhiza inoculation on number of branches/plant of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Number of branches/plant	Mean	Number of branches/plant	Mean
Clay	2	Cut 1	4.87	6.90	3.12	5.16
		Cut 2	8.93		7.20	
	4	Cut 1	5.24	7.27	3.13	5.17
		Cut 2	9.30		7.21	
	8	Cut 1	3.29	8.32	7.88	5.82
		Cut 2	13.35		3.76	
Sandy	2	Cut 1	2.91	4.93	2.35	4.37
		Cut 2	6.95		6.39	
	4	Cut 1	4.45	5.47	2.46	4.48
		Cut 2	6.49		6.50	
	8	Cut 1	3.80	6.85	2.01	5.04
		Cut 2	9.90		8.07	
L.S.D at 5%				0.66		0.73

Table 5. Effects of soil type and mycorrhiza inoculation on herb fresh weight/plant (g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Herb fresh weight/plant (g)	Mean	Herb fresh weight/plant (g)	Mean
Clay	Cut 1	45.80	50.85	27.24	31.28
	Cut 2	55.90		35.32	
Sandy	Cut 1	22.78	26.82	26.64	30.70
	Cut 2	30.86		34.76	
L.S.D at 5%			4.66		5.32
Mycorrhiza (g/plant)					
2	Cut 1	27.45	31.50	29.80	34.83
	Cut 2	35.55		39.86	
4	Cut 1	35.10	37.15	36.90	41.91
	Cut 2	39.20		46.92	
8	Cut 1	44.83	47.86	40.63	44.70
	Cut 2	50.89		48.77	
L.S.D at 5%			2.53		3.13

Table 6. Effects of the interactions between soil type and mycorrhiza inoculation on herb fresh weight/plant (g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Herb fresh weight/plant (g)	Mean	Herb fresh weight/plant (g)	Mean
Clay	2	Cut 1	39.92	44.94	49.92	51.95
		Cut 2	49.96		53.98	
	4	Cut 1	46.46	48.51	51.80	53.83
		Cut 2	50.56		55.86	
	8	Cut 1	55.00	59.05	51.03	55.06
		Cut 2	63.09		59.09	
Sandy	2	Cut 1	14.55	18.60	15.67	17.70
		Cut 2	22.65		19.73	
	4	Cut 1	22.75	25.78	25.0	31.50
		Cut 2	28.81		35. 3	
	8	Cut 1	34.59	36.62	42.33	44.35
		Cut 2	38.65		46.37	
L.S.D at 5%				3.58		4.80

value was obtained with the two soils type when combined with mycorrhiza inoculation (8 g). But, the best result was in clay soil (59.05 and 55.06 g) compared to sandy soil (36.62 and 44.35 g) in 2020/2021 and 2021/2022 seasons, respectively. These results are in agreement with Badawy (2015) on *Pimpinlla anisum* L., Ghoushchi *et al.* (2015) and Bagdat *et al.* (2017) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni* and Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis.*

4. Herb dry weight per plant:

Data dealing with the effect of soil type and mycorrhiza inoculation all of them individually on the herb dry weight per plant in g during both growing seasons were presented in Table (7). Clay and sandy soils affected the herb dry weight per plant which were 47.51 and 44.71 g in clay soil in the 1st and 2nd seasons, respectively compared with sand soil (27.54 and 21.28 g) in the 1st and 2nd seasons, respectively. Similar results were achieved by Magalhaes *et al*. (1995) on *Artemisia annual* plants, Gurumurthy and Sreenivasa (1996) on *chilli*, Badawy(1998) on tuberose, Barbara (2002) on *Solidago virgaaurea* L., Abdel-sattar *et al.* (2010) on tuberose, El-Nashar (2016) on calendeula, Youssef *et al*. (2019) on *Swietenia mahagoni*, Youssef *et al*. (2019) on *Swietenia mahagoni* and Moghith *et al*. (2021) on *Salvia hispanica.*

However, treating sage plant with mycorrhiza inoculation led to an increase in herb dry weight per plant being 46.71 and 41.34 g at 8 g level compared to 2 and 4 g levels. Similar results were reported by Badawy (1998) on tuberose, Kandeel and Sharaf (2003) on *Majorana hortensis* L. plants, Mohamed and Saad (2004) on yarrow (*Achillea milefolium*), Abdel-Sattar *et al.* (2010) on tuberose. Badway (2015) on *Pimpinlla anisum* L., Tarraf *et al.* (2017), Amer (2019), Samani *et al*. (2019), Giannoulis *et al*. (2020) on *Salvia officinalis*, Karagiannidis *et al*. (2021) on selected medicinal plants, Khaledigan *et al.* (2021) on *Ocimum basilicum* and *Satureja hortensis*, Rad and Radbakht, (2021) on *Ducrosia anethifolia*, Moghith *et al*. (2021) on chia and Gaafar *et al.* (2021) on *Hibiscus sabdariffa* L.

Data in Table (8) show the interaction between soil type and mycorrhiza inoculation on the herb dry weight per *Salvia officinalis* L. plant. It can be noticed that the highest herb dry weight per plant was obtained in both soil types with mycorrhiza inoculation (8 g). But the best result was on clay soil (57.24 and 51.21 g) in the two seasons of study compared to sandy soil (36.19 and 31.46 g) during 2020/2021 and 2021/2022 seasons, respectively. These results are in agreement with Badawy (2015) on *Pimpinella anisum* L., Ghoushchi *et al.* (2015) and Bagdat *et al.* (2017) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni*, and Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis*.

Effects of soil type and mycorrhiza inoculation and their interactions on chemical constituents of *Salvia officinalis* L.

1. Carbohydrates percentage:

Data dealing with the effect of soil type and mycorrhiza inoculation individually on the carbohydrate percentages in the dried herb of *Salvia officinalis* L. during both growing seasons were presented in Table (9). Using clay soil as a treatment for sage plants compared with sand soil significantly increased the carbohydrate contents which was 22.88% in the 1st season and 23.17% in the 2nd one. But it was 17.80 and 17.66% in sandy soil in the 1st and 2nd seasons, respectively. Similar results were reported by Bezzi (1987) and Rohricht *et al*. (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill, El-Sherbeiny *et al*. (1992) on *Pelargonium graveolens* L., Badawy (1998) on *Polianthes tuberosa*, El-Fawakhry (2001) on tuberose, Youssef *et al*. (2019) on *Swietenia mahagoni* and Gaafar *et al*. (2021) on *Hibiscus sabdariffa*.

Table 7. Effects of soil type and mycorrhiza inoculation on herb dry weight/plant (g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Herb dry weight/plant (g)	Mean	Herb dry weight/plant (g)	Mean
Clay	Cut 1	45.00	47.51	40.67	44.71
	Cut 2	50.01		48.75	
Sandy	Cut 1	22.49	27.54	17.26	21.28
	Cut 2	32.59		25.29	
L.S.D at 5%			2.99		4.77
Mycorrhiza (g/plant)					
2	Cut 1	30.20	32.22	20.75	23.30
	Cut 2	34.24		25.85	
4	Cut 1	34.35	37.40	30.79	33.82
	Cut 2	40.45		36.85	
8	Cut 1	42.70	46.71	37.30	41.34
	Cut 2	50.72		45.38	
L.S.D at 5%			2.84		5.59

Table 8. Effects of the interactions between soil type and mycorrhiza inoculation on herb dry weight/plant (g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Herb dry weight/plant (g)	Mean	Herb dry weight/plant (g)	Mean
Clay	2	Cut 1	40.80	44.81	36.31	38.36
		Cut 2	48.82		40.41	
	4	Cut 1	46.00	48.00	40.54	44.57
		Cut 2	50.00		48.60	
	8	Cut 1	54.21	57.24	47.20	51.21
		Cut 2	60.27		55.22	
Sandy	2	Cut 1	12.40	16.45	6.20	9.32
		Cut 2	20.50		12.44	
	4	Cut 1	28.97	29.98	20.06	23.07
		Cut 2	30.99		26.08	
	8	Cut 1	32.18	36.19	30.44	31.46
		Cut 2	40.20		32.48	
L.S.D at 5%				4.01		7.90

Table 9. Effects of soil type and mycorrhiza inoculation on carbohydrates percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Carbohydrates (%)	Mean	Carbohydrates (%)	Mean
Clay	Cut 1	20.86	22.88	20.14	23.17
	Cut 2	24.90		26.20	
Sandy	Cut 1	14.77	17.80	13.62	17.66
	Cut 2	20.83		21.70	
L.S.D at 5%			1.10		1.10
Mycorrhiza (g/plant)					
2	Cut 1	16.02	19.04	15.46	18.49
	Cut 2	22.06		21.52	
4	Cut 1	17.78	20.29	15.45	20.50
	Cut 2	22.80		25.55	
8	Cut 1	19.17	22.20	19.23	22.25
	Cut 2	25.23		25.27	
L.S.D at 5%			0.62		0.62

However, treating sage plants with mycorrhiza inoculation led to significant increase in carbohydrates percentage which were 22.20 and 22.25% at 8 g level in the 1st and 2nd seasons compared to 2 and 4 g levels. Similar results were achieved by Bagdat *et al*. (2017), Tarraf *et al.* (2017) on *Salvia officinalis* and Moghith *et al*. (2021) on chia, Abadi Zahra *et al*. (2018) on *Echium amoenum*, Merlin *et al*. (2020) on *Plactranthus amboinicus*, Rad and Radbact (2021) on *Ducrosia anethifolia* and Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis*.

Data in Table (10) showed that the effect of interaction between soil type and mycorrhiza inoculation on carbohydrates percentage of *Salvia officinalis* L was significant in both seasons of the study. It can be noticed that the highest values in both soils were at 8 g mycorrhiza inoculation levels. But the best result was obtained on clay soil (25.05 and 26.16%) in the two seasons compared to sandy soil (19.35 and 18.35) in the 1st and 2nd seasons, respectively. These results are in agreement with Rohricht *et al*. (1996), Amber *et al.* (2008) on rosemary, Badawy (2015) on *Pimpinlla anisum* L., Ghoushchi *et al.* (2015), Heikal *et al*. (2015) on rosemary plants. Rioba *et al.* (2015), Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis,* Khaledigan *et al.* (2021) on *Ocimum basilicum* and *Satureja hortensis*, and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

2. Carotenoids (mg/g):

Data dealing with the individual effect of soil type and mycorrhiza inoculation on the carotenoids content during both 2020/2021 and 2021/2022 growing seasons were presented in Table (11). The effect of soil type on carotenoids content of sage plants was significant in the two seasons of study. Planting in clay increased carotenoids (0.57 and 0.58 mg/g) in the 1st and 2nd seasons, respectively compared with sand soil (0.55 and 0.55 mg/g) in the 1st and 2nd seasons. These results are in agreement with Bezzi (1987) and Rohricht *et al*. (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill., Badawy (1998) on *Polianthes tuberosa,* Fawakhry (2001) on tuberose, Youssef *et al*. (2019) on *Swietenia mahagoni*, Moghith *et al*. (2021) on chia (*Salvia hispanica*) and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

However, treating sage plant with mycorrhiza inoculation with all different levels (2, 4, and 8 g) led to increasing of carotenoids content which the highest values were 0.67 and 0.64 mg/g with 8 g level compared to 2 (0.46 and 0.47) and 4 g (0.57 and 0.58) in the 1st and 2nd season, respectively. These results are in agreement with Bagdat *et al.* (2017) on *Salvia officinalis*, Tarraf *et al.* (2017) on *Salvia officinalis*, Abadi *et al*. (2018) on *Echium amoenum*, Merlin *et al*. (2020) on *Plactranthus amboinicus*, Moghith *et al*. (2021) on chia, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Rad and Radbakht (2021) on *Ducrosia anethifolia.*

Data in Table (12) showed that interaction between soil type and mycorrhiza inoculation on the carotenoids of *Salvia officinalis* L. were significant in the two seasons of study. It can be noticed that the best results of carotenoids content in both soil types were at 8 g level. But, the best result was on clay soil (0.68 and 0.67 mg/g) in two seasons compared with sandy soil (0.53 and 0.52 mg/g), respectively. These results are in agreement with Rohricht *et al*. (1996), Amber *et al.* (2008), Rioba *et al.* (2015), on *Salvia officinalis,* Badawy (2015) on *Pimpinella anisum* L., Ghoushchi *et al.* (2015), Heikal *et al*. (2015) on rosemary plants, Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis,* Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis,* and Gaafar *et al*. (2021) *Hibiscus sabdariffa* L.

3. Chlorophyll a (mg/g):

The individual effects of soil type and mycorrhiza inoculation on chlorophyll a during both growing seasons are presented in

Table 10. Effects of the interactions between soil type and mycorrhiza inoculation on carbohydrates percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Carbohydrates (%)	Mean	Carbohydrates (%)	Mean
Clay	2	Cut 1	17.20	21.23	15.60	19.61
		Cut 2	25.26		23.62	
	4	Cut 1	17.33	21.37	21.70	23.74
		Cut 2	25.40		25.78	
	8	Cut 1	20.03	25.05	22.12	26.16
		Cut 2	30.07		30.20	
Sandy	2	Cut 1	12.80	16.84	14.22	17.26
		Cut 2	20.88		20.30	
	4	Cut 1	14.18	17.21	14.32	17.36
		Cut 2	20.24		20.40	
	8	Cut 1	15.30	19.35	16.33	18.35
		Cut 2	23.40		20.37	
L.S.D at 5%				0.88		1.04

Table 11. Effects of soil type and mycorrhiza inoculation on carotenoids content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Carotenoids (mg/g)	Mean	Carotenoids (mg/g)	Mean
Clay	Cut 1	0.54	0.59	0.56	0.58
	Cut 2	0.64		0.60	
Sandy	Cut 1	0.50	0.55	0.52	0.55
	Cut 2	0.60		0.58	
L.S.D at 5%			0.07		0.06
Mycorrhiza (g/plant)					
2	Cut 1	0.43	0.46	0.43	0.47
	Cut 2	0.49		0.51	
4	Cut 1	0.53	0.57	0.56	0.58
	Cut 2	0.60		0.60	
8	Cut 1	0.65	0.67	0.60	0.64
	Cut 2	0.69		0.68	
L.S.D at 5%			0.03		0.07

Table 12. Effects of the interactions between soil type and mycorrhiza inoculation on carotenoids content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Carotenoids (mg/g)	Mean	Carotenoids (mg/g)	Mean
Clay	2	Cut 1	0.60	0.62	0.60	0.61
		Cut 2	0.64		0.62	
	4	Cut 1	0.62	0.66	0.61	0.63
		Cut 2	0.70		0.65	
	8	Cut 1	0.66	0.68	0.64	0.67
		Cut 2	0.70		0.70	
Sandy	2	Cut 1	0.40	0.45	0.40	0.45
		Cut 2	0.50		0.50	
	4	Cut 1	0.45	0.47	0.47	0.50
		Cut 2	0.49		0.53	
	8	Cut 1	0.50	0.53	0.49	0.52
		Cut 2	0.56		0.54	
L.S.D at 5%				0.05		0.10

Table (13). Clay soil treatment increased the chlorophyll a content which was 0.73 mg/g in both seasons compared with sand soil (0.70 and 0.71 mg/g) in the 1st and 2nd seasons, respectively. Similar results were reported by Bezzi (1987) and Rohricht *et al*. (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) and El-Sherbeiny *et al*. (1992) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill, Moghith *et al*. (2021) on chia (*Salvia hispanica*) and Gaafar *et al*. (2021) *Hibiscus sabdariffa* L.

However, inoculation of sage plant with mycorrhiza increased chlorophyll a (0.88 mg/g in both seasons with 8 g treatment compared to 2 and 4 g treatments which were 0.58 mg/g in both seasons for the first level and 0.70 and 0.69 mg/g in the 1st and 2nd seasons, respectively for the second level. Similar results were achieved by Bagdat *et al.* (2017), Tarraf *et al*. (2017) on *Salvia officinalis* and Moghith *et al*. on *Salvia hispanica*, Merlin *et al*. (2020) on *Plactranthus amboinicus*, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Rad and Radbakht (2021) on *Ducrosia anethifolia*.

Data in Table (14) showed that the effect of interaction between soil type and mycorrhiza inoculation on chlorophyl (a) of *Salvia officinalis* L. was significant. It can be noticed that the best values of chlorophyll a content were obtained on both soils with 8 g mycorrhiza inoculation level. But, the best result was in clay soil (0.90 mg/g) in the two seasons compared to sandy soil being 0.68 and 0.67 in 2020/2021 and 2021/2022 seasons, respectively. These results are in agreement with Rohricht *et al*. (1996), Amber *et al.* (2008), Rioba *et al.* (2015), Ghoushchi *et al.* (2015), Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis*, Badawy (2015) on *Pimpinella anisum* L., Heikal *et al*. (2015) on rosemary plants, Khaledigan *et al*. (2021) on *Ocimum basilicum and Satureja hortensis* and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

4. Chlorophyll b (mg/g):

The individual effects of soil type and mycorrhiza inoculation on the chlorophyll b content during both growing seasons of the study were presented in Table (15). The content of chlorophyll b in sage plants was increased in clay soil resulting 0.65 and 0.66 mg/g in the 1st and 2nd seasons, respectively compared with sandy soil which were 0.54 and 0.56 mg/g in the 1st and 2nd seasons, respectively. Bezzi (1987) and Rohricht *et al*. (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill, El-Sherbeiny *et al*. (1992) on *Pelargonium graveolens* L., and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

However, inoculating sage plants with mycorrhiza at 8 g level increased chlorophyll b content (0.65 and 0.67 mg/g in 2020/2021 and 2021/2022 seasons, respectively) compared with 2 and 4 g levels. This was in agreement with Bagdat *et al.* (2017), Tarraf *et al.* (2017), Abadi Zahra *et al*. (2018) on *Echium amoenum*. Also, similar results were achieved by Merlin *et al*. (2020) on *Plactranthus amboinicus,* Moghith *et al.* (2021) on chia, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Rad and Radbakht (2021) on *Ducrosia anethifolia.*

Data in Table (16) showed the interaction between soil type and mycorrhiza inoculation on the chlorophyl b content of *Salvia officinalis* L. during 2020/21 and 2021/22 seasons. It can be noticed that, the highest content of chlorophyl b were resulted in both soils with mycorrhiza inoculation at 8g level. But the best result was on clay soil being 0.73 and 0.74mg/g in two seasons compared with sandy soil (0.56 and 0.59) mg/g, respectively. These results are in agreement with Rohricht *et al*. (1996), Amber *et al.* (2008), Heikal *et al*. (2015) on rosemary plants, Badawy (2015), Ghoushchi *et al.* (2015), Rioba *et al.* (2015), Bagdat *et al*. (2017) and Amer *et al*. (2019), on *Salvia officinalis*, Khaledigan *et al*. (2021) on *Osimum basilicum* and *Satureja*

Table 13. Effects of soil type and mycorrhiza inoculation on chlorophyll a content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Chlorophyll a (mg/g)	Mean	Chlorophyll a (mg/g)	Mean
Clay	Cut 1	0.71	0.73	0.70	0.73
	Cut 2	0.75		0.76	
Sandy	Cut 1	0.65	0.70	0.68	0.71
	Cut 2	0.75		0.74	
L.S.D at 5%			0.11		0.13
Mycorrhiza (g/plant)					
2	Cut 1	0.56	0.58	0.55	0.58
	Cut 2	0.60		0.61	
4	Cut 1	0.67	0.70	0.68	0.69
	Cut 2	0.73		0.70	
8	Cut 1	0.86	0.88	0.86	0.88
	Cut 2	0.90		0.90	
L.S.D at 5%			0.05		0.05

Table 14. Effects of the interactions between soil type and mycorrhiza inoculation on chlorophyll a content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Chlorophyll a (mg/g)	Mean	Chlorophyll a (mg/g)	Mean
Clay	2	Cut 1	0.68	0.71	0.66	0.71
		Cut 2	0.74		0.76	
	4	Cut 1	0.80	0.85	0.84	0.87
		Cut 2	0.90		0.90	
	8	Cut 1	0.87	0.90	0.85	0.90
		Cut 2	0.93		0.95	
Sandy	2	Cut 1	0.54	0.57	0.53	0.57
		Cut 2	0.60		0.61	
	4	Cut 1	0.56	0.58	0.56	0.58
		Cut 2	0.60		0.60	
	8	Cut 1	0.65	0.68	0.63	0.67
		Cut 2	0.71		0.71	
L.S.D at 5%				0.07		0.07

Table 15. Effects of soil type and mycorrhiza inoculation on chlorophyll b content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Chlorophyll b (mg/g)	Mean	Chlorophyll b (mg/g)	Mean
Clay	Cut 1	0.63	0.65	0.64	0.66
	Cut 2	0.67		0.68	
Sandy	Cut 1	0.50	0.54	0.53	0.56
	Cut 2	0.58		0.59	
L.S.D at 5%			0.04		0.06
Mycorrhiza (g/plant)					
2	Cut 1	0.50	0.51	0.50	0.53
	Cut 2	0.52		0.56	
4	Cut 1	0.60	0.61	0.60	0.64
	Cut 2	0.62		0.68	
8	Cut 1	0.60	0.65	0.70	0.67
	Cut 2	0.70		0.64	
L.S.D at 5%			0.58		0.03

Table 16. Effects of the interactions between soil type and mycorrhiza inoculation on chlorophyl b content (mg/g) of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	**Mycorrhiza (g/plant)**	**Cut No.**	**Chlorophyll b (mg/g)**	**Mean**	**Chlorophyll b (mg/g)**	**Mean**
Clay	**2**	**Cut 1**	0.56	0.58	0.55	0.60
		Cut 2	0.60		0.65	
	4	**Cut 1**	0.62	0.66	0.68	0.69
		Cut 2	0.70		0.70	
	8	**Cut 1**	0.70	0.73	0.70	0.74
		Cut 2	0.76		0.78	
Sandy	**2**	**Cut 1**	0.45	0.48	0.45	0.50
		Cut 2	0.51		0.55	
	4	**Cut 1**	0.50	0.53	0.50	0.55
		Cut 2	0.56		0.60	
	8	**Cut 1**	0.52	0.56	0.58	0.59
		Cut 2	0.60		0.60	
L.S.D at 5%				0.06		0.05

hortensis and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

5. Nitrogen percentage:

Using clay soil as planting media increased nitrogen percentage which was 2.62 and 2.64% in the 1st and 2nd seasons, respectively compared with using sand soil (1.98 and 2.01%) in the 1st and 2nd seasons, respectively (Table, 17). Similar results were obtained by Bezzi (1987) and Rohricht *et al.* (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) and El-Sherbeiny *et al*. (1992) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill, Badawy (1998) on *Polianthes tuberosa*, El-Fawakhry (2001) on tuberose, Youssef *et al.*(2019) on *Swietenia mahagoni*, Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L. and Moghith *et al*. (2021) on chia (*Salvia hispanica*).

Treating sage plants with mycorrhiza fungi increased nitrogen percentages in both seasons which were 2.59 and 2.62% at 8 g compared to 2 and 4 g levels which were 2.05 and 2.05% at 2 g but were 2.26 and 2.27% at 4 g level during the 1st and 2nd season, respectively. Similar results were achieved by Bagdat *et al.* (2017), Tarraf *et al.* (2017) and Moghith *et al*. (2021) on *Salvia officinalis*, Abadi Zahra *et al*. (2018) on *Echium amoenum*, Merlin *et al*. (2020) on *plactranthus amboinicus* and Rad and Radbakht (2021) on *Ducrosia anethifolia.*

Data presented in Table (18) showed the effect of interaction between soil type and mycorrhiza inoculation on the nitrogen percentage of *Salvia officinalis* L. It can be noticed that, the highest values of nitrogen percentage on both soils were with 8g mycorrhiza inoculation level. But, the clay soil showed the best result (2.95 and 3.05%) compared with sandy soil (2.22 and 2.20%) in the 1st and 2nd seasons respectively. These results are in agreement with Badawy (2015) on *Pimpinella anisum* L., Heikal *et al*. (2015) on rosemary plants, Rioba *et al.* (2015), Ghoushchi *et al.* (2015), Bagdat *et al*. (2017) and Amer *et al.* (2019) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni*, Khaledigan *et al*. (2021), on *Ocimum basilicum* and *Satureja hortensis* and Gaafar *et al*. (2021) *Hibiscus sabdariffa* L.

6. Phosphorus percentage:

Results established in Table (19) showed the effects of soil type and mycorrhiza inoculation individually on the phosphorus percentage during 2020/21 and 2012/2022 growing seasons. Phosphorus percentage in sage plants planted in clay soil was high (0.52 and 0.42%) compared with sand soil (0.37 and 0.31%) in the 1st and 2nd seasons, respectively. This result was acceptable

Table 17. Effects of soil type and mycorrhiza inoculation on nitrogen percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Nitrogen (%)	Mean	Nitrogen (%)	Mean
Clay	Cut 1	0.60	2.62	1.62	2.64
	Cut 2	4.64		3.66	
Sandy	Cut 1	0.97	1.98	1.00	2.01
	Cut 2	2.99		3.02	
L.S.D at 5%			0.17		0.51
Mycorrhiza (g/plant)					
2	Cut 1	1.03	2.05	1.00	2.05
	Cut 2	3.07		3.09	
4	Cut 1	1.22	2.26	1.24	2.27
	Cut 2	3.30		3.30	
8	Cut 1	1.58	2.59	1.60	2.62
	Cut 2	3.60		3.64	
L.S.D at 5%			0.10		0.32

Table 18. Effects of the interactions between soil type and mycorrhiza inoculation on nitrogen percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Nitrogen (%)	Mean	Nitrogen (%)	Mean
Clay	2	Cut 1	1.26	2.28	1.40	2.43
		Cut 2	3.30		3.46	
	4	Cut 1	1.60	2.63	1.40	2.45
		Cut 2	3.66		3.50	
	8	Cut 1	1.93	2.95	2.04	3.05
		Cut 2	3.97		4.06	
Sandy	2	Cut 1	0.81	1.83	0.70	1.75
		Cut 2	2.85		2.80	
	4	Cut 1	0.88	1.89	1.00	2.05
		Cut 2	2.90		3.09	
	8	Cut 1	1.20	2.22	1.17	2.20
		Cut 2	3.24		3.23	
L.S.D at 5%				0.14		0.45

Table 19. Effects of soil type and mycorrhiza inoculation on phosphorus percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Phosphorus (%)	Mean	Phosphorus (%)	Mean
Clay	Cut 1	0.48	0.52	0.39	0.42
	Cut 2	0.56		0.45	
Sandy	Cut 1	0.34	0.37	0.27	0.31
	Cut 2	0.40		0.35	
L.S.D at 5%			0.03		0.05
Mycorrhiza (g/plant)					
2	Cut 1	0.38	0.36	0.31	0.33
	Cut 2	0.34		0.35	
4	Cut 1	0.41	0.43	0.40	0.36
	Cut 2	0.44		0.32	
8	Cut 1	0.52	0.56	0.35	0.40
	Cut 2	0.60		0.45	
L.S.D at 5%			0.08		0.05

because the clay soil was higher in nutrient elements than poor sand soil. similar results were achieved by Bezzi (1987) and Rohricht *et al*. (1996) on *Salvia officinalis* L., Rajeswara *et al.* (1990) and El-Sherbeiny *et al*. (1992) on *pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *Foeniculum vulgare* Mill Badawy (1998) on *Polianthes tuberosa*, El-Fawakhry(2001) on tuberose, Youssef *et al*. (2019) on *Swietenia mahagon*, Moghith *et al*. (2021) on chia *(Salvia hispanica*) and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

However, inoculating sage plant with mycorrhiza led to an increase in phosphorus percentage being 0.56 and 0.40% with 8 g inoculating level compared with 2 and 4 g treatments. Similar results were reported by Bagdat *et al.* (2017), Tarraf *et al*. (2017), Khaledigan *et al*. (2021) on *Salvia officinalis*, Abadi *et al*. (2018) on *Echium amoenum*, Merlin *et al*. (2020) on *Plactranthus amboinicus* and Rad and Radbakht (2021) on *Ducrosia anethifolia.*

Data in Table (20), show the effect of interaction between soil type and mycorrhiza inoculation on the phosphorus percentage of *Salvia officinalis* L. during 2020/21 and 2021/22 seasons. It can be noticed that, the best results of phosphorus percentage on both soils with 8g mycorrhiza inoculation. But, the best result was on clay soil (0.51 and 0.47%) in the two seasons compared with sandy soil (0.35 and 0.34%), respectively.

These results are in agreement with Rohricht *et al*. (1996) on *Salvia officinalis*, Amber *et al.* (2008) on *Ocimum basilcum*, Rioba *et al.* (2015) on *Salvia officinalis*, Ghoushchi *et al.* (2015), on *Salvia officinalis*, Badawy (2015) on *Pimpinlla anisum* L., Heikal *et al*. (2015) on rosemary plants, Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni*, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

7. Potassium percentage:

Data dealing with the individual effects of soil type and mycorrhiza inoculation on potassium percentage during both growing seasons were presented in Table (21). Planting sage plants (*Salvia officinalis* L.) on clay soil increased the potassium percentage (0.97 and 0.94% in the 1^{st} and 2^{nd} seasons, respectively). But sandy soil showed less potassium percentage (0.56 and 0.55% in the 1^{st} and 2^{nd} seasons, respectively). Similar results were reported by Bezzi (1987) *Salvia officinalis* Rajeswara *et al.* (1990) on *Pelargonium graveolens* L., Omidbaigi and Hornok (1992) on *F. vulgare* Mill), El-Sherbeiny *et al*. (1992) on *P. graveolens* L Rohricht *et al.* (1996) on *Salvia officinalis* L., Badawy(1998) on *Polianthes tuberosa*, El-Fawakhry (2001) on tuberose, Youssef *et al*. (2019) on *Swietenia mahagoni*, Moghith *et al*. (2021) on chia (*Salvia hispanica*) and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

However, treating sage plant with mycorrhiza inoculation led to increasing of potassium percentage which was 0.90 and 0.89% at 8 g treating level in the first and second seasons respectively, compared with 2 or 4 g treating level which were 0.65% in both seasons for the first level and were 0.74 and 0.70% in the first and second seasons respectively, for the second level. Similar results were achieved by Bagdat *et al.* (2017), Tarraf *et al.* (2017), on *Salvia officinalis*, Abadi Zahra *et al*. (2018) on *Echium amoenum*, Merlin *et al*. (2020) on *P. amboinicus*, Moghith *et al*. (2021), Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis*, and Rad and Radbakht (2021) on *D. anethifolia.*

Data presented in Table (22), showed the effect of interaction between soil type and mycorrhiza inoculation on the potassium percentage of *Salvia officinalis* L. It can be noticed that the highest potassium percentage on both two soils was obtained with 8 g mycorrhiza inoculation level. However, the best result was on clay soil treatment being 1.20 and 1.91% in two seasons compared with sandy soil (0.61 and 0.61%), respectively.

Table 20. Effects of the interactions between soil type and mycorrhiza inoculation on phosphorus percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	**Mycorrhiza (g/plant)**	**Cut No.**	**Phosphorus (%)**	**Mean**	**Phosphorus (%)**	**Mean**
Clay	**2**	**Cut 1**	0.40	0.42	0.32	0.36
		Cut 2	0.44		0.40	
	4	**Cut 1**	0.46	0.48	0.40	0.42
		Cut 2	0.50		0.44	
	8	**Cut 1**	0.47	0.51	0.44	0.47
		Cut 2	0.55		0.50	
Sandy	**2**	**Cut 1**	0.28	0.29	0.28	0.29
		Cut 2	0.30		0.30	
	4	**Cut 1**	0.25	0.30	0.25	0.30
		Cut 2	0.35		0.35	
	8	**Cut 1**	0.30	0.35	0.30	0.34
		Cut 2	0.40		0.38	
L.S.D at 5%				0.09		0.06

Table 21. Effects of soil type and mycorrhiza inoculation on potassium percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	**Cut No.**	**Potassium (%)**	**Mean**	**Potassium (%)**	**Mean**
Clay	**Cut 1**	0.95	0.97	0.98	0.94
	Cut 2	0.99		0.90	
Sandy	**Cut 1**	0.54	0.56	0.50	0.55
	Cut 2	0.58		0.60	
L.S.D at 5%			0.13		0.06
Mycorrhiza (g/plant)					
2	**Cut 1**	0.60	0.65	0.60	0.65
	Cut 2	0.70		0.70	
4	**Cut 1**	0.78	0.74	0.66	0.70
	Cut 2	0.70		0.74	
8	**Cut 1**	0.85	0.90	0.88	0.89
	Cut 2	0.95		0.90	
L.S.D at 5%			0.07		0.05

Table 22. Effects of the interactions between soil type and mycorrhiza inoculation on potassium percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	**Mycorrhiza (g/plant)**	**Cut No.**	**Potassium (%)**	**Mean**	**Potassium (%)**	**Mean**
Clay	**2**	**Cut 1**	0.75	0.77	0.74	0.78
		Cut 2	0.79		0.82	
	4	**Cut 1**	0.90	0.94	0.84	0.88
		Cut 2	0.98		0.92	
	8	**Cut 1**	0.15	1.20	0.90	1.91
		Cut 2	2.25		2.92	
Sandy	**2**	**Cut 1**	0.49	0.53	0.45	0.50
		Cut 2	0.57		0.55	
	4	**Cut 1**	0.50	0.54	0.50	0.52
		Cut 2	0.58		0.54	
	8	**Cut 1**	0.60	0.61	0.57	0.61
		Cut 2	0.62		0.65	
L.S.D at 5%				0.10		0.77

These results are in agreement with Rohricht *et al*. (1996) on *Salvia officinalis*, Amber *et al.* (2008) on *Ocimum basilcum*, Rioba *et al.* (2015) on *Salvia officinalis*, Ghoushchi *et al.* (2015) on *Salvia officinalis*, Badawy (2015) on *Pimpinlla anisum* L., Heikal *et al*. (2015) on rosemary plants, Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni*, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

8. Essential oil percentage:

The individual effects of soil type and mycorrhiza inoculation on the essential oil percentage during 2020/21 and 2021/22 growing seasons were presented in Table (23). Using the two soil types as a treatment for sage plants, clay soil increased the essential oil percentage being 1.65 and 1.71 in the 1st and 2nd seasons, respectively, compared with sand soil (5.57 and 4.79%) in the 1st and 2nd seasons, respectively. Similar results were achieved by Bezzi (1987) on *Salvia officinalis* Rajeswara *et al.* (1990) and El-Sherbeiny *et al*. (1992) on *P. graveolens* L., Omidbaigi and Hornok (1992) on *F. vulgare* Mill, Rohricht *et al*. (1996) on *Salvia officinalis* L., Moghith *et al*. (2021) on chia (*Salvia hispanica*), Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

However, inoculating sage plants with mycorrhiza increased essential oil percentage which were 1.54 and 1.64% at 8 g level compared with 2 g (1.36 and 1.16%) or 4 g (1.46 and 1.42%). Similar results were mentioned by Bagdat *et al.* (2017) on *Salvia officinalis*, Tarraf *et al.* (2017) on *Salvia officinalis*, Abadi Zahra *et al*. (2018) on *E. amoenum*, Merlin *et al*. (2020) on *P. amboinicus*, Moghith *et al*. (2021) on *Salvia officinalis*, and Rad and Radbakht (2021) on *D. anethifolia*.

Data presented in Table (24) showed that the interaction between soil type and mycorrhiza inoculation significantly affected the essential oil percentage of *Salvia officinalis* L. It can be noticed that the highest essential oil percentages were on two both soils with 8 g mycorrhiza inoculation. But, the best result was on clay soil (1.76 and 1.96%) in two seasons with sandy soil (1.32 and 1.31%), respectively. These results are in agreement with Rohricht *et al*. (1996) on *Salvia officinalis*, Amber *et al.* (2008) on *Ocimum basilcum*, Rioba *et al.* (2015) on *Salvia officinalis*, Ghoushchi *et al.* (2015) on *Salvia officinalis*, Badawy (2015) on *Pimpinlla anisum* L., Heikal *et al*. (2015) on rosemary plants, Bagdat *et al*. (2017) and Amer *et al*. (2019) on *Salvia officinalis*, Youssef *et al*. (2019) on *Swietenia mahagoni*, Khaledigan *et al*. (2021) on *Ocimum basilicum* and *Satureja hortensis* and Gaafar *et al*. (2021) on *Hibiscus sabdariffa* L.

9. Essential oil components:

Table (25) showed the different components separated and identified from sage herb oil samples produced from the growth plants on two soil type inoculated with mycorrhiza.

The obtained chromatograms revealed the presence of 17 components of which 12 components were identified by the retention times obtained from pure reference compounds. The identified components in herb sage oil are α-pinene, camphene, β-pinene, thujone, cineole, terpinene, linalool, methyl chavicol, linalyl acetate, camphor, borneol and eugenol. The relative percentage areas indicating the effect of the different inoculation on the composition of each sample are demonstrated. The results showed that, clay soil + 8 g mycorrhiza inoculation level resulted in the greatest value of α-pinene, camphene, thujone, cineole, terpinene, linalool, methyl chavicol, linalyl acetate, camphor, borneol and eugenol compared with other treatments.

CONCLUSION

Cultivation of sage in clay soils with the addition of 8 g of mycorrhizal fungi led to a significant increase in vegetative characteristics such as plant height, number of branches, fresh and dry weight, as well as a

Table 23. Effects of soil type and mycorrhiza inoculation on essential oil percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments		1st season		2nd season	
Soil type	Cut No.	Essential oil (%)	Mean	Essential oil (%)	Mean
Clay	Cut 1	0.60	1.65	0.67	1.71
	Cut 2	2.70		2.75	
Sandy	Cut 1	0.22	1.26	0.50	1.33
	Cut 2	2.30		2.15	
L.S.D at 5%			0.07		0.04
Mycorrhiza (g/plant)					
2	Cut 1	0.32	1.36	0.12	1.16
	Cut 2	2.40		2.20	
4	Cut 1	0.41	1.46	0.39	1.42
	Cut 2	2.51		2.45	
8	Cut 1	0.52	1.54	0.60	1.64
	Cut 2	2.56		2.68	
L.S.D at 5%			0.16		0.15

Table 24. Effects of the interactions between soil type and mycorrhiza inoculation on essential oil percentage of *Salvia officinalis* L. during 2020/2021 and 2021/2022.

Treatments			1st season		2nd season	
Soil type	Mycorrhiza (g/plant)	Cut No.	Essential oil (%)	Mean	Essential oil (%)	Mean
Clay	2	Cut 1	0.50	1.53	0.44	1.47
		Cut 2	2.56		2.50	
	4	Cut 1	0.63	1.66	0.65	1.70
		Cut 2	2.69		2.75	
	8	Cut 1	0.73	1.76	0.94	1.96
		Cut 2	2.79		2.98	
Sandy	2	Cut 1	0.1	1.20	0.80	0.85
		Cut 2	2.3		0.90	
	4	Cut 1	0.22	1.26	0.8	1.50
		Cut 2	2.30		2.20	
	8	Cut 1	0.28	1.32	0.29	1.31
		Cut 2	2.36		2.33	
L.S.D at 5%				0.23		0.22

Table 25. Effects of the interactions between soil type and mycorrhiza inoculation on essential oil components rcentages of *Salvia officinalis* during 2020/2021 and 2021/2022 seasons.

Soil type	Mycorrhiza (g/plant)	α -pinene	Camphene	β-pinene	Thujone	Cineole	Trpinene	Linalool	Methyl chavicol	Linalyl acetate	Camphor	Borneol	Eugenol	Unknown
Clay	2	2.03	2.38	2.693	1.73	3.09	8.16	1.19	0.89	37.16	8.58	3.59	5.92	24.04
	4	2.06	2.51	2.85	1.44	3.29	9.23	1.21	0.95	40.62	8.98	3.64	5.85	21.37
	8	2.07	2.60	2.90	1.48	3.39	9.58	1.23	0.98	40.85	9.19	4.05	5.98	13.26
Sandy	2	1.43	2.08	2.32	1.16	3.11	8.20	1.18	0.79	39.31	8.65	4.00	5.25	12.96
	4	1.69	2.11	2.40	1.18	3.30	8.36	1.54	0.84	40.65	9.05	3.53	5.42	17.65
	8	1.92	2.18	2.48	1.22	3.40	8.88	1.56	0.87	38.99	9.41	3.64	5.60	16.04

significant increase in the chemical composition of carbohydrates, pigments chlorophyll a, b and carotene, as well as NPK, and an increase in oil components and active substances, compared to cultivation in sandy soils and the addition of 2 g of mycorrhizal fungi. Therefore, it is recommended to cultivate in clay soils and add 8 grams of mycorrhizal fungi.

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تاثير نوع التربة والميكورهيزا على النمو الخضري والمحصول والتركيب الكيماوي لنبات المريمية

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هدفت التجارب إلى معرفة التأثيرات الفردية والجماعية للتسميد بالميكورهيزا عند ثلاثة تركيزات (٢، ٤ و ٨ جم/نبات) تحت تأثير نوعين من التربة (الطينية والرملية) على النمو الخضري والتركيب الكيميائي ومكونات الزيت العطري لنبات المريمية. أكدت النتائج أن استخدام الميكورهيزا بتركيز ٨جم للنبات تحت نوعين من التربة كان له استجابة معنوية على جميع المتغيرات في هذه الدراسة. كما أدى ذلك إلى دعم مؤشرات النمو الخضري وتعزيز التركيب الكيميائي وزيادة نسبة الزيت والمكونات الكيميائية للزيت العطري، خاصة عند استخدام التربة الطينية. بالإضافة إلى ذلك، فإن التفاعل بين مستويات الميكورهيزا ونوع التربة إلى تحسين جميع الصفات المدروسة، خاصة استخدام ٨جم من الميكورهيزا تحت تربة طينية.