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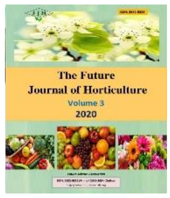

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EFFECT OF MAGNETITE AND SELENIUM IN IMPROVING GROWTH, CHEMICAL CONSTITUENTS OF *Solidago canadensis* PLANT UNDER SALINITY STRESS CONDITIONS

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ABSTRACT: An experiment was conducted at a private new reclaimed farm, Wadi El-Natrun, El-Beheira Governorate, Egypt, during 2020 and 2021 seasons, to examine the effects of foliar spraying selenium at 2 and 5 mg/L and varying rates of magnetite application (200 and 300 kg/fed) on the growth, yield, oil production, and chemical composition of the *Solidago canadensis* L. plant. The application of magnetite at a rate of 300 kg/fed and selenium as foliar application at 2 mg/L produced the best results for the same parameters. The best results from all the tested parameters were: plant height (cm), number of inflorescences/plant, inflorescence length/plant (cm), leaf length (cm), herb fresh and dry weight (g), fresh herb yield (ton fed^{-1}), essential oil percentage, and essential oil yield/fed. Moreover, the application of magnetite and selenium combined to improve the chemical constituents (N, P, and K levels), oil production, and vegetative development. The application of the second level of magnetite (300 kg/fed) and the spraying of selenium at a concentration of 2 mg/L resulted in the greatest significant rise in all metrics. After this treatment, the main constituent of the essential oil was α-Pinene (32.75%), which was followed by Germacrene D (27.49%). Conversely, employing magnetite and selenium resulted in a decrease in the *solidago canadensis* plant's Na, Cl, and proline levels.

Key words: *Solidago canadensis*, magnetite, selenium, growth, Essential oil.

INTRODUCTION

Golden rod (*Solidago canadensis* L.), a member of the Asteraceae family, is considered an ornamental plant **(Melville, 1982).** One of the most well-liked commercially cut flowers, it's utilized as filler in bouquets, corsages, boutonnieres, and automobile décor, among other floral arrangements. It has a great deal of promise for the dry flower business. This herb was utilized by the Native Americans to treat nephritis, arthritis, emphysema, and periodontal disease.

Terpenoids, saponins, phenolic acids, phenolic glycosides, and significant concentrations of flavonoids, primarily quercetin, kaempferol, and rutin, are present in plants of this genus. **Lorenzi *et al.* (2002)**. The species representing the Solidago genus also show antibacterial and antimutagenic activity (**Kołodziej *et al.*, 2011).** For this reason, they are used as raw material in herbal medicine as the so-called “blood-purifying” agents in gout, rheumatism, arthritis, eczema, and other skin disorders **(Kołodziej *et al.*, 2011).** *Solidago spp*.-infused herbal infusions are particularly advised for the management of infections and inflammations, as well as to help clear urinary gravel and avoid the development of renal calculi. They also have an antitussive effect **(Sutovská *et al.*, 2013).** In phytotherapy, *Solidago* flowers and leaves are mainly used **(European Pharmacopoeia, 2008).**

One of the main environmental factors limiting plant productivity and growth is salinity. The importance of salinity to the political and scientific agendas has grown. Twenty percent of irrigated land and more than 6% of the world's land area are affected by salt **(FAO, 2010).**

Around the world, soil salinity continues to be a significant abiotic stressor that inhibits the growth, flowering, and yield of many different plant species. **(Tester and Davenport, 2003).** Problems of salinity are especially important in arid and semiarid regions like Egypt. In Egypt, the majority of extension agricultural land and about 33% of cultivated land are already salinized **(AboelSoud *et al.*, 2022).** In most of these areas, the reduction in crop yield owing to salinity is approximately 60% when compared to normal soil.

Plant growth can be impacted by salinity in a number of ways. Initially, the plant's ability to absorb water is diminished by the presence of salt in the soil, leading to a prompt decline in growth rate. The osmotic action of the salt-containing soil solution causes this initial stage of the growth response, which results in a set of consequences akin to those of water stress **(Munns, 2002).** Salinity significantly lowers stomatal conductance, which lowers photosynthetic rate **(Munns and Tester, 2008).** Nevertheless, stomatal closure's inhibition of photosynthetic rate may encourage an imbalance between photochemical activity at photosystem II (PSII) and the amount of electrons needed for photosynthesis. **(Souza *et al.*, 2004).**

One of the most important elements influencing growth of plant, particularly in salinity conditions, is magnetite (iron ore). Having a high iron content, magnetite is a naturally occurring row rock with a black or brownish-red color and a Mohs hardness of about 6. It is one of only two naturally magnetic natural row rocks in the world **(Mansour, 2007).** According to **Taha *et al.* (2011),** applying magnetic iron to pepper plants grown in saline soil enhanced their yield and vegetative growth. Furthermore, **Yasser *et al.* (2011)** found that magnetic iron enhanced plant growth and leaf mineral content in roselle plants (Hibiscus Sabdariffal) and cauliflower **(Mansour, 2007).** Moreover, **Matsudo *et al.* (1993)** on strawberries and **Podlesny *et al.* (2005)** on peas reported that magnetic fields had a positive impact on flower count and overall yield. Furthermore, it was demonstrated by **Moon and Chung (2000)** that adding a magnetic field to irrigation water increased the nutrient content of the plants.

Selenium also has the ability to control a plant's water status in salinity or drought. Additionally, it can postpone senescence, encourage the growth of old seedlings, and increase plants' resistance to UV-induced oxidative stress **(Germ and Stibilj, 2007). Hawrylak-Nowak (2008)** discovered that the P and Ca concentrations of maize increased but the K content dropped when Se treatments were applied. At low concentrations, selenium tended to encourage plant development and root elongation; but, at higher concentrations, it drastically decreased the root tolerance index and dry mass accumulation. According to **Lan *et al.* (2019),** Because selenium increases the body's production of antioxidant compounds (flavonoids, phenolic compounds, anthocyanins, etc.) and antioxidant enzymes (catalase, peroxidase, etc.), it can help lessen the oxidative damage caused by stress. The antioxidant enzyme system, which helps scavenge free radicals generated by salt stress conditions, includes selenium as one of its key components.

Plant growth and yield are enhanced, photosynthesis is enhanced, and ion homeostasis is maintained as a result **(Desoky *et al.*, 2021).** Furthermore, it has been demonstrated that adequate Se levels improve the plant's defense system and control sodium carriers, which lessen the detrimental effects of salt stress **(Rasool *et al.*, 2022).** Se enhanced olive (*Olea europaea* L.) plants' tolerance to salinity stress, as demonstrated by ***Regni et al.* (2021).** Increases in proline content, RWC, leaf dry weight, and photosynthesis resulted from this. In a similar vein, plants treated to 50 mM NaCl showed elevated levels of proline, total soluble sugars, chlorophyll, carotenoid, RWC, and catalase enzymes in their shoots and roots after receiving Se bio fortification (*Phaseolus vulgaris* L.). **(Farag *et al.*, 2022).**

However, the aim of this experiment is to assess how magnetic iron and selenium can lessen the detrimental impacts of soil salinity on *Solidago canadensis* growth and quality.

MATERIALS AND METHODS

This study examined the effects of magnetite and selenium on the yield and quality of *Solidago canadensis* grown in saline conditions. It was carried out in the 2020 and 2021 growing seasons at a private new reclaimed farm, Wadi El-Natrun, El-Beheira Governorate, Egypt (30°23'19.89″ N latitude and 30°21'41.06″ Elongitude).

The experimental site's soil had a sandy texture. The methodology as stated by **Chapman and Pratt (1978)** (Tables 1 and 2) was followed in the analysis of the soil and the chemical composition of irrigation water.

Table (1). Physical and chemical analysis of the soil used for growing *Solidago canadensis* plants during 2020 and 2021 seasons

Soil properties	2020	2021
Physical properties		
Sand%	92.48	91.71
Clay%	3.18	3.03
Silt%	4.34	5.26
Soil texture	sand	sand
Chemical properties		
Soil (pH) 1:25	7.6	7.5
EC (dS/m)	5.22	5.49
Organic Matter (OM)	0.31	0.25
Total CaCO3 (%)	6.18	6.34
N (ppm)	3.87	3.19
P (ppm)	7.62	7.28
K (ppm)	30.11	32.65

Table (2). Chemical properties of well irrigation water

Season	pH	EC	Soluble anions (meq/l)				Soluble cations (meq/l)			
			CO3--	HCO3-	Cl-	SO4--	Ca++	Mg++	Na+	K+
2020	7.59	3.97	0.2	4.76	19.53	11.44	2.69	3.32	24.18	0.47
2021	7.63	3.66	0.2	4.54	20.26	11.87	2.14	3.58	26.39	0.45

Solidago canadensis L. seedlings with 20 cm tall were obtained from EG. Trade for Flowers company in Agriculture road, Square station, Elasafra, Dakahlyia, Egypt. The seedlings were planted on 4 th April 2020 and 2021 in a moist open field, spaced 100 cm among rows and 30 cm between plants in 4 × 10 m plots and a drip irrigation network with a 4L /H flow rate. Farm irrigation was practiced in 3-day intervals. On July 12, both seasons' harvests were completed.

Chemical fertilization with calcium superphosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O) at 300 kg and 150 kg/fed., respectively, was added to the soil during soil preparation as recommended by **Sarhan *et al.*, (2017)** Ammonium sulfate, (20.5%), was applied as nitrogen fertilizer at a rate of 200 kg/fed. The fertilizer was applied in three equal doses, the first occurring 30 days after planting and the other two times spaced 45 days apart during the growing season. The layout of the experiment was a randomized complete blocks design with nine treatments and three replicates.

Foliar Spray of Selenium and Magnetite Treatments

Two times, soil drench applications of magnetite (magnetic iron, Fe_3O_4) were made at rates of 200 and 300 kg/fed; the first batch was treated right before planting, and the second batch was applied 30 days later.

Three times, a thorough foliar spray application of sodium selenate (Na_2SeO_4) at a dose of 2 and 5 mg/L was applied. The 1st spray was done 30 days after planting (on May, 4st) and it was then repeated every 21 days until flower buds formed.

1- Control (recommended dose of NPK).

2- Adding Magnetite at rate 200 kg/fed. (M1)

3- Adding Magnetite at rate 300 kg/fed. (M2)

4- Foliar spray of Selenium at rate 2 mg/L. (Se1)

5- Foliar spray of Selenium at rate 5 mg/L. (Se2)

6- M1 + Se1

7- M1+ Se2

8- M2 + Se1

9- M2 + Se2

Solidago canadensis plants were harvested in 12th July **(flowering stage)** for the first and the second season.

Growth characteristics: Plant height (cm), Number of inflorescences/plant, inflorescence length/plant (cm), leaf length (cm), herb fresh and dry weight (g).

Crop productivity: Fresh herb yield (ton fed^{-1}).

Essential oil productivity: Essential oil content in herb was carried out according to the method of **ASTA (1985).** Oil yield/plant (ml) and oil yield/fed. (l) were also determined.

GC/MS Analysis of Essential oil: The GC-MS system was equipped with gas chromatograph (7890B) and mass spectrometer detector (5977A), according to **(Adams, 2007).**

Using the techniques of **Saric *et al.*, (1976) and Bates *et al.*, (1973),** the photosynthetic pigments (Total chlorophyll mg/g f.w.) and free proline (mg/g f.w.) in fresh leaf samples were quantified. Nitrogen (calculated using the **Pregl (1945)** micro-Kjeldahle method), phosphorus (calculated by **Luatanab and Olsen, 1965**), sodium (calculated using a Flame-photometer set), and chloride (calculated by **Jackson, 1973**) percentages were recorded in dry leaf samples.

RESULTS AND DISCUSSION

1. Growth characteristics

It is evident from data shown in Table (3) that means of all growth traits were progressively increased with magnetic iron and selenium treatment compared to those of control treatment in the two seasons. In both seasons, the most effective treatment in promoting growth characteristics was the application of 300 kg/fed of magnetite together with selenium at 2 mg/L. (M2+Se1), which gave the highest values of growth characteristics such as plant height (80.43 and 89.28 cm), inflorescence length\Plant (37.29 and 38.38 cm), Number of inflorescence\plant (8 and 7), Leaf length (8.38 and 8.80 cm), herb fresh weight/plant (436.40 and 462.58 g) and herb dry weight/plant (118.79 and 126.42 g) in the first and the second seasons. According to **Maheshwari (2009),** magnetic treatments may influence the generation of phytohormones, which would enhance cell activity and plant growth. The current findings were in line with those of **Taha *et al.* (2011),** who showed that applying magnetic fields enhanced pepper plant development in salinity-treated environments. The results reported here are consistent with those of **El-Hifny *et al.* (2008)** on cauliflower, who observed that plant development was enhanced by increasing magnetite levels up to 150 or 200 kg/fed. **El-Eslamboly and Abdel-Wahab (2014)** found similar outcomes with cantaloupe.

Se increases plant development, especially in situations where salt stress is present, according to several research. Numerous research on numerous plants, including canola, pomegranate, proso millet, and foxtail millet, have shown that selenium (Se) enhances plant growth and development **(Hashem *et al.*, 2013; Rasool *et al.*, 2020; Shah *et al.*, 2020 and Subramanyam *et al.*, 2019).** Se provides physiological benefits in this regard by stimulating the plant's antioxidant system. Thus, it improves the plant's capacity to scavenge surplus reactive oxygen species (ROS), aiding in the plant's ability to withstand stress **(Feng *et al.*, 2013 & Zhang and Gladyshev, 2009).**

Table (3). Effect of magnetic iron, selenium and their interactions on growth characteristics of *Solidago canadensis* under saline conditions throughout two seasons

Treatments	Plant height (cm)		inflorescence length\Plant (cm)		Number of inflorescence\ plant		Leaf length (cm)		Herb fresh weight/plant (g)		Herb dry weight/plant (g)	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	43.67	48.47	17.90	19.51	1.00	2.00	5.78	6.07	182.84	193.81	44.45	48.90
M1	61.51	68.28	23.84	25.98	2.00	3.00	6.87	7.22	262.83	278.60	67.29	74.39
M2	66.48	73.79	27.67	30.16	4.00	5.00	7.15	7.50	306.95	325.37	79.63	81.86
Se1	53.94	59.87	20.06	21.87	2.00	3.00	6.07	6.38	203.40	215.61	51.48	54.61
Se2	57.81	64.17	22.28	24.29	3.00	4.00	6.40	6.72	225.39	238.91	57.84	61.16
M1+Se1	70.13	77.84	29.08	31.70	4.00	5.00	7.01	7.36	346.94	367.75	91.00	99.73
M1+Se2	78.41	88.12	34.31	37.40	6.00	5.00	7.52	7.95	395.15	418.86	104.52	110.36
M2+Se1	80.43	89.28	37.29	38.38	8.00	7.00	8.38	8.80	436.40	462.58	118.79	126.42
M2+Se2	76.45	84.86	31.74	35.80	5.00	6.00	7.29	7.70	367.27	389.31	97.25	102.88
L.S.D 0.05	**3.27**	**3.65**	**2.01**	**1.63**	**1.21**	**1.09**	**1.11**	**1.00**	**16.37**	**19.52**	**6.14**	**5.73**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

2. Yield of fresh weight/fed.

Yield of fresh weight per feddan of *Solidago canadensis* was significantly increased with application of magnetic iron and selenium treatment in Table (4).

Applying foliar selenium spray and magnetite as a soil dressing around plants have a significant effect on fresh yield ton/ fed., comparing with the control. The minimum rate of selenium (2 mg/l) was less effective on crop productivity of *Solidago canadensis* plant such as fresh weight yield/fed. (4.47and 4.74 ton) in both seasons. In contrast, the highest fresh weight yield/fed values (9.60 and 10.18 tons) were obtained in both seasons at a maximum concentration of 300 kg/fed of magnetite and 2 mg/L of selenium (M2+Se1). According to Mansour's (2007) findings, there were progressive increases in the curd characteristics and production of cauliflower plants as the levels of magnetite rose. He clarified that this increase may be ascribed to the magnetite's stimulating influence on plant growth and the uptake of N, P, K, and Ca.

Furthermore, under salinity irrigation circumstances, some notable effects of magnetically treated irrigation water on the nutritional composition and productivity of snow pea and celery plants were demonstrated by **Maheshwari (2009)** and **Esitken and Turan (2004).** Applying magnetite was found to increase yield by several researchers, including **Patnaik *et al.* (2001)** on pepper and **Anchondo *et al.* (2002)** on tomatoes.

Regarding, selenium has the capacity to control the water status of plants in salinity or drought situations, delay senescence, boost plant development, and raise tolerance of plants to salinity **(Germ and Stibilj, 2007).**

Table (4). Effect of magnetic iron, selenium and their interactions on yield of fresh weight/fed (ton) of *Solidago canadensis* under saline conditions throughout two seasons

Treatments	Yield of fresh weight/fed. (ton)	
	S1	S2
Control	4.02	4.26
M1	5.78	6.13
M2	6.75	7.16
Se1	4.47	4.74
Se2	4.96	5.26
M1+Se1	7.63	8.09
M1+Se2	8.69	9.21
M2+Se1	9.60	10.18
M2+Se2	8.08	8.56
L.S.D 0.05	**0.48**	**0.58**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

3. Total chlorophyll (mg/g F.W)

Results in Table (5) showed that, total chlorophyll in *Solidago canadensis* treated with different rates of magnetic iron and sprayed with different levels of selenium. It was observed that total chlorophyll content in *Solidago canadensis* plant was decreased (11.26 and 11.93 mg/g F.W in both seasons) with control treatment, in comparison to magnetic iron or selenium independently. The combination of M2 and Se1 gave higher total chlorophyll content (21.04 and 23.63 mg/g F.W in both seasons) compared to other treatments.

The findings are in line with those of **Moustafa *et al.* (2017)** on *Moringa oleifera*, **Ahmed *et al.* (2016)** on *Acalypha wilkesiana*, **Shahin *et al.*, (2018)** on *Terminalia arjuna*, and **El-Sayed *et al.* (2019)** who found that applying Fe_3O_4 at a rate of 2 or 4 g/plant increased the concentrations of chlorophyll a, b, carotenoids, and total carbohydrates in the leaves of *Enterolobium contortisiliquum* under salt stress. Our findings concurred with those of earlier research that demonstrate the application of Se led to an increase in chlorophyll **(Chen *et al.*, 2008).** Under salt stress, it was discovered that adding 5 μM Se to cucumber plants enhanced their accumulation of carotenoids and chlorophylls **(Hawrylak-Nowak 2009).** Our findings corroborate those of **Kong *et al.* (2005)** and **Diao *et al.* (2014),** who demonstrated that applying selenium can aid in preserving the integrity of cell membranes in salinized environments.

4. Macronutrients, Micronutrients and proline content

Table (6) presents data demonstrating a steady increase in the free proline content (mg/g f.w.) and the percentages of nitrogen, phosphorus, and potassium in the leaves following application of magnetic iron and selenium treatment in comparison to the control group (untreated plants).

The treatment Se1(2 mg/l) resulted in the minimum values for nitrogen (2.57 and 2.74%) phosphorus (0.33 and 0.36%) and potassium (3.25 and 3.41%) in the first and the second seasons, respectively. While, the interaction between magnetic iron and selenium gave better effect on increasing nitrogen, phosphorus and potassium content compared to magnetic iron or selenium independently.

The combination of M2 and Se1 gave higher nitrogen 3.33% and 3.56%, phosphorus 0.76% and 0.78% and potassium 4.43% and 4.64% compared to control treatment in the both seasons, respectively.

Magnetic iron and selenium application reduced significantly Na, Cl and free proline content compared to control (untreated plants). The combination of M2+Se1 treatment significantly decreased concentration of Na (0.40 and 0.41%), Cl (0.29 and 0.25%) and free proline (0.20 and 0.21 mg/g F.W.) in two seasons.

Regarding this, **El-Hifny *et al.* (2008)** observed that the application of magnetite had a positive effect on the content of N, P, K, and Fe while decreasing that of Na and Cl. They suggested that this was due to the creation of a high energy magnetic field in the growing plants' root media, which may have stimulated the absorption of these elements and decreased the content of Na and Cl. Moreover, magnetate dissolves NaCl salt and draws it from the earth. As a result, neither Na nor Cl are taken up by the plants in greater quantities. These results are similar to those of **Ahmed *et al.* (2011)** on Hibiscus sabdariffa and **El-Sayed (2014)** on *Vicia faba*. The dosages of Se that were given were appropriate for changing the absorption and accumulation of minerals that are essential for metabolism, according to **Pazurkiewicz-Kocot *et al.* (2003).** Furthermore, selenium (Se) has been shown to positively influence cellular membrane permeability and activity, which may be among the earliest indications of Se influence in plants **(Kinraide, 2003).**

Table (5). Effect of magnetic iron, selenium and their interactions on total chlorophyll (mg/g F.W) of *Solidago canadensis* under saline conditions throughout two seasons

Treatments	Total chlorophyll (mg/g)	
	S1	S2
Control	11.26	11.93
M1	13.59	14.41
M2	16.84	17.85
Se1	12.65	13.41
Se2	14.01	14.85
M1+Se1	18.55	19.60
M1+Se2	19.26	21.65
M2+Se1	21.04	23.63
M2+Se2	20.37	22.88
L.S.D 0.05	**1.02**	**1.11**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

Table (6). Effect of magnetic iron, selenium and their interactions on Macronutrients, Micronutrients and proline content of *Solidago canadensis* leaves under saline conditions throughout two seasons

Treatments	Macronutrients						Micronutrients				Free proline (mg/g f.w.)	
	N%		P%		K%		Na%		Cl%			
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Control	2.49	2.66	0.25	0.27	2.99	3.13	0.87	0.81	0.70	0.68	0.57	0.55
M1	2.76	2.94	0.42	0.46	3.52	3.69	0.66	0.68	0.58	0.55	0.50	0.48
M2	2.96	3.16	0.46	0.50	3.73	3.90	0.57	0.54	0.50	0.49	0.44	0.41
Se1	2.57	2.74	0.33	0.36	3.25	3.41	0.77	0.74	0.69	0.64	0.55	0.52
Se2	2.62	2.80	0.37	0.40	3.36	3.52	0.71	0.66	0.62	0.59	0.53	0.50
M1+Se1	2.82	3.01	0.50	0.55	3.81	3.99	0.64	0.60	0.47	0.43	0.38	0.35
M1+Se2	3.15	3.43	0.55	0.59	4.17	4.37	0.52	0.56	0.35	0.32	0.34	0.32
M2+Se1	3.33	3.56	0.76	0.78	4.43	4.64	0.40	0.41	0.29	0.25	0.20	0.21
M2+Se2	3.27	3.49	0.62	0.66	4.39	4.59	0.51	0.52	0.30	0.28	0.20	0.22
L.S.D 0.05	**0.11**	**0.10**	**0.13**	**0.15**	**0.21**	**0.25**	**0.08**	**0.09**	**0.04**	**0.03**	**0.04**	**0.03**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

5. Essential oil productivity

The obtained results in Table (7) showed that the application of iron magnetic around the plant's root zone, foliar application of selenium recorded significant effect on essential oil content and yield compared to control treatment (untreated plants).

The combination of M2+Se1 recorded the highest content of essential oil (0.50 and 0.54%) compared to untreated plants (0.31 and 0.33%) in the two season, respectively. Also, the highest values of oil yield were 2.18 and 2.50 ml/ plant compared to 0.57 and 0.64 ml/plant in untreated plants and 48 and 54.95 l/fed. compared to 12.47 and 14.07 l/fed. on the first and the second seasons, respectively. Similar effect had reported by **Badawy and Waleed (2014)** on *Majorana hortensis.* Major components and essential oil contents increased after treatment with Se. Se's capacity to increase essential oils could be the cause of this. Selenium influences the rates at which CO_2 is assimilated, which raises the amount of photosynthetic pigments and, eventually, the composition of essential oils. **Misra *et al.* (2010).** The outcomes are in line with the research conducted by **Khalid (2011), Lee *et al.* (2001),** and **Khalid *et al.* (2017),** who discovered that Se boosted the essential oil of parsley, basil, and lemon balm when compared to a control group.

Table (7). Effect of magnetic iron, selenium and their interactions on essential oil productivity of *Solidago canadensis* under saline conditions throughout two seasons

Treatments	Essential oil %		Essential oil yield\Plant (ml)		Essential oil yield/fed. (L)	
	S1	S2	S1	S2	S1	S2
Control	0.31	0.33	0.57	0.64	12.47	14.07
M1	0.42	0.45	1.10	1.25	24.29	27.58
M2	0.45	0.48	1.38	1.56	30.39	34.36
Se1	0.32	0.34	0.65	0.73	14.32	16.13
Se2	0.34	0.36	0.77	0.86	16.86	18.92
M1+Se1	0.46	0.48	1.60	1.77	35.11	38.83
M1+Se2	0.47	0.50	1.86	2.09	40.86	46.07
M2+Se1	0.50	0.54	2.18	2.50	48.00	54.95
M2+Se2	0.48	0.50	1.76	1.95	38.78	42.82
L.S.D 0.05	**0.02**	**0.03**	**0.43**	**0.31**	**1.57**	**2.01**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

6. Essential oil components

The relative percentage of *Solidago canadensis* component identified essential oil according to their retention time are presented in Table (8). A total of 19 constituents were identified in *Solidago canadensis* oil. The essential oil was characterized by Monoterpenes components (51.49-56.96%) and Sesquiterpenes components (31.13-34.26%).

Analysis revealed that, upon identification of 19 components, α-Pinene, Germacrene D, Limonene, and Bornyl acetate were found to be the main components of essential oil.

It can be seen from control treatment that, the major component was Germacrene D (23.59%), followed by α-Pinene (19.04%), Limonene (14.22%)and Bornyl acetate (12.32%). Meanwhile, treated *Solidago canadensis* plants by M2+Se1 showed that the major components were α-Pinene (32.75%) followed by Germacrene D (27.49%), Limonene (10.55%)and Bornyl acetate (5.13%). Generally, it is noticed that, using M2+Se1 treatment led to the highest contents of Germacrene D and α-Pinene.

Table (8). Effect of magnetic iron, selenium and their interactions on essential oil components of *Solidago canadensis* under saline conditions throughout two seasons

	Treatments								
Compounds	**Control**	**M1**	**M2**	**Se1**	**Se2**	**M1+Se1**	**M1+Se2**	**M2+Se1**	**M2+Se2**
Monoterpenes									
α-Pinene	19.04	24.52	25.17	25.41	29.87	30.06	30.14	32.75	31.91
Camphene	1.25	2.01	1.06	0.99	1.08	1.20	1.38	0.87	0.66
Sabinene	0.49	0.31	0.38	0.31	0.34	0.37	0.43	0.26	0.19
β-Pinene	2.12	1.99	2.37	1.87	2.04	2.27	2.61	1.58	1.16
Myrcene	2.28	2.62	2.80	1.97	2.15	2.38	2.74	2.13	1.09
Limonene	14.22	15.94	13.73	12.92	12.26	11.05	10.76	10.55	9.73
γ-Terpinen	0.46	0.41	0.28	0.22	0.24	0.27	0.31	0.31	0.50
α-Campholenal	1.57	1.43	1.15	1.01	1.10	1.22	1.40	1.39	0.98
Carvone	0.24	0.15	0.09	0.11	0.12	0.14	0.16	0.15	0.20
Bornyl acetate	12.32	7.58	7.15	7.10	6.83	6.80	6.27	5.13	5.07
Sesquiterpenes									
β-Elemene	0.91	0.70	0.84	0.70	0.74	0.83	0.90	0.92	1.67
β-Caryophyllene	2.73	2.64	3.40	1.49	1.57	1.77	1.91	2.07	2.86
α-Caryophyllene	0.70	0.82	0.55	0.44	0.47	0.53	0.57	0.58	0.36
Germacrene D	23.59	23.74	24.64	25.60	26.69	26.94	26.88	27.49	25.93
γ-Cadinene	2.43	2.43	2.56	1.37	1.44	1.63	1.76	1.85	1.99
β-Eudesmene	0.45	0.69	0.44	0.38	0.40	0.45	0.49	0.32	0.33
Aromadendrene oxide	0.29	0.54	0.45	0.37	0.39	0.44	0.48	0.34	0.35
Caryophyllene oxide	0.69	0.85	0.37	0.42	0.44	0.50	0.54	0.47	0.47
Spathulenol	0.51	0.64	0.27	0.35	0.37	0.42	0.45	0.21	0.21
Total Monoterpenes	**53.98**	**56.96**	**54.17**	**51.91**	**56.04**	**55.76**	**56.19**	**55.13**	**51.49**
Total Sesquiterpenes	**32.30**	**33.06**	**33.53**	**31.13**	**32.50**	**33.51**	**33.96**	**34.26**	**34.18**
Other compounds	**13.71**	**9.98**	**12.30**	**16.95**	**11.46**	**10.73**	**9.85**	**10.61**	**14.33**

*Control= NPK recommended dose, M1= Magnetite at rate 200 kg/fed., M2= Magnetite at rate 300 kg/fed., Se1= Selenium at rate 2 mg/L., Se2= Selenium at rate 5 mg/L., M1+Se1= Magnetite at rate 200 kg/fed+ Selenium at rate 2 mg/L., M1+Se2= Magnetite at rate 200 kg/fed+ Selenium at rate 5mg/L., M2+Se1= Magnetite at rate 300 kg/fed+ Selenium at rate 2mg/L. and M2+Se2= Magnetite at rate 300 kg/fed+ Selenium at rate 5mg/L.

CONCLUSION

Based on the earlier findings, it is suggested that, in order to improve *Solidago canadensis* growth and quality under salt stress, 300 kg/fed of magnetic iron and 2 mg/l of selenium foliar spray should be applied.

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