Effect of Iron Nano-particle as Foliar Spray on Growth, Seed Yield and Active Constituents of *Silybum marianum* L. Plants

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Abstract: At the Experimental Farm of Ismailia Agriculture Research Station, Ismailia Governorate, Egypt, the experimental work was carried out over the course of two successive growing seasons in 2018–2019 and 2019–2020 in order to investigate the effects of iron oxide nanoparticles (7.5, 15.0, and 30.0 ppm) in comparison to unsprayed (control plants) on seed yield, growth and active *Silybum marianum* L. constituents. Three repetitions of a randomized complete blocks design were used for the experiment. Spraying *Silybum marianum* L. plants with Fe3O4-NPs at 30 ppm increased plant height, number of leaves/plant, number of inflorescences/plant, root length, stem diameter, dry weight of roots, number of roots/plant, inflorescences/plant and herb, chlorophyll a, chlorophyll b and total chlorophyll (a+b), N, P and K contents in leaves, seed yield /feddan and Fe concentrations in fruits, TXF, SBN, SCN, SDN, ISBN and total silymarin in fruits, in both seasons.

Keywords*:* *Silybum marianum* L., Fe_3O_4-NPs, vegetative growth, seed yield, TXF, SDN, SBN, SCN, ISBN and silymarin

INTRODUCTION

The Mediterranean region gave rise to the annual winter or biannual plant known as milk thistle (*Silybum marianum* L.), a member of the Asteraceae family (Sedghi *et al.,* 2010). *Silybum marianum* L. includes flavonolignan isomeric combinations such as Silychristin (SCN), Taxofillin (TXF), Silybin (SBN), Silydianin (SDN) and Isosilybin (ISBN) which are all together known as Silymarin (SM) (Kurkin *et al.,* 2001). The fruits and seeds of this plant are the main sources of silymarin, while traces of these substances can be found in all plant parts. *Silybum marianum* L. Extracts have been used for centuries to treat alcoholic patients as well as those with hepatitis, cirrhosis, and icterus as well as to combat Amanita species intoxication. Nano-Agriculture is the application of nanoparticles in agriculture that specifically benefits crops. Greater density in reactive areas or increased reactivity on particle surfaces in these places may be the cause of nanoparticles' performance in these regions. Nanotechnology has the ability to address environmental issues and increase the value of agricultural products. For instance, using nanoparticles and nanopowders, researchers can create regulated or delayed release fertilizers (Khater *et al.,* 2013).

Iron, which functions as a cofactor for over 140 enzymes, is one of the essential elements for plant growth and development, including thylakoid synthesis, chlorophyll formation and chloroplast development (Brittenham, 1994; Bozorgi, 2012). Soybean grain yield can be increased by applying iron to low-iron soils (Ghasemi *et al.,* 2006; Khater *et al.,* 2013).

Spraying with nano iron increased plant growth (Elfeky *et al.,* 2013) on *Ocimum basilicum* and (Khater *et al*., 2013) on sweet Basil and (Askary *et al.,* 2017) on *Mentha piperita*, leaf pigments (Mohammadi *et al.*, 2018) on peppermint and (Abdelkader *et al.*, 2019) on fennel yield (Rezaei-Chiyaneh *et al.*, 2018) on Black cumin and (Mahmoud and Swaefy, 2020) on sage) and active constituents (Hassanpouraghdam *et al*., 2019) on *Rosmarinus officinalis* and (El-Khateeb *et al*., 2020) on marjoram.

The purpose of the current study is to examine the effects of iron oxide (Fe3O4) nanoparticles (NPs) on plant growth and active components of *Silybum marianum* L. plants in order to develop a technical approach for the agricultural application of inexpensive nano materials.

MATERIALS AND METHODS

The experiment was conducted to determine the impact of iron oxide nanoparticles on the seed yield, growth and active components of *Silybum marianum* L. during the two succeeding seasons of 2018/2019 and 2019/2020 at the Experimental Farm of Ismailia Agriculture Research Station, Ismailia Governorate, Egypt. The experimental soil in the two seasons was sandy soil and its characteristics were shown in Table (1).

The irrigation water during the two seasons was taken from the same source and had low salts contents as presented in Table (2).

This experiment was included three concentrations of iron oxide nanoparticles Fe_3O_4-NPs as foliar spray (7.5, 15.0 and 30.0 ppm), beside unsprayed (control plants).

Table (1): The experimental soil characteristics

Characteristics	First season	Second season
Physical properties		
Sand%	96.80	96.50
Silt%	1.60	1.60
Clay%	1.60	1.90
Textural class	Sand	Sand
EC, dSm^{-1}	0.29	0.26
pH	7.92	7.87
Chemical properties		
Cations, meq /100g soil		
Ca^{2+}	0.33	0.29
Mg^{2+}	0.21	0.18
Na^{+}	0.86	0.78
K^{+}	0.04	0.04
Anions, meq/100g soil		
Cl^{-}	0.90	0.79
HCO_3^{-}	0.18	0.15
SO_4^{2-}	0.36	0.35
CO_3^{2-}	--	-
Available N mg Kg^{-1}	8.66	8.76
Available P mg Kg^{-1}	9.02	8.92
Available K mg Kg^{-1}	30.20	30.18
Total N mg Kg^{-1}	9.60	9.70
Organic Matter g Kg^{-1}	1.70	1.90

Table (2): Chemical characteristics of the water used for irrigation of *Silybum marianum* L.

EC, dSm	pH	Cations, meq /L				Anions, meq /L			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	$SO^{2}{}_4^{-}$	$CO^{2-}{}_3$
0.36	**7.10**	0.50	0.40	2.60	0.10	2.70	0.40	0.50	---

Preparation and characterization of Fe_3O_4 magnetic nanoparticles (MNPs):

Fe2+ and Fe3+ co-precipitation at a molar ratio of 3:2 with aqueous ammonia (0.3mol/L) as the precipitating agent produced the Fe3O4 nanoparticles (Yuanbi and Jiaying, 2008).

TEM imaging was used to study the physicochemical characteristics of Fe nanoparticles Fig (1). The produced magnetite nanoparticles appear to be spherical and have an average particle size of 100 nm, according to the images.

Plot area was 8.4 m^2 and contained two rows, each was (3.5 m) in length and (1.2 m) in width and planting distance was (0.5 m) apart, since the numbers of plants were seven in each row which counts (14) plants per plot. Seeds were sown in 17th and 18th October for 2018/2019, 2019/2020 seasons, respectively.

Silybum marianum L. seeds were acquired from the Horticulture Research Institute, Agriculture Research Center, Giza, Egypt's Department of Medicinal and Aromatic Plants. The plants were treated two time by foliar spraying with the different concentrations. The first time before flowering stage in 9th of February, the second time after flowering stage in 9th of March in the two seasons. The foliar spray application was done by using a manual sprayer (capacity 2 L) at 9 o'clock. In 15th October of both seasons, the soil was divided into plots (2.4×3.5 m). During the preparation process, (10 m^3/fed.) compost was added and well mixed with the soil three weeks before planting. Chemical fertilizer used was NPK at "24:12:18 kg/fed." (Urea 46% N), (calcium super phosphate 15.5% P_2O_5) and (potassium sulfate 48.5% K_2O).

Three repetitions of a randomized complete blocks design were used for the experiment.

All plants received the standard agricultural care they required.

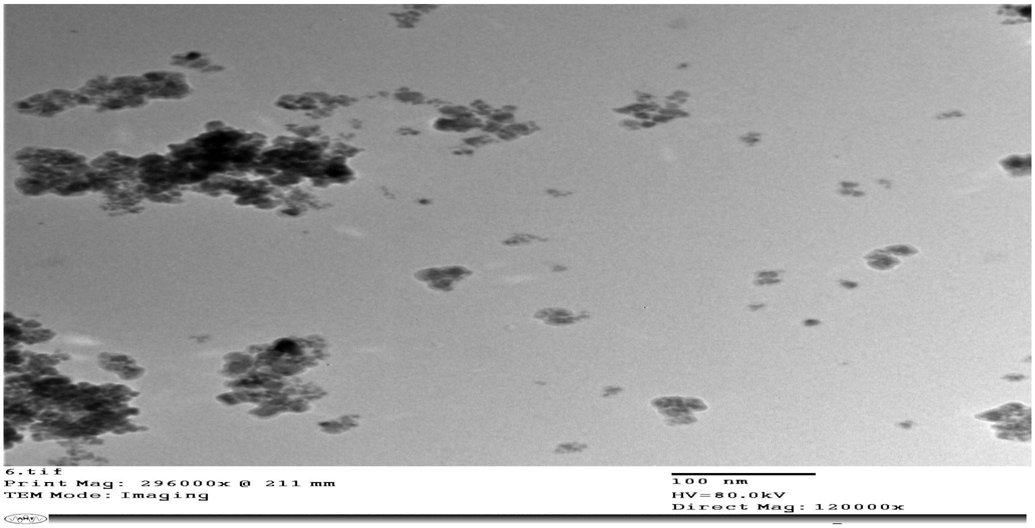

Fig. (1): TEM imaging of the prepared Fe nanoparticles revealed a spherical shape of the particles, with an average size of 100 nm (inset shows electron diffraction pattern)

Recorded data

Vegetative growth parameters:

The parameters of plant height (cm), number of leaves per plant, stem diameter (mm), root length (cm), and number of roots/plants were measured on a random sample of five plants from each plot at 150 days after planting in both seasons. Dry weight (gm) of roots, herbs, and inflorescences per plant and total dry weight (gm) per plant (roots + herbs + inflorescences) were measured after plant parts, such as roots, herbs, and inflorescences, were dried at 70 °C until they attained a constant weight.

Estimation of Chlorophylls:

A known fresh weight of leaves was homogenised for five minutes in 85% aqueous acetone 150 days after sowing in both seasons. The homogenate was centrifuged, and the supernatant was then added to the volume of the homogenate with 85% acetone. Spectrophotometric analysis was used to measure the photosynthetic pigments (chlorophyll-a, chlorophyll-b, and total chlorophyll) according to (Metzner *et al.,* 1965). Using a spectrophotometer built by VEB Carl Zeiss, Three different wavelengths (A452.5, A663, and A644) were used to assess the absorbance in comparison to a blank of pure 85% aqueous acetone (nm). The concentration of the pigment components could be found. (Chlorophyll-a, chlorophyll-b and total chlorophyll) as mg/ml using the following equations:

Chlorophyll-a = 10.3 A_{663} – 0.918 A_{644} mg/100 g fresh weight

Chlorophyll-b = 19.7 A_{644} – 3.870 A_{663} mg /100g fresh weight

Total Chlorophyll = Chlorophyll-a + Chlorophyll-b mg /100g fresh weight

Analysis of mineral elements:

Samples of air-dried leaves and fruits were collected 150 days after sowing and oven dried at 70°C to constant weight. Acid digestion was performed on 0.5 gm of dried materials using a solution of sulfuric acid and hydrogen peroxide, and the final volume was then increased to 50 ml using distilled water, to determine the following:

-Total nitrogen percentage in the leaves was determined using micro-kjeldahl method as reported by (Mazumdar and Majumder, 2003).

-Total Phosphorus percentage in the leaves was determined color metrically at 640 nm wave length according to (Mazumdar and Majumder, 2003).

- A flame photometer was used to determine the potassium percentage in the leaves according to (Mazumdar and Majumder, 2003).

- Inductively Coupled Plasma Mass Spectrometry (ICP MS) was used to measure the concentration of Fe in air-dried fruit digest solutions according to (Ammann, 2007).

Crud's yield:

In both seasons, the harvesting process took place on the first of April until the first of May. The following data regarding the fruit yield were recorded as follows: Weight of seeds (g/plant), weight of seeds per plot and Seed yield/fed. (Kg).

Determination of silymarin percentage in the dry fruits:

1. The active ingredients:

Total silymarin percentage was determined in the powdered fruits of *Silybum marianum* L. plants during the two seasons after harvesting according to the method described by (Martinelli *et al.*, 1991):

2. Extraction procedure:

(1.0 g) grounded finely powdered was extracted with petroleum ether for (4 hours) in extraction apparatus. The extraction solution discarded and the apparatus extracted by methanol for (5 hours). The methanol evaporated and vacuum dried in about (50°C).

3. HPLC conditions:

The extracted material solubilized with (100 ml) methanol. Filtered with Millipore (0.3 um) for three times and (50 ul) of extraction injected into HPLC apparatus with flow rate 1 ml/min. Standard silymarin mixture (Taxifolin TXF, Silychristin SCN, Silydianin SDN, Silybin SBN and Iso silybin ISBN) used as total amount of Silymarin and injected into column in gradual series standards: (0.05, 0.2, 0.5, 1.0, 1.5, 3.0 and 6 mg/ml).

Statistical analysis:

The experiment was arranged in randomized complete blocks design and collected data were subjected to proper statistical analysis of variance according to (Snedecor and Cochran1, 980).

RESULTS AND DISCUSSION

Effect of foliar spray with iron oxide nanoparticles (Fe_3O_4-NPs) on growth, photosynthetic pigments, seed yield and active ingredients of *Silybum marianum* L.:

Morphological characters

Data in Table (3) indicated that treating of *Silybum marianum* L. with iron oxide nanoparticles (Fe_3O_4-NPs) at different concentrations 7.5, 15 and 30 ppm significantly increased plant height, number of leaves/plant, number of inflorescences/plant and stem diameter at 150 days after sowing in both seasons.

Table (3): Effect of foliar spray with iron oxide nanoparticles concentrations on vegetative growth characters of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	Plant height (cm)	Number of leaves/plant	Number of inflorescences/plant	Stem diameter (mm)
		2018/2019 season		
Control	71.26	6.66	7.26	14.33
7.5 ppm	83.60	7.20	9.20	16.66
15 ppm	83.86	7.60	9.70	16.80
30 ppm	87.10	8.06	10.90	17.40
LSD at 0.05 level	**2.43**	**0.76**	**0.65**	**0.87**
		2019/2020 season		
Control	65.73	8.33	7.80	13.20
7.5 ppm	83.00	9.73	7.93	16.66
15 ppm	86.56	10.20	8.73	17.33
30 ppm	88.43	11.33	12.13	17.73
LSD at 0.05 level	**5.15**	**0.26**	**0.90**	**1.24**

The involvement of nano iron's stimulatory effects on the production of mitochondrial respiration, chlorophyll, photosynthesis, and hormone biosynthesis, ethylene, including gibberellic acid and jasmonic acid, may be responsible for enhancing vegetative development (Hänsch and Mendel, 2009). The outcomes were in line with what was previously stated by Elfeky *et al.* (2013) on *Ocimum basilicum* (Khater *et al*., 2013) on sweet Basil Plant and (Rezaei-Chiyaneh *et al*., 2018) on black cumin.

Root system

Root system, i.e., root length and number of roots/plant of *Silybum marianum* L. at 150 days after sowing increased with increasing Fe_3O_4-NPs up to 30 ppm Table (4). This means that Fe_3O_4-NPs at 30 ppm increased root length and number of roots/plant in both seasons.

The outcomes obtained are consistent with what was reported by (Dhoke *et al.,* 2013) on mung bean, indicated that spraying nano FeO increased root length as compared to untreated plants.

Table (4): Effect of foliar spray with iron oxide nanoparticles concentrations on root parameters of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	Root length (cm)		Number of roots/plant	
	2018/2019 season	2019/2020 season	2018/2019 season	2019/2020 season
Control	17.73	16.40	4.46	5.40
7.5 ppm	20.80	20.60	5.06	6.80
15 ppm	20.93	21.66	5.80	7.00
30 ppm	21.86	22.20	6.06	7.53
LSD at 0.05 level	**1.67**	**1.42**	**0.61**	**0.57**

Dry weight

Spraying *Silybum marianum* L. with Fe_3O_4-NPs at 30 ppm increased dry weight of roots, herbs, inflorescences and total dry weight/plant followed by Fe_3O_4-NPs at 15 ppm in both seasons Table (5). Treating with Fe_3O_4-NPs at different concentrations dry weight of roots, herb, dry weight of inflorescences and total dry weight/plant, compared to control (unsprayed plant). The increases in total dry weight/plant were about 80.6 and 93.2% for spraying with Fe_3O_4-NPs at 30 ppm, 57.6 and 72.3% for spraying with the Fe_3O_4-NPs at 15 ppm and 19.4 and 46.5% for spraying with Fe_3O_4-NPs at 7.5 ppm over unsprayed plants in the 1st and 2nd seasons, respectively.

Table (5): Effect of foliar spray with iron oxide nanoparticles concentrations on dry weight of *Silybum marianum organs* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	DW of roots/ plant (g)	DW of herb/ plant (g)	DW of inflorescences/ plant (g)	Total DW / plant (g)	Relative increases in total DW over control
			2018/2019 season		
Control	70.00	140.00	25.71	235.71	00.0
7.5 ppm	87.50	162.50	31.42	281.42	19.4
15 ppm	119.00	221.00	31.42	371.42	57.6
30 ppm	136.50	253.50	35.71	425.71	80.6
LSD at 0.05 level	**8.41**	**8.82**	**2.32**	**35.67**	
			2019/2020 season		
Control	93.33	173.33	24.05	290.71	00.0
7.5 ppm	138.83	257.83	29.28	425.94	46.5
15 ppm	164.50	305.50	30.95	500.95	72.3
30 ppm	183.17	340.17	38.57	561.91	93.3
LSD at 0.05 level	**4.88**	**8.39**	**1.48**	**43.41**	

DW=dry weight.

Iron's role in plant metabolism, including the activation of catalase enzymes linked to superoxide dismutase, nitrogen fixation, photorespiration, and the glycolate pathway, may account for Fe3O4-NPs' greater dry weight property (Marschner, 1995).

Results are harmony with (Askary *et al.,* 2017) on *Mentha piperita*, (Hassanpouraghdam *et al.*, 2019) on *Rosmarinus officinalis*, (El-Khateeb *et al.,* 2020) on marjoram and (Mahmoud and Swaefy, 2020) on sage plants.

Leaf pigments

Chlorophyll a, chlorophyll b and total chlorophyll (a+b) concentrations in leaf tissues of *Silybum marianum* L. increased with increasing Fe_3O_4-NPs up to 30 ppm Table (6). This means that spraying with Fe_3O_4-NPs at 30 ppm increased chlorophyll a, chlorophyll b and total chlorophyll (a+b) in leaf tissues in both seasons.

Table (6): Effect of foliar spray with iron oxide nanoparticles concentrations on leaf pigments (mg/100g FW) of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	Chlorophyll a		Chlorophyll b		Total chlorophyll (a+b)	
	2018/2019 Season	2019/2020 Season	2018/2019 season	2019/2020 Season	2018/2019 season	2019/2020 Season
Control	137.3	156.9	88.2	100.2	225.5	257.1
7.5 ppm	181.9	171.3	101.7	108.9	283.6	280.2
15 ppm	188.4	188.9	106.5	118.1	294.9	307.0
30 ppm	194.9	191.2	111.0	127.7	305.9	319.0
LSD at 0.05 level	**12.6**	**9.27**	**13.41**	**13.07**	**22.4**	**20.2**

This rise is a result of iron's ability to stimulate the activity of the enzymes that produce chlorophyll. Furthermore, earlier studies have demonstrated that iron participates in the synthesis of a particular kind of RNA that controls the synthesis of chlorophyll. Iron is necessary for plant growth and development, including the formation of chloroplasts, chlorophyll and thylakoids (Bozorgi, 2012). It is a cofactor for approximately 140 enzymes (Brittenham, 1994) and is essential for photosynthetic activities.

The addition of Fe enhanced leaf surface, plant growth, net photosynthetic speed, and plant chlorophyll content. Plant iron deficiency causes chlorosis, decreases in plant growth, decreases net photosynthetic rate and plant chlorophyll content (Huda *et al*., 2009).

These results are in agreement with those reported for (Jia *et al.*, 2012) on basil, (Khater *et al.,* 2013) on basil and (Mohammadi *et al.*, 2018) on peppermint.

Seed yield

Foliar spray with Fe_3O_4-NPs at 7.5, 15.0 and 30 ppm had significant effect on seed weight/plant, seed weight/plot and seed weight/feddan compared to control (unsprayed plant) as shown in Table (7).

Treating with Fe_3O_4-NPs at 30 ppm increased seed weight/plant, seed weight/plot and seed weight/ feddan, followed by treating with Fe_3O_4-NPs at 15.0 ppm in both seasons.

The increases in total seed weight/feddan were about 27.1 and 47.3 % for spraying with Fe_3O_4-NPs at 30 ppm, 11.9 and 18.2% for spraying with the Fe_3O_4-NPs at 15.0 ppm and 12.0 and 11.8 for spraying with Fe_3O_4-NPs at 7.5 ppm over unsprayed plants in the 1[st] and 2[nd] seasons, respectively.

Table (7): Effect of foliar spray with iron oxide nanoparticles concentrations on seeds yield of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	Yield of seeds/plant (g)	Yield of seeds/plot (g)	Yield of seeds /fed. (kg)	Relative increases in total seeds yield/fed. over control
		2018/2019 season		
Control	12.783	178.97	89.48	000
7.5 ppm	14.320	200.50	100.25	12.0
15 ppm	14.300	200.20	100.10	11.9
30 ppm	16.253	227.50	113.75	27.1
LSD at 0.05 level	**0.27**	**3.84**	**1.92**	**---**
		2019/2020 season		
Control	11.920	166.83	83.41	00.0
7.5 ppm	13.323	186.55	93.25	11.8
15 ppm	14.083	197.17	98.58	18.2
30 ppm	17.550	245.70	122.85	47.3
LSD at 0.05 level	**0.46**	**6.52**	**3.26**	**--**

The simulative effect of Fe_3O_4-NPs at 30 ppm on seed yield may be due to that spraying with Fe_3O_4-NPs at 30 ppm increased number of inflorescences/plant Table (3), root, herb and inflorescences dry weight as well as total dry weight Table (5), leaf pigments Table (6). This could be explained by the fact that foliar application of Fe_3O_4-NPs increased vegetative growth, resulting in higher production.

These results agree with those reported by (El-Sherbini *et al*., 2015) on pea plants, (Torabian *et al.,* 2017) on sunflower plants, (Abdelkader *et al*., 2019) on fennel plants and (Mahmoud and Swaefy, 2020) on sage plants.

Chemical composition

Contents of N, P and K in leaves as well as Fe in fruits of *Silybum marianum* L. significantly were increased with increasing Fe_3O_4-NPs up to 30 ppm Table (8). The lowest values of N, P and K contents in leaves and Fe concentrations in fruits were recorded by control plant.

Fe3O4-NPs may have improved nutritional benefits by making more nutrients available to plants through their leaves (Naderi and Danesh-Shahraki, 2013). These results agree with those reported (Askary *et al.,* 2017) on *Mentha piperita* and (Mohammadi *et al*., 2018) on peppermint.

Active ingredients in fruits

Silymarin components in the fruits TXF, SDN, SBN, SCN, ISBN and total silymarin of *Silybum marianum* L. increased with treating with Fe_3O_4-NPs at 30 ppm as foliar application in both seasons Table (9). Spraying with Fe_3O_4-NPs at different concentrations increased all components of Silymarin in fruits than control plants.

Additionally crucial to plant physiology, iron nutrients are needed for processes like respiration, meristematic development, chlorophyll synthesis, and the synthesis of phenolic compounds like gossypol and tannin (Bhatt *et al*., 2005).

Table (8): Effect of foliar spray with iron oxide nanoparticles concentrations on N, P and K contents in leaves as well as Fe concentrations in fruits of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	Leaves (%)			Fruits (ppm)
	N	P	K	Fe
		2018/2019 season		
Control	1.01	0.086	1.07	1.4
7.5 ppm	1.77	0.141	1.85	2.1
15 ppm	2.56	0.180	2.40	2.9
30 ppm	2.96	0.195	2.6	4.2
LSD at 0.05 level	**0.45**	**0.022**	**0.38**	**0.22**
		2019/2020 season		
Control	1.04	0.089	1.08	1.7
	1.68	0.116	1.66	2.6
	2.34	0.154	2.04	3.4
	2.94	0.202	2.59	4.8
LSD at 0.05 level	**0.49**	**0.034**	**0.55**	**0.36**

Similar findings were reported by (Abdel Wahab and Taha, 2018) on *Eruca sativa*, (Rezaei-Chiyaneh *et al.,* 2018), (Hassanpouraghdam *et al*., 2019) on *Rosmarinus officinalis* and (El-Khateeb *et al*., 2020) on marjoram plant.

From the aforementioned findings, it was determined that, spraying Silybum marianum plants with Fe3O4-NPs at 30 ppm increased number of leaves/plant, plant height, stem diameter, number of inflorescences/plant, root length, number of roots/plant, dry weight of roots, herb and inflorescences/plant, chlorophyll a, chlorophyll b and total chlorophyll (a+b), seed yield /feddan., N, P and K contents in leaves and Fe concentrations in fruits, TXF, SDN, SBN, SCN, ISBN and total silymarin in fruits, in both seasons.

Table (9): Effect of foliar spray with iron oxide nanoparticles concentrations on active constituents of *Silybum marianum* during 2018/2019 and 2019/2020 seasons under sandy soil conditions

Treatments with Fe_3O_4-NPs	TXF (%)	SDN (%)	SBN (%)	SCN (%)	ISBN (%)	Total Silymarin (%)
			2018/2019 season			
Control	0.13	80.40	3.34	0.011	0.052	0.79
7.5 ppm	1.74	80.57	4.10	0.024	0.098	1.69
15 ppm	3.50	80.89	5.01	0.035	0.151	2.27
30 ppm	5.12	81.25	6.45	0.049	0.210	2.68
			2019/2020 season			
Control	0.13	80.25	4.09	0.013	0.054	0.72
7.5 ppm	1.83	80.48	4.22	0.023	0.107	1.60
15 ppm	3.78	80.72	5.34	0.035	0.155	2.20
30 ppm	5.90	81.08	6.82	0.048	0.225	2.46

TXF= Taxifolin, SDN = Silydianin, SBN= Silybin, SCN =Silychristin and ISBN= Iso silybin all used as total amount of Silymarin.

REFERENCES

Abd El-Wahab, M. Mahmoud and S. S. Taha (2018). Main sulphur content in essential oil of *Eruca sativa* as affected by nano iron and nano zinc mixed with organic manure. Agriculture (Poľnohospodárstvo), 64(2): 65-79.

Abdelkader, M. A. I., F. R. Ibrahim and E. E. Metwaly (2019). Growth and productivity of fennel (*Foeniculum vulgare* Mill) plants as affected by phosphorus rate and nano-micronutrients concentration. J. Plant Production, Mansoura Univ., 10(7): 483-488.

Ammann, A. (2007). Inductively coupled plasma mass spectrometry (ICP MS): A versatile tool. Journal of Mass Spectrometry*,* 42: 419-427.

Askary, M., S. Talebi, F. Amini and A. Bangan (2017). Effects of iron nano-particles on *Mentha piperita* L. under salinity stress. Biologija, 63(1): 65-75.

Bhatt, L., B. K. Srivastava and M. P. Singh (2005). Studies on the effect of foliar application of micronutrients on growth, yield and economics of tomato (*Lycopersicon esculentum* L.). Progressive Hort., 36(2): 331-334.

Bozorgi, H. R. (2012). Effects of foliar spraying with marine plant *Ascophyllum nodosum* extract and nano iron chelate fertilizer on fruit yield and several attributes of eggplant (*Solanum melongena* L.) J. Agric. Bio. Sci., 7(5): 357-362.

Brittenham, G. M. (1994). New advances in iron metabolism, iron deficiency and iron overload. Current opinion in Hematology, 1(2): 101-106.

Dhoke, S. K., P. Mahajan, R. Kamble and A. Khanna (2013). Effect of nanoparticles suspension on the growth of mung bean (*Vigna radiata*) seedlings by foliar spray method. Nanotechnology Development, 3(1): 1-5.

Elfeky, S. A., M. A. Mohammed, M. S. Khater, Y. A. H. Osman and E. El-Sherbini (2013). Effect of magnetite nano-fertilizer on growth and yield of *Ocimum basilicum* L. Inter. J. Indigenous Medicinal Plants, 46(3): 1286-1293.

El-Khateeb, M. A., A. B. El-Attar and Z. A. M. Abo-Bakr (2020). Effect of nano-microelements on growth, yield and essential oil production of sweet marjoram (*Origanum majorana*) plants. Plant Archives, 20(2): 8315-8324.

El-Sherbini, E., H. G. Abd El-Gawad, M. A. Kamal and Souad A. El-feky (2015). Potential of He-Ne laser irradiation and iron nanoparticles to increase growth and yield of pea. American-Eurasian J. Agric. & Environ. Sci., 15(7): 1435-1446.

Ghasemi, F. R., R. Maftoun and N. A. Karimian (2006). Effect of iron chalate on seed yield and chemical composition of soybean genotypes. J. Agric., 29(2):1-22.

Hänsch, R. and R. Mendel (2009). Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl). Curr Opin Plant Biol., 12(3): 259-266.

Hassanpouraghdam, M. B., L. V. Mehrabani and N. Tzortzakis (2019). Foliar application of nano-zinc and iron affects physiological attributes of *Rosmarinus officinalis* and quietens NaCl salinity depression. Journal of Soil Science and Plant Nutrition, 20(2): 1-11.

Huda, K. M. K., M. S. R. Bhuiyan, N. Zeba, S. A. Banu, F. Mahmud and A. Khatun (2009). Effect of $FeSO_4$ and pH on shoot regeneration from the cotyledonary explants of Tossa Jute. Plant Omics J., 2(5): 190-196.

Jia, M. S., A. Kmateen, D. S. Sohani, C. M. William, C. T. Elizabeth and J. G. Dixie (2012). Fe^{+2} binds iron responsive element- RNA, selectively changing protein- binding affinities and regulating mRNA epression and activation PNAs, 109(22): 8417-8422.

Khater, M. S., M. A. El-Kereti, S. A. El-Feky, Y. A. Osman and E. El-Sherbini (2013). Effect of He-Ne Laser irradiation and Fe_3O_4 NPs foliar spray on growth and yield of sweet basil plant. Inter. J. Indigenous Medicinal Plants, 46(2): 1410-1421.

Kurkin, V. A., G. G. Zapeschnaya, A. V. Volotsueva, E. V. Avdeeva and K. S. Pimenov (2001). Flavolignans of *Silybum marianum* fruit. J. Natural Prod, 37: 315-317.

Mahmoud, M. A. and H. M. Swaefy (2020). Comparison between effect of commercial and nano NPK in presence of nano zeolite on sage plant yield and components under drought stress. Zagazig J. Agric. Res., 47(2): 435 -457.

Marschner, H. (1995). Mineral nutrient of higher plants. Second Ed., Academic Press Limited. Harcourt Brace and Company, Publishers, London; pp. 347-364

Martinelli, E. M., P. Morazzoni, S. Livio and E. Ubertin (1991). Farmacopea Official Italiana J. Liq Chrom., 4:1285.

Mazumdar, B. C. and K. Majumder (2003). Methods of Physiochemical Analysis of Fruits. Daya Publishing House Delhi, India.

Metzner, H., H. Rau and H. Senger (1965). Untersuchungen Zur synchronixier Barkelt Einzelner pigment mangel. Multantent Von Chlorella planta, 65 :186.

Mohammadi, M., N. M. Hoseini, M. R. Chaichi, H. Alipour, M. Dashtaki and S. Safikhani (2018). Influence of nano-iron oxide and zinc sulfate on physiological characteristics of peppermint, Communications in Soil Science and Plant Analysis, 49(18): 2315-2326.

Naderi, M. R. and A. Danesh-Shahraki (2013). Nanofertilizers and their roles in sustainable agriculture. Int. J. Agric. Crop Sci., 5 (19): 2229-2232.

Rezaei-Chiyaneh, E., S. Rahimi, A. Rahimi, H. Hadi and H. Mahdavikia (2018). Response of seed yield and essential oil of black cumin (*Nigella sativa* L.) affected as foliar spraying of nano-fertilizers. Journal of Medicinal Plants and By-products, 7(1): 33-40.

Sedghi, M., A. Nemati, B. Amanpour-Balaneji and A. Gholipouri (2010) .Influence of different priming materials on germination and seedling establishment of *Silybum marianum* L. under stress. World Applied Sciences Journal, 11 (5): 604-609.

Snedecor, G. W. and W. G. Cochran (1980). Statistical Methods 7th Edition. Iowa State Univ. Press. Amer. Iowa, U.S.A.

Torabian, S., M. Zahedi and A. Khoshgoftar (2017). Effects of foliar spray of nano-particles of $FeSO_4$ on the growth and ion content of sunflower under saline condition. J. Plant Nutr., 40(5): 615-623.

Yuanbi, Z. Z. Q. and H. Jiaying (2008). Preparation and Analysis of Fe_3O_4 Magnetic Nanoparticles Used as Targeted-drug Carriers. Chinese J. Chem Eng., 1(3): 451-455.

تأثير الرش الورقى بجزيئات الحديد متناهية الصغر على نمو ومحصول البذور والمواد الفعالة لنبات شوكة مريم

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تم إجراء العمل البحثي بالمزرعة التجريبية بمحطة البحوث الزراعية بالإسماعيلية بمحافظة الإسماعيلية مصر، لدراسة تأثير الحديد بتركيز (صفر، ٧.٥، ١٥، ٣٠ جزء في المليون) على صورة أكسيد الحديديك النانوي على النمو، محصول البذور و المواد الفعالة لنبات شوكة مريم خلال موسمي ٢٠١٩/٢٠١٨ و ٢٠٢٠/٢٠١٩ م. وقد صممت التجربة في قطاعات كاملة العشوائية و في ثلاث مكررات. وقد أدى رش نباتات شوكة مريم بأكسيد الحديد النانوي بمعدل ٣٠ جزء في المليون إلى زيادة طول النبات، عدد الأوراق/نبات، عدد النورات/نبات، قطر الساق، طول الجذر، عدد الجذور/نبات، الوزن الجاف للجذور والعرش والنورات/نبات، الكلوروفيل أ، الكلوروفيل ب والكلوروفيل الكلي أ + ب، محصول البذور/فدان، محتويات الأوراق من النيتروجين والفوسفور والبوتاسيوم وكذلك الحديد في ثمار نبات شوكة مريم، التاكسيفولين، السيليديانين، السيليبين، السيليكريستين، الأيزوسيليبين و السيليمارين الكلي في الثمار في كلا الموسمين.

الكلمات الدالة: نبات شوكة مريم – أكسيد الحديد النانوي – النمو الخضري – محصول البذور – التاكسيفولين – السيليديانين – السيليبين – السيليكريستين – الأيزوسيليبين – السيليمارين