Effects of nano, chelated and conventional iron as soil addition on growth, anatomy and early yield of cucumber plants (Cucumus sativus l).

Conference Paper · April 2018

Heba S. Eldesouky
Benha University

Effects of nano, chelated and conventional iron as soil addition on growth, anatomy and early yield of cucumber plants *(Cucumus sativus l)*.

El-Desoukey, Heba[1], S.;Abd-El-Dayem[1], H.M; Islam[2] R.K; Harker,T[3].; Gao, G [3]; Bergefurd, B.[3];.Ismail, Faten,[1] H. and Mady[1], M. A.

1-Botany Department Faculty of Agric. Benha Univ. Egypt, 2- Soil, Water and Bioenergy Resources Department, Ohio State University South Centers, Piketon, OH, USA. 3-Horticulture Department, Ohio State University South centers, Piketon, OH, USA.

Corresponding author: heba.alabd@fagr.bu.edu.eg

Abstract

Two greenhouse experiments in Randomized complete block design with four replications were conducted at Soil, Water and Bioenergy Resources, South Centers, Piketon, OH, Ohio State University, USA, to study the effect of iron forms (conventional Ferric chloride ($FeCl_3$-$6H_2O$),chelated iron(6% Fe) and Nano Iron Oxide (Fe_2O_3, alpha, 99%,)at different doses(0, 50 and 100 mg/kg^{-1} soil) on growth, anatomy and early yield in cucumber plants (*Cucumus sativus L.*) cv.(Tyria F1) during 2015 and 2016 seasons. Results showed that, the different applied treatments increased plant height, leaf number, leaf area (LA) (cm^2), fresh weight and dry weight at60 and 90 days after transplanting during the both seasons of cultivation. Also, anatomical studies were carried out on stems i.e.(stem thickness, xylem and Phloem thickness, and numbers, cambium region thickness, Fiber tissue thickness and pith thickness) and leaves measurements i.e.(plaside and spongy tissue and xylem thickness, number of vessels and phloem at 30 days of plant age in the second season. Data showed positive response to the different applied treatments especially with nano iron at 100 mg/kg^{-1}.In addition, early fruits number/plant, fruit length, fruit diameter and early fruit weight per plant increased due to the different applied treatments in the first and second seasons. Results also, showed that soil application of nano iron at 100 mg/kg^{-1} is the most effective treatment in this respect compared with other tested iron sources and control treatments.

Keywords: nano ferric, chelated, growth, anatomy, early yield.

Introduction

With the development of nanotechnology, nanomaterials are being used in the field of agriculture **(Li *et***

***al*.,2014).** Nanomaterials consist of nanometer-scale particles with a very small diameter and a large specific surface area. In comparison with traditional materials; nanomaterials have many special functions resulting from the quantum size effect, microscopic quantum tunneling, and dielectric confinement effect **(Michal *et al*.,2005; Hochella *et al*.,2008),** and also have some new functions **(Gui *et al*.,2015).** Consequently, such nanomaterials have many potential applications. . In September 2003, the United States Department of Agriculture stated the importance of using nanotechnology in agricultural production; since then, many other countries have increased research efforts in this field **(Sanguansri and Augustin, 2006).** In addition, many experts have proposed that nanoparticles should be used in the field of soil–plant nutrition to achieve sustainable development of agricultural production with minimal environmental impacts **(Sastry *et al*., 2007).** Nowadays, nanotechnology considered a new technical revolution. Therefore, nanomaterials will become the new materials for agricultural development, and represent new ideas and directions for global agricultural production **(Chen and Yada, 2011).** Iron (Fe) is an essential nutrient for all organisms **(Zuo and Zhang, 2011)** and its deficiency is widespread among many different crops **(Sánchez-Alcalá *et al*., 2014).** Despite of Fe content in soil is usually high, but a large proportion is being fixed to soil particles **(Mimmo *et al*.,2014; Bindraban *et al*.,2015)**. Also, Fe is mainly in the form of insoluble Fe3+, especially in high-pH and aerobic soils; therefore, these soils are usually deficient in the available form of Fe2+.Because plants usually absorb Fe2+ from soil, Fe-deficient soils lead to Fe-deficient plants **(Kobayashi and Nishizawa, 2012).** In plants, Fe participates in many physiological processes including chlorophyll biosynthesis, respiration, and redox reactions. Hence, iron fills many essential roles in plant growth and development, including chlorophyll synthesis, thylakoid synthesis and chloroplast development **(Miller *et al*.,1995).(Mimmo *et al*.,2014; Ye *et al*.,2015; Zargar *et al*.,2015).** In this respect, since. Iron (Fe) is a cofactor for approximately 140 enzymes that catalyze unique biochemical reactions **(Brittenham, 1994).** Iron is required at several steps in the biosynthetic pathways. , Fe deficiency not only affects the growth and development of plants, but can also lead to anemia in animals and humans **(Li *et al*., 2014).** Therefore, it is important to improve the utilization efficiency of Fe fertilizers. The idea is quite simple: nanodevices can help to deliver the nutrients in the right place at the right time and to reduce the action of external agents leading to losses by degradation, etc. The expected effect should be a reduction in the amount of active chemicals incorporated into the plants and soils leading to a reduced negative impact on the environment. However, many researches and knowledge are needed to accomplish those goals not only for the development and synthesis of nano carriers and nano materials, but also for studying the interactions of such nano devices with the plants and the environment. Indeed, it is necessary to study how plants absorb and uptake nanoparticles, how they move inside the plant, and how they interact with the plant cell. Cucumber is one of the vegetable crops which is very important for the human nutrition and human health due to its high content from fiber, minerals and many other compounds**.** Foliar application of chelated iron increased vegetative and reproductive growth and fruit quality of cucumber plants**(Mohsen 2013).** Nano fertilizer has a positive effect on spinach wet weight by increasing growth indexes such as leaf area index, crop growth rate and leaf numbers of treated plants based on the same effect of different nano fertilizer concentrations **(Alirezaladan*et al.*, 2012)**. reported that the epidermis cells of the control were similar in shape and size, while the epidermal cells of the NP-treated leaves became larger in size and reached a maximum size when 3mg/kg^{-1} Fe_3O_4 nano Particles NPS foliar spray was used. In addition, the thickness of mesophyll tissue, which is specialized photosynthetic tissue that contains chloroplasts in palisade and spongy parenchyma tissue, was greater in Fe_3O_4 treated leaves compared to control leaves. The leaf spray treatment was also more effective than soil treatment, and the air spaces were largest in foliar sprayed leaves. Therefore, foliar spray was the most effective treatment, followed by soil treatment, compared to control leaves. This finding was clear based on the chlorophyll concentration, which was higher in leaves receiving the foliar treatment compared to soil treatment. Therefore, this study aimed to evaluate the effect of different doses of Nano iron as soil addition on growth, growth performance, anatomical structure of (stem and leaf)and early fruits yield in cucumber plants in comparison with other iron forms i.e., conventional or chelated ones.

Materials and Methods

Two greenhouse experiments in randomized complete block design (RCBD) with four replications were conducted at Soil, Water and Bioenergy Resources, South Centers, Piketon, OH, Ohio State University, USA to study the effect of iron sources conventional ferric chloride ($FeCl_3$-$6H_2O$), chelated iron (6% Fe) and nano Iron oxide (Fe_2O_3, alpha, 99%, 30-100 nm) at doses of 0, 50 and 100 mg/kg^{-1} soil on growth, anatomical structure and fruit yield of cucumber, (*Cucumus sativus L.*)(Tyria F1) during 2015-2016 and 2016-2017 seasons .Seeds of cucumber cv,(Tyria F1) (*Cucumus sativus.*) imported from LTD. USA company. the seeds were sowing in October 6th cucumber seeds were planted respectively in the growth chamber and were moved from the growth chamber to the green house on November 13thcucumber seedlings were transplanted to the greenhouse in plastic bags (30 cm) the bags size 12 lb (5.44 kg) of soil media promixpx ingredients (Canadian sphagnum peat moss (75-85 %), perlite horticulture grade, vermiculite horticulture grade, dolomitic and cacitic limestone (PH adjuster) wetting agent, starter nutrient. Imported from premier tech horticulture INC.127 South 5th street, suite 300 Quaketown, BA USA. 18951.

All the different designed treatments were added to the soil after 10 days from transplanting in both the first and second seasons. All recommended agricultural managements through plant growth and development were applied in both seasons. The characteristics of both the irrigation water quality and growing media are presented in Table1**.**

Table 1. Main characteristics of the Water used for irrigation and plant growth media.

pH	dsm^{-1}	P	K	Ca	Mg	S	Al	B	Cu	Fe	Mn	Mo	Na	Zn
Elemental composition of the irrigation water (mg/l)														
7.3	0.71	6.5	36	208	24	20	13	0.2	1.6	7.7	1	0.3	12	1.4
Elemental composition of the Growth media characteristics (mg/kg^{-1})														
4.7	0.8	118	617	112	31	84	6	3.2	1.5	2.5	3.7	0.3	43	0.7

Iron Sources:

Conventional Fe fertilizer ($FeCl_3$- 6H2O):

Ferric chloride certified A.C.S. (Lump) $FeCl_3$- 6 H2O F.W. 270.32 limit about 0.002 % P T. imported from Fisher Scientific Company.

Chelated Iron:

EDDHA Chelated Iron 6%: Ethylenediamine-N,N'-bis (2-hydroxyphenylacetic acid) imported from Grow More Company.

Nano iron:

Nano iron imported from Nanostructured & Amorphous Materials, Inc.
16840 Clay Road, Suite #113, Houston, TX 77084, USA

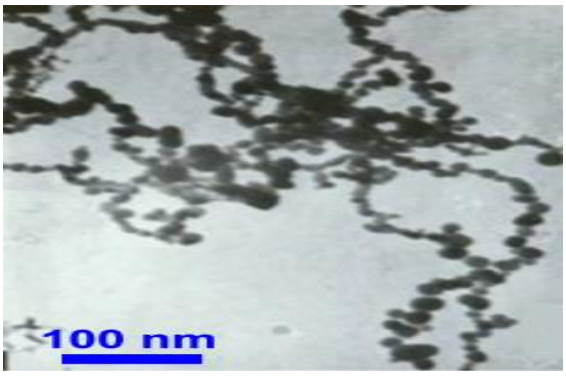

Fig (1) Nano particles Characteristics under electronic microscope from Nano structured & Amorphous Materials, Inc. Company.

All iron sources at different doses were added to the soil one time after 10days from transplanting during 2015 and 2016 seasons.

Data Recorded

I- Morphological growth measurements:

Different morphological characteristics of cucumber plants were measured at 60 and 90 days after transplanting. These characteristics involved: Plant height (cm), number of leaves / plant, shoot fresh weight and dry weight (g) / plant and total leaf area /plant (cm^2) using Handheld Laser Leaf Area Meter imported from CID Bio-Science,Inc,1554 NE 3rd Avenue Camas, WA USA 98607.The samples of each treatment were dried in oven at 65 °C for 48 hours to take the dry weight .

II- Anatomical studies:

At 30 days after transplanting in the second growing season specimens of stem and leaf were taken from the 2^{nd} apical internode of the stem and from the second apical leaf. Those vegetative specimens were killed and fixed in F.A.A. according to **(Sass, 1951).**The selected materials were washed in 50 % ethyl alcohol, dehydrated in a normal butyl alchohol series, embedded in paraffin wax of melting point 56^{o}C, section to thickness of 20 micrometer (µm), double stained with saffarine and fast green, cleared in xylene and mounted in Canada balsam **(Nassar and El-Sahhar, 1998)**. Four section treatments were microscopically inspected to detect histological manifestations of noticeable responses resulted from treatments. Count and measure (µ) were taken using a micrometer eye piece.

III-Early Yield and Yield components:

From the harvesting start until reach three weeks the early yield per plant was calculated (kg/plant),fruit length(cm) , fruit diameter($cm^{2)}$) and fruits number/plant were measured at the same time.

Statistical analysis:

Statistical analysis was performed using SAS 9.3 (SAS 2010). Different iron forms were considered as fixed effects. F-protected simple and interactive treatment means were separated by the Tukey's significant difference test, when the ANOVA showed significant effects ($p \leq 0.05$) of predictor variables on dependent variables, with a value of $p<0.05$ unless otherwise mentioned. Regression and correlation analyses were performed by using Sigma Plot® software.

Results & Discussions

Vegetative Growth parameters:

Data in Table (2) indicates that the different iron forms i.e. the conventional, chelated and nano iron at the different doses 0, 50 and 100 mg/kg^{-1} significantly increased growth parameters i.e., plant height, leaves numbers, leaf area cm^2/plant (LA) at 60 and 90 days after transplanting compared with the control during 2015 and 2016 seasons. The most effective treatment among these iron forms is nano at 100 mg/kg^{-1} during 2015 and 2016 seasons at the aforementioned different times.

These results are in agreement with those of **Mohamed *et al.*,(2014**) reported that foliar application of wheat plant with nano iron at 0.2.4 and 6 g/l) increased plant height, tillers numbers and number of leaves/plant.

Abo-Sedera *et al.*,(2016) on snap bean and Abou-Shlell (2017) on moringa plants reported that foliar application with Lithovit (Ca, Mg and Fe nano particles) increased plant height, No. of leaves /plant, No. of branches /plant, fresh and dry weight/ plant and leaf area /plant. **Jayvanth *et al.*,(2017)** found that foliar application of strawberry plants with iron oxide nano particles at 150 mg/l^{-1} increased plant height, number of leaves and petiole length.,

Data in Table (3) show that nano iron at 100 mg/kg^{-1} was the most effective treatment on fresh weight and dry weight at 60 and 90 days after transplanting (DAT) during 2015 and 2016 seasons. In context the different applied treatments of iron sources (conventional at 50 and 100, chelated at 50 and 100 and nano at 50 and 100 mg/kg^{-1}) significantly increased the same characteristics at 60 and 90 days after transplanting during 2015 and 2016 seasons. The application of Fe shown significant positive effects, in most cases, on growth measurements and chemical composition of cumin and soybean **(Kobayashi and Nishizawa, 2012)**.

Table 2. Effect of Nano, Chelated and Conventional iron on plant height, (cm), leaves number and leaf area (cm^2)of cucumber plants at 60 and 90 days after transplanting during 2015 and 2016 seasons.

Charactractics / Treatments		**After 60 days**						**After 90 days**					
Iron Source	**Dose mg/kg^{-1}**	**Plant Height (cm)**		**Leaves Number/plant**		**Leaf Area (cm^2)**		**Plant Height (cm)**		**Leaves Number/plant**		**Leaf Area (cm^2)**	
		1st Season	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
CONVFe		206.7b	195.2c	27.4c	30.9c	2461.4c	2393.2c	233.2b	229.1c	35.9a	37.5c	2743.1c	2733.2c
CHELFe		206.8b	197.8b	28.2b	34.1b	2841.7b	2664.9b	233.6b	232.4b	36.0a	39.0b	3037.5b	3103.9b
NANOFe		214.9a	202.0a	28.3a	35.1a	2677.8a	2839.5a	238.5a	237.4a	36.3a	41.9a	3760.3a	3750.2a
	0	205.5y	192.1z	27.7z	29.7z	2326.7z	2258.5z	231.2y	227.8z	32.0z	35.6z	2619.4z	2567.7z
	50	212.8x	200.9y	27.9y	34.8y	2798.8y	2766.9y	234.1x	233.1y	36.7y	41.3y	3423.6y	3403.4y
	100	210.1x	202.0x	28.3x	35.7x	2855.3x	2872.2x	240.1x	237.9x	39.5x	41.5x	3497.9x	3616.1x
Source x Dose													
CONVFe	**0**	204.2	193.4	27.3	29.0	2179.6	2186.3	230.8	227.5	32.5	36.3	2424.8	2412.5
	50	207.1	194.1	27.0	32.0	2513.2	2436.3	235.2	228.0	37.0	38.3	2848.8	2820.5
	100	208.7	198.2	28.0	31.8	2691.3	2557.0	233.7	231.9	38.3	38.0	2955.8	2966.5
CHELFe	**0**	206.3 ^{ns}	191.1*	28.3^{ns}	29.8*	2434.4*	2259.1*	231.1^{ns}	228.5*	32.8^{ns}	34.5*	2698.5*	2609.7*
	50	208.0	202.5	28.8	35.8	3033.6	2805.9	230.7	232.3	36.5	41.5	3269.9	3309.6
	100	206.2	199.8	27.5	36.8	3057.0	2929.6	239.1	236.3	38.8	41.0	3144.2	3392.4
NANOFe	**0**	205.9	191.7	27.5	30.3	2366.0	2329.9	231.6	227.6	30.8	36.0	2734.9	2681.0
	50	223.3	206.1	28.0	36.5	2849.6	3058.6	236.3	239.1	36.5	44.3	4152.2	4080.1
	100	215.5	208.1	29.3	38.5	2817.8	3130.1	247.5	245.6	41.5	45.5	4393.8	4489.4

* indicates significant interaction among iron source x dose over time at $p<0.05$.

¥ Means separated by same lower case letters in each column is not significantly different among iron sources at $p<0.05$.

€ Means separated by same lower case letters in each column is not significantly different among iron doses at $p<0.05$. ns means Non-Significant.

Table 3. Effect of nano, chelated and conventional iron on shoot fresh and dry weight (g) of cucumber plants(*Cucumus satives* L.) at 60 and 90 days after transplanting during 2015 and 2016 seasons.

Characteristics		After 60 days				After 90 days			
Treatments									
Iron Source	Dose mg/kg^{-1}	Fresh weight (g)/plant		Dry weight (g)/ plant		Fresh weight (g)/plant		Dry weight (g)/ plant	
		1st season	2nd season	1st season	2nd season	1st Season	2nd season	1st season	2nd season
CONVFe		1190b	1141c	169c	162c	1629b	1607c	248c	249c
CHELFe		1200b	1198b	198b	201b	1651b	1643b	256b	251b
NANOFe		1249a	1269a	271a	252a	1779a	1775a	358a	305a
	0	1071z	1064z	168z	148z	1538z	1515z	217z	224z
	50	1243y	1257y	228y	224y	1736y	1723y	277y	288y
	100	1325x	1287x	243x	243x	1784x	1787x	367x	293x
Source X Dose									
CONVFe	0	1091	1075	157	143	1602	1539	232	234
	50	1153	1195	179	176	1627	1623	255	263
	100	1325	1154	171	169	1657	1660	257	252
CHELFe	0	1071*	1066*	180*	156*	1508*	1507*	210*	217*
	50	1262	1263	199	198	1677	1652	271	270
	100	1267	1264	215	250	1769	1770	286	267
NANOFe	0	1051	1049	166	147	1504	1500	209	221
	50	1314	1314	305	299	1905	1895	306	332
	100	1382	1445	343	310	1927	1931	558	361

* indicates significant interaction among iron source x dose over time at $p<0.05$.
¥ Means separated by same lower case letters in each column is not significantly different among iron sources at $p<0.05$.
€ Means separated by same lower case letters in each column is not significantly different among iron doses at $p<0.05$.

II- Anatomical studies:

1-Stem anatomy

Data in Table (4) and Fig (2) indicate that stem diameter, fibers thickness and number, Cambial region thickness, phloem thickness upper and outer, xylem thickness, number of rows and vessel diameter are increased due to application of iron forms at different doses compared with the control in cucumber plants. The highest values were achieved due to application of nano iron source at 100 mg/kg^{-1} dose in different traits. Meanwhile, control treatment gave the lowest value in different stem anatomy parameters. The increase existed in stem diameter with different applied iron forms were preceded with obvious increases in the phloem units that well help the plant to translocate more photosynthates production from sources (leaves and stem) to fruits, thereby, increased in fruits size and number per plant (Table 6).

2-Leaf anatomy

Data in Table (5)and Fig (3) indicate that different iron applied treatments i.e. conventional at 50, 100 mg/kg^{-1}, chelated at 50and 100 mg/kg^{-1} and nano at 50 and 100 mg/kg^{-1} increased thickness of leaf midrib, length of large vascular bundle, width of large midrib in the vascular bundle, , phlome thickness, (upper & lower) , xylem thickness, and rows number, vessel diameter, plaside and spongy tissue thickness compared with the control treatments in cucumber leaf at 30 days after transplanting in second season.

The increases of the anatomy measurements could be attributed to the beneficial effects of nano iron on increasing the different structures of leaf tissue during plant growth and development, i.e. palisade and spongy tissue thickness, outer and inner phloem, different xylem parts (thickness, numbers and size). The increment of the conductive tissues (xylem &phloem) are also of a great importance because they could be also involved in the interpretation about why vigorous growth and high yielded fruits were existed with different applied treatments specially in case of nano iron at 100 mg/kg^{-1}. The positive alterations in cucumber stem &leaf anatomy treated with different treatments led to vigorous growth and enhancement of flowering and fruit setting of treated plants. Also, it could be noticed that the increases in stem &leaf anatomy measurements were completely reversed upon vegetative and reproductive growth of treated plants. So the, present study revealed increases of xylem tissue, i.e. the route of mineral nutrients and water translocation from roots to leaves and the phloem tissue (outer and inner) i.e., the pathway of different assimilates from leaves to fruits and different sinks in cucumber plants.,thereby, improvements of translocation events directly could be considered as a direct reason for increment the final fruit yield.

In general, the stimulatory effects of applied iron forms on the anatomy features of treated plants could be attributed to the effect cambium activity. The increment of cambium activity could mainly attributed to the increase of endogenous hormones level especially cytokinins and auxins, **(Sotiropoulos *et al.*,2002).**,thereby the plant yield and yield component will increase (Tabe 6).

These results are in agreement with **Agamy (2004)**on fennel plants and **Abbas (2013)** on dill plants, showed that all rates of foliar application of Fe at 0, 50, 100 and 150 mg/l significantly increased cortex, thickness, number and thickness of vascular bundles and vascular units (diameter of stem) while pith thickness decreased with the same foliar application. **Abou-Shlell (2017)** reported that foliar application of moringa plants with Lithovit(nano particles) at 500mg/l increased anatomical measurements in stem and leaf i.e. stem diameter, phloem and xylem thickness and vessel diameter.

III- Early yield and its components (quality)

The results in Table (6) and Fig (2) indicate that fruit number/plant, fruit length(cm) and fruit early yield kg/plant significantly increased with application of nano iron at 100 mg/kg^{-1} by 1.5 to 3 times over the control during 2015 and 2016 seasons. While conventional and chelated forms of iron at 50 and 100 mg/kg^{-1} increased fruit number /plant, fruit length(cm) and fruit yield kg/plant during first and second seasons.

Early fruit number and yield /plant were in parallel to the applied dose of each iron source. Also, the highest early fruit yield /plant was existed with nano iron at 100 mg/kg^{-1} (8.51 kg) followed by chelated at 100 mg/kg^{-1} (5.45 kg)and conventional at 100 mg/kg^{-1} (4.11 kg), while the control value was (3.29 kg) , during first season. **Shankramma *et al.*, (2016**) reported that soil addition of nano iron improve tomato yield and quality.

In this respect the obtained increases in cucumber fruit number, length and cucumber yield it augmented plants ability to harvest more light energy by delivering carbon nanotubes into chloroplast, andalso carbon nanotubes could serve as artificial antennae that allow chloroplast to capture wavelengths of light which is not in their normal range, such as ultraviolet, green, and near-infrared**(Cossins 2014).** Also, increased in plant growth measurements (Table 2) and biomass production (Table 3), thereby increased cucumber fruits number and size and cucumber yield production and quality.

Table 4. Effect of nano, chelated and conventional iron on stem anatomy measurements microns (µ)of cucumber plants at 30 days after transplanting in the second cultivation season.

Treatments / **Measurements micron (µ)**		**stem anatomy at 30 days after transplanting**								
			Fibers			**Phloem Thickness µ**		**Xylem**		
Iron source	**Dose mg/kg^{-1}**	**stem diameter µ**	**Thickness µ**	**Num.**	**Cambial region thickness µ**	**upper**	**lower**	**Thicknes µ**	**No. of rows**	**Vessel diameter µ**
Control		7283	80	3	33	301	291	370	3	201
CON.	50	8673	95	5	43	310	302	570	3	231
	100	8538	99	7	51	352	312	550	5	212
CHEL.	50	8852	101	9	95	320	501	591	4	311
	100	9233	105	10	110	315	521	579	5	331
NANO	50	9434	109	12	130	456	478	632	6	318
	100	9972	110	18	150	569	577	615	7	415

Table 5. Effect of nano, chelated and conventional iron on leaf anatomy measurements micron (μ) of cucumber plants at 30 days after transplanting during the second cultivation season.

Treatments: Iron Source	Dose mg/kg^{-1}	Thickness of leaf midrib (μ)	Length of large midrib vascular bundle (μ)	Width of large midrib vascular bundle(μ)	Phloem thickness. (μ) upper	Phloem thickness. (μ) lower	Xylem tissue: Xylem tissue thick(μ)	Xylem tissue: No. of xylem rows	Xylem tissue: Vessel diameter (μ)	Plaside tissue thick.(μ)	Spongy Tissue thick.(μ)
Control		2780	752	315	310	131	310	4	74	112	236
CONV.	50	2876	835	366	280	205	350	5	91	115	315
	100	3054	982	387	333	215	434	5	112	136	320
CHEL.	50	3125	1140	395	363	324	453	6	123	158	341
	100	3168	1194	412	351	330	513	6	162	178	381
Nano	50	3289	1287	455	372	352	563	6	168	189	410
	100	3470	1388	562	415	391	582	7	192	226	439

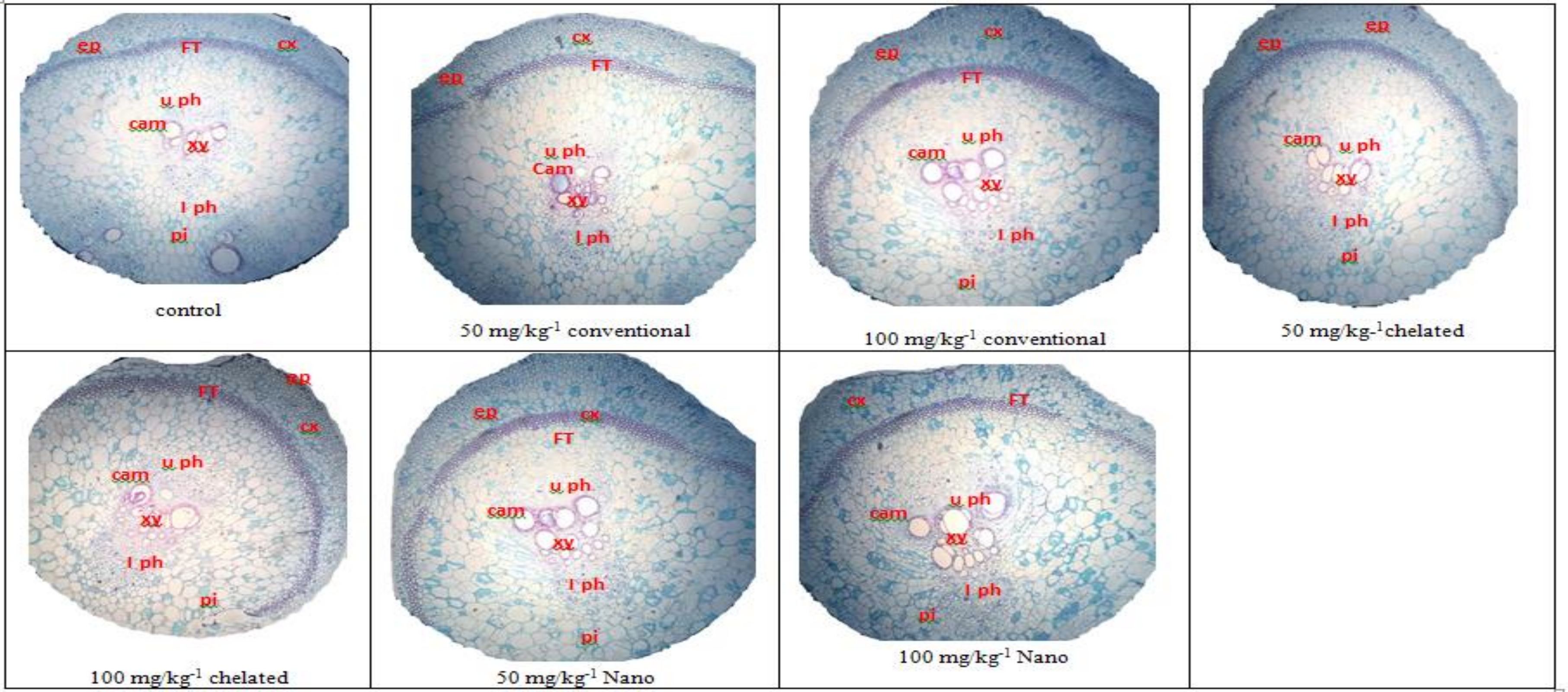

Fig. (2): Transverse sections (X = 24) through 2nd internode of the main stem of cucumber at 30 days after transplanting as affected by the different applied treatments.

ep= Epidermis cx= Cortex u ph= upper Phloem tissue I ph= lower phloem cam=Cambium xy= Xylem tissue pi= Pith

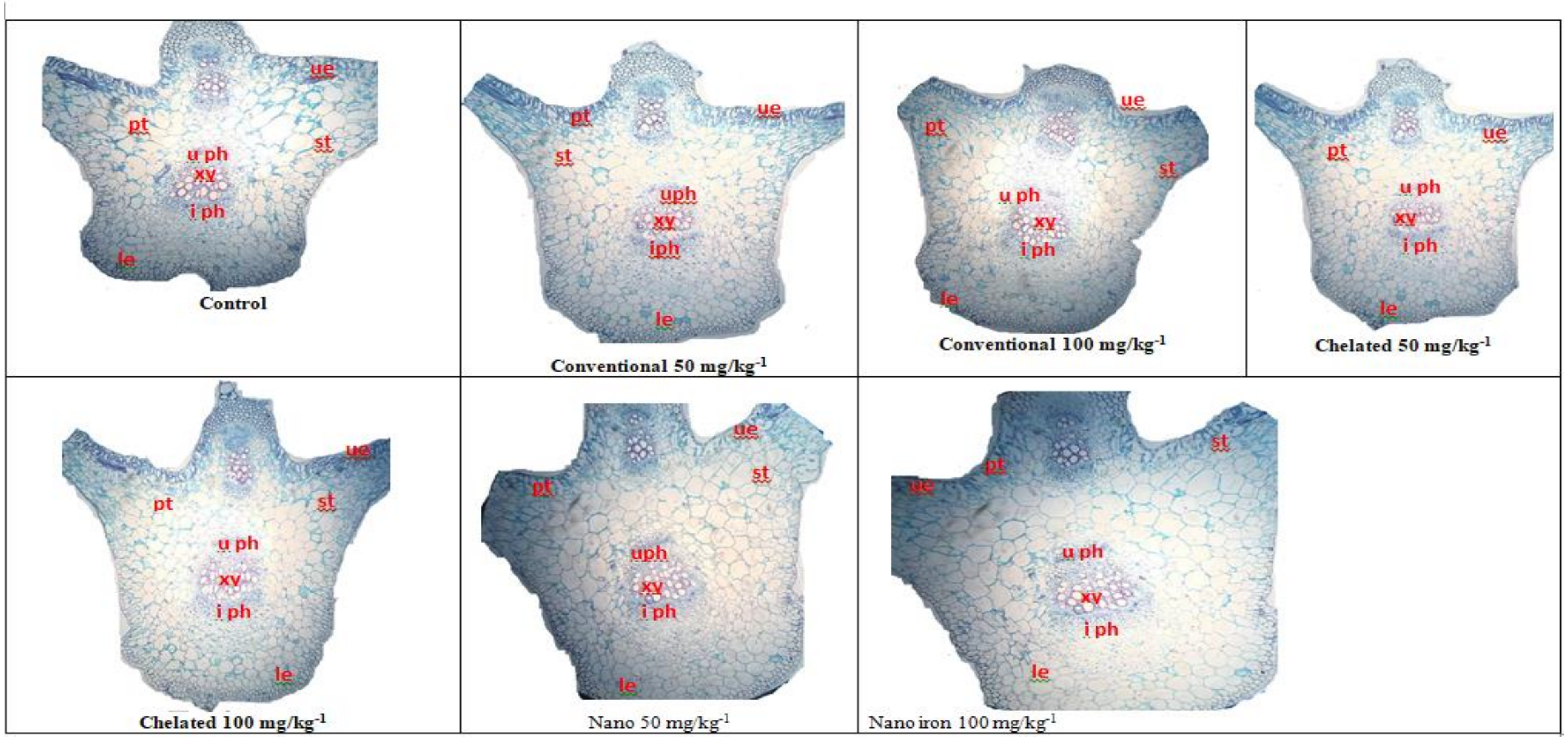

Fig. (3):Transverse sections (X = 24) through 2nd apical leaf of cucumber plants at 30 days after transplanting as affected by the different applied treatments.

ue= Upper epidermis pt= Palisade tissue st= Spongy tissue le= Lower epidermis u ph= upper Phloem tissue I ph = lower phloem tissue xy= Xylem tissue

Table 6. Effect of nano, chelated and conventional iron on early yield and yield characteristics of cucumber plants (*Cucumas satives L.*) during 2015 and 2016 seasons.

Charactractics / Treatments		Early Fruit Number./plant		Fruit length(cm)		Fruit Diameter (cm)		Early Fruit Yield (kg/plant)	
Iron Source	Dose mg/kg-1	1St season	2nd season	1St season	2nd season	1St season	2nd Season	1St season	2nd season
CONVFe		5.00c¥	3.75c	27.74b	25.68c	5.58b	5.28c	2.66c	2.27b
CHELFe		8.50 b	5.00b	32.74b	31.88b	6.23b	6.15b	3.66b	3.27b
NANOFe		9.50a	6.25a	36.40a	38.94a	7.15a	8.39a	6.16a	5.82a
	0	8.33z€	7.50y	28.78y	28.68y	5.00z	5.72z	3.29z	3.15y
	50	9.66y	8.75y	30.86y	31.67y	7.17y	7.27y	4.99y	4.66y
	100	10.66x	11.00x	34.24x	39.85x	9.15x	9.12x	6.11x	6.55x
Source X Dose									
CONV.	0	3.15*	4.00*	25.68*	28.24*	5.11*	5.24*	2.55*	2.66*
	50	3.52	3.98	28.58	29.34	5.36	5.74	3.15	3.85
	100	4.21	4.80	28.42	31.45	5.98	6.11	4.11	4.25
CHEL.	0	4.25	4.50	30.35	30.35	5.29	5.47	3.58	3.94
	50	9.50	7.50	27.89	32.97	5.88	6.97	4.36	4.66
	100	9.00	8.25	33.58	33.58	6.87	7.65	5.45	5.08
NANO	0	6.25	3.50	23.44	28.27	5.36	5.85	4.94	5.88
	50	10.00	11.75	38.94	41.61	8.12	8.46	7.37	6.27
	100	11.50	13.75	48.11	50.57	9.19	10.25	8.51	8.34

¥ Means separated by same lower case letters in each column is not significantly different among iron sources at p<0.05.
€ Means separated by same lower case letters in each column is not significantly different among iron doses at p<0.05.
* indicates significant interaction among iron source x dose over time at p<0.05.

Conclusion

Soil application of nano iron at 50 and 100 mg/kg^{-1} improved plant growth characteristics, shoot fresh and dry weight, stem and leaves anatomical features, early fruit numbers, fruit length and early fruits yield in cucumber plants (*Cucumus sativus*)under greenhouse conditions.

References

Abbas, M.K. (2013).Effect of foliar fertilizer and some growth regulators on vegetative and anatomical characters of dill (*Anethumgraveolens L.*) Middle-East J.of Sci. Res. 13 (6): 803-811.

Abo-Sedera, F. A.; Shams. A. S. Mohamed, M. H. M.; Hamoda, A. H. M. (2016). Effect of organic fertilizer and foliar spray with some safety compounds on growth and productivity of snap bean., Annals of Agric. Sci., Moshtohor 54 (1), 105-118.

Abou-Shlell, M. K. **(2017)**.Botanical studies on Moringa plant. M. Sci. of thesis Botany Dept. Fac. Agric. Moshtohor pp 154.

Agamy, R.A. (2004). Effect of mineral and/ or biofertilizers on morphological and anatomical characters, chemical constituents and yield of sweet fennel (Foeniculumvulgare Mill.Cv.Dulce) plants grown in calcareous soil. Egypt. J. Appli sci., 19 (3): 55-75.

AlirezaLadan, M.; Hesam, V., Nasim, B. and Narges ,K..(2012).Effect of different Levels of fertilizer nano_Ironchelates on growth and yield characteristics of two Varieties of Spinach (Spinacia oleracea L.): Varamin 88 and Viroflay .Research Journal of Applied Sciences, Engineering and Technology 4(12): 4813-4818, 2012 ISSN: 2040-7467

Bindraban, P. S.; Dimkpa, C.; Nagarajan, L.; Roy, A. and Rabbinge, R. (2015). Revisiting fertilisers and fertilisation strategies for improved nutrient uptake by plants. Biol. Fertil. Soils 51 897–911.

Brittenham, G.M. (1994). New advances in iron metabolism, iron deficiency and iron overload. Current Opinion in Hematology, 1, 549-556.

Chen, H. D. and Yada, R. (2011). Nanotechnologies in agriculture: new tools for sustainable development. Trends Food Sci. Technol. 22585–594.

Cossins, D. (2014) Next generation: nanoparticles augment plant functions. The incorporation of synthetic nanoparticles into plants can enhance photosynthesis and transform leaves into biochemical sensors. The scientist, news & opinion, March 16.http://www.the-scientist.com/?articles. view/articleNo/39440/title/Next-Generation–Nanoparticles-Augment-Plant-Functions/

Fraceto, L. F.; Grillo, R.; Medeiros, G. A.; Scognamiglio, V.; Rea, G. and Bartolucci, C. (2016). Nanotechnology in agriculture: which innovation potential does it have? Front. Environ. Sci. 4:20.

Gui, X.; HeX., M. Y. H.; Zhang, P.;Li, Y., and Ding, Y. (2015). Quantifying the distribution of ceria nanoparticles in cucumber roots: the influence of labeling. RSC Adv. 5 4554–4560.

Hochella, M.F.; Lower, S.K.; Maurice, P.A.; Penn, R.L.; Sahai, N.; Sparks, D.L. and Twining, B.S. (2008) .Nanominerals, mineral nanoparticles, and Earth systems.Science. 2008 Mar 21; 319(5870):1631-5.

Jayvanth, K.; Vijay, B. V.M.; Prasad, S.; Mishra, A. and Shukla, P.K. (2017).Effect of Different Concentrations of Iron Oxide and Zinc Oxide Nanoparticles on Growth and Yield of Strawberry (Fragaria x ananassaDuch) cv. Chandler,Int.J.Curr.Microbiol.App.Sci 6(8): 2440-2445.

Kobayashi, T. and Nishizawa, N.K. (2012). Iron uptake, translocation, and regulation in higher plants.Annu Rev Plant Biol. 2012;63:131-52.

Li, V.N; Rui, ; Gui, X.; Li, X.; Liu, S. and Han, Y.(2014). Uptake, transport, distribution and Bio-effects of SiO2 nanoparticles in Bt-transgenic cotton.JNanobiotechnology. 2014 Dec 5; 12():50.

Michalet, X.; Pinaud, F.F.; Bentolila, L.A., Tsay, J.M., Doose, S., Li, J.J., Sundaresan, G.; Gambhir ,S.S. and Weiss, S. (2005).Quantum dots for live cells, in vivo imaging, and diagnostics.Science. 2005 Jan 28; 307(5709):538-44.

Miller, G.W.; Huang, I.J.; Welkie, G.W. and Pushmik, J.C. (1995). Function of iron in plants with special emphasis on chloroplasts and photosynthetic activity. In: Abadia, J., (Ed.), Iron nutrition in soils and Plants. Kluwer Academic Publishers, Dordecht, pp.19-28.

Mimmo, T. D.; Buono, D.; Terzano, R.; Tomasi, N.; Vigani, G. and Crecchio, R.,. (2014). Rhizospheric organic compounds in the soil–microorganism–plant system: their role in iron availability. Eur. J. Soil Sci. 65 629–642.perspective. Trends Food Sci. Technol. 17 547–556.

Mohamed, A.; Sadegh, A. and Saaeid, M. (2014) Effect of time and concentration of nano-Fe foliar application on yield and yield components of wheat.Int.J. Of Biosicnce, (IJB) Vol4, (9):69-75.

Mohsen, K. (2013). Effect of Foliar Application of Iron and Zinc on Growth and Productivity of Cucumber., Bull. Env.Pharmacol. Life Sci., Vol 2 (11): 11-14.

Nassar, M. A. and El-Sahhar, K. F. (1998).Botanical preparations and microscopy (Microtechnique). Academic Bookshop, Dokki, Giza, Egypt, pp: 219 (In Arabic).

Sánchez-Alcalá, I.; delcampillo, M. D.; Barrón, V. and Torrent J. (2014). Evaluation of preflooding effects on iron extractability and phytoavailability in highly calcareous soil in containers. Plant Nutr. Soil Sci. 177 150–158.

Sanguansri, P. and Augustin, M. A. (2006). Nanoscale materials development-a foodindustry.Plant growth nutrition. 13 114-125.

Sastry, R. K..; Rao, N. H.; Cahoon, R. and Tucker, K. (2007). “Can nanotechnology provide the innovations for a second green revolution in Indian agriculture,” in Proceedings of the Nanoscale Science and Engineering Grantees Conference, Arlington, VA.

Sass, J.E. (1951).Botinical microtechnique. Iowa state collage press, Ames, Iowa, pp228.

Shankramma, K. S.; Yallappa,R.C.; Shivanna, M. B. and Manjanna, J. (2016). Fe2O3 magnetic nanoparticles to enhance *S. lycopersicum* (tomato) plant growth and their biomineralization, Applied Nanoscience,Volume 6, pp 983–990.

Vasconcelos, M. W. and Grusak, M. A. (2014). Morpho-physiological parameters affecting iron deficiency chlorosis in soybean (Glycine max L.). Plant Soil 374 161–172.

Sotiropoulos, T.E.; Therios, I.N.; Dimassi, K.N.; Bosabalidis, A. and Kofidis, G. (2002). Natritional status, growth , Co2 assimilation and leaf anatomical responses in two kiwi fruit species under boron toxicity . J. of plant Nuti., 25 (6):1249-1261.

Ye, Li. L.; Wang, L.; Wang, S.; Li, S.; DuJ, Z. S. and Shou, H. (2015).MPK3/MPK6 are involved in iron deficiency-induced ethylene production in Arabidopsis. Front Plant Sci. 6(1):953-956.

Zargar, S. M.; Agrawal, G. K..; Rakwal, R. and Fukao, Y. (2015). Quantitative proteomics reveals role of sugar in decreasing photosynthetic activity due to Fe deficiency. Front. Plant Sci. 6:592

Zuo, Y. and Zhang, F. S. (2011). Soil and crop management strategies to prevent iron deficiency in crops. Plant Soil.,339: 83–95.