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Effect of Different Levels of Fertilizer Nano_Iron Chelates on Growth and Yield Characteristics of Two Varieties of Spinach (*Spinacia oleracea* L.): Varamin 88 and Viroflay

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Abstract: In order to investigate effect of different concentrations of iron chelate Nano fertilizer on growth and performance of two kinds of Spinach, an experiment was performed as a plan of completely random plot in three alternations and in study field of Khazra Company in 2012. First studied factor was different types of Spinach including Varamin 88 and Viroflayand second studied factor was different concentrations of fertilizer (0, 2 and 4 ppt, respectively). Nano fertilizer solution injection was performed in early morning when plant had 8-13 leaves. Results show that wet weight and maximum leaf area index is influenced by concentration of iron chelate Nano fertilizer and dry weight is influenced by both type of Spinach and concentration of Nano fertilizer. Using 4 kg/ha Nano fertilizer causes 58 and 47% increase inwet weight and maximum leaf surface index, respectively comparing to use of no fertilizer. Using 4 kg/ha Nano fertilized leaded to maximum value of aerial organs dry weight for Sugar beet type and minimum value was obtained for treating both types of Spinach without using fertilizer. Studying leaf area index trend and growth rate diagrams indicate that Nano fertilizer has a positive effect on all plant growth steps.

Keywords: Growth properties, iron chelate, nano fertilizer, performance, spinach

INTRODUCTION

Fruits and vegetables doubtlessly have a great and essential contribution in supplying required mineral elements for body especially iron and calcium whose shortage is prevalent. Shortage of these elements causes malnutrition such as Ryktz, Astyvmalashya and anemia (Yazdanparast, 1372). Some vegetables and especially Spinach are richer sources of iron comparing to most of other vegetables and fruits (Khoshkhoui *et al*., 1991). Spinach whose scientific name is *Spinacia oleracea L.* is one of important vegetables of Chenopodiaceae family. Spinach has been naturalized in central parts of Asia and possibly Iran (Kallo and Bergh, 1993; Kawazu Okimura *et al*., 2003) and has cultivation history of more than 2000 years (Daneshvar, 2000; Salunkhe and Kadam, 1998). Spinach is one of the most important leafy vegetables and has important nutritional value and its stems are consumed freshly or after processing (Salunkhe *et al*., 1991) such that among 42 types of prevalent vegetables and fruits has second rank for having relative amount of 10 types of vitamins and minerals (Kawazu Okimura *et al*., 2003). It is considered as one excellent source of minerals and vitamins specially vitamin C. Spinach is rich in Calcium and iron and its calcium is in the form of Calcium Oxalate which is not accessible (Ramachandran *et al*., 2005).

Acid oxalate is combined with magnesiumand iron and makes them inaccessible (Rubatzky and Yamaguchi, 1997). Poor accessibility of Calcium in Spinach has been proved for rabbit and human. Amount of acid oxalic present in Spinach leaf has been reported to be 658-1670 mgr/100 gr. Spinach leaf has 3.2% protein which reduces cholesterol. Spinach leaf has 0.6% fat and Linolenic acid (Omega-3) and Linoleic acid (Omeg-6) are most important fatty acids of spinach leaf (Salunkhe and Kadam, 1998). Present fiber in spinach leaf has been reported to be 0.65%. Spinach is rich in antioxidant compounds such as Beta-carotene and Lutein. These two compounds have antioxidant and anticancer properties. Beta-carotene improves lung operation and decreases risk of diabetes. Lutein reduces risk of cataract and improves vision in old ages. Spinach seed has tranquilizing property and is effective in reduction of fever, gastritis and inflammation of intestines. Seed of this plant has fever reduction property due to its high mucilage. There are some compounds in spinach that have antibacterial property. Some compounds in spinach called Folic acid are very

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useful for curing anemia (Singh *et al*., 1997). Regarding importance of spinach in supplying mineral elements, fiber of phenol compounds, essential fatty acids and protein, it is necessary to increase performance of this plant specially its essential mineral elements.

This plant the same as other agricultural plants needs optimized agricultural managements as well as appropriate whether and soil condition for maximum usage of environment potentials and consequently maximum performance (Behnia, 1370). Chemical fertilizers may have high consumption elements (Nitrogen, Phosphor, potassium and...) or low consumption elements (iron, zinc and magnesium and ...). Iron is one of fundamental constitutions of plants oxidizing and reducing systems and due to its capability to change its valance, as a basic element in oxidizing and reducing systems it facilitates electron transfer (Talaei, 1998).

Iron is abundant in soil and its compounds constitute 5% of earth crust weight (Talaei, 1998). Despite of being abundant, due to its inaccessibility its shortage is common for plants. Most of present iron is insoluble. Only a small amount of iron is soluble ($Fe (OH)_2$, $Fe (OH)^{+2}$, Fe^{+3}, Fe^{+2}). Amount of these soluble forms of iron depend on pH so that they are maximum in acidic pH and minimum in pH range between 6.5 and 7.5 (Kangueehi, 2008).

Iron is an essential element for growth of plants, lack of iron causes young leaves to yellow and photosynthesis activity to reduce significantly and consequently biomass is produced (Briat *et al*., 2007). This not only has a negative effect on agriculture and economy but also causes iron inadequacy in human body which is one of most prevalent nutritional problems (Cesco *et al*., 2002).

Using different shapes of chelates that are obtained by reaction between metal salts and artificial and natural complexes is the most important way for preserving iron against increasing precipitation of iron in soil with increasing pH (Köksal *et al*., 1998)

In order to investigate effect of iron chelate Nano fertilizer on qualitative and quantitative performance of spinach and consequently to increase income of farmers who cultivates spinach, this experiment was planned.

Iron chelate Nano fertilizer can be considered as a rich and reliable source of bivalentiron for plant because of its high stability and gradual release of iron in a wide pH range (3 to 11). One advantage of this Nano fertilizer is using no ethylene compounds in its structure. Ethylene enhances growth process and prevents appearing indications caused by chlorosisin leaves.

Table 1: Soil experiment results

Type of test	Test method	Soil (SS-90-678)
EC (Ds/m)	Conductometer	2.00
OC (%)	Black volatile	0.64
N (%)	Kjeldahl	0.07
P (ppm)	Olsen	17.60
K (ppm)	Flame photometer	282.00
Sand (%)	Hydrometer	34.00
Silt (%)	Hydrometer	36.00
Clay (%)	Hydrometer	30.00
Type	---	Clay loam
Fe (ppm)	Atomic	2.02
Ca (meq/L)	Titration	12.68
TNV (%)	Titration	8.63

Second advantage of iron chelate Nano fertilizer is increasing ratio of ferrous iron to ferric iron in chelate surface which results in increasing synthesis of chlorophyl in plant (Hokmabadi *et al*., 2006)

MATERIALS AND METHODS

In order to investigate effect of different concentrations of iron chelate Nano fertilizer on growth and quantitative and qualitative performance of two kinds of Spinach, an experiment was performed as a plan of completely random plot in three alternations and in study field of Khazra Company with longitude 35°35'38" north and latitude 51°21'27" east in 2012. First studied factor was different types of Spinach including Varamin 88 and Viroflay and second studied factor was different concentrations of fertilizer (0, 2 and 4 ppt, respectively). Nano fertilizer solution injection was performed in early morning when plant had 8-13 leaves.

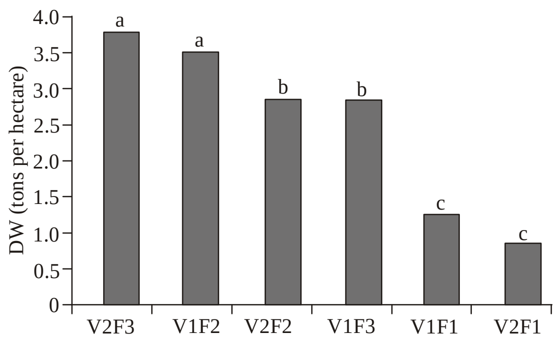
Land preparation process before cultivation was performed by deep plow and two step perpendicular disc and distribution of basic fertilizers, based on related recommendations and soil experiment results, including 145 kgr/ha triple superphosphate, 80 kgr/ha potassium sulphate and 100 kgr/ha urea. The result of soil test is shown in Table 1. Seed were cultivated manually in depth of 2 cm and with cultivation density of 15*40 in 1 September 2012. At the end of growth season plants were harvested in a surface area equal to 1 m^2 and performance features, harvest index, shrub height, petiole length, stem diameter, amount of chlorophyll and aggregation of iron in leaf (by spectrophotometer instrument) were calculated. Variance analysis and statistical calculations were performed by SAS software and Excel.

RESULTS AND DISCUSSION

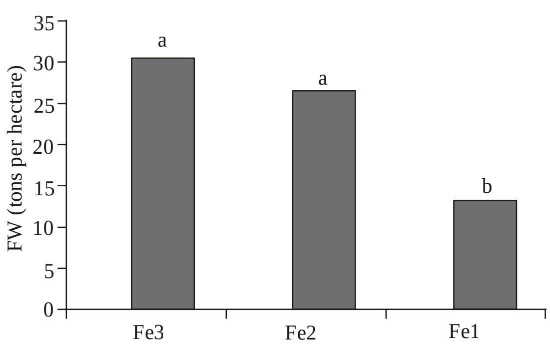
Wet weight variance decomposition showed that effect of fertilizer concentration becomes significant at

Table 2: Variance decomposition results for wet weight, dry weight and maximum leaf area index features

		Mean squares			
Change resources	DF	FW	Dry weight	Max. LAI	Number of leaves
Repeat	2	5/58 $^{n.s}$	68388/12 $^{n.s}$	0.96	5/28
Type	1	2469/63 $^{n.s}$	18056/33 $^{n.s}$	0.46	571/22*
Fertilizer	2	18275/46 **	960286/52 **	4/55**	96/62*
Type* fertilizer	2	1594/66 $^{n.s}$	1046980/28**	0.58	23/48
Percent error	10	678/51	109892/14	0.29	21/32
Coefficient of variation		18/8	13	19/28	16/7

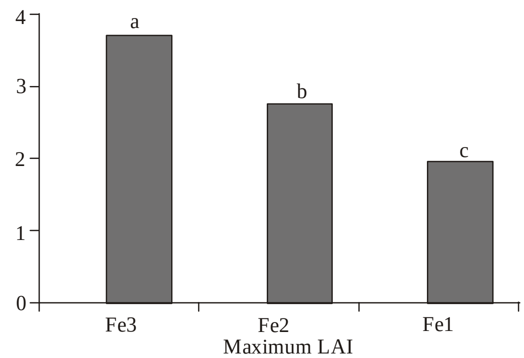


(a)

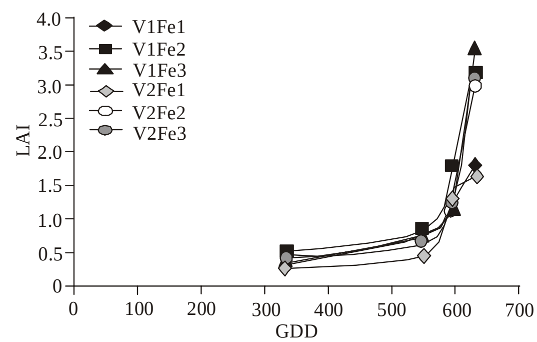


(b)

Fig. 1: Comparing average wet weigh and dry weight values V_1 and V_2: Varimin 88 and sugar beet, respectively; Fe1, Fe2 and Fe3: Different concentrations of iron chelate nano fertilizer (2, 4 and 0, respectively)



(a)



(b)

Fig. 2: (a) Comparing average maximum leaf area indexes, (b) Trend of leaf area index changes

1% level (Table 2). Average wet weight of spinach aerial organs increased by different concentrations of iron chelate Nano fertilizer and using 4 kgr/ha Nano fertilizer caused wet weight to increase 58% comparing to witness (Lack of fertilizer or control). Also application of 2 kgr/ha and treatment by 4 kgr/ha both statistically are in the same group (Fig. 1). Increasing leaf area can cause performance of wet weight and dry weight of aerial organs to increase and therefore effective factors in this index such as fertilizer and irritation water are considered important. Appropriate use of different fertilizers creates more leaf area by producing more leafy texture and consequently leads to higher performance (Hossein-Pour *et al*., 1998).

Studying Trend of leaf area index in Fig. 2b shows that this index is higher than witness in all growth steps when Nano fertilizer is used. According to an increase in photosynthesis and plant dry weight, wet weight increased due to increase of maximum leaf area in treatments by iron chelate Nano fertilizer. Also Burger *et al*. (2007) studied effect of iron chelate Nano fertilizer on qualitative and quantitative properties of various cut flowers and found that treatments by 1 and 1.5 gr/L iron chelate Nano fertilizer with possibility of 95% have a positive and significant effect on increasing this index (Bugr Rahimian *et al*., 2011).

Obtained results from Table 2 indicate that simultaneous effect of different spinach types and concentrations of iron chelate Nano fertilizer on dry weigh of plant aerial organs showed statistically significant difference at 1% level. Comparing average values indicates that maximum average aerial organs dry weight whose value is 3.7 tones/ha is for Viroflay type and in treatment by 4 kgr/ha Nano fertilizer. This treatment is in the same statistical group as treatment by 2 kgr/ha Nano fertilizer whose average dry weight is 3.5 tones/ha for Varamin 88 type. Minimum average aerial organs dry weight is related to treatment by no Nano fertilizer in both types of spinach (Fig. 1).

Abdolhadi (2006) injected solutions of iron, zinc and manganese to several plants such as sugar beetand found that performance increase between 1 to 51%. Results of (Abdolhadi, 2006). Hodgsin *et al*. (2007) show that application of iron in soil before cultivation increases amount of soybean aerial organs dry weight by 46% in early vegetative season.

Kumusu *et al*. and Kuhura *et al*. showed that iron chelate fertilizer increases significantly performance of tomatocomparing to other iron fertilizers (Kallo and Bergh, 1993; Kawazu Okimura *et al*., 2003).

Results of correlation Table 2 and 3 show that dry weight with wet weight and both with leaf area index have a positive and significant correlation in simple effect of different concentration of Nano fertilizer. Also a positive correlation was obtained in mutual effect of spinach type and concentration of Nano fertilizer between dry weight and wet weight and number of leaf and also between wet weight and leaf area index. Since there is a direct relation between performance and aerial organs of spinach, leaves and in less ratio its constitution petiole, increasing number of leaves leads to an increase in plant dry and wet weight.

Leaf Area Index (LAI): In spinach, increasing leaf area increases sun ray reception and consequently increases performance (Hossein-Pour *et al*., 1998)

Experiment Results show similar changes of leaf area index changes during growth season for all treatments (Fig. 2) so that leaf area index increases gradually in early season thereafter it increases linearly until it reaches its maximum in 629.5 Degree Day Growth (GDD). According to leaf area index changes diagrams, in early growth leaf area index is the same for all treatments except treatment of Sugar beet by no Nano fertilizer and after 540° day growth some differences appear between treatments.

Correlation of spinach type and Nano fertilizer concentration shows significant difference at 1% level

Table 3: Correlation coefficients for simple effect of nano fertilizer concentration on studied properties of spinach

	LAI	Dry weight	FW	Number of leaves
LAI	1			
Dry weight	0.99**	1		
FW	0.99*	0.99*	1	
Number of leaves	0.98	0.99	0.97	1

**: Correlation significant at 5%; *: Correlation significant at 1%

Table 4: Correlation coefficients for mutual effects of spinach type and nano fertilizer concentration on studied properties of spinach

	LAI	Dry weight	FW	Number of leaves
LAI	1			
Dry weight	0.79	1		
FW	0.95**	0.93**	1	
Number of leaves	0.62	0.88**	0.76	1

**: Correlation significant at 5%; *: Correlation significant at 1%

for maximum leaf area index (Table 2). Maximum leaf area index for treatment of Sugar beet by 4 kgr/ha Nano fertilizer and treatment of Varamin 88 by 2 kgr/ha Nano fertilizer is maximum and its minimum value is attributed to treatment by no Nano fertilizer in both types of spinach. Yarnya *et al*. (2010) studied effect of usingmicro nutritious elements on production of sugar beet and found that consumption of iron sulphate by soil resulted in maximum development of leaf area during the entire growth period.

Crop Growth Rate (CGR): Crop growth rate is an index which determines amount of dry material aggregation per unit area and time (Yadavy *et al*., 1385). According to Fig. 3, CGR has an increasing trend in all treatments and finally reaches a maximum value. In early growth period, growth rate is the same for all treatments and after about 550° day growth they can be distinguished. Javaheri *et al*. (2004) showed that a rapid increase in plant growth rate occurs with growing agricultural plant because leaves surface extends and less light reaches soil surface among plant leaves. Comparing slope of crop growth rate diagrams in third sampling and final harvest showed that growth rate was maximum for treatment of sugar beet by 4 kgr/ha. Generally using Nano fertilizer increased crop growth period comparing to witness treatments due to negative slope of diagram after third sampling of non-treated plants by Nano fertilizer.

Number of leaves: Results in variance decomposition Table 2 show that simultaneous effects of spinach type and concentration of Nano fertilizer on leaf numbers become significant at 1% level. Comparison of average data reveals that Varamin 88 type has moreleaves than Sugar beet type. This difference is about 31%.

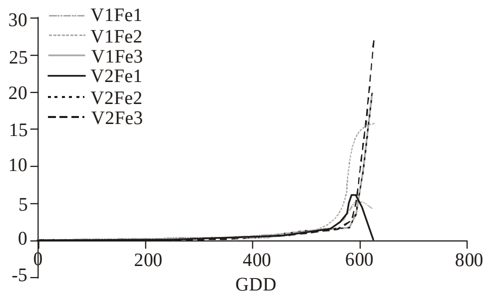


Fig. 3: Crop growth rate changes

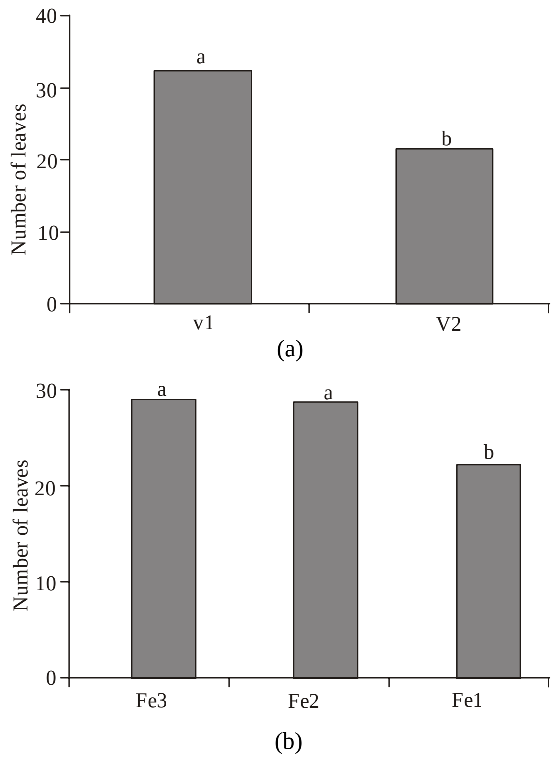


Fig. 4: (a) Leaf numbers versus spinach type, (b) leaf numbers versus concentration of nano fertilizer

Also different concentrations of Nano fertilizer are in the same statistical group and increase leaf numbers by 23% comparing to witness (Fig. 4). According to Table 3 and 4, a positive and significant correlation was observed between leaf numbers and plant dry weight due to simultaneous effects of spinach type and concentration of Nano fertilizer.

CONCLUSION

According to obtained results, iron chelate 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, concentration of 2 kgr/ha is recommendable because it is more economical and has better crop performance.

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