Biological Forum – An International Journal **7**(1): 679-683(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

The Effect of Iron Nanoparticles Spraying Time and Concentration on Wheat

Mitra Bakhtiari*, Payam Moaveni* and Behzad Sani*
**Department of Agronomy,*
Shahr-e-Qods Branch, Islamic Azad University, Tehran, IRAN

(Corresponding author: Payam Moaveni)
(Received 07 February, 2015, Accepted 13 March, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT. Fe deficiency is a widespread nutritional problem in plants growing mainly in high pH and calcareous soils. Foliar application of Fe compounds with the technology of Nano may be a solution to the problem. So, this experiment was conducted in 2014 at the Research Field of Islamic Azad University, Shahr-e-Qods Branch, Iran, to evaluate the response of wheat growth, yield and quality to iron nanoparticles spraying. The experiment was conducted in factorial in the form of a randomized complete block design with four replications and two treatments: time of spraying in two levels (May 23 and June 6) and concentration of Fe Nano-oxide solution in five levels (0, 0.01%, 0.02%, 0.03% and 0.04%). The measured traits included: spike weight, 1000 grain weight, biologic yield, grain yield and grain protein content. Results showed that spraying time and concentration significantly affected all measured traits; however, the effect of interaction of the two factors was not significant. Mean comparison of the spraying times indicated that the highest values of spike weight (614.88 g), 1000 grain weight (36.10 g), biologic yield (8830 kg/ha), grain yield (3639.5 kg/ha) and protein content (16.01%) were achieved in the first spraying time. Among the Fe concentrations, the highest values of spike weight (666.96 g), 1000 grain weight (37.96 g), biologic yield (8895.0 kg/ha), grain yield (3776.5) and protein content (16.44%) were achieved in 0.04% Fe concentration and the lowest values were achieved in the control.

Keywords: Fe Nano-oxide, foliar application, micronutrients, *Triticum aestivum* L.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a monocotyledon member of Poaceae family. It is a herbaceous annual plant. Wheat is probably the first crop plant which is domesticated and cultivated by human and in modern world it is the most important food crop in all over the world. There are a large number of wheat cultivars which adopted to different climatic conditions and that is why wheat is being cultivated in nearly all over the world (Khodabandeh, 2008; Noormohammadi *et al.,* 2007).

Wheat yield is under influence of various factors such as climate, agronomic practices, cultivar, pests, diseases and weeds infestation. Among these factors, nutrient management is of a high importance. However, increased application of macronutrients especially N and P in the form of chemical fertilizers, and the lack of application of micronutrients to agricultural fields, salinity of soils, low organic matter content in soils and repeated farming have resulted in the sever lack of micronutrients in soils and in plants (Salispour, 2007). Iron is the most important rare elements which is required for plants and animals. It is a key element in cell metabolism and it is involved in photosynthesis, respiration, enzymes activity, etc. (Rashno *et al.,* 2013; Wiedenhoeft, 2006).

Introduction of the first generation of technology to agriculture resulted in the green revolution and changed the traditional agriculture to modern intensive agriculture. Today, nanotechnology as a novel technology has solved many problems in different fields of science and industry and has found its position and functions in agriculture. Nanotechnology has various functions in all stages from production, processing, storage, packing and transportation of agricultural products (Scott and Chen, 2003). Nanofertilizers are the most important function of nanotechnology in the production phase of agriculture. Application of nanofertilizers instead of common fertilizers, nutrients are provided to plants gradually and in a controlled manner. The nanotechnology increases the application efficiency of fertilizers, reduces soil pollution and environmental risks of chemical fertilizers (Naderi *et al.,* 2011).

Because Nano materials are much smaller and lighter, they interact better in the environment and may be a solution for the problem of iron nutrition in saline and lime soils. Iron Nano-oxide is smaller than the common iron oxides and forms more complexes and makes the Fe more available to plants (Mazaherinia *et al.,* 2010). Ladan Moghadam *et al.* (2012) tested the effect of iron nanofertilizer on spinach and reported that application of 4 kg/ha iron nanofertilizer increased leaf weight by 58% and leaf area index by 47% compared with the control. Delgado and Sanchez-Raya (2007) reported that application of Fe fertilizer in sunflower resulted in the reduction of adverse effects of stress and enhancement of NPK absorption and consequently plant growth and yield. Balali and Malakouti (2002) found that application of iron fertilizer increased protein and Fe concentration in grains and straw of wheat and increased grain yield by 20%. The positive effect of spraying basil plants with iron nanofertilizer was also observed in the experiments of Peyvandi *et al.* (2011) who reported that Fe nanoparticles increased root length, stem length, chlorophyll content and shoot dry weight compared with the common iron fertilizers. Amuamuha et al. (2012) also studied the effect of different concentrations of iron nanoparticles (1, 2 and 3 g/l) on marigold in three growth stages of stem elongation, flowering and after harvest. They reported that the highest flower yield and essential oil percentage were achieved when 1 g/l iron nanoparticles was applied at stem elongation stage.

Regarding the effects and benefits of iron nanoparticles on plants growth and yield, and the lack of information on this subject, this experiment was conducted to evaluate the effect of iron Nano-oxides on growth, yield and protein content of wheat.

MATERIALS AND METHODS

This experiment was conducted in 2014 at the Research Field of Islamic Azad University, Shahr-e-Qods Branch, Iran (27° 38' N, 40° 21' E). The area has an average annual precipitation of 215 mm and average annual daily temperature of 31°C. The soil at the test site was loamy sand (28.6% sand, 25.2% silt and 46.2% clay) with the pH of 7.7 and EC of 3.4 mhos/cm.

A factorial experiment was conducted in the form of a randomized complete block design with four replications and two treatments:

Time of spraying in two levels:

$\mathbf{T_1}$: spraying on May 23, 2014

$\mathbf{T_2}$: spraying on June 6, 2014

Iron nanoparticles concentration in five levels:

$\mathbf{D_1}$: control (0%)

$\mathbf{D_2}$: 0.01%

$\mathbf{D_3}$: 0.02%

$\mathbf{D_4}$: 0.03%

$\mathbf{D_5}$: 0.04%

The field was prepared by a moldboard plow; then, 5 t/ha chicken manure, 150 kg/ha triple-superphosphate, 50 kg/ha urea and 50 kg/ha potassium sulphate were added to soil. At the end, a disk was used for final preparation. Plots size was 6 × 8 m with 0.5 m gap between the planting rows. Wheat seeds (Triticum aestivum L. cv. Pishtaz) were planted manually on November 24, 2013, at the density of 500 seeds/m^2. The field was irrigated regularly during the growth season and weeds were also controlled manually and chemically. Iron Nano-oxide solution was sprayed to plants using a back-pack sprayer.

The measured traits included: spike weight, 1000 grain weight, biologic yield, grain yield and grain protein content. For measuring 1000 grain weight, the weight of 1000 grain was measured at the moisture of 14%. Grains were randomly selected from each plot and were weighted with an accurate digital scale. Protein content was obtained by Kjeldahl method. To measure biologic yield and grain yield, the harvest was conducted on June 25, 2014. The middle rows were harvested from each plot and were dried in open air and weighted. Then, grains were separated from the straw and the grain yield was calculated.

Statistical analysis was conducted by SAS software. Means were compared according to the Duncan's multiple range test at P≤0.05.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) showed that spraying time significantly affected spike weight, biologic yield and protein content at P≤0.01 and 1000 grain weight and grain yield at P?0.05. Fe concentration had also a significant effect on spike weight, 1000 grain weight, grain yield and protein content at P≤0.01 and biologic yield at P?0.05. However, the interaction of spraying time × spraying concentration had no significant effect on any of the measured traits.

Mean comparison of two spraying times (Table 2) indicated that the highest values of spike weight (614.88 g), 1000 grain weight (36.10 g), biologic yield (8830 kg/ha), grain yield (3639.5 kg/ha) and protein content (16.01%) were achieved in the first spraying time and the lowest values were achieved in the second spraying time. The lowest spike weight was 591.83 g, 1000 grain weight was 34.64 g, biologic yield was 84.50 kg/ha, grain yield was 3444.5 kg/ha and protein content was 15.25%.

Table 1: Analysis of variance of the effect of treatments on the measured traits.

SOV	df	Mean Squares (MS)				
		Spike weight	1000 grain weight	Biologic yield	Grain yield	Protein content
Block	3	ns	*	ns	**	ns
Spraying time (A)	1	**	*	**	*	**
Fe concentration (B)	4	**	**	*	**	**
A × B	4	ns	ns	ns	ns	ns
Error	49	627.05	3.297	151277.77	65038.14	0.137
CV (%)	-	4.15	5.13	4.50	7.20	2.37

ns, nonsignificant; *, significant at P≤0.05; **, significant at P≤0.01.

Table 2: The effect of spraying time on the measured traits.

Times	Spike weight (g)	1000 grain weight (g)	Biologic yield (kg/ha)	Grain yield (kg/ha)	Protein content (%)
May 23, 2014	614.88a	36.10a	8830.0a	3639.50a	16.01a
June 6, 2014	591.83b	34.64b	8450.0b	3444.50b	15.25b

Means in a column followed by the same letter are not significantly different at P≤0.05.

Table 3: The effect of iron Nano-oxide concentration on the measured traits.

Concentrations (%)	Spike weight (g)	1000 grain weight (g)	Biologic yield (kg/ha)	Grain yield (kg/ha)	Protein content (%)
0	536.33c	32.82d	8320.0bc	3316.5c	13.77c
0.01	561.33c	34.12dc	8520.0ab	3421.5bc	15.51b
0.02	604.21b	35.46bc	8620.0ab	3506.5abc	15.86b
0.03	647.96a	36.49ab	8845.0a	3689.0ab	16.59a
0.04	666.96a	37.96a	8895.0a	3776.5a	16.44a

Means in a column followed by the same letter are not significantly different at P≤0.05.

Mean comparison of iron nanoparticles concentrations (Table 3) showed that spike weight was the highest in 0.04% concentration (666.96 g) and the lowest in the control (536.33 g). The highest value of 1000 grain weight was related to 0.04% concentration (37.96 g) and the lowest value was related to the control (32.82 g). Results showed that both biologic yield and grain yield were the highest in 0.04% concentration (8895.0 and 3776.5 kg/ha) and the lowest in the control (8320.0 and 3316.5 kg/ha). Moreover, the highest protein content was also related to 0.04% concentration (16.44%) and the lowest protein content was related to the control (13.77%).

Results indicated the significant effect of iron spraying on all measured traits. Iron is the most important rare elements which is required for plants and animals. It is a key element in cell metabolism and it is involved in photosynthesis, respiration, enzymes activity, etc. Iron is essential for plants growth and under Fe deficiency conditions, chlorophyll production disturbs and plants show interveinal chlorosis, which appears first in younger tissues because iron is not easily translocated inside plant body. Under more sever Fe deficiency conditions, the symptoms of chlorosis are observed in the tissue around the veins and the entire leaf may look pale yellow or white. Iron deficiency is more common in high pH and calcareous soils (Fernandez and Ebert, 2005; Rashno *et al.*, 2013; Wiedenhoeft, 2006). Although Fe is commonly found in earth's crust; however, it is not easily available to plants because of low solubility. So, spraying Fe compounds to plant leaves may be a good solution for the problem. Foliar application of Fe is an environmentally friendly alternative to the common methods of Fe applications to soil (Rodriguez-Lucena *et al.*, 2010).

Foliar application of Fe may increase the efficiency of Fe use by the plants. Subrahmanyam *et al.* (1992) compared the effect of Fe application to soil and on plant leaves in order to cure the symptoms of Fe deficiency in Japanese mint. They observed that oil yield of the plant was equal in foliar application of 30 kg/ha Fe-EDTA and soil application of 140 kg/ha Fe-EDTA. In their experiment, Fe applications increased the concentration and the total uptake of Fe by the crop. Moreover, Fe-EDTA foliar application in two weeks interval alleviated the symptoms of Fe chlorosis in Japanese mint.

Yuan *et al.* (2012) tested the effect of Fe foliar application on rice plants and found that Fe concentration in plants was improved by 14.5%. They also found an improvement in grain yield, protein content and total amino acid content as the result of Fe foliar application. Pareek and Poonia (2011) observed that Fe foliar application increased pod and haulm yield of groundnut by 14.8% and 11.2%, respectively. Movahhedy-Dehnavy *et al.*, (2009) also observed that yield and quality of safflower was improved as the result of Fe foliar application. In another experiment, enhancement of root yield and quality of ginseng (Panax ginseng C.A. Mey) was observed when high concentration of Fe was applied to the plant leaves (Zhang *et al.*, 2013).

Keikha *et al.* (2005) studied the effect of Fe foliar application at the beginning of flowering stage on canola and observed that the treatment increased grain yield from 4136 kg/ha in the control to 4557 kg/ha. Amiry Hosinkhani et al. (2013) also conducted experiments to evaluate the effect of Fe foliar application at stem elongation and 50% flowering stage of wheat and reported that the biologic yield was the highest when the foliar application was conducted at the stem elongation stage.

In some cases, Fe application may not have effect on plants yield; however, it improves the quality of the products. Zhang *et al.* (2010) reported that foliar application of Fe had no effect on grain yield and the biomass production of wheat; however, it increased grain Fe concentration by 7-36%. Fang et al. (2008) also reported that Fe foliar application significantly affected rice protein, ash and Fe contents; however, it had no significant effect on plant yield. Results of our experiment also proved that Fe foliar application increased protein content of wheat grain.

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