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# Effect of time and concentration of nano-Fe foliar application on yield and yield components of wheat

**Mohammad Armin[1*], Sadegh Akbari[2], Saaeid Mashhadi**

*Department of Agronomy and Plant Breeding, Sabzevar Branch, Islamic Azad University, Sabzevar, Iran*

**Key words:** Foliar application, Nano-Fe, application time, Wheat.

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**Abstract**

Iron (Fe) is one of the essential elements for plant growth and plays an important role in the photosynthetic reactions. The purpose of this study was to evaluate the effects of different concentrations and different application times of Nano-Fe fertilizer on quantitative and qualitative aspects of wheat. A field experiment was carried out at the Research Center Research for Agriculture and Natural Resources of Sabzevar, northeastern Iran, during 2011-2012 to evaluate the effect of concentration and time of application of Nano-Fe on wheat (*Triticum aestivum*) yield and yield components with a factorial arrangement of treatments in a randomized complete block design with 3 replicates. Treatments consisted of 3 application times (tillering, stem elongation and tillering+stem elongation) and 4 Nano-Fe application rates (spraying with concentrations of 0, 2‰, 4‰ and 6 ‰ as corresponding with 0, 2, 4 and 6 kg Fe $ha^{-1}$ water-soluble Fe (Nano_Fe Chelates). Nano_Fe Chelates used in this study contained 9% Fe, 1% Zn and 1% Mn without ethylene compounds from Khazra Company. Results revealed that the time of application had a significant effect on tillers number, seeds per spike, grain yield, biological yield and thousand grains weight. Foliar application of Fe at tillering+stem elongation and at tillering had 9.17% and 5.19% more grain yield, respectively, compared to foliar application of Fe at stem elongation. Increasing Nano-Fe concentration, increased wheat yield and yield components. In this study, spraying with concentrations of 4‰ produced maximum grain yield, with no significant differences found between 4‰ and 6‰ concentrations.. Foliar application of Fe at 2‰, 4‰ and 6‰ produced an increase of 12%, 22.09% and 19.07% grain yield, respectively, over the control.

* **Corresponding Author:** Mohammad Armin ✉ Armin@iaus.ac.ir

## Introduction

More than 3 million people worldwide suffer from zinc and iron deficiency (Cakmak, *et al.*, 2010). Intensive and multiple cropping, cultivation of crop varieties with heavy nutrient requirements, and the unbalanced use of chemical fertilizers, especially nitrogen and phosphorus fertilizers, have caused a reduction in yields with symptoms of micronutrient deficiencies in crops. While balanced fertilization and micronutrient applications will increase yield and crop quality, it will also insure better peoples' health (Seilsepour, 2005). Iron is an essential nutrient for plants as it is required in many functions including chlorophyll biosynthesis, respiration, and photosynthesis. Fe deficiency is the most common micronutrient deficiency in human populations affecting the health of people worldwide (Cakmak, *et al.,* 2010). According to a report published by the World Health Organization, deficiencies of Fe rank fifth and sixth, in terms of the leading causes of disease, in developing countries. Fe is also utilized in many enzymatic systems like chlorophyll synthesis. Calcareous soils, high soil and water pH, high concentration of HCO3 (Bicarbonates), instability and misapplications of different fertilizers are the main reasons for Fe deficiency in soils and plants. Quantitative and qualitative yield of crops can be affected by the utilization of micronutrient fertilizer (Abadía *et al.,* 2011).

The amount and type of Fe application has affected yield and yield components in crops. For example, in a study in Iran, Haghyghatneya and Rajai (2005) reported that the foliar application of Fe had more of an effect on economic and biologic yields than any other application method. Balalei *et al.,* (2009) showed that using of 10 kg. $ha^{-1}$ as Sequestrine increased wheat yield by 20%. Seilsepour (2005) during his investigation of Fe application in Iran, indicated that foliar application of Fe and Zn increased seed yield, protein content, and Zn concentration in wheat. Increase of grain yield, grain weight, grains per spike, spike length due to Fe fertilization were reported by Hemantaranjan and Garg (1988). The reports showed that Iron+Zinc (applied to the soil as ferrous sulphate and zinc sulphate) significantly increased number of spikes per plant, spike's length, number of grains per spike, grain yield per wheat plant and per unit area proportional to the Fe concentration used both in pot and field experiments. This was coupled with the increase in total carbohydrate, starch, and crude protein contents of wheat grains (Hemantaranjan and Garg,1988).

Presently, Fe Chelate Nano fertilizer can be considered a rich and reliable source of bivalent iron for plants because of its high stability and gradual release of Fe in a wide pH range (3 to 11). One advantage of this Nano fertilizer is that no ethylene compound is used in its structure. Ethylene enhances the growth process and prevents appearance of chlorosis on leaves. The purpose of this study was to evaluate the effects of different concentrations and application at different growth stages of Nano-Fe fertilizer on wheat production (quantity and quality).

## Materials and methods

The experiment was conducted in 2011 in Razavi Khorasan Province, Iran (latitude of 36 °13', longitude 57 °39 'and altitude of 980 m above sea level). This region is semi-arid and the soil is clay-loam (with pH= 7.8, EC= 1.45 ds/m and organic matter 0.78% (Tables 1, 2).

### *Experimental design*

The experimental design was a factorial arrangement in a Randomized Completely Block Design with three replications. Factors were three times of application (tillering, stem elongation and tillering +stem elongation) and four Nano-Fe concentration (0, 2, 4 and 6 grams per liter). The soil was under sunflower cultivation in the previous year and plowed before wheat cultivation. Wheat (Ghods cultivar) was planted in plot sizes of 1m x 4m. Each plot consisted of 5 planting rows with 4m length and 0.2 m row spacing. Wheat was hand seeded on October 2, 2011. Before planting, P and K fertilizers were incorporated with soil at 100 kg $ha^{-1}$. Nitrogen fertilizer (150 kg $ha^{-1}$) was applied at two stages (early after planting and during stem elongation).

*Measurement*

At physiological maturity the area of 1 m² of each plot was harvested and grain yield, biological yield, number of seed per ear (by counting 30 randomly selected ears in each plot), thousand grain yield (by counting 1000 randomly selected grain) and plant height (in 30 randomly selected plants) were measured.

*Statistical analysis*

Data was subjected to analysis of variance using SAS software and means were compared using Duncan multiple range test at P=0.05.

## Result and discussion

*Tiller number*

The analysis of variance showed that spraying time had a significant effect on tillers number, but the Fe concentration had no significant effect on tillers number (Table 3).

**Table 1.** Physico-chemical properties of soil.

| Organic matter | Mg | Ca | Na | B | K | Available P | Total N | EC | pH | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (%) | | | | mg kg$^{-1}$ | | | | ds.m$^{-1}$ | | (%) | | |
| 1.12 | 5.09 | 8.27 | 35 | 0.34 | 175 | 3.35 | 0.014 | 1.5 | 7.8 | 70 | 10 | 20 |

**Table 2.** Chemical properties of irrigation water.

| Boron | Magnesium | Calcium | Sodium | Bicarbonate | Chloride | Sulfate | EC | pH |
|---|---|---|---|---|---|---|---|---|
| | | | mg L$^{-1}$ | | | | ds.m$^{-1}$ | |
| 0.12 | 6.0 | 9.2 | 2.2 | 13.4 | 3.3 | 0 | 1.2 | 6.5 |

Foliar application of Nano-Fe at tillering+stem elongation and stem elongation had the highest and the lowest tillers number in wheat, respectively. There was no significant difference between foliar applications of Nano-Fe at tillering+stem elongation and at tillering (Table 4). Boorboori and Tehrani (2011) showed that an increase in the amount of micronutrients, whether in form of soil fertilizer or solution spray, somehow increased the number of tillers and had little positive effect. With soil applications of Fe, the maximum number of fertile tillers was obtained in treatment with 10 mg/kg as soil fertilizer which showed a 4.82% increase compared to the control. In contrast, Tandon (1999) believed that genetic factors determined the tiller number in crops, especially in wheat, and nutrition had less or a negligible role in this matter.

**Table 3.** Analysis of variance table for the on Tiller number, Seeds per spike, Grain yield, Biological yield and 1000-seed weight.

| SOV | df | Tiller number | Seeds per spike | Grain yield | Biological yield | 1000-seed weight |
|---|---|---|---|---|---|---|
| Replication | 2 | 3.88 ** | 16.46 ns | 1851.07 ** | 2268.7 ns | 0.06 ns |
| Application time | 2 | 0.699 * | 593.83 ** | 2264.37 ** | 568825 ** | 60.77 * |
| Concentration | 3 | 0.276 ns | 399.83** | 5.38** | 198966** | 54.65* |
| Interaction | 6 | 0.025 ns | 43.47 ns | 8803.81 ** | 32691.6 ** | 16.10 ns |
| Error | 22 | 0.15 | 34.45 | 3794.68** | 4968.75 | 11.33 |
| CV | | 10.8 | 18.32 | 5.66 | 11.98 | 9.38 |

ns: not significant; (*) and (**) represent significant difference over control at P < 0.05 and P < 0.01, respectively.

*Seeds per spike*

Nano-Fe fertilizer application at tillering + stem elongation did increase the number of seeds per spike, whereas early application of Fe fertilizer decreased the number of seeds per spike (Table 4). Nadim *et al.*, (2012), however, showed that micronutrient application methods had no significant effect on number of grains spike$^{-1}$. Among trace elements, the use of B produced the highest number of grains/spike followed by Fe application . In this study, the foliar application of Fe was more suitable than seed dressing or soil application.

**Table 4.** Effect of Nano-Fe Application time on Tiller number, Seeds per spike, Grain yield, Biological yield and 1000-seed weight**.**

| Application time | Tiller number | Seeds per spike | Grain yield ($g.m^{-2}$) | Biological yield ($g.m^{-2}$) | 1000-seed weight (g) |
|---|---|---|---|---|---|
| Tillering | 3.68 a | 24.68 c | 291.85 a | 357.50 c | 33.58 b |
| Stem elongation | 3.32 b | 32.72 b | 276.72 b | 617.50 b | 35.91 ab |
| Tillering+stem elongation | 3.78 a | 38.70 a | 304.15 a | 790 a | 38.08 a |

* Values followed by the same letter within the same columns do not differ significantly at *p* = 5% based on DMRT.

The concentration of Nano-Fe had a significant effect on number of seeds per spike (P≤0.01, Table 3). A significant increase in number of seeds per spike was observed when the level of Nano-Fe was increased from 0 to 6‰. At the same time, differences between spraying with concentration of 4‰ and 2 ‰ were not significant. The application result of 6‰ was an increase of 41.08% seed per spike compared to the control (Table 5). Similarly, Monjezi *et al.*, (2013) reported that under drought stress at the flowering stage in wheat, Fe spray increased the number of spikelet per surface area (13.7%), number of seeds per spikelet (13.5%) and number of spikelet per spike(10.4%), compared with the control.

**Table 5.** Effect of Nano-Fe concentration on Tiller number, Seeds per spike, Grain yield, Biological yield and 1000-seed weight.

| Nano-Fe concentration ‰ | Tiller number | Seeds per spike | Grain yield ($g.m^{-2}$) | Biological yield ($g.m^{-2}$) | 1000-seed weight (g) |
|---|---|---|---|---|---|
| 0 | 3.42 a | 22.72 b | 249.98 c | 433.33 c | 33.48 c |
| 2 | 3.51 a | 33.49 a | 284.12 b | 496.67 b | 34.15 bc |
| 4 | 3.82 a | 33.37 a | 320.89 a | 670 a | 37.11 ab |
| 6 | 3.63 a | 38.55 a | 308.65 a | 753.33 a | 38.70 a |

*Values followed by the same letter within the same columns do not differ significantly at *p* = 5% based on DMRT.

*Grain yield*

Wheat grain yield was significantly affected by Nano-Fe concentration, time of spraying, and the interaction between time and concentration (Table 3). Foliar application of Nano-Fe at tillering+stem elongation and tillering had 9.17% and 5.19% more grain yield compared with foliar application of Nano-Fe at stem elongation (Table 4). Yield increase due to foliar applications at tillering + stem elongation may be due to the large amount of Nano-Fe applied ( spraying twice), in addition to being a suitable time for seed formation. Moreover, Fe availability can increase the leaf area index, leaf area duration, and decreased leaves senescence that can increase economic yield. Monjezi *et al.,* (2013) suggested that the increase in seed yield was due to the presence of Fe which enhanced photosynthesis, and consequently, increased yield. The present results are further supported by Jaberzadeh *et al.,* (2013) who obtained a 23.3% increase in grain yield with a foliar application of 2‰ Nano-Fe compared to the control. Nano-Fe concentrations significantly (*P=0.05*).

affected economic yield (Table 3), with maximum grain yield obtained by spraying the 4‰ concentration. A 2‰ , 4‰ and 6‰ foliar application of Nano-Fe resulted in an increase of 12%, 22.09% and 19.07% of grain yield over the control. No significant difference was found between 4‰ and 6‰ foliar application (Table 5). It was reported earlier that in plants with Fe deficiency, decreased photosynthesis led to decreased grain yield (Boorboori and Tehrani, 2011).

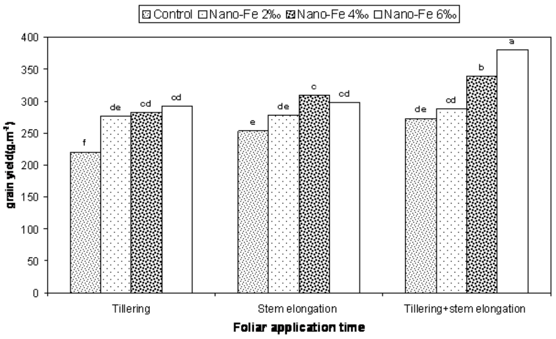


**Fig. 1.** Interaction of Nano-Fe concentration and the time of spraying on grain yield. Means sharing similar letter(s) in a column do not differ significantly at p=0.05.

Interaction effects of Nano-Fe concentration and the time of the spraying showed that an application of Nano-Fe 6‰ increased grain yield when applied at both tillering + stem elongation or at tillering, but foliar applications with 4‰ concentration at stem elongation had the maximum grain yield. At this stage, the increase of Fe concentration to 6‰ resulted in decreased grain yields (Figure 1). Grain yield was less responsive to Nano-Fe concentration when foliar spray was applied at tillering. Foliar application of Nano-Fe 6‰ increased grain yield by 32.36, 17.80 and 39.34% compared with the control at tillering, stem elongation and tillering+stem elongation, respectively.

*Biological yield*

Biological yield was affected by the timing of foliar application of the Nano-Fe (p≤0.01, Table 3). The greatest biological yield was observed with a foliar application of Fe at tillering+stem elongation with significant difference compared with other treatments. Foliar application at tillering had the least biological yield (Table 4). This finding was supported by Monjezi *et al.,* (2013) who reported that foliar applications of Fe resulted in increased biological yield by 13% and proved more significant than the increasing of biological yield due to Zinc applications (12.6%). During this study, simultaneous applications of Fe and Zinc resulted in an increased biological yield of 13%. Ziaeian and Malakoti (2001) compared the effect of Fe and manganese application in soil with foliar application, and the combination of both, increased grain yield, biological yield, and protein content.

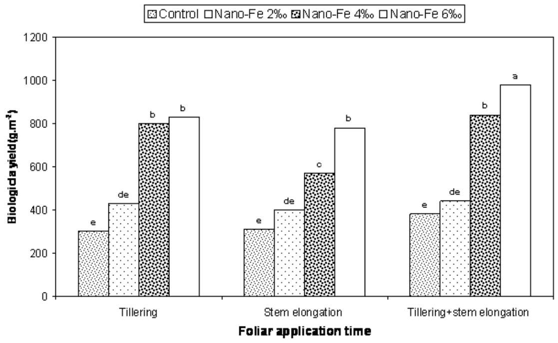


**Fig. 2.** Interaction of Nano-Fe concentration and the time of spraying on biological yield. Means sharing similar letter(s) do not differ significantly at p=0.05.

The results of the analysis of variance showed that Nano-Fe concentration had significant effect on biological yield (Table 3). As shown in Table 5, there was a positive relation between biological yield and Nano-Fe concentration, and increasing Nano-Fe concentration increased biological yield by 8.39%. The foliar application of Nano-Fe at 2‰ , 4‰ and 6‰ concentration increased biological yield by 12.75%, 35.32% and 42.477% over the control (Table 5). In experiments conducted earlier, biological yield loss due to Fe deficiency has been reported (Mahmoudi *et al.*, 2005). Biological yield was affected by the interaction of Nano-Fe concentration and the time of spraying. As shown in figure 2, the results of an increase in Nano-Fe concentration increased biological yield regardless of the time of foliar application.

*1000-seed weight*

Thousand grain weights were affected by the time of foliar application of Nano-Fe (Table 3). The application of Nano-Fe at tillering+stem elongation increased the grain weight of wheat and was followed by an application at stem elongation. Foliar application at tillering had an 18% less thousand grain weight than application at tillering+stem elongation (Table 4). Conditions after anthesis determined thousand grain weights. Some unfavorable conditions such as high temperature and biotic and non-biotic stress, that decrease photosynthesis, could also have affected thousand grain weights. Some researchers have shown earlier that grain weight is not affected by different fertilizers application methods. Arif *et al.*, (2006) reported that three sprays of micronutrients in wheat increased 1000 grains weight (26.8 g), followed by two sprays (25.7 g).

**Conclusion**

Our experiment results suggest that yield and yield components in wheat plants are mostly affected by foliar applications of Nano-Fe at tillering + stem elongation, rather than other spraying times. Maximum yield was obtained in the highest level of Fe treatments (6‰ Nano-Fe concentration). There was no statistical difference between 4‰ and 6‰ Nano-Fe concentration for most traits. Overall, the application of Nano-Fe concentration with 4‰ dose at tillering + stem elongation was the best treatment for obtaining the maximum economic yield in wheat.

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