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Comparison of Effectiveness of Some Domestic and Foreign Iron Chelate Fertilizers on Plant Growth and Their Stability in Soils

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Abstract: Six iron chelate fertilizers (four domestic brands denoted as F2, F3, F4, F5 and two well known foreign brands F1 and F6) used commonly by Iranian farmers in the country were compared for agronomic effectiveness. The work was conducted in three stages (one incubation test and two green house experiments) comparing their stability in soil and relative effectiveness on plant growth. In the incubation experiment equal amounts (8 kg Fe ha^{-1}) of the fertilizers were added to 500 g soil samples and kept under controlled optimum conditions for 56 days during which sub samples at 7, 21, 35 and 56 days were collected for analysis. In the greenhouse experiments, pots filled with 4700 g of soil-sand mixtures were used to compare the relative effectiveness of fertilizers on plant growth and iron content after foliar spraying and soil applications. In both experiments sorghum was used as a test crop within a 9 weeks growth period. Seven treatments in three replications of each were used in a completely randomized design arrangement. Factors of fresh and dry yield, average plant height and dry matter's Fe content was measured and compared. The results showed that all tested fertilizers had a positive effect on changing plant available iron in soil. There was a similar trend in fertilizer response in soil which indicates relatively similar behavior with respect to chemical and biological changes affecting iron availability. One important factor controlling the fertilizer responses in this research was the differences in fertilizer solution pH value. Two foreign fertilizers had a better performance as indicated with the measured factors, with plant iron content significant at $P<0.01$ level. Among the domestic products, the F2 fertilizer showed a better performance compared to others when applied into soil and was comparable with the two foreign fertilizers. Given the relatively similar results in the three stages of evaluation in this research, it is suggested that this type of fertilizer tests be considered as a practical and reliable method of fertilizer performance evaluation. Further work is required to validate the method and increase its reliability.

Key word: DTPA-extractable Fe · fertilizer evaluation · iron chelate · iron deficiency

INTRODUCTION

Among the so called micronutrients, iron has a special rule in plant nutrition. It is not a structural element in chlorophyll, but it is required for synthesis and production of chlorophyll molecules. Under iron deficiency conditions, the structure of some proteins which are necessary for chlorophyll synthesis is damaged. Iron also acts as an enzyme activator in some physiological process within the plant [1,2]. Iron deficiency in general causes the reduction in chlorophyll and in turn reduction in yield and quality of the plants.

Iron chlorosis in plants is an old problem occurring in areas of calcareous and/or alkaline soils [2,3]. Diagnosis and correction of iron chlorosis are still being studied as well as many physiological and biochemical aspects of this nutritional disorder [4,5]. Iron exists in soils as hematite, geotite, pyrite and olivine and in the structure of aluminosilicate minerals and also in organic matter complexes.

Average content of most soils is between 1000 to 10000 ppm [3]. At the same time due to low solubility of iron compounds such as oxides and hydroxides in usual pH range of most agricultural soils, iron deficiency is observed for most crops especially under low moisture, high soil pH, low organic matter, presence of high HCO_3^- ions and high phosphate concentrations. An imbalance in plant nutrient concentrations in soil due to improper use of fertilizers can also cause micronutrient deficiency problems especially in the case of iron [6-8]. Chlorosis due

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to iron deficiency has been related to an imbalance between Fe and other nutrients such as Cu and Mn orexcess P in soil by some researchers. In Iran due to presence of alkaline and calcareous soils iron deficiency has been reported for most agronomic and horticultural crops [9].

Plant available iron content of alkaline and calcareous soils is measured by DTPA extraction method [10] and the critical concentration range of 2.5 to 4.5 ppm have been suggested in this method [10,11]. Iron is absorbed by plants in the forms of Fe^{2+} and Fe^{3+}. Iron which is absorbed by roots as Fe^{3+} will reduce to Fe^{2+} form inside the roots.

Iron absorption is an active process and requires use of energy. It is also absorbed in the form of natural and synthetic chelates by plants. Iron concentrations in plant dry matter ranges between 50 to 250 $\mu g\ g^{-1}$ under normal conditions and deficiency symptoms appear under lower concentrations [8,12]. Iron's translocation inside the plant tissue is limited and its deficiency, which appears first in the younger plant parts, may not be recovered through older tissues. Inter venial chlorosis in younger leaves is a characteristic deficiency symptom which can increase to more intense conditions and eventually to necrosis at leaf margins [12,4].

In general, interactions within the root zone which results to release of hydrogen ions and organic acids or natural organic chelates, can prevent iron deficiency even in calcareous soils. However in most cases increase in CO_3 in soil and HCO_3 in soil solution at the presence of $CaCO_3$ results in higher pH and decrease in availability of iron. Soil compaction, improper irrigation and any other factor limiting soil aeration can intensify iron deficiency [13,6].

Treatment of iron deficiency in soils is difficult especially under high pH and calcareous soils, as iron compounds can precipitate fast and make the element unavailable for plant uptake. Under such conditions, soil acidification is the first step which may be done by sulfur or gypsum applications. Each unit change in pH can cause an increase of up to 1000 fold in iron solubility which may not be achieved or practical in many soils with high pH [6,1]. Therefore use of fertilizers for iron deficiency treatment is a common practice for agricultural and horticultural crops.

The history of iron's mineral fertilizer use is relatively long and includes various products such as $FeSO_4$, $Fe_2(SO_4)_3$, FeO, Fe_2O_3, $FeNH_4PO_4$ and some other iron compounds. Inserting nails in the tree trunk or injection of iron salts into the plants were also common practices to cure iron deficiency. Adding the specific compounds to soil and direct application as foliar sprays over the leaves is among the most common methods for use of iron fertilizers. For most agricultural systems soil application of iron compounds is the dominant practice to supply plant requirements and correct iron deficiency [14,5]. Among all soil-applied iron fertilizers, synthetic chelates are the most effective and commonly used. Chelate is a complex of an organic compound and a metal ion. The organic base has a number of covalence bonds and holds the metal cation inside resulting in a strong ring structure. Chelates used for calcareous and alkaline soils are less affected by unfavorable conditions such as high HCO_3, high pH and microbial hydrolysis [15,2]. Metal chelates are soluble in water and those commonly used in agriculture have low dissociation. Therefore, although they reduce the activity of metal ions in solution, the solubility of these ions in reaction with the chelating agent will increase substantially. There are many chelating agents among which some are very important in agriculture.

The mechanisms involved in uptake of chelated ions by plants are not very clear and requires more research. However it is understood that the chelating agent and the metal cation are not absorbed at the same rate by plant roots. Under low pH conditions some of the chelating agent remains in the root zone solution, while the metal is absorbed. Chelates can separate the non-soluble forms of heavy metals in the soil from the more soluble forms. Chelates of iron, manganese, zinc and copper exist in the form of sodium salts.

Consumption of chelates to prevent or correct iron deficiency has been practiced since 1950‘s and has increased through the introduction of various products. Various organic compounds have been used for the production of iron chelates depending on the soil type and the conditions of use. The performances of these chelates have been tested under different chemical conditions and crops using different methods [11,16,17].

Synthetic metal chelates are quiet effective in producing iron uptake response in the plants and can be characterized according to their stability in soil, solubility in water, absorption potential to the plant roots and their suitability for foliar or soil applications. They are suggested based on soil conditions and properties for various crops [3,12,18].

Applications of iron as Fe-EDDHA in calcareous soils according to most reports have resulted in increase in Fe concentration of plant. Solubility of iron is dependent on soil pH and in the range of pH 7.4-8.5 is the least. Therefore, In calcareous soils of Iran, iron chelates with higher stability constants are required to supply the iron requirement of plants. Research results from incubation experiments with iron chelates have shown that these organic substances can go under constant changes and their efficiency is related to interactions with soil particles or release of the metal from the chelating agent or both factors [2].

Some contradictory results could be explained by lack of agreement between the declared and the actual chelated iron content of commercial products (reported by Hernández-Apaolaza *et al.* [19] and Álvarez-Fernández *et al.* [20], since this fact implies that in the experiments published until now, the doses of active component applied were probably different to the actual ones. On the other hand, a proper evaluation of the efficacy of the iron treatments to correct iron chlorosis requires the assessment of the iron nutrition status of the plants during the treatment period. The most straight forward approach to detect nutrient deficiencies in plants is to analyze the mineral content of the leaves.

Physical and chemical properties of fertilizers especially synthetic iron chelates are determined through standard tests and usually presented with the product in the form of information brochures. These information, although useful in the selection and use of fertilizer, but are not enough for qualitative and agronomic comparison of various fertilizers under natural conditions. In this regard, conducting quality control and agronomic experiments in soil with the presence of plants under controlled conditions can provide more accurate and reliable information to be used by producers and consumers of fertilizers. In this research, agronomic evaluation of a number of iron chelate fertilizers was preformed through incubation and greenhouse experiments at three stages including;

- Incubation experiment (soil and fertilizer) to test the stability of the element in the available form.
- Greenhouse experiment (soil and plant) to evaluate uptake of the iron from soil fertilizer application.
- Greenhouse experiment (soil and plant) to evaluate foliar absorption of the fertilizer element.

MATERIALS AND METHODS

Six iron chelate fertilizers (four domestic brands denoted as F2, F3, F4, F5 and two well known foreign brands F1 and F6) were used based on their market availability and use by Iranian farmers, descriptions of which are presented in Table 1. Notation was used to avoid direct commercial use of the results for the domestic products and will be used throughout this paper.

Incubation experiment: This experiment was designed to evaluate the fertilizers for continuity of providing available Fe in the soil over a period of time. The basic assumption was that although all the fertilizers were similar in the form of nutrient element to some extent but they would behave differently in the soil according to their properties and the possible reactions in the soil under controlled conditions of temperature and moisture. This difference will be reflected in the amount of DTPA extractable [10] iron during the incubation period.

For this experiment, two soil samples from Kordan and Palang Abad regions (both in the suburbs of Karaj – Iran) were selected based on the required properties and iron content. Soil samples were air dried and passed through 2 mm sieve after which chemical and physical properties of the soils were determined using standard methods [21], (Table 2).

Soil samples (500 g) were mixed with the fertilizers in plastic pots and incubated under optimum conditions for 8 weeks. The experimental units (pots) were marked based on the 7 treatments (F0, F1 ….and F6) in three replicates (T1, T2 and T3) for both Kordan (K) and Palang Abad (P) soils. After calculating the field capacity (FC) and soil moisture content, the fertilizers were added to the soil (at a rate of 8 kg Fe ha^{-1}) in the form of solutions containing 200 mg L^{-1} Fe by a burette until obtaining the optimum moisture (80% field capacity).Each pot was covered by a thin nylon (having a hole for aeration) layer and incubated at 27°C. In order

Table 1: Description and some properties of the fertilizer materials used

Percent and form of iron in samples**	Fertilizer solution pH	Water soluble Fe* (%)	Description	Fertilizer notation	Fertilizer name
6% as Fe-EDDHA	7.0	5.74	Foreign- dark brown powder	F1	Feriline
7% as chelated Fe	6.8	7	Domestic- dark brown powder	F2	Y-1 dom.
7.6% as Fe-EDDHA	7.5	6.9	Domestic- dark red slurry liquid	F3	F-Fe dom
5.5% as Fe-EDDHA + 3.5% Mn	5.8	5.45	Domestic- red color fine granules	F4	F- fe2 dom
6% as chelated Fe	8.3	6	Domestic- red color fine granules	F5	Sh- dom
6% as Fe-EDDHA-Na	7.2	6	Foreign- dark brown powder	F6	Sequestrine

* Iron content of the fertilizer samples used in this experiment determined in the laboratory.

** Iron content and form in the fertilizer material as claimed by the manufacturer.

Table 2: Some soil properties of Kordan and Palang Abad samples

DTPA Fe ppm	$CaCO_3$ %	EC* dS/m	pH*	Texture	Soil Series Name
2.25	17.0	0.59	8.00	Silt clay loam	Kordan
2.65	9.9	3.00	8.10	Silt clay loam	Palang Abad

*measured in the saturation extract.

Table 3: Some physicochemical characteristics of soil samples for greenhouse experiments

DTPA-Fe ppm	$CaCO_3$ %	EC* ds/m	pH*	Texture	Soil location
3.6	4.4	0.217	7.7	Loam	Billaghan
2.8	8.3	0.189	7.85	Sandy loam	Azimieh
2.4	14.4	0.357	7.95	Clay loam	Apple Garden (Karaj)

* in 1:1 soil:water extraction.

to maintain the moisture in optimum level, sufficient amount of water (based of the weight loss) was added to the pots every 2 or 3 days.

A 50 g sub sample was taken from each pot in the intervals of 7, 21, 35 and 56 days and the available Fe content was measured for each sub sample. Also the Zn, Cu and Mn contents in the same extracts were measured [10].

Greenhouse experiments

Foliar application test: For greenhouse evaluation experiments, 3 soil samples were collected from; Billaghan, Azimieh and Apple Garden of Faculty of Agriculture (Karaj, Iran). The results of soil analysis are given in Table 3. The suitable soil was selected according to its texture and chemical characteristics from the Apple Garden of Faculty of Agriculture (South of Karaj, Iran) for both experiments. Evidence of iron deficiency was also observed in some of trees at the sampling area. The soil was mixed with acid washed sand (2.5% HCl) at a ratio of 1:4 to make the texture lighter.

Pot preparation: Experimental units (pots) for two tests (soil and foliar application) included 42 pots. Two holes (0.7 cm diameter) were made at the bottom of each pot and after placing a filter paper about 300 g coarse sand was placed at the bottom of each pot. The pots were filled with the mixture of soil and sand until the total weight of 4700g. For the foliar application test 21 pots were selected and marked (7 treatments of fertilizer type in three replications). For all pots nitrogen (in urea form 150 kg N ha^{-1}) were added (50 ml for each pot) according to the soil weight.

Then 100 ml distilled water was added to each pot. 24 hours after fertilizing 15 sorghum seeds were sowed in each pot. The soil moisture was adjusted to field capacity and humidity and temperature were controlled in optimum level. The irrigation was done based on weight loss of each pot every one or two days. During the growth period, the pots were rotated every 3 days. Other macro- and micronutrients fertilizers were added as Hogland solution (without Fe) at three different times (during 9 weeks) to each pot. After germination, the number of sorghum seeds was thinned to 4 plants in each pot.

Fertilizer application and harvest: For the foliar application test, the plants were grown for 46 days (45–60 cm height) and after observing some signs of Fe deficiency, three pots from each treatment were selected randomly and marked. Some spots showing the Fe chlorosis signs on the leaves were indicated and marked. For foliar application a 10 ppm Fe solution of each fertilizer was prepared and sprayed manually on the surface of leaves as evenly as possible. Two applications with a one week interval were conducted. Ten days after the second foliar application, the average height of plants were measured after which above ground plant parts were harvested separately as stem and leaves. The fresh weight of samples was measured and the plant materials were dried in an oven (at the 75°C) for 24 hours. The results of fresh and dry weight measurements are shown in Table 6.

Soil application test: In order to observe the fertilizer ability in supplying Fe from soil, this green house experiment was carried out simultaneously with the foliar application experiment. The pot preparation was exactly the same as it was mentioned before. In this experiment, after preparing the pots, the amounts of fertilizer needed for each treatment (based on 10 kg Fe ha^{-1} and considering Fe concentration measured for each fertilizer) were calculated and added to each pot in solution form.. The number of pots was 21 (7 fertilizer treatments with 3 replications). Macro and micro nutrients with calculated amounts for each pot were added before sowing (half of nitrogen 2 weeks after sowing). The control received all fertilizers except Fe. Five sorghum plants were sowed in each pot. The maintenance and irrigation condition were the same as spraying test. After 8 weeks of growth in greenhouse above ground plant was harvested in stem and leaf separately, fresh and dry matter weight, plant height and Fe content in dry matter of leaves were determined.

Leaf Fe-content: After drying the samples, the leaves were ground and 1 gram of each sample was put into the marked porsline crucibles. The plant samples were analyzed using dry ashing method in 450°C oven. The ashes were transferred quantitatively into a 100 ml beaker using 10 ml 2 M HCl and distilled water. The beakers were placed on sand bath and heated for 45 minutes at low temperature and below boiling point. Then the samples were filtered into 100 ml volumetric flasks and water was added to obtain 100 ml, these extracts were used to measure the amount of iron.

RESULTS AND DISCUSSION

Incubation test: The results of DTPA-Fe which was carried out 4 times during the incubation period were statistically analyzed in CRD format. As indicated in ANOVA table (Table 4) the main effects of fertilizer, soil and time were significant at (P<.01). Also the interaction effect of soil and fertilizer as well as time and soil were significant at (P<.01). Comparing the main effect of fertilizer type and using LSD=0.203 values, we can rank the 6 tested fertilizers according to their main effects for both soils in this order (Table 5):

$$F1 = F6 > F4 = F2 = F5 = F3$$

In which = sign indicates higher value but no significant difference compared to the LSD. This grouping indicates the significant difference between two kinds of foreign and domestic fertilizers. However, regarding to the Fe-content of control treatments (Blank), it can be concluded that all fertilizers have increased the amount of available Fe in the soil during the incubation period, but with no significant difference between the domestic fertilizers. Even though, the obtained mean for 4 domestic fertilizers were different with each other and fertilizers F_4 and F_3 had the highest and the lowest mean, respectively.

The comparison of the changes in the amount of DTPA-extractable Fe during the incubation period (Figure 1) also shows the similar behavior of the fertilizers, which can be interpreted that the fertilizer treatments have the same effect in terms of Fe interactions in the soil. According to this figure, the increase in DTPA–Fe was observed between a period of 20–40 days that could be considered as the best time to observe the effects of fertilizers in the amount of plant available Fe.

Furthermore, the significant difference (occurred in the first 20 days) between F1, F6 and also other tested fertilizers can prove the better and faster efficiency of foreign fertilizers. Lucena *et al.* [22] also reported a short response time for similar iron chelates in a calcareous soil.

Table 4: Statistical analysis of available Fe measurements in the incubation test

Source of variations	Degree of freedom	Sum of square	Means of square	Variance	Probability
Time	3	88.052	29.3508	712.58	< 0.01
Soil type	1	5.772	5.7720	140.13	< 0.01
Fertilizer Treatment	5	1.736	0.3473	8.43	< 0.01
Time * Soil	3	7.984	2.6615	64.62	< 0.01
Time * Fertilizer	15	0.713	0.0476	1.15	0.321
Soil * Fertilizer	5	0.721	0.1441	3.5	0.006
Time * Soil * Fertilizer	15	0.656	0.0437	1.06	0. 402
Repetition	2	0.021	0.0107	0.26	0. 772
Error	94	3.872	0.0412		
Total	143	109.528			

Table 5: The main effect of fertilizer treatments for both soils (LSD=0.203) mg kg^{-1}

F6	F5	F4	F3	F2	F1	Fertilizer type
3.284	3.035	3.139	2.961	3.079	3.295	DTPA-Fe mean

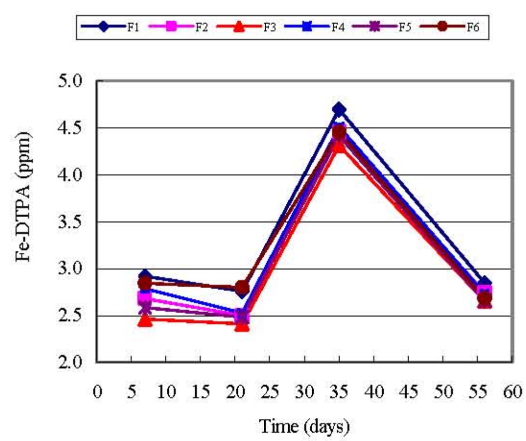

Fig. 1: Changes in the soil DTPA-Fe during incubation experiment

Foliar application test: The variables compared in this experiment included amounts of Fe and yield (fresh and dry matter) which were analyzed in CRD (complete randomized design) by Genstat soft ware. Part of the results is shown in the form of statistical summary (Table 6) and mean comparison of fertilizer effects by LSD method are indicated in Table (8). The effects of foliar application on dry matter and fresh weight was not significant and only in the case of available Fe in plant,

Table 6: Statistical summary of various parameters in the foliar application test

Parameter	Degree of freedom	Mean square	Variance	F- value
Dry weight	6	1.3444	1.71	0.202
Fresh weight	6	12.34	0.87	0.544
Plant Fe- content	6	453.1	3.89	0.020

Table 7: Statistical summary of various parameters in the soil application experiments

Parameter	Degree of freedom	Mean square	Variance	F- value
Fresh weight	6	133.09	3.33	0.036
Dry weight	6	3.83	3.65	0.027
Plant Fe-content	6	455.1	5.33	0.007
Plant height	6	92.55	1.06	0.403

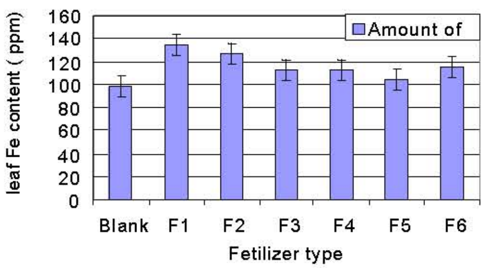

Fig. 2: Comparison of the Effects of fertilizers on leaf Fe-content of sorghum seedlings after foliar application

there was significant difference between fertilizer treatments at (P< 0.05). For this comparison the fresh and dry matter data of the leaves were used. Because of the short time gap between spraying and harvesting, this was predictable, but by comparing these results with those of leaves Fe content, it can be mentioned that the fertilizers did influence the nutrient uptake process. Based on the mean comparisons of Fe content in plants in this test, we can categorize the fertilizers in the following order of effectiveness:

F1 > F2 > F6> F3 > F4 > F5> Blank

Although the difference between the means of fertilizer treatments and control in the case of Fe content and for some fertilizers is less than LSD this difference for fertilizer treatments (except F5) are at least 15 and at most 36 mg kg^{-1} which shows the effect of spraying on Fe absorption.

In addition the mean comparison shows the significant difference between F1, F2 and F6 with other fertilizers. F1 and F6 are the known foreign fertilizers and

Table 8: Mean comparison of fertilizer treatments for various parameters in the foliar application experiment

Plant height (cm)	Leaf Fe content (ppm)	Leaves dry weight (g)	Leaves fresh weight (g)	Fertilizer type
74.6 ^{a}	96.6 ^{c}	5.33 ^{a}	24.30 ^{a}	Blank
82.7 ^{a}	132.6 ^{a}	6.27 ^{a}	25.93 ^{a}	F1
80.3 ^{a}	127.4 ^{ab}	5.63 ^{a}	27.00 ^{a}	F2
78.1 ^{a}	112.4 ^{b}	4.57 ^{b}	26.27 ^{a}	F3
79.3 ^{a}	112 ^{bc}	4.27 ^{b}	21.17 ^{a}	F4
65.8 ^{b}	105.3 ^{c}	5.47 ^{a}	24.80 ^{a}	F5
81.2 ^{a}	115.4 ^{ab}	5.10 ^{a}	23.03 ^{a}	F6
9.2	9.1	14.3	13.90	C.V
16.23	17.09	1.47	6.09	LSD

Table 9: Mean comparison of fertilizer treatments for various parameters in the soil application experiment

Plant height (cm)	Fe content (ppm)	Dry weight (gr)	Fresh weight (gr)	Fertilizer type
77.1 ^{a}	98.5 ^{c}	12.77 ^{c}	111.2 ^{b}	Blank
84.7 ^{a}	134.6 ^{a}	15.27 ^{ab}	115.8 ^{b}	F1
81.6 ^{a}	126.4 ^{ab}	15.3 ^{ab}	122.9 ^{a}	F2
81.1 ^{a}	115.7 ^{b}	14.4 ^{bc}	107 ^{c}	F3
82.1 ^{a}	112 ^{bc}	15.23 ^{ab}	119.3 ^{ab}	F4
68.8 ^{b}	104.3 ^{c}	14.2 ^{bc}	112.2 ^{b}	F5
80.13 ^{a}	118.4 ^{ab}	16.33 ^{a}	126.5 ^{a}	F6
11.8	8.0	6.9	5.4	C.V
14.6	16.2	1.72	11.25	LSD

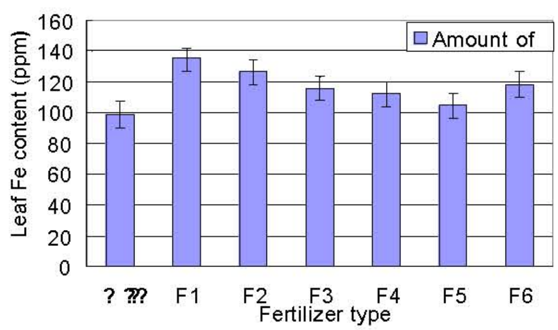

Fig. 3: Comparison of the effects of different chelate fertilizers on leaf Fe-content of sorghum seedlings after soil application

F2 is one of the native fertilizers. Figure 2, shows the apparent difference between the fertilizer effects through foliar application.

Soil application test: According to the results in Table (7) analysis of variance indicated that effects of fertilizer treatments in fresh and dry weight were significant at (P < 0.05). Their effects on Fe content in leaves were significant at ($P < 0.01$). The results also revealed that there was no significant effect in plant height treated by the fertilizers. The mean comparisons show the apparent difference between control and fertilizer treatments (Table 9). The means for fresh weight factor can be categorized like this:

$$F_6 > F_2 > F_4 > F_1 > F_5 > F_3 > F_0$$

For dry weight (dry matter factor) at least 4 fertilizers had significant difference with control and the means for the two other fertilizers were somewhat different with that of control. The groups would be like this:

$$F_6 > F_2 > F_1 > F_4 > F_3 > F_5 > F_0$$

The means for the Fe-content of leaves is categorized as:

$$F_1 > F_2 > F_6 > F_3 > F_4 > F_5 > F_0$$

Results indicate that all used fertilizers had a positive and in most cases significant impact on measured components. According to the means and LSD.there is a clear difference between control and fertilizer treatments. The effects of the two foreign fertilizers (F1 and F6) and one native product (F2) on fresh and dry matter and also Fe content of plants are comparable and are almost the same in this experiment. Figure 3 shows the effect of Fe chelate fertilizer on Fe content of dry matter.

DISCUSSION

In the implementation of the incubation experiment, the hypothesis was that by maintaining the equal conditions of the amount of Fe added to soil, moisture, temperature and aeration, the changes in the amount of Fe extracted with DTPA is mostly effected by chemical and biological interactions in soil. Also we can relate these changes for different fertilizers to the range of their stability and function in soil.

This can be interpreted through comparing the changes in time. The results of incubation test revealed that the performance of all fertilizers in changes of available Fe for plants is similar with time and probably is the results of the same chemical and biological changes in soil.

Furthermore, we can trust the better function of the two foreign fertilizers during the first 20 days of incubation. The increase in extractable Fe by DTPA in all fertilizer treatments showed that the best observation of fertilizer effects is between 2 or 3 weeks, especially when they are added to soil. In this test, there were no plants but it can be expected that in the presence of plant?s root, there would be some changes in fertilizers effects on Fe content.

The results of foliar application test showed that leaf absorption of Fe in all fertilizers occurred but the amount was different. Considering the fact that in practice usually the spraying is carried out 2 or 3 times, this can be a limiting factor for exact effects on growth indices and the amount of Fe absorbed. Among tested fertilizers the two foreign and one native (F2) fertilizers had similar and better function leading to better Fe absorption. According to the effects of fertilizer solution pH in the amount of leaf absorption [16,18] and existence of clear different solution pH among tested fertilizers, we can relate the better function of these three fertilizers to this factor. Further studies showed that the high acidity or alkalinity in fertilizer solution is a limiting factor in leaf absorption of nutrient elements [16].

Results of this study indicated the use of fertilizers in soil had a positive and significant effect on measured factors. In the case of fresh and dry matter fertilizer, F6 had a better function, F1 and F2 had the same function and the results were not significantly different from those of spraying and incubation tests. The plants average height in treatments was not different. Because of the fact that this character is affected by other factors like plant intensity, the amount of absorbable N and P and environmental condition, we cannot say that the lack of Fe or the different factors of exposing Fe in soil is the main factor in plant's growth and height. In addition the amount of Fe available in soil or sand used in the experiment might have be enough for the plants.

In this research the fertilizer samples, were obtained from the producers (native fertilizer) or market place (foreign fertilizer). Some essential characteristics and Fe content of samples were tested but in the case of fertilizer compounds or the type of organic chelate, the information was based on the producer s comments. It is obvious that the results of this research are only for these tested samples and every changes or heterogeneity in fertilizer production may influence the final result.

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