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Effect of varied soil matric potentials on the iron use efficiency of soybean genotypes (*Glycine max* L.)

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ABSTRACT:

Bicarbonate has g enerally much more effect on iron chlorosis in soils having excess moisture than in soils having lower moisture. But, soil moisture level may or may not affect the severity of iron deficiency depending on the plant species or genotypes. In this study, a pot experiment was conducted using calcareous soil by growing A-3735, A-3127, SA-88, S-4340, Ilisulu-20 soybean genotypes. Iron fertilizer as FeEDDHA (sequestrene 138, 6% iron) at the levels of 0, 4, 8, 12 µg Fe g^{-1} was applied to the soil. Pots were irrigated based on increasing soil matric potentials of – 65 kPa (I_1), -45 kPa (I_2) and -25 kPa (I_3), respectively. Chlorophyll contents were measured in fresh leaf samples. After harvest, plant dry matter yield was recorded and total phosphorus, iron, zinc and managnese concentrations in top of soybean plants were determined. Total phosphorus, iron, zinc and manganese contents and accumulations were generally varied among soybean genotypes depending on soil matric potentials. Significant differences were obtained among soybean genotypes for dry weight. Significant correlations (r = 76, P< 0.01) were also found between iron use efficiency of soybean genotypes and soil matric potentials for different iron levels.

Keywords:

Soybean genotypes, iron, soil matric, FeEDDHA.

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INTRODUCTİON

Iron (Fe) is one of the essential elements for plant growth, and it is needed for many physiological and biochemical processes. Iron deficiency problems can occur in agricultural production, even if the total amount of this element in the soil is in high levels. Many physical and chemical properties of soils may greatly affect Fe availability and Fe use efficiency of plants. Iron deficiency generally occurs on calcareous soils, and high bicarbonate concentrations decrease the availability of Fe in these soils (Miller et al.,1984). For example, it has been estimated that about 57.6 % of the Turkey's soils was covered with calcareous soils (Eyüpoğlu and Kurucu, 1997). In these soils, Fe availability decreases due to the high pH conditions. Iron fertilizer and water management practices affect yield, quality and Fe use efficiency in crops. The effectiveness of synthetic chelates in controlling of Fe chlorosis is usually better than inorganic Fe sources (Moraghan et al., 1986). But, their high costs generally restrict the wide use of these Fe sources in the agricultural crops (Chen and Barak,1982; Hagstrom,1984). Thus, economicial benefits will be obtained by increasing Fe use efficiency and resistance to Fe deficiency of agricultural crops. On the other hand, Fe use efficiency and resistance to Fe deficiency are affected by many factors. For example, soil moisture levels closely affect metabolic activity and Fe use efficiency of plants. But, soil moisture may increase or decrease severity of Fe deficiency depending on plant species or genotypes and some soil conditions. Low soil moisture and dry surface layers may restrict root growth and absorption capacity. Hence, Fe deficiency may be enhanced (Clarkson and Sanderson, 1978). Whereas, excess soil water lead to poorly aerated soil conditions. Hence, growth and absorption capacity of the roots are also restricted (Lindsay, 1984).

On the other hand, many studies revealed that there were broad differences among plant species and genotypes associated with susceptibility to Fe deficiency due to the different strategies of these varieties (Byron and Lambert, 1983; Marschner et al., 1986a). But, soil moisture level in the calcareous soils have not the main role on Fe deficiency in strategy-II type plants due to the poor effect of bicarbonate on Fe absorption mechanisms of these plants (Romheld and Marschner, 1986; Yen et al., 1998). It was also reported that excess irrigation or high soil water status in the calcareous soils can also increase Fe deficiency in strategy-I type plants due to the greater effect of bicarbonate on Fe-stress response mechanisms of these plants (Chaney, 1984; Romheld and Marschner, 1986). As a result, there may be a close relationship between soil moisture levels and Fe use efficiency of plant species or genotypes. It is generally known that soil moisture levels and plant species or genotypes affects the Fe availability and uptake by plants, whereas additional studies would be needed concerning these relationships. The objectives of this study were to test the soybean genotypes for their resistance to iron deficiency under the different soil moisture levels based on soil matric potentials, and to determine the relationship between varied soil moisture levels and Fe use efficiency of soybeans under the experimental calcareous soil.

MATERİALS AND METHODS

A pot experiment, based on a completely randomized design with three replications, was conducted under the real soil and air conditions in the garden of Agricultural Faculty. The phosphorus deficient soil, Calcareous Usthochrepts, was used for this experiment. Each pot consisted of 4000 g of absolute dry soil was taken. Soybean genotypes of A-3735, A-3127, SA-88, S-4340, Ilisulu-20 were obtained from Agricultural Research Institue of Rural Services, Adana. There were three plants per pot after emergence. Iron fertilizer as FeEDDHA (sequestrene 138, 6 % Fe) at the levels of 0, 4, 8, 12 µg Fe g^{-1} was applied to soil. In addition, a basal dressing of some macro and micro nutrients were applied to all pots. Pots were irrigated based on increasing soil matric potentials of – 65 kPa (I_1), -45 kPa (I_2) and -25 kPa (I_3), respectively. The aim of different irrigation programs of I_1, I_2 and I_3 was to supply nearly lower, medium and higher levels of soil moisture, respectively. In general, I_2 treatment was an average of I_1 and I_3 treatments. Visual chlorosis decreases in the soybean genotypes were observed depending on the following visual chlorosis definition: 1, no chlorosis; 2, very slight chlorosis; 3, mild chlorosis; 4, moderate chlorosis; and 5, severe chlorosis. Chlorophyll a and b (Withan et al., 1970) contents were detected in the fresh leaf samples, collected as an average of three repplications before harvesting. The plants were harvested 46 days after emergence, and dry weights in the top of soybean plants were recorded. In tops of soybean plants, the analysis of total phosphorus was made by spectrophotometry (Barton, 1948), and the analyses of total iron, zinc and manganese were made by atomic absorption spectrophotometry after digestion (Perkin, 1971). Soil matric potentials were randomly and nearly measured using the tensiometers (Anonymous, 1984). DTPA-extractable iron, cupper, zinc, manganese were determined by the method of Lindsay and Norvell (1978). The textural analysis was made with a Bouyoucos hydrometer (Gee and Bouder, 1986). Organic matter contents were determined by the Walkley-Black method from Jackson (1956). Available phosphorus (Olsen et al., 1954), exchangable potassium, cathion exchange capacity (Richards, 1954), $CaCO_3$ (Chapman and Pratt, 1961) and pH (1:2.5) (McLean, 1986) values were also determined in the experimental soil. Some of the experimental data were subjected to the statistical analysis of variance using MSTAT package program, and the means were seperated by Duncan's multiple range test. Coefficients of variance concerned with some relationships were also calculated using the computer program StatMost (StatMost, 1995). The calcareous soil used in this study had a clay texture with 47.32, 30.11 and 22.56 percent clay, silt and sand, respectively, and the calcium carbonate content was 200.0 g kg^{-1}. It had also the following chemical properties: pH (soil:H_2O = 1:2.5) = 7.93, organic matter content = 1.87, cation exchange capacity = 37.87 me 100 g^{-1}, exchangable potassium = 0.79 me 100 g^{-1}, available phosphorus = 5.75 mg kg^{-1}, DTPA extractable Fe = 1.8 µg g^{-1}, cupper = 0.8 µg g^{-1}, zinc = 0.1 µg g^{-1}, and manganese = 1.9 µg g^{-1}.

RESULTS AND DİSCUSSİON

Soybean genotypes (A) showed significant differences for all the measured parameters except chlorophyll ranking and zinc content **(Table 1).** Soil matric potentials (B) did not affect phosphorus, iron and zinc contents and zinc accumulation, whereas all the parameters were affected by Fe levels (C). In general, interaction of A x B was significant, meaning that soybean genotypes differently responded to iron applications under varied soil matric potentials.

Response of soybean genotypes to iron fertilization varied depending on soil matric potential. All soybean genotypes seemed to be very slightly responsive to iron fertilization under the lower soil matric potential caused by I_1. Any significant differences between soybean genotypes were observed for visual chlorosis when averaged across soil matric potentials and iron fertilizer levels, but the trend of chlorosis ranking showed an important increase with decreasing soil matric potential caused by lower irrigations (Table 2). Maximum average chlorosis ranking was observed under the lowest irrigation. Increasing soil moisture levels and iron appliacations decreased the chlorosis, visually. Significant differences were found among soybean genotypes for dry weight. The highest dry weight was obtained in A-3127 soybean variety, whereas the lowest dry weight was obtained in SA-88 soybean variety under the open experimental conditions. In general, by increasing of soil matric potential caused by higher irrigations, dry weight of soybeans was significantly increased, whereas they were significantly reduced due to the lower soil matric potential. In a similar irrigation study, Hegde and Srinivas (1990) have also reported that plant

Table 1. Significance of F tests for soybean genotypes, varied soil matric potentials caused by different irrigations and iron treatments.

	F tests of significance									
Source of variation	**Chl. rank**	**Dry w. g pot^{-1}**	**Phosphorus**		**Iron**		**Zinc**		**Manganese**	
			g kg^{-1}	**mg pot^{-1}**	**µg g^{-1}**	**µg pot^{-1}**	**µg g^{-1}**	**µg pot^{-1}**	**µg g^{-1}**	**µg pot^{-1}**
A+	N.S.	**	*	**	**	**	N.S	***	*	**
B‡	**	**	N.S.	**	N.S.	**	N.S	N.S	**	**
C§	***	*	*	**	**	**	**	**	**	**
A x B	N.S.	*	*	*	**	**	N.S	N.S	**	**
A x C	N.S.	N.S.	***	N.S.	**	*	N.S	N.S	**	*
B x C	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	***	*	**	N.S
A x B x C	N.S.	N.S.	**	*	N.S.	N.S.	N.S	N.S	**	*

*** Significant at the 0.05 probability level, ** Significant at the 0.01 probability level**
***** Significant at the 0.10 probability level, + A; Soybean genotypes,**
‡ B; Varied soil matric potentials caused by different irrigations, § C; Fe levels

growth, marketable yields of fruit and other growth parameters were decreased by decreasing of soil matric potential from –25 kPa to –85 kPa in tomatoes. Iron application affected dry weight of soybeans, but application of high levels of iron fertilizer resulted only a small increase in dry weight when averaged across soil matric potentials. Dry weight was increased by the application of iron fertilizer compared to control treatment under the high soil matric potential, whereas response of soybeans to iron fertilization was generally non significant.

In general, the values of total phopshorus, iron, zinc and manganese concentration and accumulation were varied among genotypes, but the trend remained similar **(Table 2).** The highest phopshorus content was found in A-3735 soybean variety. Similar results have also been reported by Moraghan (1987), who also found that phopshorus concentrations were varied among soybean varieties. Increasing soil matric potential did not significantly affect phopshorus content, but significantly increased phopshorus accumulation in all the soybean genotypes. In general, differences in the values of phopshorus content and accumulation caused by different levels of iron fertilization were significant. The highest Fe content was observed in SA-88 variety, whereas the highest Fe accumulation was observed in A-3127 variety, possibly as a result of its higher dry weight. Decreasing soil matric potential significantly decreased Fe contents and accumulations in the soybean genotypes. It has also raported that the availability and uptake of mineral nutrients were modified by soil water status (Begg and Turner, 1976). As a result, Fe levels in the excess of plant demand increased Fe accumulation in the plants. Similar results have also been reported by Baxter and Osman (1988). Different Zn content and accumulation values were found among genotypes, and the highest average values of Zn content and accumulation were detected in A-3127 soybean variety. Soil moisture level had non significant effect on the zinc content and accumulation, whereas effect of Fe levels on the zinc content and accumulation was significant. Increasing levels of Fe, except the highest rate, generally increased zinc content and accumulation as compared to control treatment. The highest manganese content was detected in SA-88 soybean variety, whereas the highest manganese accumulation was observed in A-3127 soybean variety as a result of its higher dry weight. Manganese content was decreased by increasing Fe application in all genotypes, which could be attributed to antagonistic effect of Fe levels. This antagonism observed between Fe and Mn hass also reported by Baxter and Osman, (1988). Marschner et al. (1986b) also reported that Fe-stress condition

Table 2. Influence of iron fertilizer on visual chlorosis definition, dry weight and total Phosphorus, iron, Zinc, Manganese concentrations and accumulations in the soybean genotypes grown under different irrigations.

Treat-ments	Chlo. rank.	Dry w. g pot^{-1}	Phosphorus		Iron		Zinc		Manganese	
			g kg^{-1}	mg pot^{-1}	µg g^{-1}	µg pot^{-1}	µg g^{-1}	µg pot^{-1}	µg g^{-1}	µg pot^{-1}
Soybean genotypes										
A-3735	1.3	6.60 b	1.64 a	10.87 a	151 b	957 b	20	130 ab	73 b	489 a
A-3127	1.3	7.27 a	1.53 ac	10.99 a	166ab	1326 a	22	161a	68 b	496 a
SA-88	1.6	5.83 c	1.59 ab	9.28 ab	181a	1055 ab	16	94 b	98 a	383 b
S-4340	1.5	6.33 bc	1.39 c	8.83 b	156ab	1018 ab	16	104 b	73 b	461a
Ilis. –20	1.5	6.22 bc	1.43 bc	8.93 b	149 b	939 b	14	85 b	70 b	449 ab
Irrigations										
I_1	2.0 a	5.55 c	1.52	8.45 b	158	882 b	18	106	66 b	372 b
I_2	1.3 b	6.66 b	1.53	10.25 a	158	1029 b	15	99	72 ab	481a
I_3	1.1 b	7.15 a	1.50	10.63 a	166	1265 a	19	139	92 a	515 a
Fe levels, µg g^{-1}										
0	1.6 a	6.29 b	1.41 b	8.81 b	133 b	830 c	12 b	76 b	106 a	506 a
4	1.4 ab	6.25 b	1.52 ab	9.44 b	159 a	955 bc	17 ab	107ab	70 b	446 ab
8	1.5 a	6.45 ab	1.49 ab	9.60 b	174 a	1236 a	26 a	168 a	66 b	431b
12	1.3 b	6.81 a	1.63 a	11.27 a	177 a	1215 ab	15 ab	108 ab	65 b	441b

could increase the mobilization and uptake of soil Mn in dicots. **Fig. 1.** shows the results of the regression analyses between chlorophyll and chlorosis ranking. Chlorosis ranking and chlorophyll content were closely correlated for soybean genotypes, and the following regression equation was obtained: Chlorosis ranking = 3.039 – 1.260 x chlorophyll content.

It was also observed that soybean genotypes significantly differed in Fe use efficiency under different soil matric potentials. In all soybean genotypes, changes in Fe use efficiency parameter were closely related to the soil matric potentials. In soybean variety of ilisulu-20, Fe use efficiency decreased with increasing soil matric potential from lower to higher level caused by different irrigations, possibly due to the higher concentration of bicarbonate under the high soil moisture condition. It has also reported that the concentration of bicarbonate had more effect on iron deficiency in soils under the excess moisture than that under the lower moisture (Inskeep and Bloom, 1986; Tong Yue et al., 1987). But, soil moisture level had no negative effect on the Fe use efficiency in soybean varieties of A-3735, A-3127, S-4340, possibly due to the resistance of these genotypes to Fe deficiency under higher soil matric potential. In these soybean genotypes, Fe use efficiency were increased with increasing soil matric potential, whereas Fe use efficiency of SA-88 soybean variety slightly increased with increasing soil matric potential. These results showed that effect of varied soil moisture status on the Fe use efficiency was not the same for all soybean varieties. Significant correlations were also established between Fe use efficiency and soil matric potentials for different Fe levels, and the following regression equations were obtained: Fe use efficiency = 503.46 + 2.51 x matric potential for 4 $\mu g\ g^{-1}$ Fe level, Fe use efficiency = 249.82 + 1.07 x matric potential for 8 $\mu g\ g^{-1}$ Fe level, and Fe use efficiency = 191.99 + 1.11 x matric potential for 12 $\mu g\ g^{-1}$ Fe level, respectively. The highest correlation coefficient was found for 12 $\mu g\ g^{-1}$ Fe level, which indicates that Fe use efficiency can also be highly correlated with Fe fertilizer.

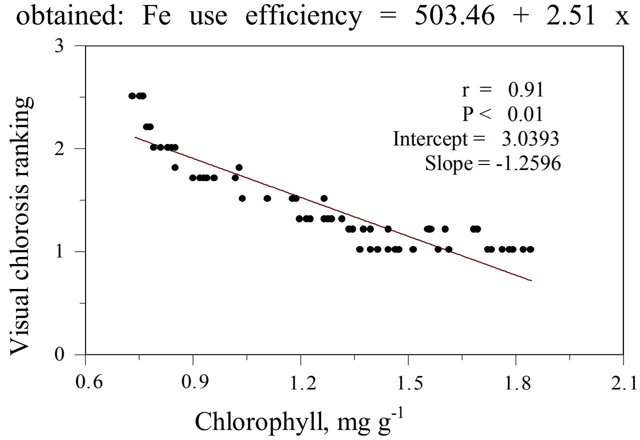

Figure 1. Relationships between total chlorophyll content and visual chlorosis ranking in soybean genotypes.

As a concluding remark, the presented data showed that the values of Fe efficiency parameters were varied among the soybean genotypes depending on varied soil matric potentials caused by different irrigations. Classification and characterization of Fe efficient and responsive genotypes will be a primary step to provide valuable data for breeding studies on developing and selecting of new varieties under the varied soil moisture conditions. Developing of new genotypes that are resistant to iron deficiency under the varied soil moisture levels will be beneficial to increase Fe use efficiency, and to decrease Fe deficiency in the agricultural production, especially on calcareous soils. Consequently, two new terms can be used for different genotypes: 'susceptible to higher soil moisture' or 'resistance to lower in related to Fe use efficiency. Additional pot and field experiments would be needed for the determination of Fe use efficiency of different soybean genotypes under the varied conditions.

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