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Rootstock has an Important Role on Iron Nutrition of Apple Trees

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Abstract: This study was carried out to determine the rootstock effect on iron (Fe) nutrition of apple cultivar "Red Chief". For this purpose, 0, 1.5, 3.0 and 4.5 g Fe tree^{-1} from Fe-EDDHA (6% Fe) were applied to the soil. Total and active Fe concentrations and SPAD index of leaves were determined to find out rootstock response to applied Fe. Total and active Fe concentrations and SPAD index of leaves significantly increased with Fe application. Total and active Fe concentrations of trees significantly varied among rootstocks, but no significant differences were determined for SPAD index. Increase in total and active Fe concentrations in leaf showed that dwarf rootstocks (M 9 and M 26) were more affected by applied Fe than semi-dwarf rootstock (MM 106). On the other hand, close-positive relations were found among total Fe, active Fe and SPAD index.

Key words: Fertilization · iron · nutrient uptake · rootstock

INTRODUCTION

High pH and high level of $CaCO_3$, low levels of organic matter and some other soil factors are predominantly responsible for low availability of Fe to plants. Plant factors have an important role controlling plant's nutrient uptake as well. Because use of soil Fe by plant is genetically controlled, plant species and varieties show different response to Fe nutrition even they are grown in the same conditions [1]. Plants develop some adaptation mechanisms to Fe deficiency [2, 3]. A cultivar that can use Fe in unfavorable soil conditions is called Fe-efficient, whereas a cultivar developing Fe chlorosis is called Fe-inefficient [4]. These mechanisms vary with plant species and some cases may not be enough to overcome Fe nutritional problem. Thus, under unfavorable conditions for Fe availability, some alternative ways must be practiced to increase plant Fe uptake. Iron chlorosis is a major nutritional problem of fruit trees growing in alkaline, calcareous soils [5-7]. Under these conditions trees need iron fertilization to prevent yield and quality loses [8, 9]. Previous works indicated that applications of Fe from different sources are effective ways for improving plant Fe nutrition [10-12]. In fruit trees, soil application of iron compounds is the dominant practice to correct iron chlorosis [13]. Among all soil applied iron fertilizers, Fe-SO_4 and synthetic Fe-chelates mainly Fe-EDDHA are the most effective and commonly used [13]. One of the ecological ways to solve Fe deficiency problems is to choose suitable rootstocks and cultivars [14, 15]. Rootstocks have been reported to influence performance and survival of the cultivar and choosing proper rootstock is important for successful orchards establishment [16, 17]. Although iron itself is not actually a constituent of chlorophyll, it is one of the elements affecting pigment synthesis directly. Apart from being a constituent of chlorophyll precursors, it is also implicated in their synthesis and synthesis of chlorophyll itself through various enzyme systems [2]. So, chlorosis is closely associated with Fe deficiency and chlorophyll contents can decrease drastically in Fe-deficient plants. Because 10 to 20 percent of iron is physiologically active, total iron content in leaves sometimes, does not reflect plants iron nutrition [18, 19]. Thus, determination of active iron (Fe^{+2}) content beside total iron, is better way to evaluate plant's iron nutrition [19, 20]. The green color of the leaf is often positively related to the concentration of chlorophyll [21]. Peryae and Kammereck [22] proposed to use the green color of the leaf, measured with a SPAD chlorophyll meter, as an unbiased quantitative measure of severity of leaf chlorosis associated with iron deficiency and of the relative effectiveness of iron fertilization treatments.

Purpose of this study was to compare the effect of about tree times less Fe containing chelated iron form (Fe-EDDHA, 6% Fe), to inorganic iron (FeSO4 7 H_2O, 19% Fe) on iron nutrition of apple cultivar grafted on different rootstocks grown on a calcareous soil. The other

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objective of this experiment was to find out the differences of Fe uptake between rootstocks.

MATERIALS AND METHODS

The trial was carried out on a drip-irrigated orchard of 5-year- old "Red Chief" apple grafted on M9, M26 (dwarf) and MM106 (semi-dwarf) at spacing 1.5 x 4.5 m, at Suleyman Demirel University (Isparta, Turkey) experimental station, in year 2006. The experimental soil was clay loam having pH 7.8 (1:2.5 soil to water ratio), 17% $CaCO_3$, 1.5% organic matter, 30 kg ha^{-1} 0.5 M $NaHCO_3$ extractable P, 600 kg ha^{-1}1 N NH_4OAC exchangeable K and Mg. The available Fe, Cu, Zn and Mn as determined in DTPA extract by Atomic absorption spectrophotometer (AAS) were 3.1, 1.0, 0.4 and 3.0 mg kg^{-1}, respectively. The trees received a basic N, P, K and Mg dressing of 55 g N, 35 g P, 45 g K and 20 g Mg per tree, along growth cycle. Trees received Fe(III)-chelate (Fe-EDDHA, 6 % Fe) at the rates of 0, 1.5, 3.0 and 4.5 g Fe $tree^{-1}$ in April.

Leaf samples were collected from current year's terminals in July representing whole tree from four sides [2]. Leaves samples were used for SPAD measurements first, than were put into plastic bags and brought to the laboratory. They were washed thoroughly with fountain water, dilute acid (0.2 N HCl) and distilled water to remove surface residues, dried at 65±2°C until stable weight then grounded for iron analysis.

Leaf samples were wet-digested in HNO_3+$HClO_4$ acid mixture and total Fe concentration was measured using AAS. Active Fe concentration in leaves was determined as described by Takkar and Kaur [23].

The SPAD index was measured using a Minolta SPAD-502 chlorophyll meter [24]. Fully expanded 20 young leaves were collected around the tree canopy and SPAD measurements were made in the field in the morning. For each leaf, four measurements between the central vein and the leaf edge were made and the average was used as a single data.

Experiments was conducted as randomized complete block design with three replicates and data were analyzed with COSTAT program according. Differences between the means were separated by Duncan's Multiple Range Test.

RESULTS

Total Fe, active Fe and SPAD index: While total and active Fe concentrations of apple, Red Chief, were significantly affected by main factors and their interactions, only Fe doses had significant effect on SPAD index (Table 1).

Table 1: F values from analysis of variance of data obtained from the experiment

		F		
Source of variation	d.f.	Total Fe	Active Fe	SPAD
Variety	2	60***	28.3***	n.s.
Dose	3	341***	153.7***	45.6***
Variety x dose	6	89***	17.2***	n.s.
Error	24			

***P<0.001; d..f., degrees of freedom; n.s., not significant

Table 2: Total Fe, active Fe and SPAD index of apple trees with different Fe and rootstock treatments

Treatments	Total Fe (mg kg^{-1})	Active Fe (mg kg^{-1})	SPAD index
M9 + Fe-EDDHA + Fe_0	87	13.6	33.4
M9 + Fe-EDDHA + Fe_{25}	106	25.2	41.0
M9 + Fe-EDDHA + Fe_{50}	129	26.5	42.7
M9 + Fe-EDDHA + Fe_{75}	159	25.1	44.9
M26 + Fe-EDDHA + Fe_0	88	15.8	33.3
M26 + Fe-EDDHA + Fe_{25}	121	19.8	39.3
M26+ Fe-EDDHA + Fe_{50}	112	21.4	43.3
M26 + Fe-EDDHA + Fe_{75}	121	21.7	42.5
MM106 + Fe-EDDHA + Fe_0	109	16.9	34.2
MM106+ Fe-EDDHA + Fe_{25}	134	22.6	40.3
MM106+ Fe-EDDHA + Fe_{50}	117	21.1	41.6
MM106+ Fe-EDDHA + Fe_{75}	128	21.8	41.5

$LSD_{(p<0.05)}$ for total Fe, 5.0; for active Fe, 4.8; for SPAD index 3.9

Table 3: Effect of Fe level and rootstock on mean values of total Fe, active Fe and SPAD index

Treatments		Total Fe	Active Fe	SPAD index
Fe Level	Fe_0	95	15.4	33.6
(g $tree^{-1}$)	Fe_{25}	120	22.2	40.2
	Fe_{50}	119	23.0	42.5
	Fe_{75}	136	22.9	43.0
$LSD_{(p<0.05)}$ for total Fe, 6.0; for active Fe, 4.7; for SPAD index, 2.2				
Rootstock	M9	120	22.4	40.5
	M26	111	19.7	39.6
	MM106	122	20.6	39.4

$LSD_{(p<0.05)}$ for total Fe, 4.0; for active Fe, 1.2

Total Fe concentrations of leaves were the lowest at control treatments (Fe_0) for whole rootstocks, but these values were increased with Fe-EDDHA applications (Table 2). Comparing to control treatment, total Fe concentrations of leaves increased at the rates of 83, 38 and 23% for M 9, M 26 and MM 106, respectively. Comparing the control, active Fe concentrations in the scion leaves significantly increased with Fe application,

Table 4: Correlations among total Fe, active Fe and SPAD index obtained from Fe-EDDHA treatments for different rootstocks

	Fe-EDDHA application		
Rootstock	Total Fe-Active Fe	Total Fe-SPAD index	Active Fe-SPAD index
M 9	y=0.14x+5.6	y=0.14x+23.2	y=0.77x+23.6
	r= 0.73**	r= 0.85***	r= 0.88***
M 26	y=0.15x+2.8	y=0.22x+14.8	y=1.62x+7.8
	r= 0.84***	r= 0.69*	r= 0.86***
MM 106	y=0.21x-4.8	y=0.21x+14.1	y=1.13x+16.2
	r= 0.88***	r= 0.63*	r= 0.81***

*P<0.05; **P< 0.01; ***P<0.001; n.s., not significant

but the effects of Fe doses were found to be similar. The control plants gave the minimum SPAD index whereas there were significant increases in Fe-treated plants for each rootstock. According to mean values, the highest total Fe concentration was received from Fe_{75}, whereas the lowest was from the control. The effect of both Fe_{25} and Fe_{50} were found to be similar. Significantly different active Fe concentrations were recorded depending on rootstocks. As in total Fe, active Fe concentrations of Red Chief on M9 and MM106 were higher than that of on M26. Rootstocks did not significantly affect SPAD index (Table 3).

Relations among total Fe, active Fe and SPAD Index: Results showed that there were positive correlations among whole examined parameters for apple trees on M 9, M 26 and MM 106 fertilized with Fe-EDDHA. With the increase of total Fe concentration of leaves cv. 'Red Chief' on different rootstocks, active Fe and SPAD index (green color intensity) increased as well (Table 4).

DISCUSSION

Increase in total Fe concentrations with Fe applications indicates deficiency of soil Fe although there is moderate DTPA extractable Fe in the soil. Under control conditions (Fe_0) for two experiments, leaf total Fe concentrations were around the critical level, but with Fe applications, leaf Fe concentrations reached up to sufficient ranges [25, 26] with Fe-EDDHA application. The effect of Fe applications on active Fe was similar to that of on total Fe concentration generally. Active Fe concentrations showed similar tendency with total Fe depending on the Fe doses. According to results obtained from Fe-EDDHA application, about 18 percent of total Fe was determined as active Fe and this rate was in agreement with studies conducted before [18, 19]. Iron concentration of apple, on M 9, M 26 and MM 106 was different from each other and it was found that trees grafted on MM 106 had significantly higher Fe contents. This finding is in accordance with previous studies [27-30]. In a study by Kucukyumuk [15] it was found that leaf iron concentrations of different apple varieties on MM 106 was highest whereas Fe concentrations was lowest on M 26 and leaf Fe concentration of varieties on M 9 was between MM 106 and M 26. The differences in total leaf Fe concentrations among the rootstocks may be caused by different Fe absorption capacities through the roots [31, 32]. As known, MM 106 is semi-dwarf rootstock whereas, M9 and M26 is dwarf. This implies that, root growth causes a greater absorption capacity in MM 106. This characteristic of MM 106 provides a higher nutrient uptake from the soil. Also, differences in total Fe concentrations among rootstocks are may be due to the different lowering capacity of pH in their rhisozphere [33]. Fruit trees depend on their root systems for the acquisition of mineral nutrients. Total length of the root system is the most important factor influencing nutrient uptake. Uptake of immobile nutrients like iron particularly depends on root absorptive surface area [34, 35]. As in previous study [36], SPAD index was used to estimate chlorophyll concentrations in this study. SPAD index, meanly green color index increased with Fe levels. Soil Fe applications significantly increased SPAD readings compared to control trees. Our results are in agreement with those by Tagliavini *et al.* [13] and Banuls *et al.* [37]. This can be related to increase in chlorophyll content due to total and active Fe increment.

In summary, results indicated that under Fe-scarce conditions, if dwarf rootstocks such as M 9 and M 26 or semi-dwarf rootstock such as MM 106 are to be planted, it should be taken consideration that Fe fertilization of Red Chief on M 9 and M 26 is more important than on MM106.

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